SP-412
May 1998

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Third Euro-Latin American

Space Conference

Mexico City, 10-14 November 1997

European Space Agency
Agence spatiale européenne

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Co-sponsored by:

European Space Agency
Comisión Federal de Telecomunicaciones, Mexico

European Space Agency
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Cover image: *ERS-2 SAR multitemporal colour composite image of Mexico City generated from three SAR images acquired at the Norman ground station (USA) on 21 June 1996 (red), 29 December 1995 and 19 September 1997 (blue).*

ESA SP-412 – **Third Euro-Latin American Space Conference**
Mexico City, 10-14 November 1997

Proceedings published by: ESA Publications Division
ESTEC, Noordwijk, The Netherlands

Compiled by: Tan-Duc Guyenne

Price: 100 Dfl.

ISBN 92-9092-648-1 Printed in The Netherlands

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Earth Observation

New Trends in Remote Sensing from Spaceborne Imaging Systems

Jean-Marc NASR
AEROSPATIALE Espace et Défense
Cannes Center
France

SUMMARY

- **Introduction**
- **"user- provider" Relationship**
- **Evolutions for imagery actors**
- **Conclusions - Recommendations**

INTRODUCTION

MAJOR EVOLUTION OF "IMAGE BASED ÍNFORMATION" SINCE THE LAST 5 YEARS

- **IBImandatory for crisis forecasting and monitoring**
- **IBI interest proven in operational conditions**

- **Increasing number of existing commercial civil satellites RADARSAT, SPOT 5, high resolution commercial satellites.**
- **High performances military satellites**
- **High performances ground segments**
- **Huge generated databases**
- **A real military - civil synergy**

IN DEPTH EVOLUTION OF REMOTE SENSING MARKET TO BE SET UP IN THE NEXT YEARS

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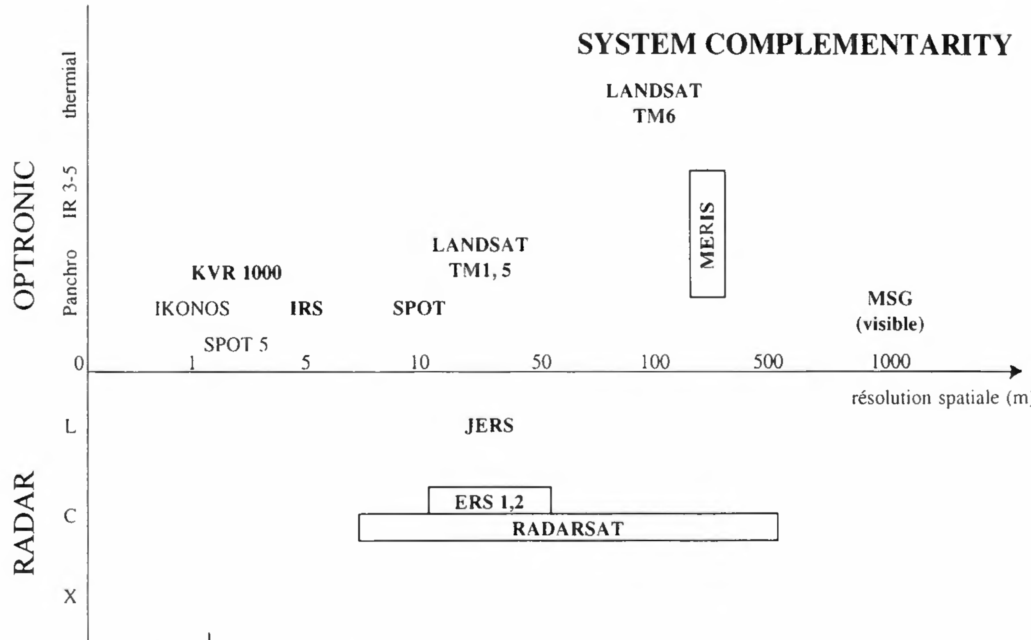
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X
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TM1, 5
KVR 1000
IKONOS
IRS
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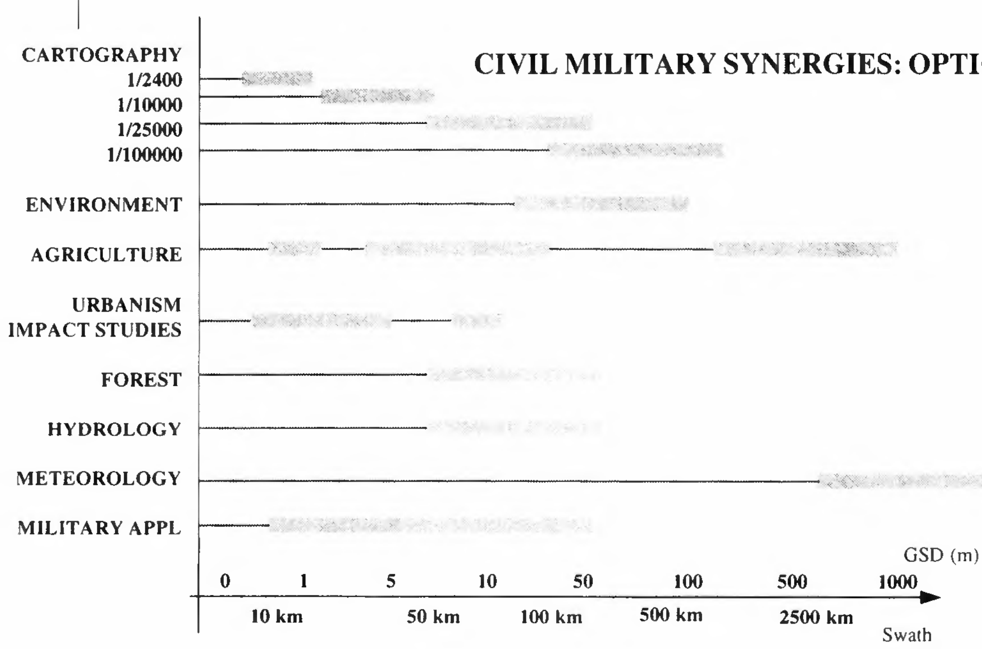
RADARSAT


CIVIL MILITARY SYNERGIES: OPTIC
CARTOGRAPHY
1/2400
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ENVIRONMENT
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IMPACT STUDIES
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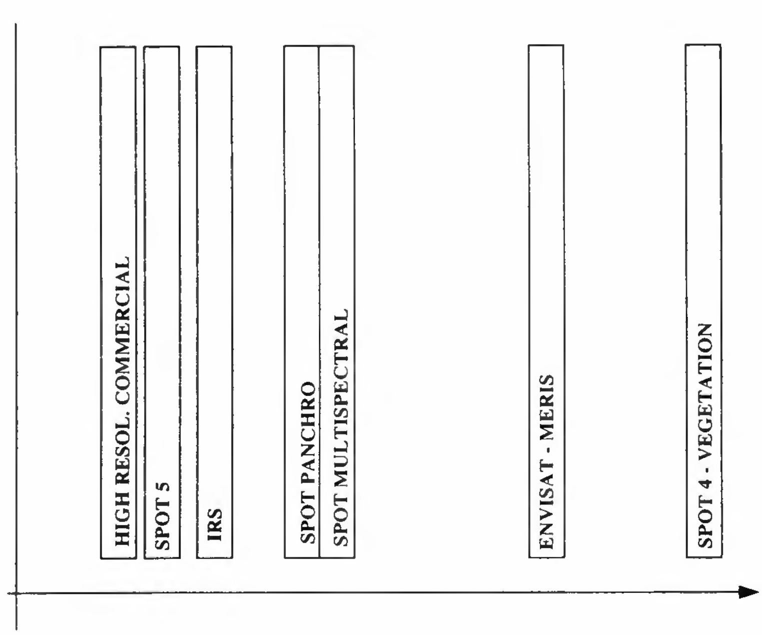
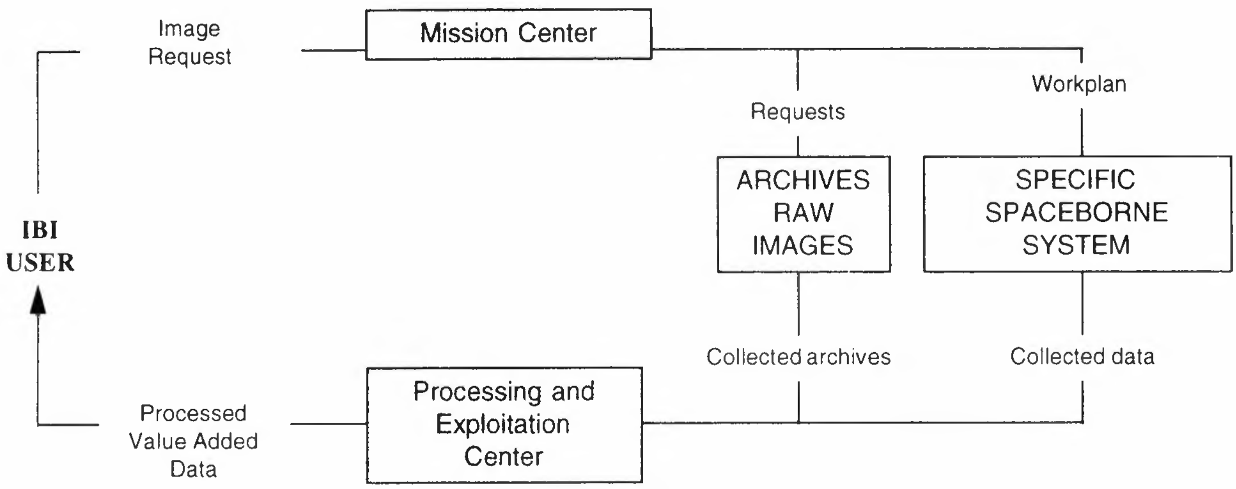
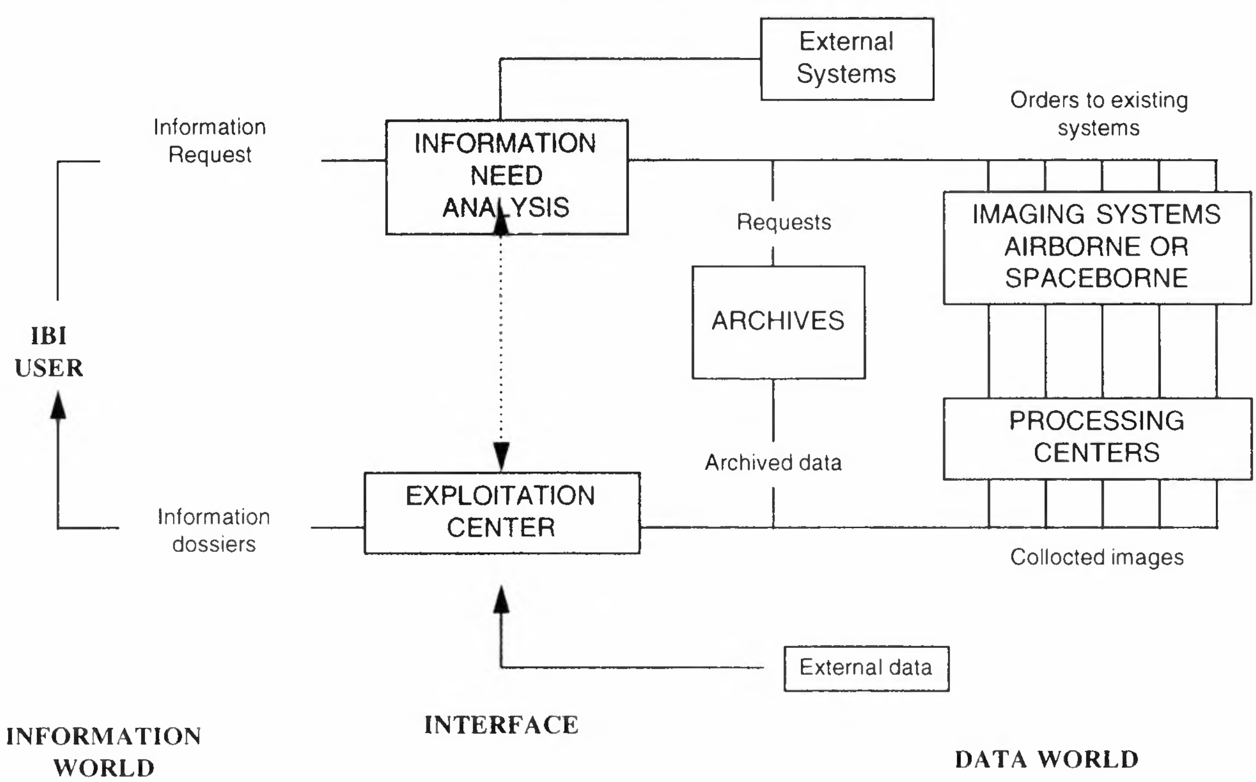

HIGH RESOL. COMMERCIAL
SPOT 5
IRS
SPOT PANCHRO
SPOT MULTISPECTRAL
ENVISAT - MERIS
SPOT 4 - VEGETATION

The remote sensing loop: Mono sensor case



The remote Sensing Loop: The multi system sensor case



MultiSensor IBI: New actors

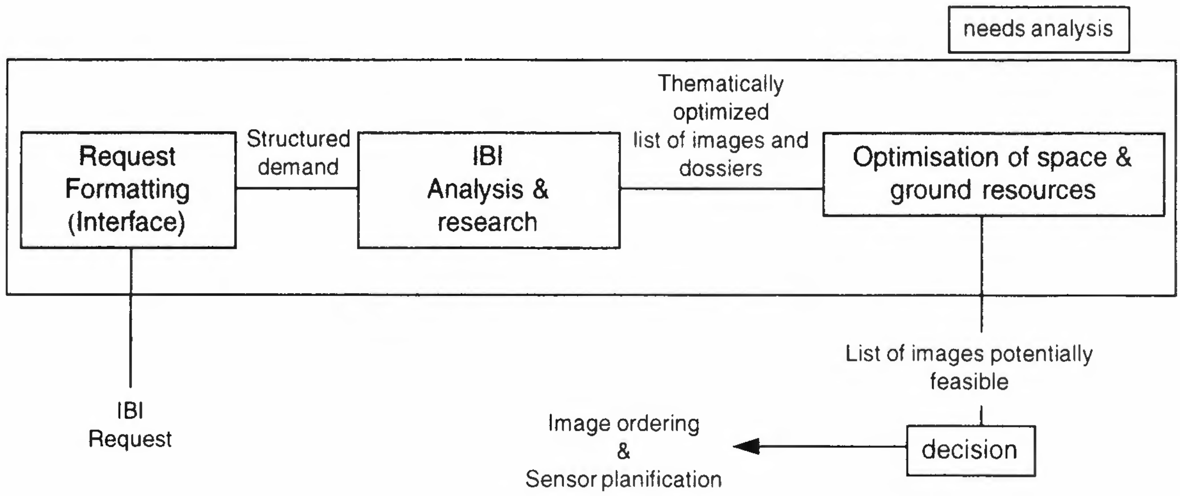
- **1. NEED ANALYSIS AND ASSISTANCE TO SYSTEM SELECTION**
- **2. VALUE ADDED IN EXPLOITATION CENTER**
- **3. NEW "USER" IN IBI**

RAPID EVOLUTION OF THESE THREE ACTORS IN THE COMING YEARS

Need Analysis And System Selection

AEROSPATIALE "IQA" CONCEPT: IMAGE QUERY ASSISTANT

- **Totally New Function**
- **Duality with Exploitation (Need Analysis=fission / Exploitation=fusion)**
- **REQUEST A NEW EXPERTISE**



Exploitation Center

VALUE ADDED SOFTWARES TO TAKE INTO ACCOUNT THE MULTISENSOR COMPLEMENTARITY

- **Standardisation of data loaders**
- **Adaptation of MMI to sensor specificity**
- **Select cooperative approach against pixel fusion**
- **Growing importance of the photo interpreter**
- **MAKE THE DIFFERENCE BETWEEN A PHOTO INTERPRETATION SOFTWARE AND AN IMAGE PROCESSING TOOLBOX**

- **CLOSE RELATIONSHIP BETWEEN IBI SOFTWARES AND GIS SOLUTIONS TO STORE AND RETRIEVE MULTISENSOR MULTIDATE INFORMATION**

Value-added tools multisensor approach

- **STRONG INTERACTION: CAPI - GIS**
  - **Software interoperability**
  - **Standardisation of export/import formats (vector / raster)**

- **CAPI**
  - **On line help**
  - **Multiwavelength cooperative approach**
  - **Automatic Georeferencing**
  - **Up to date handling of Geometric Defomation Model (GDM)**

- **THINK OPEN!**

The IBI user and the photointerpreter

TO FACILITATE THE EXPANSION OF THE REMOTE SENSING MARKET AND TO FILL THE GAP BETWEEN THE IBI USER AND THE DATA WORLD, IT IS NECESSARY TO ENHANCE

- **TRAINING OF RS COMMUNITY THROUGH EASY WAYS**
  - **Internet based training**
  - **Self Training through CAT softwares widely distributed**

- **MAKE IBI USERS TO PARTICIPATE TO FUTURE SYSTEMS SPECIFICATIONS**
  - **Use simultation softwares to understand user needs and associate the user to the decision process**
  - **Define adapted CAPI tools**

Conclusions - Recommendations

- **DO NOT THINK MULTISENSOR FUSION WITHOUT SELECTION OF ADAPTED IMAGES TO SATISFY THE USER: IQA CONCEPT**

- **DEVELOP TRAINING TO FILL THE GAP BETWEEN THE USER AND THE REMOTE SENSING TECHNICAL COMMUNITY.**
  DEVELOP A COMMON LANGUAGE

- **ADAPT THE SOFTWARES TO THIS NEW RELATIONSHIP**
  (On line help, Cooperative approach, exchanges standardization, ..)

DETECCION DE CAMBIOS EN LAS CUBIERTAS FORESTALES DE ZONAS AUSTRALES

Roberto Castro Ríos

PONTIFICIA UNIVERSIDAD CATÓLICA DE CHILE. FACULTAD DE AGRONOMÍA E INGENIERÍA FORESTAL. CENTRO DE PERCEPCION REMOTA Y SIG
Avda Vicuña Mackena 48 60. Santiago. Chile. EMAIL: rcastro@sas.puc.cl

Marion Espinosa Toro

CENTRO DE INFORMACIÓN DE RECURSOS NATURALES DE CHILE (CIREN - CORFO).
Avda Manuel Montt 1164. Santiago. Chile. EMAIL: ciren@reuna.cl

Abstract

The present work is being conducted in the Tierra del Fuego Island, XII Region, Chile, the southernmost territory of the world. The objective is to evaluate the images from standard mode radar (S5) in order to use them in the identification and monitoring of plant cover - specially of native forest - as well as disturbances following human intervention (cut of trees and forest fires). In this opportunity the results of the first part - identification -are discussed. First, the plant formation in the area, such as medows, low woody bushes and forest, is defined. Secondly, various classes in the forest formation - according to environmental conditions - are defined also.

The radar images were geometrically corrected, then the speckel was reduced by means of the Gamma map filter. Later a textural segment of homogeneity was obtained and digitally classed. These results allow the separation of plant formation and of two forest types, based on plant density, species, and present condition.

Conclusions are drawn on the validity of radar data in order to discriminate alterations in native forests.

Introducción

Los recursos vegetacionales nativos de Chile se enfrentan en la actualidad a una presión creciente por disponer de ellos para diversos usos. como madera y celulosa.

Recientemente Chile termino su primer inventario nacional de vegetación nativa, corroborándose que una de las zonas de mayor dificultad para conocer es la correspondiente a la zona Austral (Tierra del Fuego) y, es precisamente aquí donde se concentra una de las superficies de bosque nativo **(Nothofagus pumilio)** más extensas del país.

La característica de esta zona, de el punto de vista climático y la accesibilidad a ella son las principales dificultades para obtener información permanente de estos bosques, debido a que no permite la utilización de sensores ópticos, es por ello que los datos de RADAR (SAR) se presentan como la única alternativa eficiente para realizar el seguimiento de los recursos naturales, especialmente de las alteraciones por causas humanas como son cosechas de bosque e incendios forestales.

La utilización de datos RADAR sin embargo, en primer lugar requiere de los investigadores latinoamericanos abrirse a un nuevo paradigma y con ello mediante la investigación llegar a conocer los nuevos datos, de tal forma que se llegue a traspasar metodologías operativas a los usuarios y tomadores de decisiones, con el fin que estos planifiquen en forma sustentable la utilización de los recursos y, al mismo tiempo estas metodologías y nuevas herramientas permitan vigilar la explotación de estos.

En los últimos años en Europa y Canadá han ido surgiendo distintas aplicaciones de datos de RADAR, que constituyen el punto de partida para elaborar el conocimiento a nivel de Latinoamérica. Un buen ejemplo es el mosaico de Africa Central, realizado con 477 imágenes de RADAR permitiendo la ubicación y cuantificación de la desforestación y distribución de este problema en el continente africano (Maligreau, et al. 1994). En Indonesia datos del SAR del ERS-1 y 2 han sido utilizados con éxito en el inventario de los recursos agrícolas (Harms, J. 1996); de igual forma son fuente de datos única para la planificación territorial y manejo de los bosques tropicales (Kuntz, S. Wanninger, K. 1995).

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Experiencias similares se tiene en Brasil (Wooding et al, 1996), Argentina (Salgado y Maris, 1996).

En Chile, la experiencia es escasa en todo los campos y especialmente en el campo forestal y agrícola, por lo anterior la presente comunicación, que forma parte de un proyecto de investigación a tres años plazo, en el marco del proyecto GLOBERSAR II, se justifica y valoriza de cara a los desafios futuros.

El objetivo de este proyecto es evaluar los datos de RADAR para identificar las cubiertas de bosques nativos, las alteraciones que se producen en estos producto de intervenciones humanas y detectar estos cambios en el tiempo (análisis multitemporal).

En este marco esta comunicación da cuenta de un aspecto de la primera fase del proyecto, que consiste en la clasificación de las principales cubiertas vegetales del área de estudio y de la discriminación de la condición de la cobertura de bosque nativo.

Area de Estudio

El área de estudio se encuentra ubicada en la comuna de Tierra del Fuego (isla), cuyos límites son: por el Norte, línea recta que pasa por lago Mercedes; por el Sur y Oeste el Océano Pacifico y por el Este a 10 Km. al este del lago Blanco. La superficie aproximada es de 70 kilómetros cuadrados. Esta zona se sitúa en la XII Región de Chile, entre los grados 53,30 y 54,30 de Latitud Sur y entre los 71,50 y 69,20 grados de Longitud Oeste..

Las condiciones climáticas de esta zona corresponden a un clima estepárico frío, con temperatura media anual de 6 grados celcius, llegando a mínimas de -18 grados. La precipitación media anual es de 432 milímetros, con fuertes vientos, permanente presencia de nubes.

El territorio presenta terrenos de pendientes suaves a onduladas, con excepción de la parte de la cordillera de los Andes donde el terreno es quebrado y abrupto con porcentajes de pendientes altas, sector asociado a los bosques nativos de Lenga (figura 1).

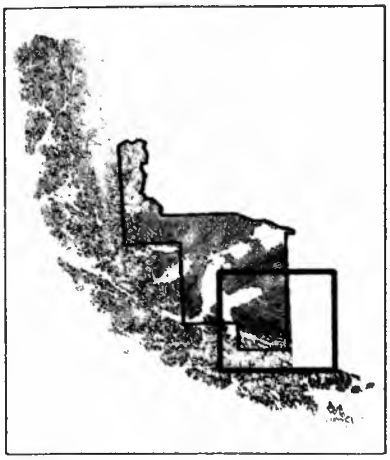


Figura 1. Ubicación área de estudio (imagen NOAA)

Material y método

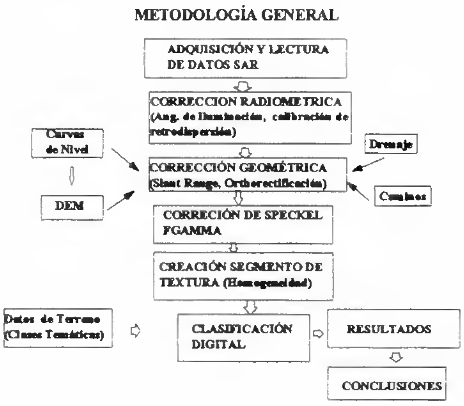
Para el presente trabajo se contó con datos provenientes del satélite RADARSAT, modo Standard 5 (S5), órbita 6657 descendente, ángulo de incidencia entre 45° a 48°, espaciamiento de 12,5 m entre pixeles y formato CEOS.

Como material complementario se tuvo una clasificación digital de imágenes Landsat (10 febrero de 1994), cartografía de cobertura vegetacional (Castro et al, 1996), cartas bases de curvas de nivel, hidrografía y caminos.

El análisis se realizó en PC, con los software PCI y ERDAS, más el apoyo del SIG ARC-INFO.

La metodología general se presenta en el esquema de la figura 1.1:

Figura 1.1



La primera etapa consistió en la adquisición de la imágenes y su posterior lectura. Se seleccionó tres fechas dos en cada verano y una de

Las especies citadas como dominantes son las siguientes: DW: **Drimys winteri**, NB: **Nothofagus betuloide**, MM: **Maitenus magellánica,** NP: **Nothofagus pumilio**, NA: **Nothofagus antártica,** Cd: **Chiliotrichium diffusum** Bb: **Berberis buxifolia,** fg: **festuca gracillima,** fr: **Festuca rubra,** ab: **Agrostis brachyathora,** aa: **Acaena sericea, bp: Blechnum pennamarina,** sm: **Splagnum magellanicum,** mg: **Marsippospermun grandiflorum,** tu: **Polytrichum alpestre.**

La definición de las clases espectrales correspondientes a las clases informacionales descritas entregaron los siguientes resultados:

Clases espectrales:

Nº	Mínimo	Media	Desv. Estándar	Máximo	Clases Temáticas
1	19	33.4	5.7	60	Bosque1
2	19	34.4	5.6	56	Bosque2
3	23	37.8	5.8	59	Bosque3
4	21	35.5	5.7	59	Bosque4
5	21	35.3	6.6	60	Bosque5
6	22	41.3	7.5	68	Bosque6
7	24	38.7	5.3	56	Bosque7
8	24	38.5	4.9	57	Bosque8
9	25	39.6	5.5	57	Bosque9
10	16	33.1	5.5	56	Bosque10
11	21	32.4	5.0	48	Bosque11
12	23	36.9	5.2	55	Bosque12
13	31	45.4	7.5	74	Bosque13
14	21	37.7	6.8	60	Bosque14
15	14	21.7	3.4	34	Prade1
16	12	18.9	2.4	27	Prade2
17	12	20.2	3.1	33	Prade3
18	13	20.5	3.0	31	Prade4
19	5	30.2	6.1	54	Turba1
20	22	37.7	5.1	67	Turba2
21	16	27.7	5.4	38	Mator1
22	15	34.1	5.6	53	Mator2
23	21	36.9	5.3	55	Mator3

Las clases espectrales indican confusión entre las pertenecientes a una misma formación vegetal, y en el caso de matorral con algunas clases de bosque, especialmente las más heterogéneas o ralas, por lo que el proceso de clasificación se realizó en dos pasos, el primero con la totalidad de las muestras y posteriormente sólo con las correspondiente a la formación de bosque, para esto ultimo se preparó una máscara que se aplicó al segmento textural. En ambos casos la clasificación se realizo considerando 1 desviación estándar, disminuyendo de esta forma la confusión.

Resultados Obtenidos

Un primer análisis visual de la información de la imágenes originales y de textura nos indican que en este segundo caso se tiende a agrupar las áreas de ND similares, presentando una mayor correspondencia con la distribución espacial y una relación con la densidad de los bosques. Este hecho en las clasificaciones digitales (figura 4 y 5) se ve corroborado, identificándose en verde las zonas de bosques de menor regularidad y en café las de mayor regularidad.

La primera clasificación digital, con la totalidad de las muestras (figura 5), separa las tres formaciones vegetales de mayor dominancia en el área que son los bosques, los matorrales leñosos bajos y las praderas, incluyéndose en esta formación las turbas (no son diferenciables de la pradera), resultados similares son descritos por estudios realizados sobre imágenes de ERS (Bijker, 1996; Dominic Sacales et al, 1996).

En la segunda clasificación al interior de los bosques, considerando las distintas muestras de inició de primavera. Para esta comunicación se trabajo específicamente con la correspondiente a la del 12 de Febrero de 1997, tomada a las 9.14 h. Una segunda etapa consistió en la corrección radiométrica de los datos y posteriormente la corrección geométrica, en este caso se utilizó un modelo de elevación digital (DEM) y el modelo orbital, más puntos de control (GCP) identificados en la cartografía base, el algoritmo de asignación utilizado fue el vecino más cercano.

Al resultado obtenido se aplico el filtro FGAMMA con una matriz de 5 x 5, situación intermedia a la encontrada como óptima por Wooding et al (1996) con el fin de disminuir el moteado (speckel). En el paso siguiente se obtuvo el segmento de textura (homogeneidad), el cual fue utilizado para obtener mediante clasificación digital (maxclas) supervisada la separación de las formaciones vegetacionales.

En el proceso seguido, la etapa de terreno se realizó en forma simultánea a la toma de la imagen. En ella se identificó y seleccionó las parcelas de seguimiento, representativas de cada clase temática (bosques aclarados o ralos, renovales, sobremaduros, cosechas y zonas quemadas) (figura 2 y 3), las que se habían identificado previamente en base a los antecedentes cartográficos recopilados. Las clases temáticas identificadas fueron debidamente digitalizadas y utilizadas en la etapa de clasificación. Las clases son las siguientes:

Clases de bosque:

No.	Especie	Estructura	Densidad	Sotobosque	Tapiz	Pendiente
1	DW,NB,MM	Adulto	Denso	Semidenso	Herbáceo	5 a 10%
2	NB,NP,DW	Adulto	Semidenso	Semidenso	Hojarasca	5 a 10%
3	NP,NB	Renoval	Denso	Ralo	(cosecha)	5 a 15%
4	NB, NP	Adulto	Semidenso	Ralo	Hierba y troncos	5 a 10%
5	NA	Adulto	Ralo	Denso	Hierbas	5 a10%
6	NP	Renoval	Denso	Ralo	Hierbas	> 30%
7	NP	Adulto	Denso	Ralo	Troncos	>30%
8	NP	Sobremaduro	Ralo	Denso	Hierbas	>30%
9	NP,NA	Sobremaduro	Ralo	Semidenso	Hierba y troncos	5 a 10%
10	NP,NA	Adulto	Semidenso	Ralo	Hierbas	5 a 10%
11	NA,NP	Adulto	Denso	Ralo	Hojarasca	>30%
12	NA,NP	Adulto	Ralo	Semidenso	Hierba	5 a 10%
13	NA	Sobremaduro	Ralo	Denso	Hierba	5 a 10%
14	NP	Adulto	Ralo	Semidenso	(incendiado)	Varias

Clases de matorral:

No.	Especie	Densidad	Tapiz	Pendiente
15	Cd	Denso	Hierbas	5 a 10%
16	Cd	Semidenso	Hierbas	10 a 25%
17	Cd,Bb	Ralo	Hierbas	5 a 10%

Clases de Pradera

No.	Especie dominante	Densidad	Tapiz	Pendiente
18	fg,fr,ab	densa	hierbas	5 a 10%
19	fg, ab	rala	suelo	10 a 20 %
20	aa,bp	semidensa	hierbas	5 a 10%
21	fg,fr,ab	rala	suelo	5 a 10%

Clases de Turba:

No.	Especie dominante	Densidad	Tapiz	Pendiente
22	sm,mg	densa		5 a 10%
23	tu,sm	densa		5 a 10%

estos, la separación se produce sólo a nivel de la mayor o menor densidad o regularidad de los bosques, no importando el origen (especie, sobremadurez o intervención humana), así por ejemplo quedan clasificados en un mismo grupo la muestra de bosque incendiado, la de intervención sílvicola (cosecha) y los bosques ralos por sobremadurez. En otro grupo separa los bosques de densidades regulares independiente de la composición.

Finalmente, se evidencia también que la clasificación de los bosques es independiente de la topografía (figura 4), en esta se identifican dos situaciones similares en pendientes diferentes.

Conclusiones.

De lo expuesto se concluye lo siguiente:
a) Los datos de radar son independiente de la actividad fotosintética de los bosques, al igual que lo son de la composición florística de estos.

b) Los datos se encuentran en directa relación con la densidad y uniformidad de los bosques, partiendo de este hecho es posible inferir que si se parte de una situación inicial conocida es posible identificar los cambios por intervención humana, como incendios y cosechas,en un periodo de tiempo dado.

c) La densidad y composición del sotobosque no modifica la condición de alteración o discontinuidad de los bosques, es el caso de los bosques de ñirre que se caracterizan por ser ralos y con abundante sotobosque, clasificándose de igual forma en el grupo de los bosques discontinuos (figura 4).

d) En el caso de los renovales densos, estos quedaron clasificados en el grupo de los bosques homogéneos.

e) La textura y en especial el algoritmo de homogeneidad utilizado en este trabajo constituye una buena herramienta para separar los grupos de bosques según la heterogeneidad o continuidad que presentan y en consecuencia para realizar seguimiento de las alteraciones en el tiempo.

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Figura 2: Terreno

Figura 3: terreno

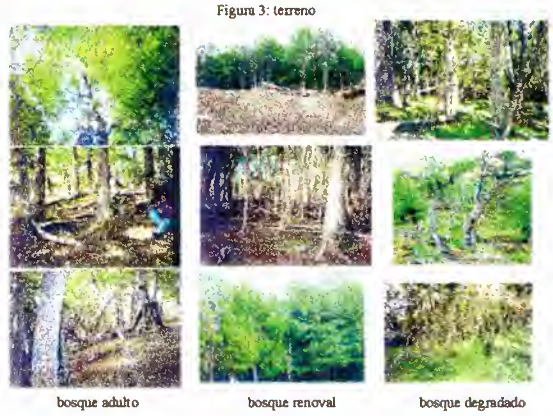
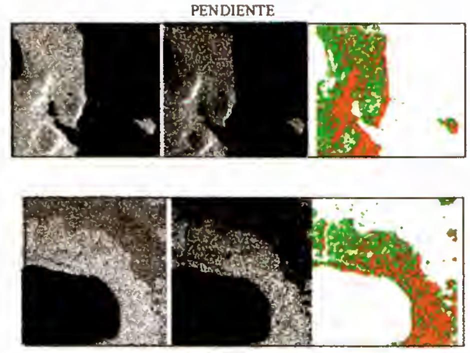


Figura 4

TIERRA DEL FUEGO. BOSQUE NATIVO

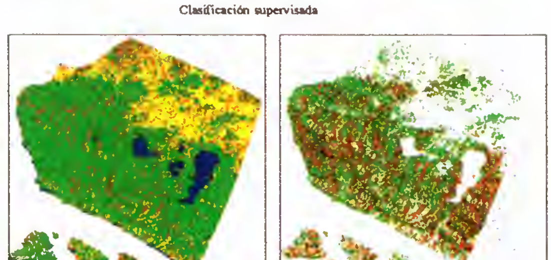
PENDIENTE



RADAR ORIGINAL   RADAR TEX-HOMOG.   CLASIFICACION -MAX

Figura 5

Clasificación supervisada



Formaciones vegetales   Clasificación de bosque

LAND DEGRADATION STATUS IN THE PATAGONIAN REGION: DESERTIFICATION CATEGORIES

Héctor F. del Valle

Centro Nacional Patagónico (CENPAT). CONICET.
CC 128. (9120) Puerto Madryn (Chubut). Argentina.
Fax: 54-965-73680 - E-mail: delvalle@cenpat.edu.ar

ABSTRACT

In 1996, the first survey of desertification status that encompassed a wide range of degradation forms was carried out in Patagonia (Argentina). Delineations on the maps of desertification status usually are combinations of different desertification categories. However, in the Patagonian region these categories were not described until this approach. The objectives of this research were: (i) to assess the location, extent, and severity of various desertification categories, in the Patagonian arid, semiarid and subhumid region of Argentina, (ii) to create a methodology to accurately determine the distribution of land degradation from satellite imagery, and (iii) to develop a map of desertification categories with recommendations for decision-makers. Data were obtained from NOAA/AVHRR LAC mosaic, existing data, and intensive field observations. According to the degree of land degradation, the following desertification categories were defined: six for the slight status, four for the moderate status, and three for each one of the status moderate to severe, severe and very severe.

1. INTRODUCTION

Land degradation has been subject of concern in Patagonia (Argentina) since the early to mid-1900s. Desertification advance is the main socio-ecological problem in arid, semiarid and subhumid areas. However, soil erosion and degradation in humid areas have almost similar effects, leading to the decline in the productive capacity of an ecosystem.

By being the soil erosion a dynamic process, the study and its cartography involved certain difficulties in Patagonia, mainly for the lack of thematic basic maps and places of difficult access. For this reason, pioneers (Monteith et al., 1969; Movia, 1984) in methodologies of intensive use of aerial photos and satellital images interpretation, demonstrated their utility in the region. The first systematic survey of soils that included characteristics of soil degradation was carried out in Argentina (SAGyP-INTA, 1990). However, the results of this study for Patagonia (mostly in Río Negro, Chubut and Santa Cruz Provinces) were obtained from remote sensing and existing data, rather than from intensive field observations. The comparisons among the surveys are impossible owing to a lack of consistent criteria for the assessment of type and severity of land degradation. Although a first document in Patagonian arid, semiarid and subhumid region which ranks, delimits and defines orders of magnitude of environmental damage (desertification process), was reported by del Valle et al. (1996).

Delineations on the maps of desertification status usually are combinations of different desertification categories. However, in the Patagonian region these categories were not described until this approach. The objectives of this research were: (i) to assess the location, extent, and severity of various desertification categories, in the Patagonian arid, semiarid and subhumid region of Argentina, (ii) to create a methodology to determine accurately the distribution of land degradation from satellite imagery, and (iii) to develop a map of desertification categories with recommendations for decision-makers.

2. METHODOLOGY

2.1 Study region and environmental characteristics

The vast territory in southern Argentina known as Patagonia (Figure 1) extends from about 37° to 55° S, or south of the Colorado River. This region includes the Provinces of Neuquén, Río Negro, Chubut, Santa Cruz and Tierra del Fuego. It covers an area of about 780,000 km^2, which represents 28% of all continental Argentina. The humid Andean region is not considered in this study, except in small portions within the Tierra del Fuego archipelago.

Patagonian climate is dry, cold and windy in most of the region. The Andean and Sub-Andean regions are identified by strong west to east precipitation gradients (> 3,000 mm to 300 mm). In the Extra-Andean region, precipitation is concentrated in winter and declines from 300 mm in the west to less than 150 mm in the east, increasing slowly towards the Atlantic coast.

Along the gradient of decreasing precipitation, starting from the subantarctic forest border, grass steppes give way to shrub-grass steppes and those to deserts. The region studied exhibits quite a rich spectrum of vegetation types, from real desert to shrub or grass steppe. An approximation of the different physiognomic

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

units present, given by Soriano (1983), are: 45% shrub desert, 30% shrub-grass semi-desert, 20% grass steppe and 5% water surface and minor types like meadows.

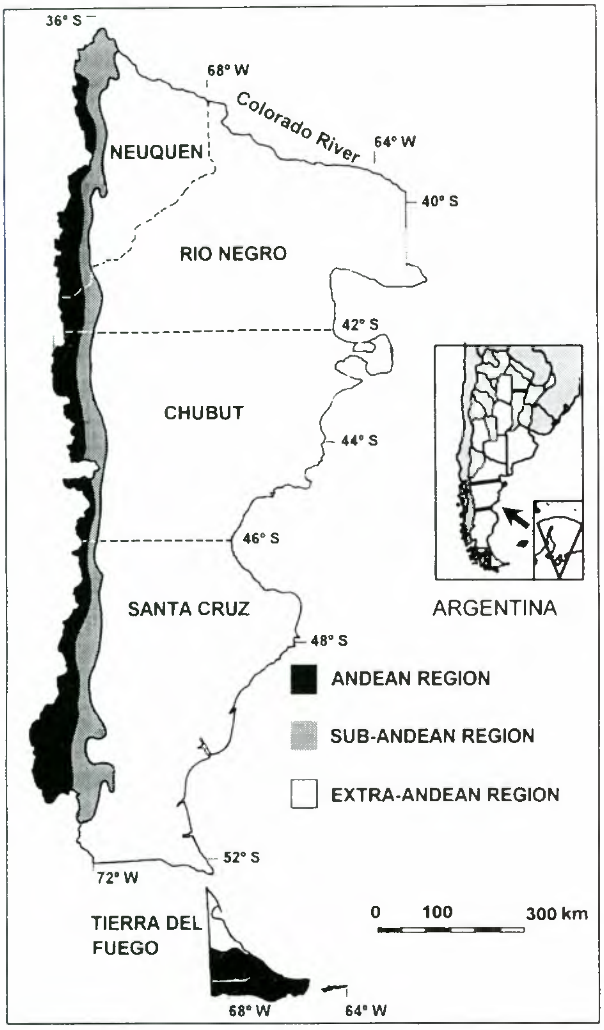


Figure 1. Study region.

2.2 Land degradation status

The methodological procedure to obtain and evaluate information on degradation status - aided with digital processing methods - followed the guidelines set forth in LUDEPA (1995) and in del Valle et al. (1996). Status can be considered the state or condition of an indicator (FAO/UNEP, 1984). Five status of desertification were adequate to show intensity: slight, moderate, moderate to severe, severe and very severe.

2.3 Data sources

Data included a mosaic of NOAA/AVHRR LAC (del Valle et al., 1996) as most suitable for this study, existing data, and intensive field observations. In addition to the AVHRR imagery, scenes of Landsat-MSS (LUDEPA, 1995) were used as training samples. Data directly recorded included degradation of soil and of vegetative cover. An additional 400 sample points at unequal intersections of the Patagonian Map Grid, obtained from the Atlas of the Soils of Argentina (SAGyP-INTA, 1990), were also collected. A sample point refers to the area within a 49-km^2 box (7x7 LAC pixels).

2.4 Processing of remote sensed data

Image processing analysis was performed using ERDAS 7.5 software (ERDAS, 1991). Prior to the classifications and enhancements, masks were created for each desertification status identified by del Valle et al. (1996). This step was peformed using the original file and the broadly classified file as input, to create new files containing the original data for one broad class. More specific classes could then be derived using supervised and unsupervised training.

A combination of supervised and unsupervised classification procedures on bands 1 and 2 was used The unsupervised classification was performed using ISODATA clustering, with a 99 percent threshold. First, 15 subclasses, preliminarily defined like landform types, were identified for each desertification status. These subclasses were examined one at a time, and contrasted with ancillary map information. Since the subclasses obtained at first were not always interpreted, it was necessary to test them qualitatively. Unimodal histograms of regular distribution with none or few intersections with other subclasses, were used whenever possible. According to this criterion, it was necessary in some cases to eliminate subclasses or to combine several into only one.

The supervised classification was performed using MAXCLAS algorithm (classification with signatures). The assignment of pixels to the classes thus obtained was carried out by using the maximum likelihood method. Once the classification was over, surface categories were related to the classes that were automatically generated. Each one of the classes was chromatically codified according to its increasing severity. Accuracy of each classification was expressed as an error matrix.

3. RESULTS AND DISCUSSION

3.1 Slight desertification categories

Figure 2 shows the location, extent, and severity of six slight desertification categories. Class 1 (blue) represents the irrigated lands, meadows and grass meadows (river-valley landforms). Irrigation is important in the northern plains (Limay, Colorado and Negro Rivers), and in small valleys in the southeast. Class 2 (greenpine) is characterized by grass meadows with reduction of the vegetative cover, and the exposure of the soil to degradation processes. Class 3 (greensea) is identified by the old glacial landscape associated with fluvial environments and high mountain slope (semiarid and subhumid areas). Classes 4, 5 and 6 (yellow, orange and red, respectively), represent the arid and semiarid rangelands (plain and border plateaus, small valleys, terraces and complexes of footslopes and backslopes).

The results presented in Table 1, show the spectral characteristics and the order of land degradation processes for each slight desertification category. Salinization & sodication (class 1) of irrigated lands has caused trouble for decades. Salty irrigation water and soils are the source of the trouble.

Table 1. Spectral and spatial characteristics of slight desertification categories

Signature *	Data file values Mean ± S.D. X1	X2	Min. Max. X2		Order or priority of processes **
1 (blue)	68 ± 10	113 ± 8	104	210	SWECV
2 (greenpine)	159 ± 15	135 ± 13	104	190	VSW
3 (greensea)	27 ± 4	87 ± 6	77	111	VWE
4 (yellow)	50 ± 5	87 ± 6	76	107	VEWC
5 (orange)	38 ± 5	62 ± 4	35	69	VEWC
6 (red)	16 ± 7	37 ± 7	9	57	VWEC

* See Figure 2; S.D.: standard deviation; X1: Band 1, X2: Band 2; Min.: minimum value, Max.: maximum value; ** V: degradation of vegetative cover, W: water erosion, E: wind erosion, S: salinization & alkalinization, C: soil crusting & compaction.

Figure 3 shows the location, extent, and severity of four moderate desertification categories. Class 1 (greensea) represents several geomorphic environments linked mostly to the vulnerability of the land (climate, relief and soil). The representative landforms of this class are mountain upland, upland plain, intermontane basin and border plateaus. In class 2 (yellow), the dominant desertification processes are vegetation degradation followed by wind erosion (mountain upland, tablelands of basalt and of gravel, plain and border plateaus, and upland plain). Classes 3 (orange) and 4 (red) present degradation of vegetative cover and water erosion as the major causes of desertification (plain and border plateaus, old glacial landscape, litoral marine environments, and upland plains). Generally, the last three classes comprise also the processes, which have provoked a subsurface cementation or an outcrop of subsurface crusting. Table 2 shows the spectral characteristics and the order of land degradation processes for each moderate desertification category.

Table 2. Spectral and spatial characteristics of moderate desertification categories

Signature *	Data file values Mean ± S.D. X1	X2	Min. Max. X2		Order or priority of processes **
1 (greensea)	43 ± 4	80 ± 3	73	87	VWE
2 (yellow)	61 ± 4	74 ± 7	38	101	VEWCS
3 (orange)	29 ± 4	67 ± 4	60	79	VWECS
4 (red)	37 ± 3	48 ± 3	17	52	VWECS

* See Figure 3; S.D.: standard deviation; X1: Band 1, X2: Band 2; Min.: minimum value, Max.: maximum value; ** V: degradation of vegetative cover, W: water erosion, E: wind erosion, S: salinization & alkalinization, C: soil crusting & compaction.

Figure 4 shows the location, extent, and severity of three moderate to severe desertification categories. The most prevalent forms of degradation in classes 1 (yellow) and 2 (orange) are sheetwash, rill and gully erosion (upland plains, plain plateaus, and exhumed and covered landscapes). This erosion is taking place where areas are cleared mainly by overgrazing and overcollection of fuelwood. Class 3 (red) represent a high diversity of geomorphic environments (mountain upland, plain and border plateaus, old glacial landscape, exhumed and covered landscapes, coastal deserts, tablelands of basalt and of gravel, river-valley landforms, and intermontane basin). The only explanation for land deterioration and moderate to severe soil erosion in these landscapes is a break in plant succession, due to human activities and/or to natural factors. Combined erosion (water & wind) is also present in all categories.

Table 3 shows the spectral characteristics and the order of land degradation processes, for each moderate desertification category.

Table 3. Spectral and spatial characteristics of moderate to severe desertification categories

Signature *	Data file values Mean ± S.D. X1	X2	Min. Max. X2		Order or priority of processes **
1 (yellow)	66 ± 5	82 ± 2	65	97	VWECS
2 (orange)	80 ± 5	99 ± 5	72	210	VWECS
3 (red)	42 ± 5	63 ± 10	5	109	VWECS

* See Figure 4; S.D.: standard deviation; X1: Band 1, X2: Band 2; Min.: minimum value, Max.: maximum value; ** V: degradation of vegetative cover, W: water erosion, E: wind erosion, S: salinization & alkalinization, C: soil crusting & compaction.

Figure 5 shows the location, extent, and severity of three extreme desertification categories. Class 1 (yellow) indicates loss of canopy cover and decline in range conditions (plain and border plateaus, exhumed and covered landscapes, and intermontane basin). Class 2 (orange) exhibits land degradation by displacement of soil material, principally by water and wind (high mountain slope, tablelands of basalt and of gravel, plain and border plateaus, and intermontane basin). Class 3 (red) shows subsoil presence (water erosion), surface affected by gullies, and characteristic groups growing on skeletal soils (mountain upland and coastal desert). Figure 6 shows the location, extent, and severity of three very extreme desertification categories. Class 1 (yellow) characterizes the presence of rock outcrops, desert pavement, and mostly winds erosion forms. Gully erosion, mass movement and wind erosion (deflation and active dunes) are relationed with Class 2 (orange). Class 3 (red) represents particularly salt flats without plants (playa lake). Tables 4 and 5 show the spectral characteristics and the order of land degradation processes, for each extreme and very extreme desertification category.

Table 4. Spectral and spatial characteristics of severe desertification categories

Signature *	Data file values Mean ± S.D. X1	X2	Min. Max. X2		Order or priority of processes **
1 (yellow)	77 ± 4	90 ± 5	62	104	VWECS
2 (orange)	52 ± 5	67 ± 7	33	85	WECSV
3 (red)	27 ± 6	46 ± 13	2	62	WECSV

Table 5. Spectral and spatial characteristics of very severe desertification categories

Signature *	Data file values Mean ± S.D. X1	X2	Min. Max. X2		Order or priority of processes **
1 (yellow)	59 ± 4	80 ± 9	29	111	EWCSV
2 (orange)	91 ± 3	105 ± 7	70	136	WECSV
3 (red)	125 ± 10	132 ± 8	87	175	SWECV

* See Figure 6; S.D.: standard deviation; X1: Band 1, X2: Band 2; Min.: minimum value, Max.: maximum value; ** V: degradation of vegetative cover, W: water erosion, E: wind erosion, S: salinization & alkalinization, C: soil crusting & compaction.

4. CONCLUSIONS

The maps show the areas where problems exist. The survey has provided basic data will allow regional land managers to make better decisions at a broad scale about environmental damage. The use of dry rangelands of this region should continue in the future, but conservation strategies have to be improved.

5. ACKNOWLEDGMENTS

I want to thank Lic. M.C. Dentoni for the critical revision of this manuscript.

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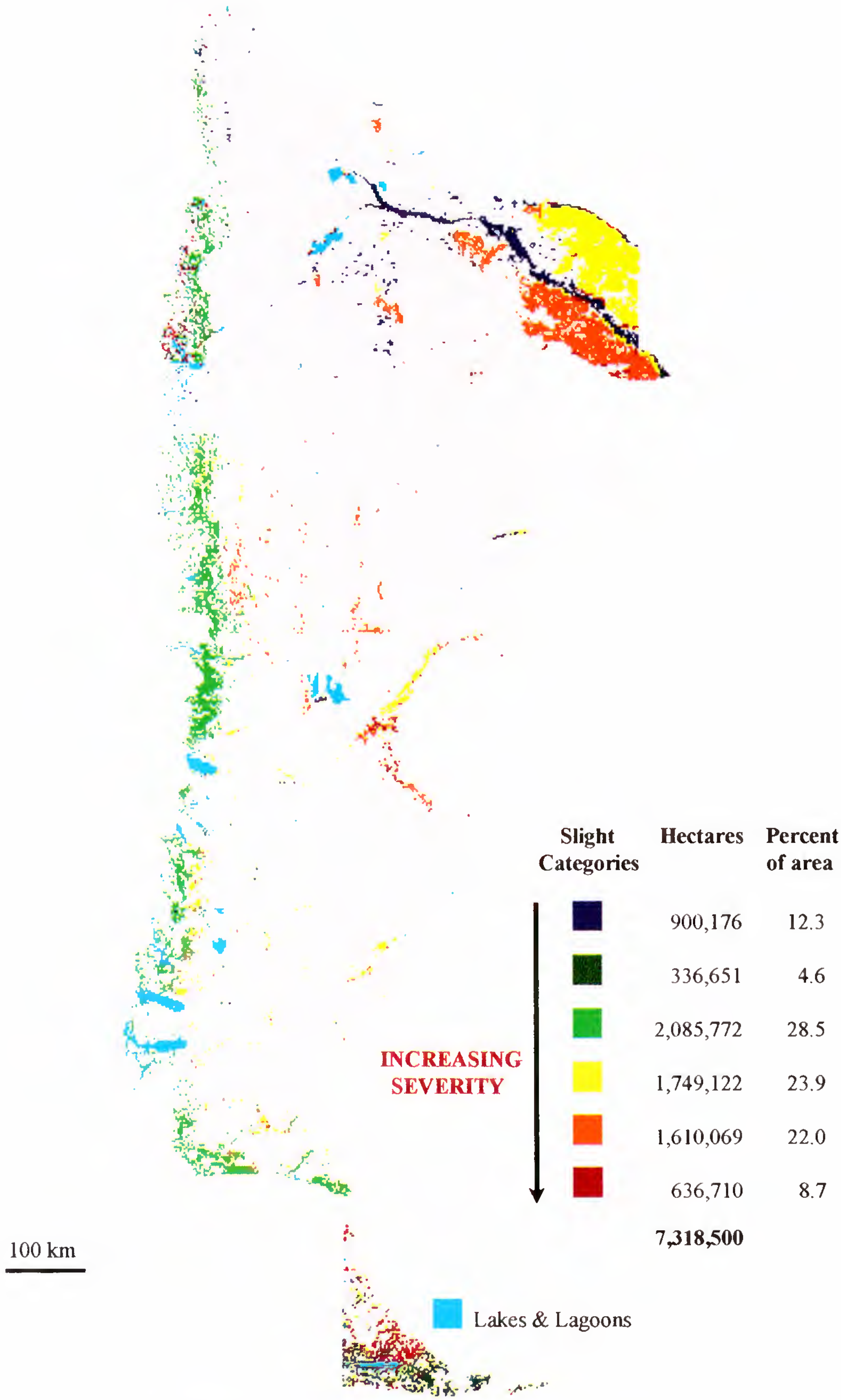


Figure 2. Slight desertification categories (hectares and percent of area).

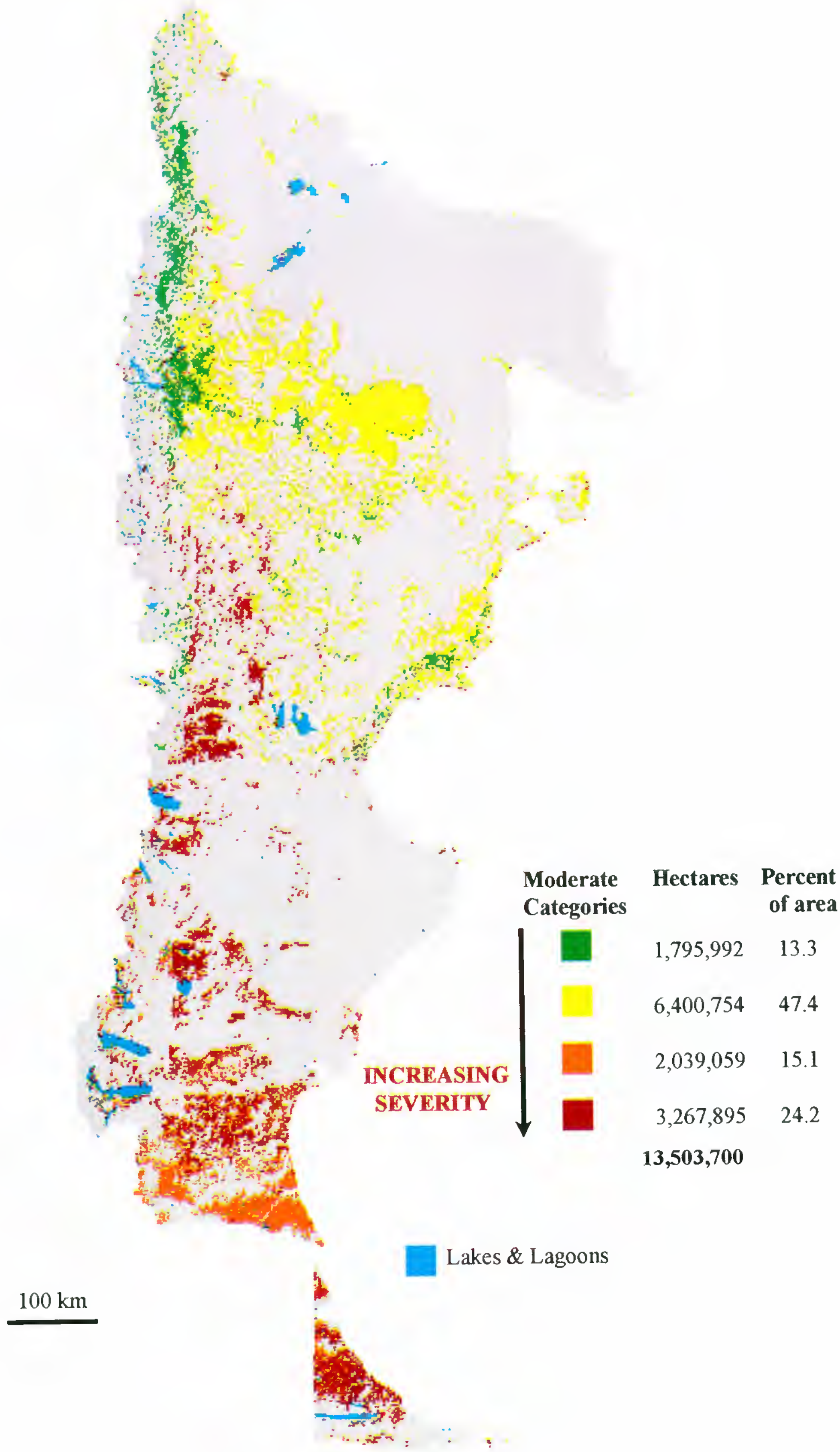


Figure 3. Moderate desertification categories (hectares and percent of area).

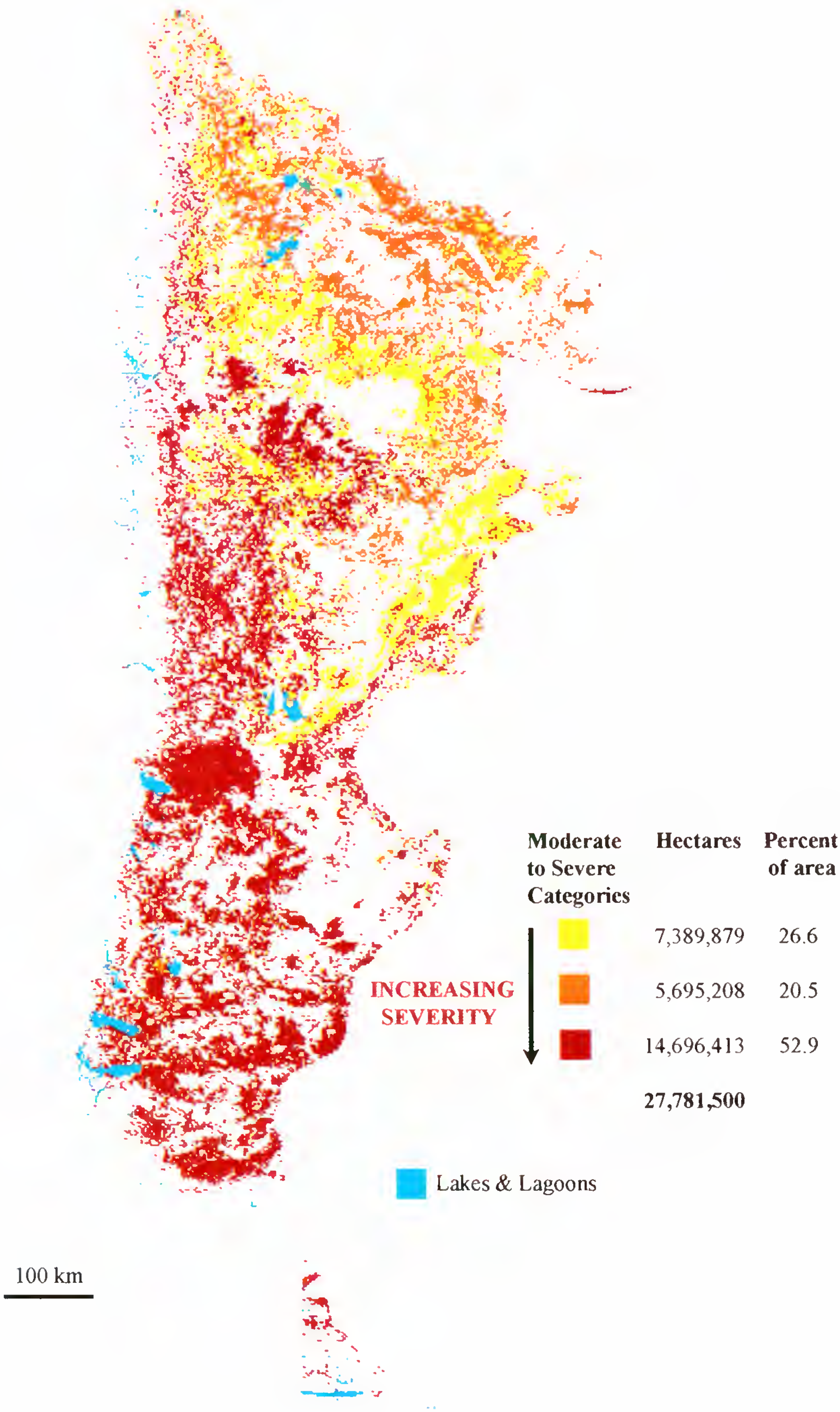


Figure 4. Moderate to severe desertification categories (hectares and percent of area).

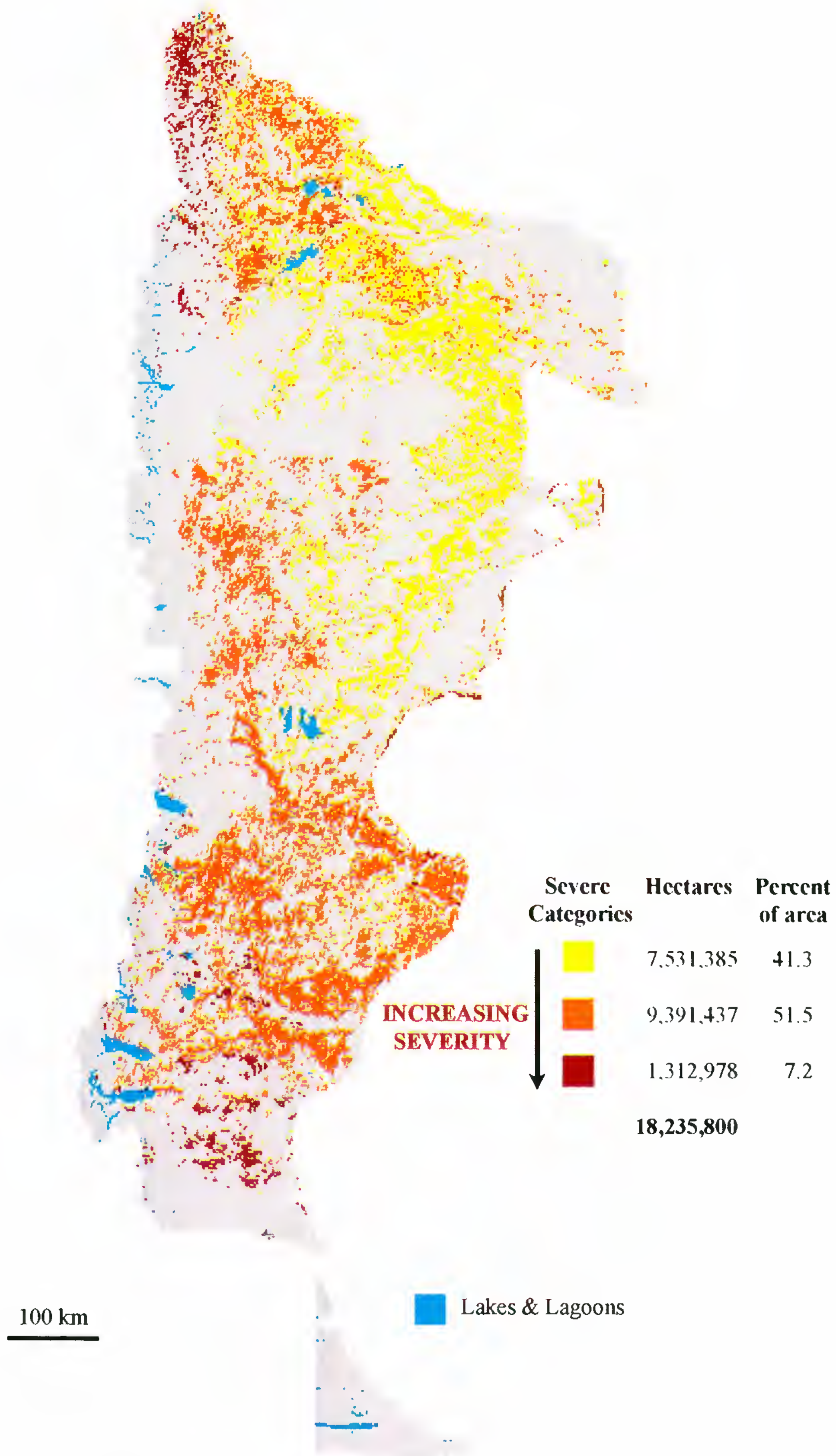


Figure 5. Severe desertification categories (hectares and percent of area).

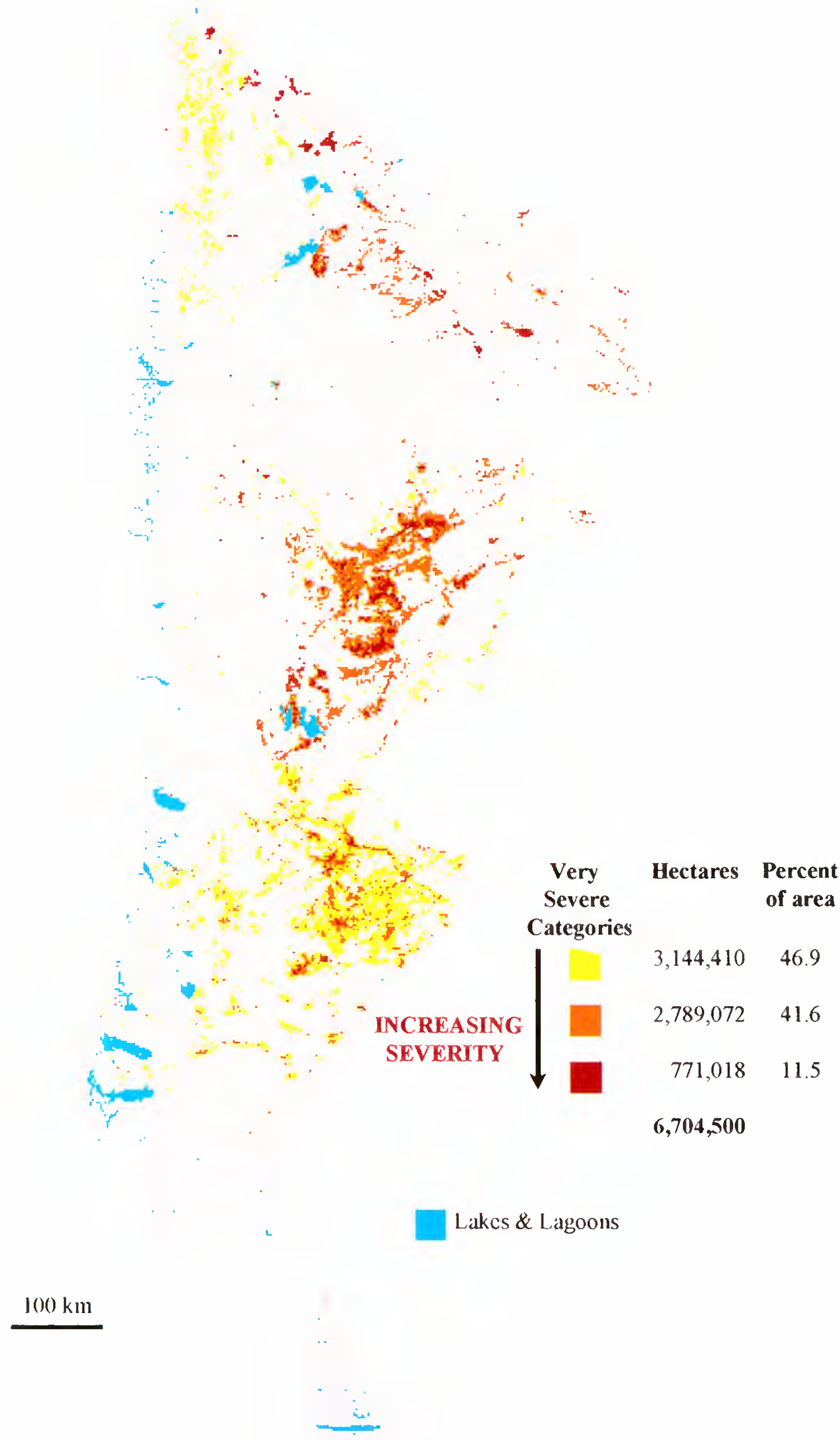


Figure 6. Very severe desertification categories (hectares and percent of area).

QUANTIFICATION OF SOIL MOISTURE AND BIOMASS OF NATIVE FORAGES IN THE NORTHERN BOLIVIAN ALTIPLANO THROUGH C-BAND SAR DATA

A02 -ESA PROJECT

S. MOREAU, T. LE TOAN, B. ROSICH TELL & R. QUIROZ
ABTEMA - CESBIO - ESA - CONDESAN

INTRODUCTION

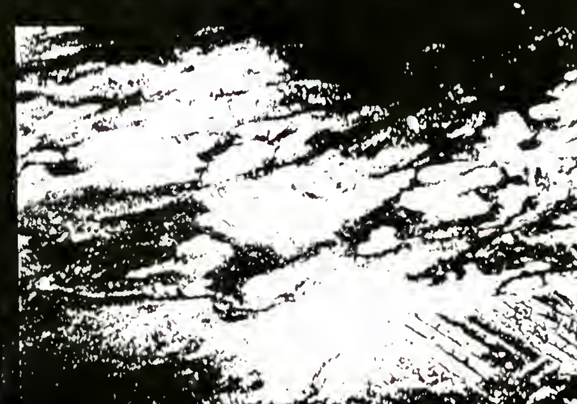
LIVESTOCK. PRODUCTION (BEEF,DAIRY CATTLE & CAMELIDS) RELIES MAINLY ON UTILIZATION OF NATIVE FORAGES (TOTORA & BOFEDAL)

ALTIPLANO, WITH 46% OF THE BOLIVIAN POPULATION, HAS AN ECONOMY HIGHLY DEPENDENT UPON CROP AND LIVESTOCK

A 2 TO 3 FOLD INCREASE IN THE DEMAND FOR THESE FORAGES IS REQUIRED TO SATISFY ANIMALS' DRY MATTER REQUIREMENT

HIGHER DEMAND ENFORCE A MORE PRECISE MANAGEMENT OF THIS NATURAL RESOURCE TO AVOID ITS DESTRUCTION

BETTER KNOWLEDGE OF SPATIAL AN TEMPORAL PATTERN OF PRODUCCTION & BIOMASS YIELDS ARE NEEDED TO GUARANTEE A SUSTAINABLE USE OF THESE FORAGES



Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

INTRODUCTION

FORAGES ARE HIGLY DEPENDENT ON SOIL HUMIDITY, A DETERMINANT FACTOR IN CROP PRODUCTION

INFORMATION ON SOIL HUMIDITY IS CRITICAL TO EVALUATE DROUGHT RISKS WHICH AFFECT FORAGE CROP PRODUCTION

IT IS NECESSARY, AS WELL, TO OPTIMIZE THE DETERMINATION OF VOLUMES OF AVAILABLE WATER FROM THE TITICACA LAKE FOR IRRIGATION PURPOSES, KNOWING THAT MODELS USED TODAY BY THE BOLIVIAN-PERUVIAN REGULATORY PLAN OF THE TITICACA WATERSHED DO NOT CONSIDER THAT FACTOR

OBJECTIVES

STUDY THE PATTERN OF ANNUAL VARIATION OF TOTORA (MACROPHYTE) & BOFEDAL

MAP AND MONITOR SPATIALLY NATIVE FORAGES CRITICAL FOR LIVESTOCK

QUANTIFY THROUGH SATELLITE DATA TOTORA AND BOFEDAL BIOMASS & - SOIL HUMIDITY

COMPARE VV ERS SAR AND HH RADARSAT POLARIZATIONS, AS WELL AS MICROWAVE AND OPTICAL NOAA-AVHRR DATA IN THE QUANTITATIVE STUDY

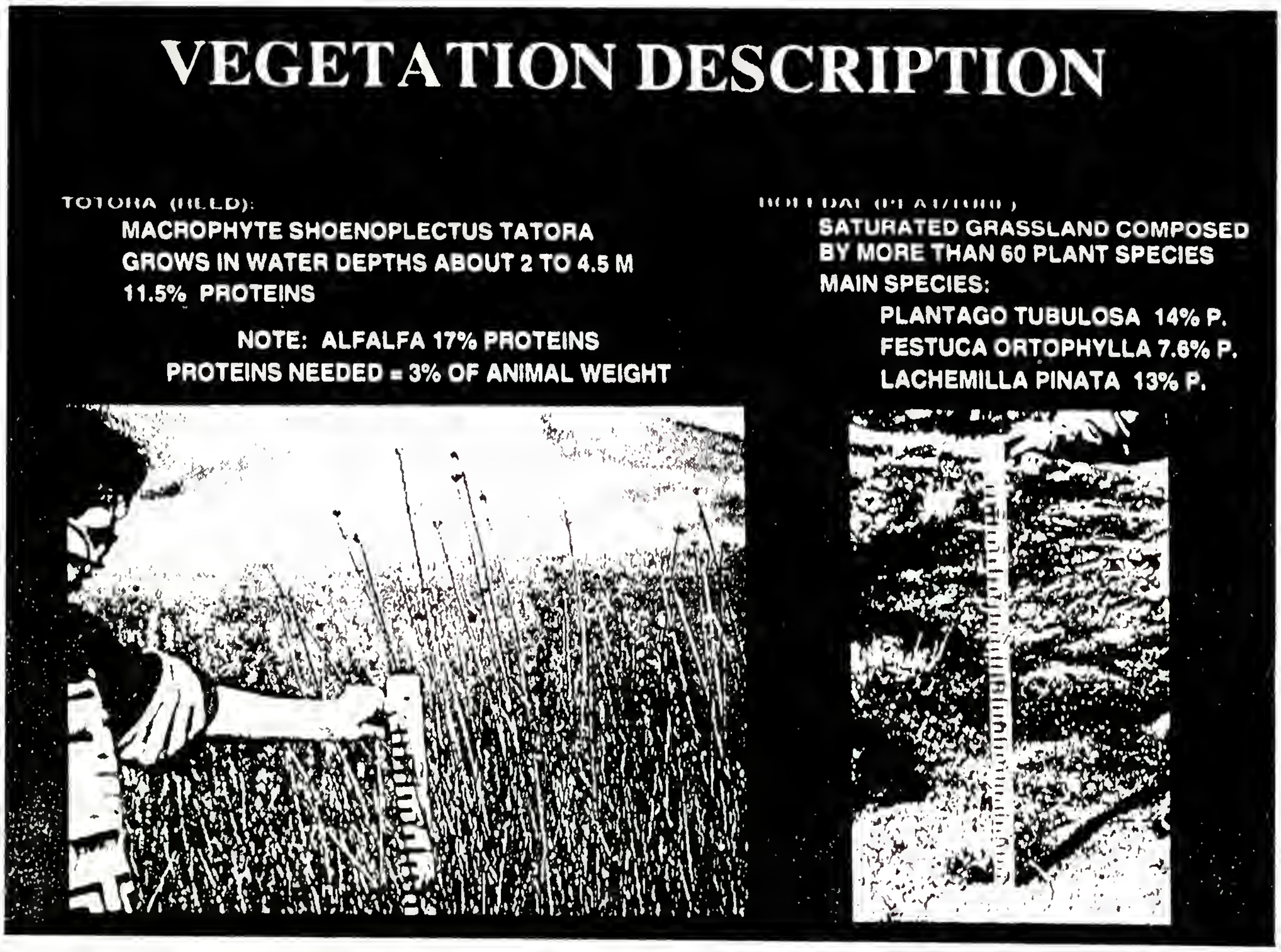
LOCATION & SITE DESCRIPTION

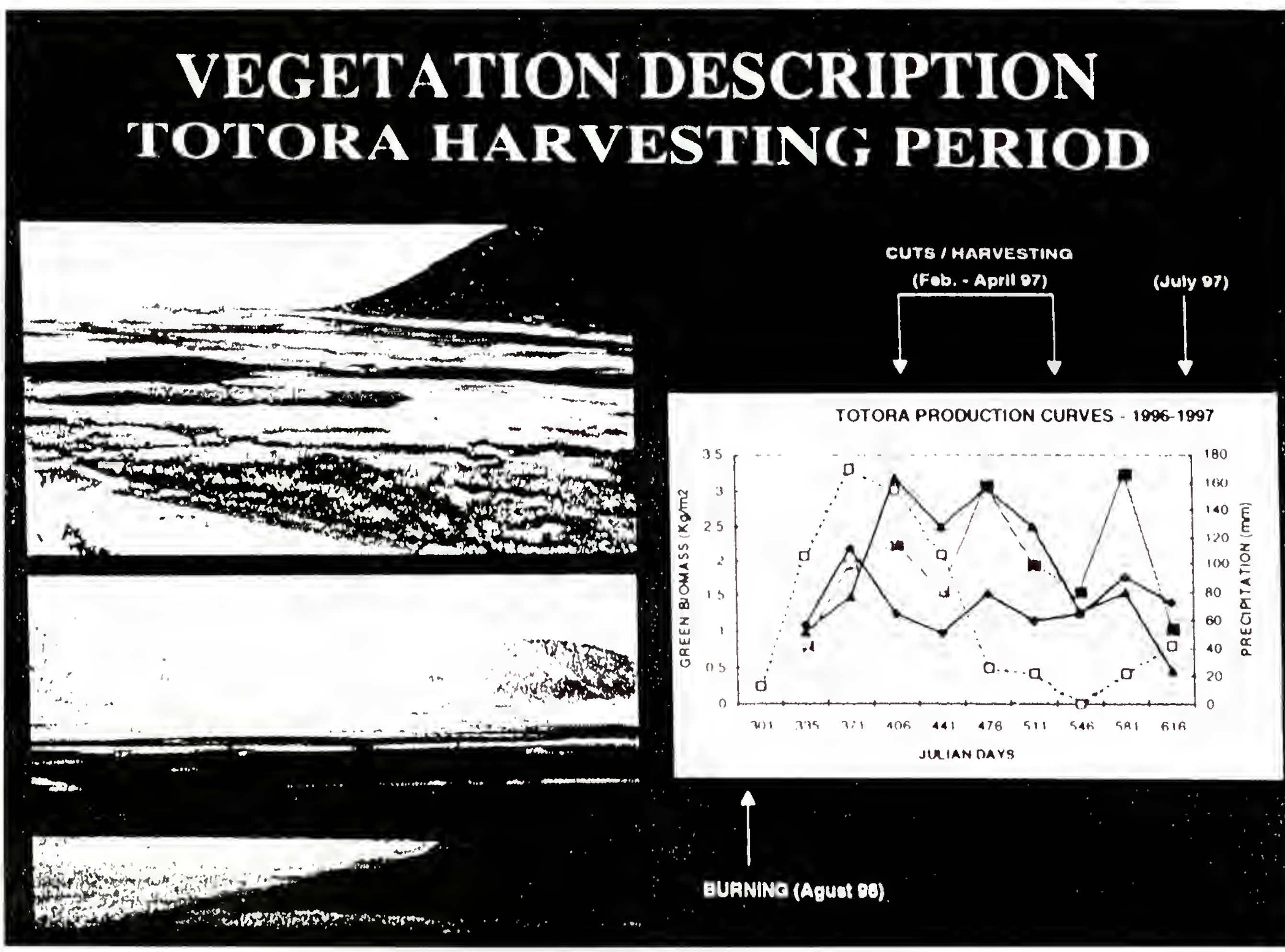
BETWEEN 16° AND 17° LATITUDE SOUTH IN THE NORTHERN BOLIVIAN ALTIPLANO AT ALTITUDES FROM 3800 AND 5000 METERS

BETWEEN THE EASTERN SHORE OF THE SMALL TITICACA TROPICAL LAKE AND THE EASTERN CORDILLERA

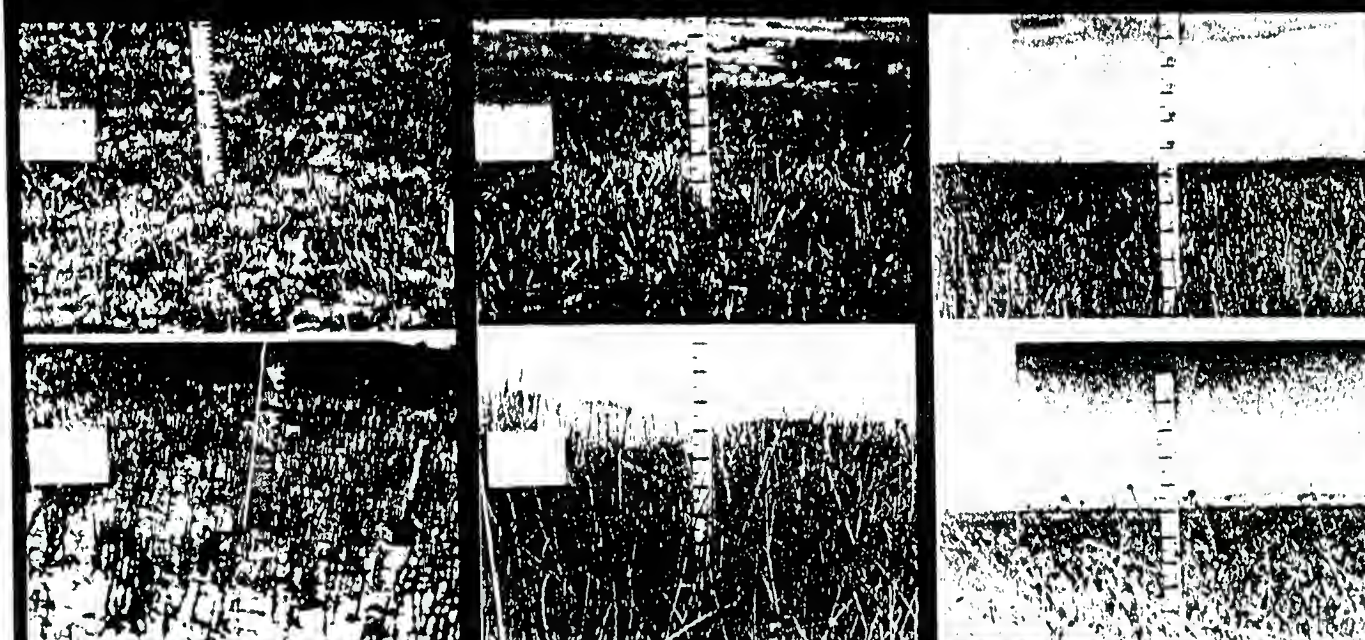
CLIMATE: SEMIARID WITH 700 mm OF PRECIPITATION CONCENTRATED BETWEEN NOVEMBER & MARCH

PRINCIPAL PRODUCTION: BEEF / DAIRY CATTLE & POTATOES, QUINUA, BEANS, ALFALFA, OCA ..


VEGETATION DESCRIPTION
MACROPHYTE SHOENOPLECTUS TATORA
GROWS IN WATER DEPTHS ABOUT 2 TO 4.5 M
11.5% PROTEINS
NOTE: ALFALFA 17% PROTEINS
PROTEINS NEEDED = 3% OF ANIMAL WEIGHT
SATURATED GRASSLAND COMPOSED BY MORE THAN 60 PLANT SPECIES
MAIN SPECIES:
PLANTAGO TUBULOSA 14% P.
FESTUCA ORTOPHYLLA 7.6% P.
LACHEMILLA PINATA 13% P.


VEGETATION DESCRIPTION
TOTORA HARVESTING PERIOD
CUTS / HARVESTING
(Feb. - April 97)
(July 97)
TOTORA PRODUCTION CURVES - 1996-1997
GREEN BIOMASS (Kg/m2
PRECIPITATION (mm)
JULIAN DAYS
406
441
476
616
BURNING (Agust 96)

VEGETATION DESCRIPTION
TOTORA ANNUAL VARIATION



VEGETATION DESCRIPTION
BOFEDAL ANNUAL VARIATION

DATA ACQUISITION

SATELLITE DATA

DATE OF SOIL HUMIDITY MEASUREMENTS	AVHRR DATA ACQUIRED	RADARSAT RECEIVED AT ABTEMA	ERS TRACK	ORBIT	STATE OF ACQUISITION	RECEIVED FROM ESA AT ABTEMA
			[illegible]	[illegible]	YES	
[illegible] 07 96				[illegible]	NO	
[illegible] 08 96				[illegible]	YES	YES
21 [illegible] 96				[illegible]	NO	
[illegible] 10 96				[illegible]	YES	YES
[illegible]				[illegible]	YES	YES
[illegible] 01 97	[illegible] 01 97			[illegible]	YES	YES
[illegible] 02 97		[illegible] 97		[illegible]	YES	
17 [illegible] 97		[illegible] 97		[illegible]	YES	YES
21 04 97		[illegible] 04 97		[illegible]	YES	YES
[illegible] 05 97	[illegible] 05 97			[illegible]	YES	
[illegible] 97	07 07 97			[illegible]	YES	
[illegible] 97	[illegible] 97	[illegible] 97		[illegible]		
[illegible] 97	[illegible] 97					
[illegible] 97	[illegible] 97					
17 [illegible] 97						
[illegible] 97						

WEATHER DATA

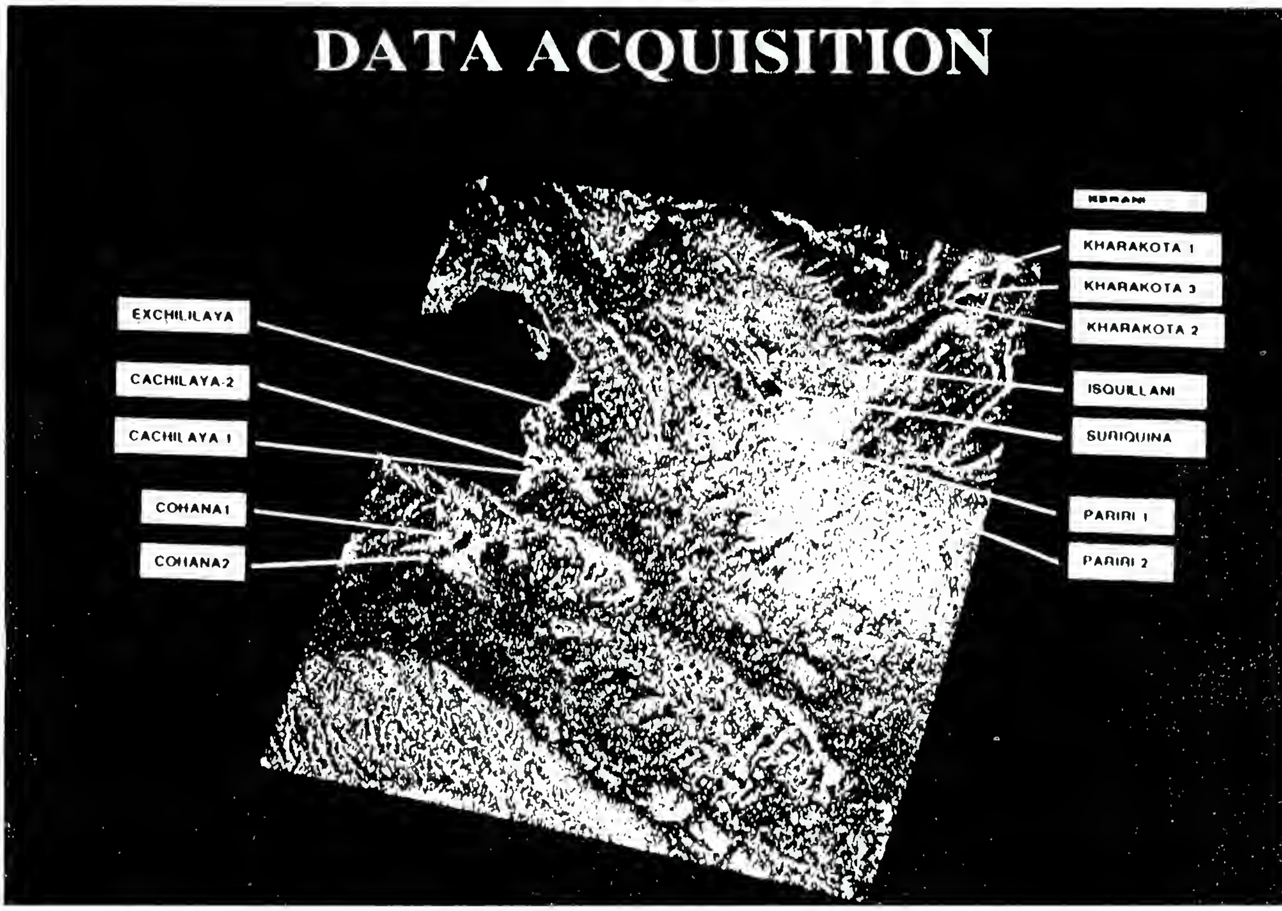
- FROM 4 METEOROLOGICAL STATIONS (PENAS, BATALLAS, HICHU KHOTA, CHIRAPACA)
- 3 DAYS BEFORE & DAY DURING SATELLITE PASS + ON MONTHLY BASIS

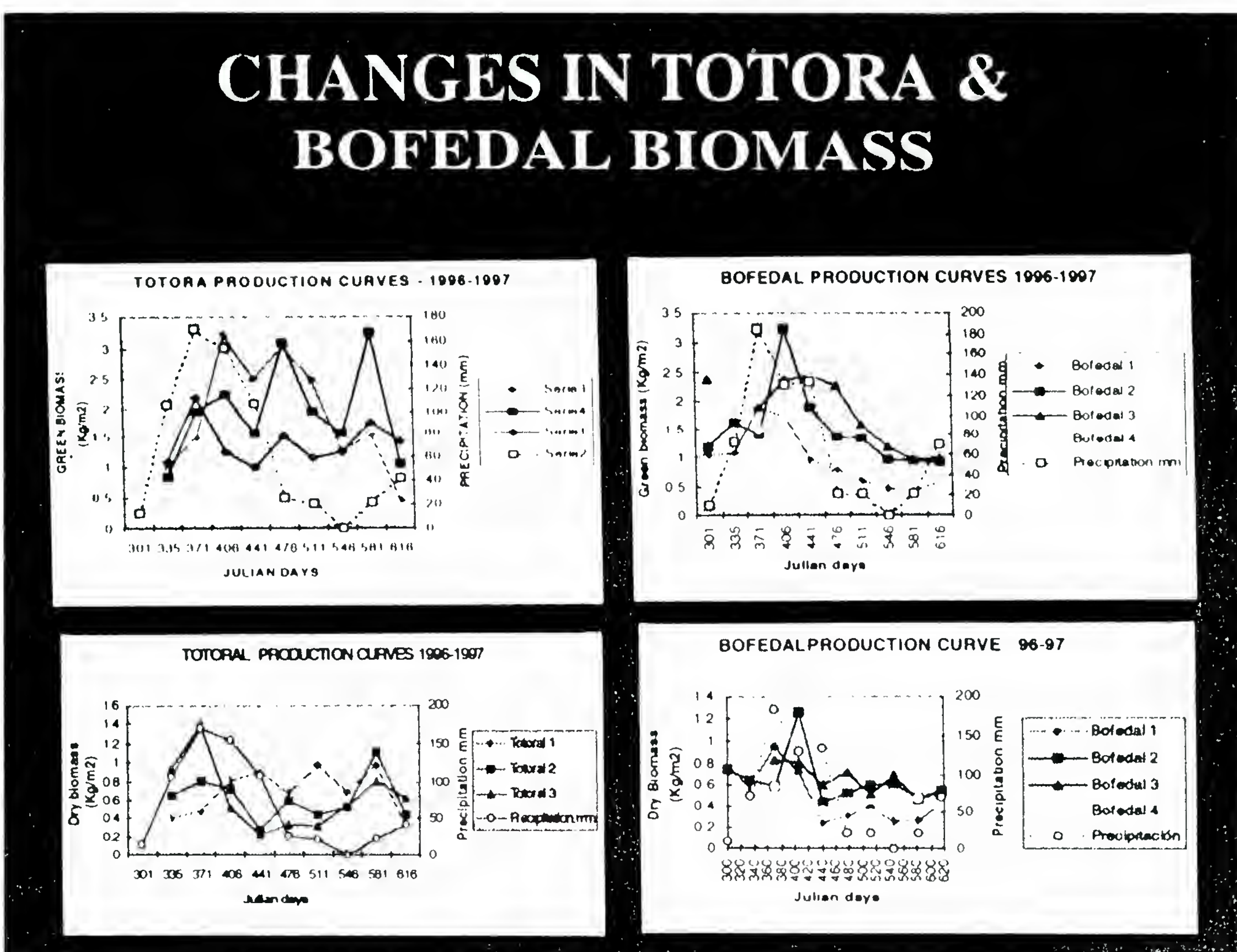
FIELD DATA

- SOIL HUMIDITY:
  - 16 SAMPLING SITES REPRESENTATIVE OF MORE THAN 5000 m2 WERE SELECTED ON THE BASIS OF THEIR REPRESENTATIVITY IN A 3x3 Km GRID CELL AND ACCESSIBILITY
  - IN EACH SAMPLING SITE, 5 SOIL SAMPLES SEPARATED BY AT LEAST 100 m WERE TAKEN DOWN TO 5 cm DEPTH, EVERY 35 DAYS FOR ERS, AND DURING THE PASS OF RADARSAT, 2 HOURS BEFORE TO TWO HOURS AFTER THE PASSES, SINCE JULY 1996
  - THEY WERE WEIGHTED IN THE FIELD & IN LABORATORY AFTER DRYING IN AND OVEN (GRAVIMETRIC METHOD)
  - TOTAL ABOVE GROUND BIOMASS, SEPARATED INTO GREEN AND SENESCENT MATERIAL, WERE TAKEN EVERY 35 DAYS FOR ERS AND AT THE PASS OF RADARSAT DURING 4 DAYS, SINCE JULY 1996, USING THE HAYDOCK & SHAW (1975) "DOUBLE SAMPLING SCHEME" IN 5 SAMPLING FIELDS FOR TOTORALES AND 8 FIELDS FOR BOFEDALES, EACH APPROXIMATELY OF 700 x 700 METERS
  - FOR EACH FIELD SAMPLED, 5 REFERENCE QUADRATS WERE SELECTED EACH TIME TO BUILD THE CALIBRATION LINE
  - IN ADDITION 100 TO 200 VISUAL SAMPLES WERE RATED ACCORDING TO THE REFERENCE QUADRATS IN EACH FIELD
  - A LINEAR REGRESSION (CLIPPED BIOMASS AS A FUNCTION OF REFERENCE CODES) WAS FITTED TO THE DATA TO OBTAIN THE SLOPE B OF THE CURVE AND THUS THE FRESH AND DRY BIOMASS

> BIOMASS = MEAN OF CLIPPED SAMPLES + b (MODE OF RATING - MEAN OF NB. OF REFERENCE QUADRATS)

- THE BOTANICAL COMPOSITION OF THE SATURATED GRASSLANDS (BOFEDALES) IS ESTIMATED USING THE DRY - WEIGHT - RANK METHOD OF MANNEJE & HAYDOCK (1963)
  - IN ORDER TO CALCULATE THE BOTANICAL COMPOSITION, THE 3 DOMINANT SPECIES IN EACH VISUAL QUADRAT ARE REGISTERED AND THE FINAL PROPORTION OF EACH SPECIE OCCUPYING 1st, 2nd OR 3rd PLACE IS MULTIPLIED BY A SPECIFIC COEFFICIENT IN ORDER TO OBTAIN THE DRY - WEIGHT - RANK

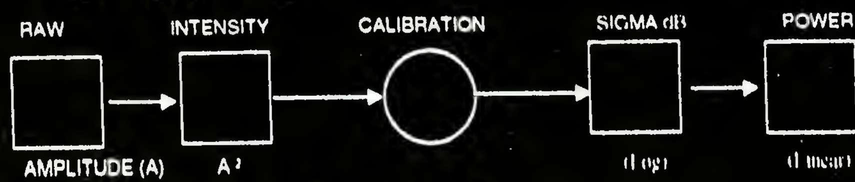

DATA ACQUISITION
KHARAKOTA 1
KHARAKOTA 3
KHARAKOTA 2
ISQUILLANI
SURIQUINA
PARIRI 1
PARIRI 2
EXCHILILAYA
CACHILAYA-2
CACHILAYA 1
COHANA1
COHANA2


CHANGES IN TOTORA & BOFEDAL BIOMASS
TOTORA PRODUCTION CURVES - 1996-1997
GREEN BIOMASS (Kg/m2)
PRECIPITATION (mm)
JULIAN DAYS
BOFEDAL PRODUCTION CURVES 1996-1997
Green biomass (Kg/m2)
Precipitation mm
Julian days
Bofedal 1
Bofedal 2
Bofedal 3
Bofedal 4
Precipitation mm
TOTORAL PRODUCTION CURVES 1996-1997
Dry biomass (Kg/m2)
Precipitation mm
Julian days
Totoral 1
Totoral 2
Totoral 3
BOFEDALPRODUCTION CURVE 96-97
Dry Biomass (Kg/m2)
Precipitation mm
Julian days
Bofedal 1
Bofedal 2
Bofedal 3
Bofedal 4
Precipitación

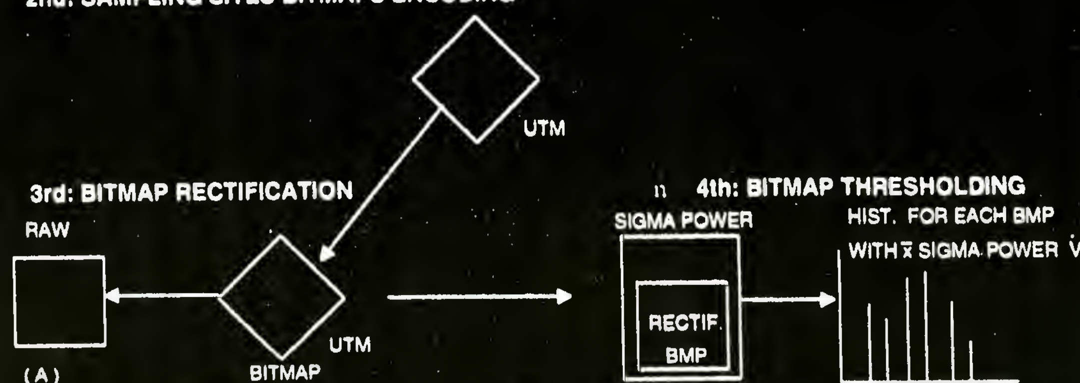
REMOTE SENSING METHODOLOGY

QUANTIFICATION OF BIOMASS & SOIL HUMIDITY THROUGH C BAND SAR DATA

1st: CALIBRATION OF SAR DATA



2nd: SAMPLING SITES BITMAPS ENCODING



5th: $\overline{X}sp$ VALUE TRANSFORMED IN SIGMA dB (S= 10 (log $\overline{X}sp$))

QUANTIFICATION OF BIOMASS WITH NOAA - AVHRR DATA

- TWO NORMALIZED VEGETATION INDEX (NDVI) MEASUREMENTS WERE COMPARED WITH OBSERVED HERBAGE BIOMASS:
  - THE MAXIMUM OBSERVED NDVI FOR THE GROWTH SEASON (NDVI MAX) FOR EACH SAMPLING FIELD
  - THE BACKGROUND CORRECTED MAXIMUN NDVI (NDVI bc) CALCULATED AS THE DIFFERENCE BETWEEN THE MAXIMUN OBSERVED NDVI VALUE AND THE BACKGROUND (MINIMUM) NDVI PRIOR TO THE GROWTH SEASON

- LINEAR REGRESSION WAS USED TO EVALUATE THE RELATIONSHIP BETWEEN HERBAGE BIOMASS OBTAINED FROM THE GROUND SURVEY (1995 - 1996) WITH NDVI max AND NDVI bc

1st RESULTS & DISCUSSION
RADAR

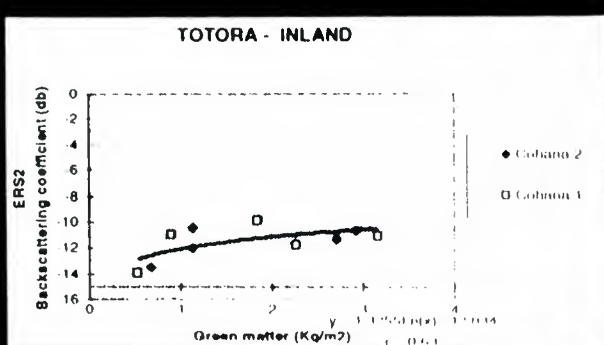
GENERAL TENDENCY INCREASE OF BACKSCATTERING WITH AN INCREASE OF PLANT GREEN BIOMASS

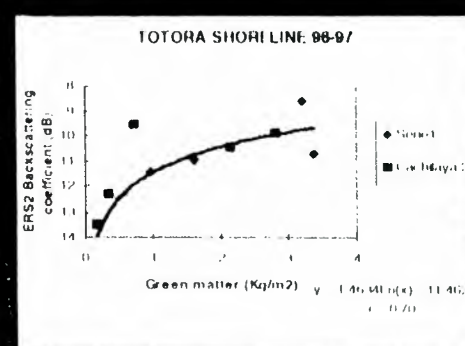
INLAND

THE RELATIVELY WEAK CORRELATION BETWEEN σ^0 AND GREEN BIOMASS (Log CORRELATION WITH r=0.64) SEEMS TO INDICATE THAT SOIL HAS AN IMPORTANT INFLUENCE ON BACKSCATTERING REDUCING ITS VALUES

SHORELINE

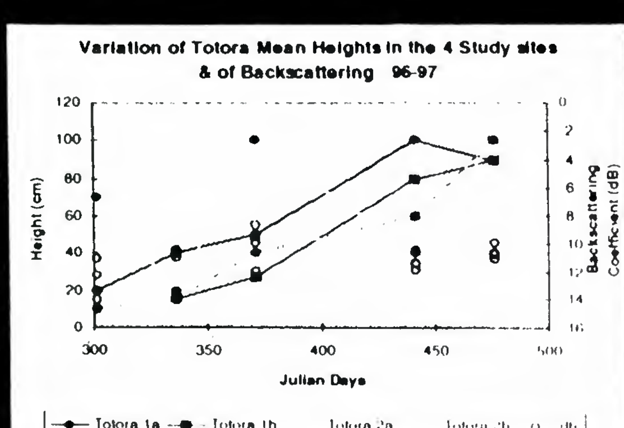
THE HIGHER CORRELATION BTW σ^0 & GREEN BIOMASS (r=0.75) SEEMS TO BE EXPLAINED BY THE IMPACT OF WATER WHICH ACTS WITH THE VERTICAL SMOOTH CYLINDRICAL STRUCTURE OF THE TOTORA PLANT, AS A DIHEDRALCORNER REFLECTOR

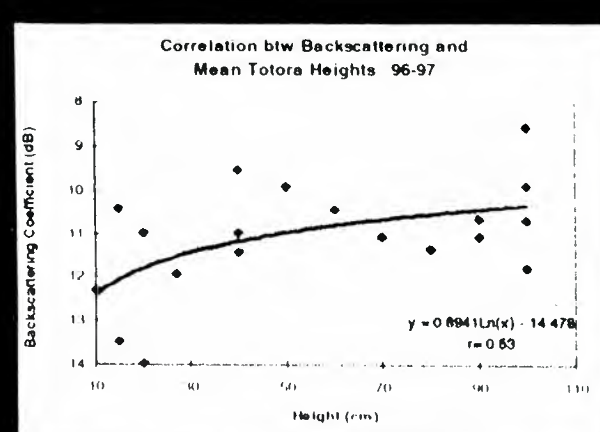




THE CORRELATION ANALYSIS BETWEEN VARIATION OF TOTORA HEIGHTS IN THE SUBZONES OF THE STUDY SITES AND RADAR BACKSCATTERING INDICATES A POSITIVE TREND

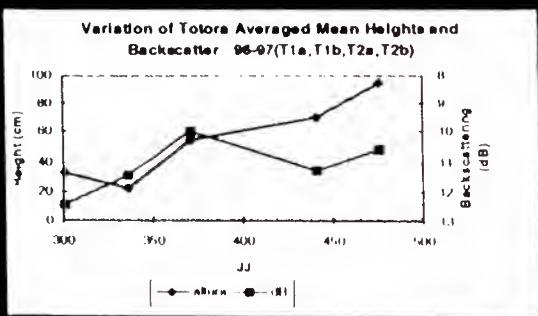
HOWEVER, THE GRAPH OF TOTORA MEAN HEIGHTS VARIATION IN THE 4 SUBZONES DEPICTS CLEARLY THE ABNORMAL BEHAVIOR OF SUBZONE "TOTORA 2A" WHICH MIGHT BE EXPLAINED BY A TOTALLY DIFFERENT MANAGEMENT OF THIS FORAGE CROP BY THE COMMUNITY

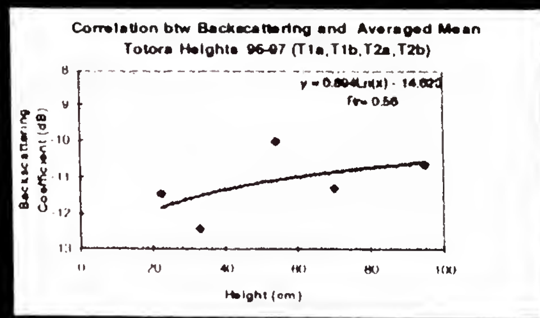


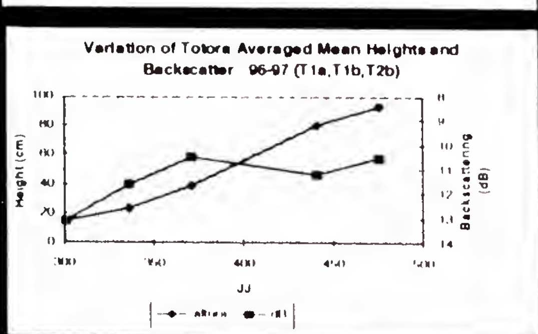


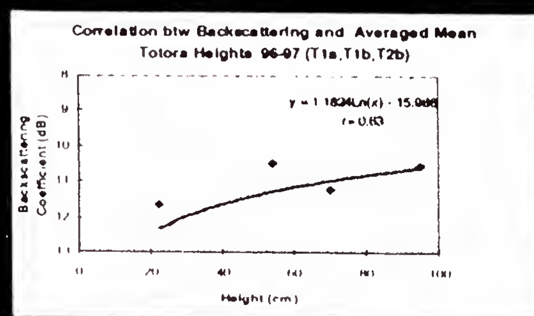
1st RESULTS & DISCUSSION
RADAR

IN ORDER TO EVALUATE THE INFLUENCE OF THAT "TOTORA 2a" SITE, A COMPARISON HAS BEEN MADE BTW THE VARIATION IN TIME OF TOTORA AVERAGED MEAN HEIGHTS WITH AND WITHOUT THIS SITE AND THEIR CORRELATION WITH RADAR BACKSCATTERING. CORRELATION IS HIGHER WITHOUT "TOTORA2a"



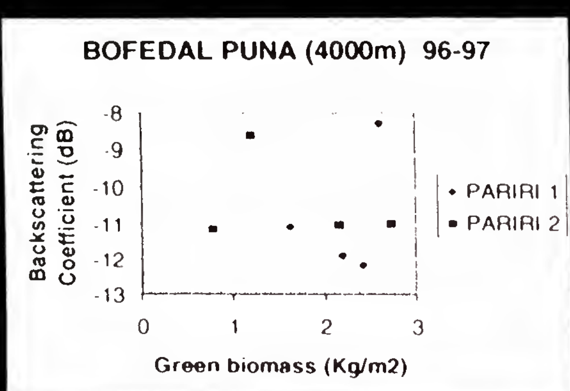


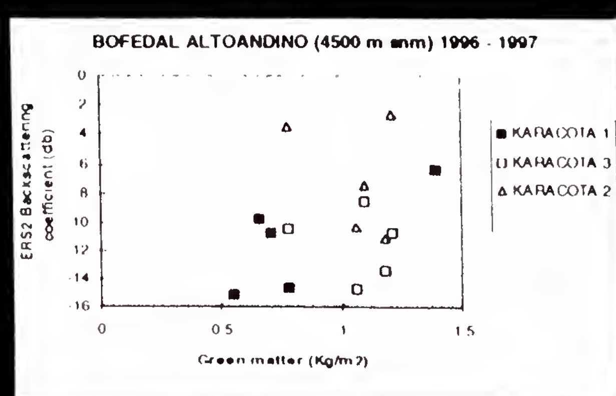


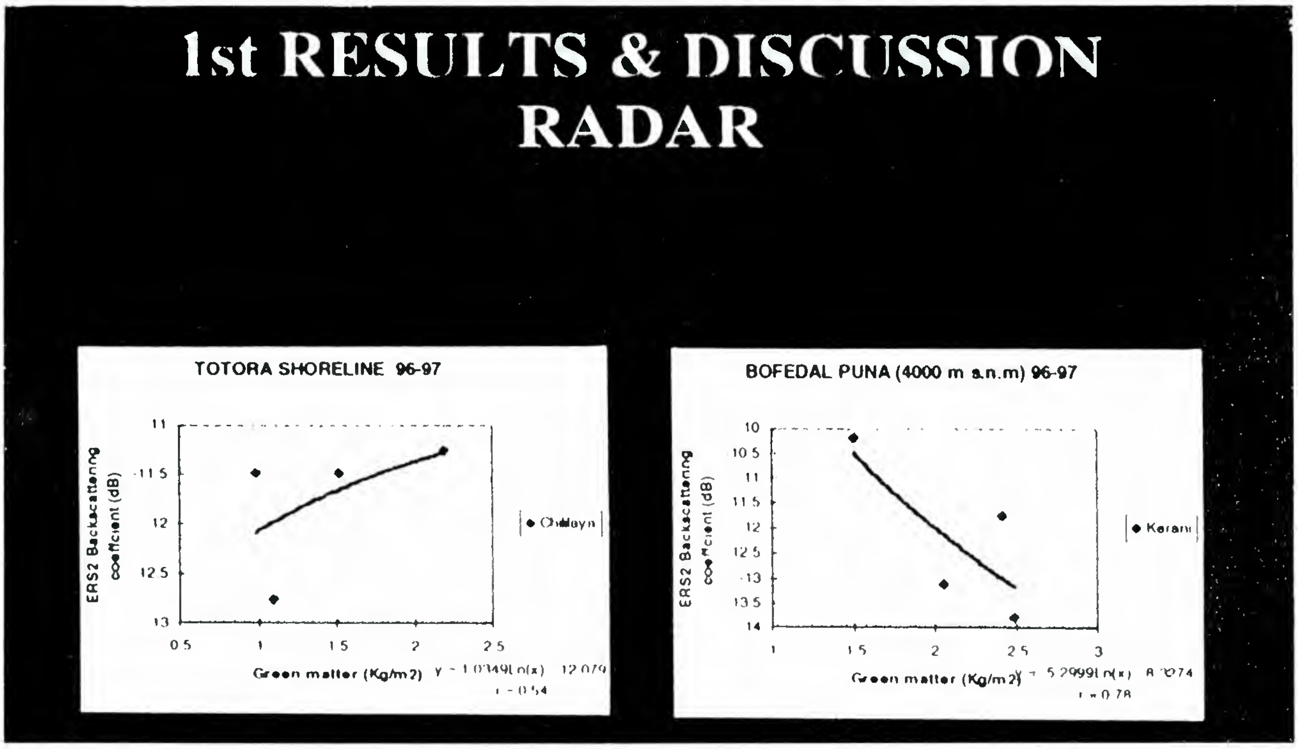


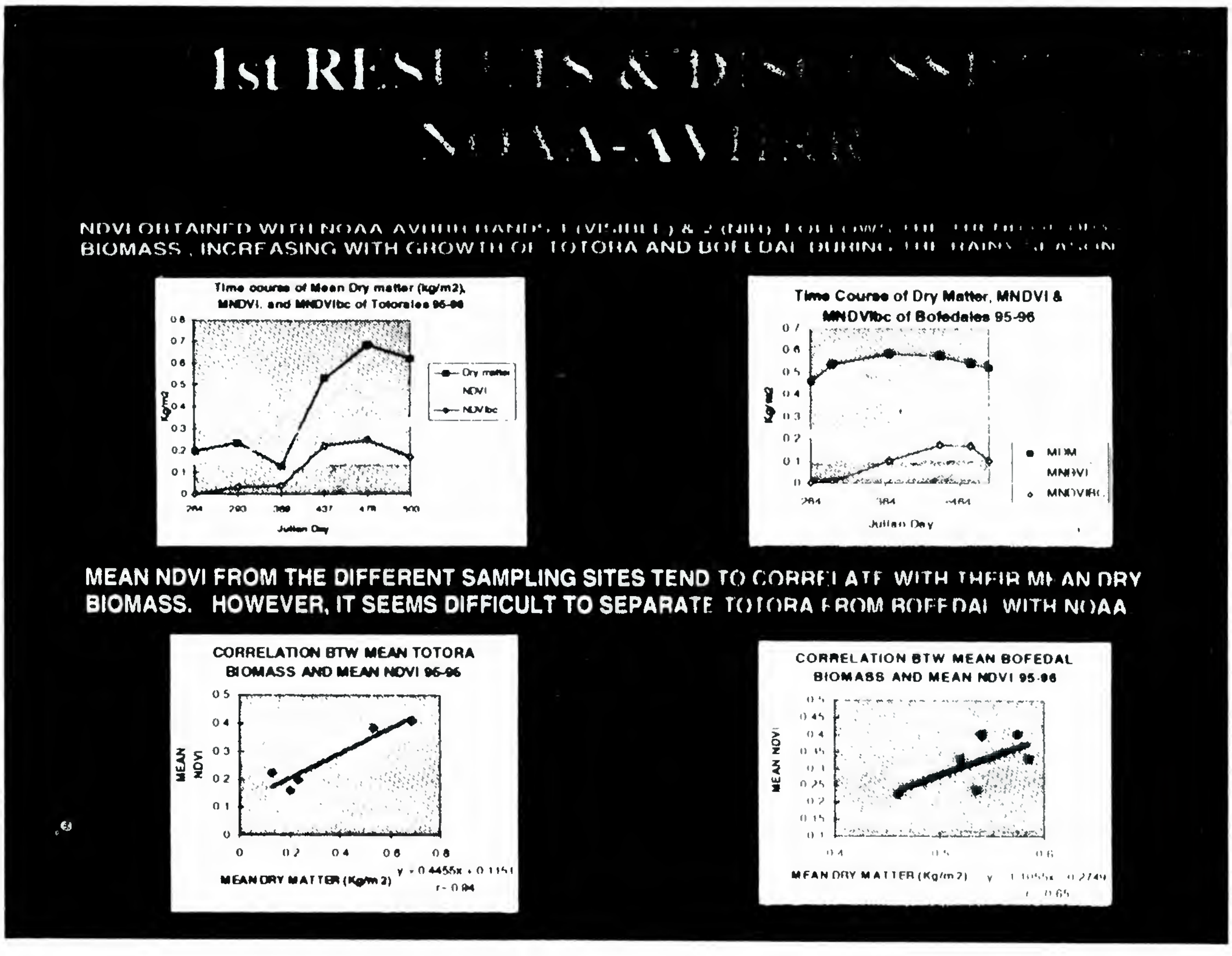
GENERAL TENDENCY: DECREASE OF BACKSCATTERING WITH AN INCREASE OF PLANT GREEN BIOMASS WHICH SEEMS TO BE DUE TO PRESENCE OF STANDING WATER DURING THE RAINY SEASON. VERY WEAK CORRELATION BETWEEN GREEN BIOMASS AND BACKSCATTERING IN THE CASE OF PUNA BOFEDAL AND NONE IN THE CASE OF BOFEDAL ALTOANDINO.

PUNA **ALTOANDINO**






1st RESULTS & DISCUSSION
RADAR
TOTORA SHORELINE 96-97
ERS2 Backscattering coefficient (dB)
Green matter (Kg/m2)
r = 0.54
BOFEDAL PUNA (4000 m s.n.m) 96-97
Green matter (Kg/m2)
r = 0.78


BIOMASS , INCREASING WITH GROWTH OF TOTORA AND BOFEDAL DURING THE RAINY SEASON
Time course of Mean Dry matter (kg/m2), MNDVI, and MNDVIbc of Totorales 95-96
Julian Day
Time Course of Dry Matter, MNDVI & MNDVIbc of Bofedales 95-96
Julian Day
MEAN NDVI FROM THE DIFFERENT SAMPLING SITES TEND TO CORRELATE WITH THEIR MEAN DRY BIOMASS. HOWEVER, IT SEEMS DIFFICULT TO SEPARATE TOTORA FROM BOFEDAL WITH NOAA
CORRELATION BTW MEAN TOTORA BIOMASS AND MEAN NDVI 95-96
MEAN NDVI
MEAN DRY MATTER (Kg/m 2)
y = 0.4455x + 0.1151
r = 0.94
CORRELATION BTW MEAN BOFEDAL BIOMASS AND MEAN NDVI 95-96
MEAN NDVI
MEAN DRY MATTER (Kg/m2)

CONCLUSION & PERSPECTIVE

MORE RADAR DATA IS NEEDED TO CONFIRM THE GENERAL TRENDS OBSERVED:

- INCREASE OF SIGMA NOUGHT WITH INCREASE IN TOTORA BIOMASS
- SLIGHT DECREASE OF SIGMA NOUGHT WITH INCREASE IN BOFEDAL BIOMASS

A SERIE OF 5 ERS SAR-PRI IMAGES IS BEING PROCESSED BY THE GERMAN PAF WHICH WILL ALLOW TO COVER THE FULL PLANT CYCLE

COMPARISON OF CORRELATION WITH DRY AND GREEN BIOMASS AS WELL AS WITH AVERAGE DATA HAS TO BE PERFORMED

A SERIE OF NOAA-AVHRR DATA IS BEING ACQUIRED AT ABTEMA'S RECEIVING STATION IN ORDER TO GET NDVI DATA FOR THE PERIOD CORRESPONDING TO RADAR DATA (1996-97). IT WILL ALLOW TO VERIFY ASSUMPTIONS MADE WITH RESPECT TO THE BETTER CORRELATION OBTAINED BETWEEN NDVI & BIOMASS vs. THE LOWER CORRELATION OBTAINED WITH RADAR BACKSCATTERING AFFECTED BY PARAMETER DIFFERENT THAN THE CELL STRUCTURE AND PIGMENTS, SUCH AS ROUGHNESS AND DIELECTRIC PROPERTIES.

UTILIZACIÓN DE IMÁGENES LANDSAT Y ERS-1 EN LA IDENTIFICACIÓN DE ÁREAS BANANERAS EN LA ZONA DE MACHALA PROVINCIA DEL ORO - ECUADOR.

BYRON A. VÁSCONEZ C.
BIÓLOGO
CLIRSEN
clirsen@uio.satnet.net
Fax 5932 581066

RESUMEN

La información satelitaria obtenida por el LANDSAT 5 TM (Mapeador temático), que capta las longitudes de onda del espectro electromagnético y en especial las del infrarrojo medio y del visible, presentan características de brillantez en especial de la vegetación. Así también el ERS-1, tiene la característica de la transmisión de ondas electromagnéticas en función de la longitud de onda, que abarca la región del espectro electromagnético, correspondiente al visible, infrarrojo y de las microondas y la extensión de la penetración depende de la humedad y de la densidad de la vegetación; características especiales que presentan estos dos satélites permitieron identificar el cultivo de las plantaciones bananeras y diferenciarle de los otros cultivos y usos del suelo, tomando en cuenta que el banano es un cultivo de carácter perenne, de hoja ancha y robusta, lo que nos permitió realizar la interpretación híbrida entre la clasificación digital y la visual, posteriormente se realizó el ajuste y depuración de la misma ,así como también la geocodificación y finalmente la obtención de 10 cartas temáticas que cubren la zona de Machala, en la que a más de obtener las superficies en forma general, se pudo también identificar a los propietarios de las parcelas del cultivo bananero en esta zona.

1. ANTECEDENTES.

El cultivo del banano en el Ecuador es uno de los más importantes , por la gran cantidad de divisas que genera para el país, es también el primer productor de esta fruta del mundo.

Esta circunstancia ha motivado para que se realice esta investigación a fin de obtener estudios básicos como son: evaluación cualitativa y cuantitativa del cultivo, zonificación real y la formación de la base de datos para posteriormente ser manejados bajo el ambiente de un Sistema de Información Geográfica (SIG).

A fin de concretar lo anteriormente mencionado el Programa Nacional del Banano (PNB) y El Centro de Levantamientos Integrados de Recursos Naturales por Sensores Remotos (CLIRSEN), suscribieron un Convenio de Cooperación técnica para realizar " El Inventario y Monitoreo de las superficies de

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

Banano en el Ecuador ", contando para esto con la información satelitaria ceptada, grabada y procesada en la Estación del Cotopaxi.

Como resultado de esta investigación, se extrae el presente trabajo técnico de una de las zonas más importantes de producción bananera como es Machala , conocida en nuestro medio como "La Capital Bananera del Mundo".

2. OBJETIVOS.

- Evaluar cualitativa y cuantitativamente las superficies del cultivo del banano en el Ecuador.

- Evaluar cualitativa y cuantitativamente las superficies del cultivo del banano en el Ecuador.

3. METODOLOGÍA.

Dentro de este estudio la caracterización espectral de las masas vegetales es de mucha importancia, sin embargo de lo cual se debe tomar muy en cuenta el estado fenológico, forma, contenido de humedad y la propia reflectancia de la hoja; además también se debe considerar las características morfológicas de la planta, su altura, perfil y grado de cobertura del suelo.

Para el presente estudio se utilizaron los Programas de Procesamiento Digital de Imágenes Erdas 8.2, Sistema de elaboración de Cartografía Cat Microstation, y el Sistema de Información Geográfica Arc-Info.

Para el Procesamiento Digital se utilizó la información del Landsat 5 TM , de la banda 3 (0.63 - 0.69 micrones) , banda 4 (0.76 - 0.90 micrones), y la banda 5 (1.55 - 1.75 micrones), la primera en el visible, la segunda en el infrarrojo cercano que presenta su más alta respuesta en la vegetación vigorosa y la tercera en el infrarrojo medio, presenta su más alta respuesta en el suelo, con estas especificaciones se procedió a efectuar una composición a color con la combinación de las bandas 3 - 4 - 5.

Para este estudio se utilizó una sub-escena de (1536 x 1661), del cuadrante 4, Path 11, Row 62 , correspondiente a la escena de Guayaquil.

La interpretación visual se lo realizó directamente en la pantalla del computador , la misma que nos sirvió de base para realizar la comparación de la interpretación digital, la misma que de acuerdo al tipo y densidad de cobertura del cultivo se aplico la clasificación supervisada, siguiendo el análisis correspondiente hasta llegar a un refinamiento de las clases espectrales, poniendo especial énfasis en el cultivo del banano.

Por otro lado y en forma paralela también se utilizó información de Radar del satélite ERS - 1 SAR, looks 3 de la órbita 6955, frame 3645 de Machala, a la que se hizo correcciones radiométricas en especial del ruido " SpecKle ", que es uno de los factores principales que degradan la calidad de las imágenes SAR, cuyo efecto visual es de una textura granulosa, que dificulta la interpretación, reduciendo la separabilidad entre las distintas clases de uso del suelo, para esto se utilizó el método del filtraje de Lee, porque minimiza el error medio cuadrático y es un filtro adaptativo y general.

La información de Radar se utilizó especialmente en sectores en donde el porcentaje de nubes de la información del Landsat era muy alto, con lo que se cubrió toda la zona de estudio obteniéndose excelentes resultados en los dos casos mencionados anteriormente, tanto para la interpretación visual como para la interpretación digital.

Una vez obtenidas las 10 cartas preliminares se procedió a realizar el trabajo de campo, poniendo énfasis en ciertos sectores en donde existían dudas de asignación e identificar claramente las clases espectrales como producto de la interpretación y por otro lado tomando en cuenta la leyenda como única clase de identificación sobre el cultivo del banano materia de este estudio.

Esta comprobación de campo también nos permitió tener mejores elementos de juicio para discriminar la clase en cada carta temática, durante el proceso de edición.

Luego de la comprobación de campo se procedió a la realizar ciertos cambios que fueron detectados, los mismos que no incidieron mayormente en la interpretación final así como también se realizó la eliminación de el fenómeno de sal y pimienta que esta en intima relación con la unidad de interpretación de 6.5 Ha, para lo cual se estableció como referencia una celda de 10 x 10 pixeles, de una resolución de veinte y cinco metros y finalmente se procedió a la geocodificación en función de las hojas bases en escala 1:25.000.

Posteriormente se obtuvieron los archivos digitales en formatos ajustados a los establecidos para la escala 1: 25.000 y en relación al los planos temáticos de tipo raster, a continuación se realizó la vectorización es decir la conversión de los archivos raster con la información temática sobre el banano a archivos de tipo vectorial y la edición del archivo vector y su compatibilización con los planos vectoriales componentes de las cartas temáticas, previo a la obtención de los productos finales se realizó un control de calidad y a la generación de archivos en formatos DXF, compatibles con los sistemas de información geográfica en especial con Arc/Info, realizándose la identificación de cada polígono y el cálculo de las superficies bananeras.

Para la elaboración de la cartografía analógica se partió del diseño el del paquete Cat-Microstation, en el que se incluyo los diferentes niveles del mapa base la información temática y la información marginal, en la que se incluyo la leyenda, escala, tarjeta de identificación, información utilizada, simbología convencional y el título del estudio. De la información digital elaborada bajo un formato establecido por CLIRSEN, para la escala 1: 25.000, se paso a la impresión en papel estable en un plotter de inyección a tinta.

Como ilustración a todo lo anteriormente mencionado se presentan dos imágenes, la primera de la imagen Landsat de Guayaquil y la segunda con la imagen de radar del ERS - 1 de Machala, las dos imágenes con la misma zona de estudio.

La zona de estudio corresponde a Machala, la misma que esta dada de acuerdo a la zonificación del Programa Nacional del Banano, la misma que cubre 10 cartas a escala 1: 25.000 y que son las siguientes: La Raquel, Machala, Pasaje, Pto Jelí, La Virginia, Jumón, Sta Rosa de el Oro, Arenillas, La Avanzada, y Palmales. (Gráficos 1 y 2).

RESULTADOS.

Cartográficos.

Se obtuvieron 10 cartas a escala 1: 25.000 en las que constan el número de la zona , el número de propietarios en general y el número de propietarios por carta, en la que se especifica el nombre del propietario y/o compañía - cooperativa y el héctareaje.

Listados.

Para la identificación de los propietarios de las plantaciones bananeras se contó con la participación de el Programa Nacional del Banano, que proporciono los listados correspondientes de la zona de Machala y con la colaboración de los técnicos de la zona y del CLIRSEN, se fueron identificando a cada uno de los propietarios y su respectivo héctareaje, así como también se fueron confeccionando los listados definitivos, uno de la zona y otro por carta.

Estadísticos.

Los resultados estadísticos se encuentran detallados en cinco cuadros y gráficos, los mismos que serán analizados a continuación:

En el cuadro N° 1 se analizan estadísticas en base a las superficies bananeras en relación a las 10 cartas, siendo la de mayor hectareaje la de Pasaje (6553.5 Ha), tiene la media más baja con (12.4 Ha), un mínimo de (1 Ha) y el valor máximo de (303 Ha).

La carta de La Avanzada es la de menor hectareaje, tiene la media más alta (22.8), así como también el mínimo más alto (7.0 Ha). Cabe mencionarse también la carta de Palmales, que tiene el menor valor máximo (39.0 Ha). En el cuadro N° 2 de la distribución de frecuencias de propietarios, tenemos que el mayor número de ellos se encuentra en el intervalo (>0-10) con 1157 propietarios, el intervalo (>10-30), es el segundo con 496 propietarios, y en el intervalo de (>200), encontramos el menor número de 6 propietarios y con el más bajo porcentaje 0.3% . De un total de 1860 propietarios observamos que en los intervalos (>0-10 y 10-30), están los porcentajes más altos con 62..2% y 26.7%, en los intervalos (>30-50, >50-100, >100- 200), que tienen 98.8 y un número de 20 propietarios y con porcentajes del 5.3% , 4.5% y 1.1%, respectivamente pese a que tiene un porcentaje del 10.9%, consideramos representativos pero de menor importancia.

En el cuadro N° 3 de la distribución de frecuencias por superficies (Hectareaje), encontramos que la mayor superficie de bananeras esta en el intervalo (>10-30), con 9216.5 Ha, además tiene el porcentaje más alto con el 31 %, en intervalo (>0 -10), es el segundo con 6742.6 Ha y un porcentaje del 22%, el intervalo (> 50 - 100), con 5864.2 Ha es el tercero en importancia y con un porcentaje del 20%, el cuarto lugar ocupa el intervalo (>30 -50), con 3968.2 Ha y con un porcentaje del 13%, el quinto lugar esta el intervalo (>100-200), con 2652.3 Ha y un porcentaje del 9% y el intervalo (> 200), con 1606.0 Ha y un porcentaje del 5%, es el último tanto en hectareaje y porcentaje.

Para analizar el cuadro N° 4 y establecer la comparación de la distribución de frecuencias por propietarios y por superficies, en relación de los propietarios pondremos especial atención a los intervalos (>0-10 y >10-30), por que se encuentra en el mayor número de propietarios con 1157.0 y con 496.0 con un porcentaje de 62.2 %, 26.7 %, y una frecuencia acumulada de 62.2 y 88.9 respectivamente y que se convierte en el 89% de los propietarios, quedando 207 propietarios que se encuentran en los intervalos (>30-50, >50 -100, >100-200, >200), que representan el 11 % de un total de 1860 propietarios que corresponden a la zona de Machala.

Al analizar el cuadro comparativo de distribución de frecuencias por superficies, también presentan características dianas de especial atención, así en los mismos intervalos (>0-10, >10-30), se encuentran las mayores superficies y que el intervalo (>10-30), es el de mayor superficie con 9216.5 Ha, con el porcentaje más alto 30.7% y una frecuencia acumulada del 53.1 , el intervalo (>0-10), es el segundo en importancia con una superficie de 6742.6 Ha, con un porcentaje de 22.4% y una frecuencia acumulada de 22.4.

En tercer lugar se encuentra el intervalo (>50-100), con 5864.2 Ha, con un porcentaje de 19.5% y una frecuencia acumulada de 85.8 , que en nuestro caso viene a convertirse en el punto intermedio en superficies.

A continuación, esta el intervalo (>30-50), con 3968.2 Ha de superficie, 13.2% de porcentaje y una frecuencia acumulada de 66.3, en quinto lugar se encuentra el intervalo (>100-200), con una superficie de 2652.3Ha, un por centaje de 8.8% y una frecuencia acumulada de 95.0 y finalmente el intervalo (>200), con 1606.0 Ha , tiene un porcentaje de 5.3% y una frecuencia acumulada de 100.

Finalmente analizaremos el cuadro N° 5 , referente al resumen de parámetros estadísticos por carta de la zona de estudio en relación a las superficies y propietarios. Pasaje es la carta más representativa tanto en superficie como en propietarios con 6553.5 Ha y 527 propietarios, una media de 12.4, un mínimo de 1.0 y un máximo de 303; en segundo lugar se encuentra La Virginia con 5600.1 Ha, 303 propietarios, una media de 18.5, un mínimo de 1.0 y un máximo de 300; en tercer lugar esta Puerto Jelí con 5378.8 Ha, 272 propietarios, una media de 19.8, un mínimo de 1.5 y un máximo de 170; en cuarto lugar esta Machala con 5075.3 Ha, con 301 propietarios, una media de 16.9, un mínimo de 1.0 y un máximo de 225. En quinto lugar esta Santa Rosa de Machala, con 2375.6 Ha, 115 propietarios, una media de 20.7, un mínimo de 1.0 y un máximo de 102. Acontinuación se encuentra la Raquel con 2208.8 Ha y 158 propietarios, una media de 14.0, un mínimo 1.0 y un máximo de 251; seguidamente esta Jumón , con 1313.4 Ha, 64 propietarios, una media de 20.5, un mínimo de 2.5 y un máximo de 64.0, sigue Arenillas, con 995.7 Ha, 92 propietarios, una media de 10.8, un mínimo de 1.0 y un máximo de 53; en noveno lugar esta Palmales, con 343.0 Ha, 19 propietarios, una media de 18.1, un mínimo de 3.0 y un máximo de 39 ; y finalmente esta La Avanzada, con 205.5 Ha y con apenas 9 propietarios, una media de 22.8, un mínimo de 7 y un máximo de 62.

Como análisis final tenemos que para las 30.049.7 Ha, que existen en la zona, hay 1860 propietarios de plantaciones bananeras .

CONCLUSIONES.

De la zonificación de las plantaciones bananeras, en la provincia de El Oro, (Zona de Machala), que cubren 10 cartas a escala 1: 25.000, se determina que la carta de Pasaje, es la que más superficie tiene (6553.5 Ha), mientras que la carta de menor superficie es la de La Avanzada, con (205.5 Ha).

También se concluye que de un total de 1860 propietarios, 1653 (89%), tienen sus plantaciones bananeras en 15.959.1 Ha y que en superficie representa el 53.2%, en tanto que los 207 propietarios (11%), tienen sus plantaciones bananeras en 14.090.7 Ha, que se constituye en el 46.8% de superficie de dicho cultivo.

RECOMENDACIONES.

- Continuar anualmente con el Monitoreo del cultivo del banano.

- Establecer un banco de datos con todas las variables obtenidas en la investigación.

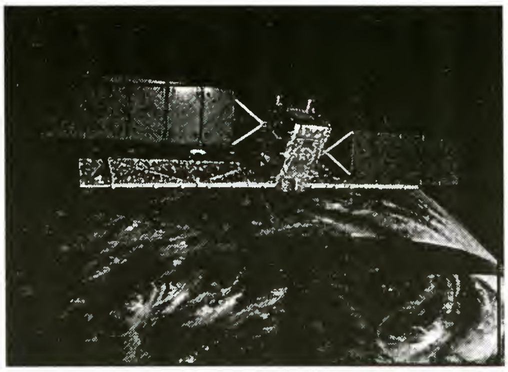
- Sentar las bases para el establecimiento de un Sistema de Información Geográfica (SIG).

-Implementar y asesorar al PNB, en la creación de un Departamento de TeledetecciónProcesamiento Digital y Cartográfico).

RADARSAT

Two Years of RADARSAT Operations: An overview

Marcel St-Pierre
Canadian Space Agency



Key Dates

RADARSAT

Launched	4 th November 1995
First Image	28 th November 1995
First Imaging for Ice Operations	4th February 1996
Images for System Commissioning	February 1996
Operations Qualification Review	28th March 1996
Antarctic Mapping	Sept.9-Oct. 29, 1997

Operations Enhanced

RADARSAT

1st April, 1996	Enhancement Since
Manual planning of recorder	Automated recorder planning
6 recorded images per day max	20 recorded images/day average
3 minutes minimum image	1 minute minimum imaging
Single order desk	5 Order desks
Automated Gain imaging	Fixed gain imaging added
Two receiving stations available	Six receiving stations available

Key Statistics

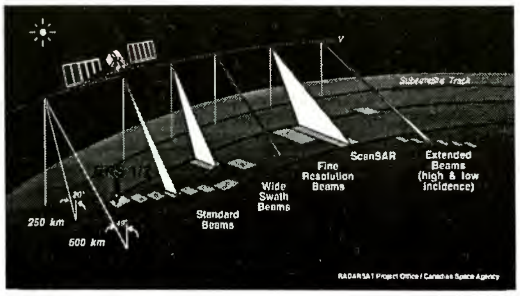
(Dec. 3 96-Feb. 97)

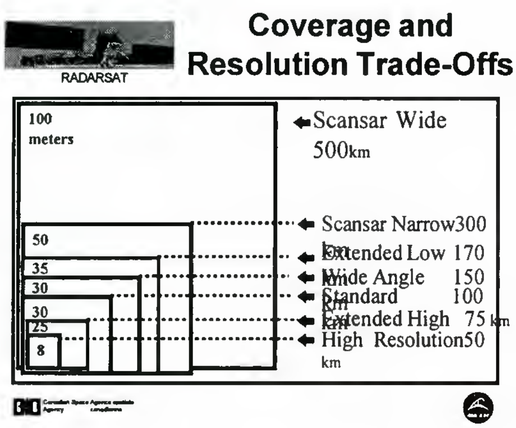
RADARSAT

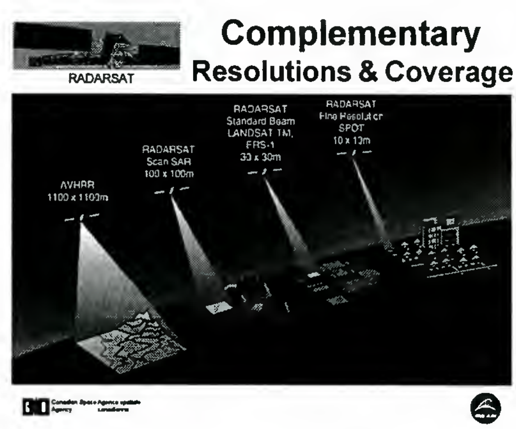
Real-Time SAR on-time/day	86 minutes
Recorder SAR on-time/day	21 minutes
Number Images/day acquired	38 images
Production Orders processed at CDPF	800/month
Average System Performance Figure	95%

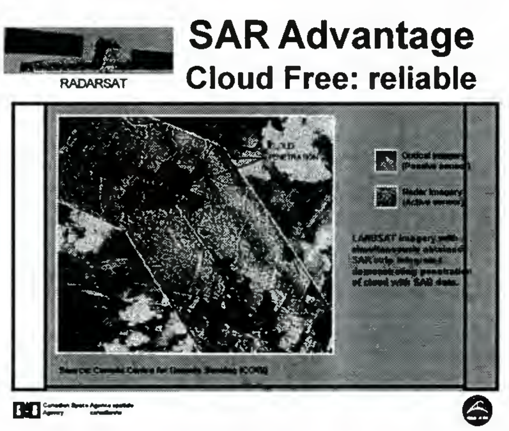
RADARSAT Beam Modes

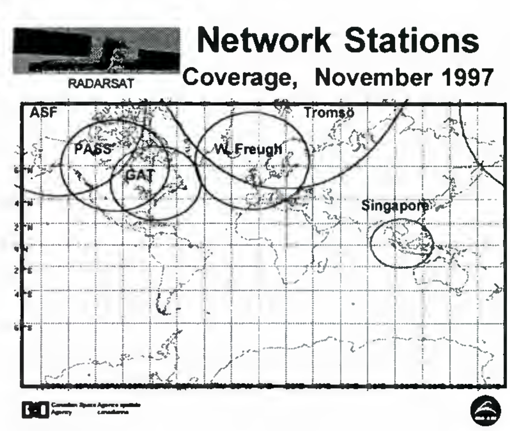
RADARSAT

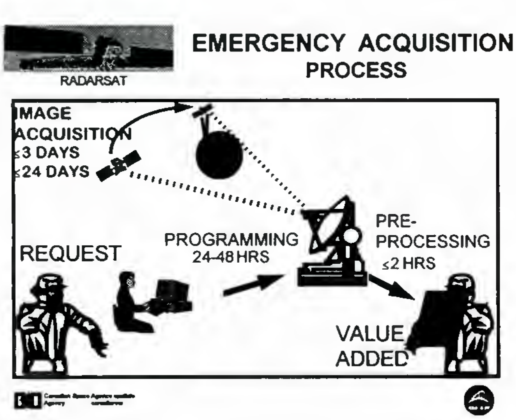



RADARSAT
Coverage and
Resolution Trade-Offs
100
meters
Scansar Wide
500km
Scansar Narrow300 km
Extended Low 170 km
Wide Angle 150 km
Standard 100 km
Extended High 75 km
High Resolution50 km
50
35
30
30
25
8

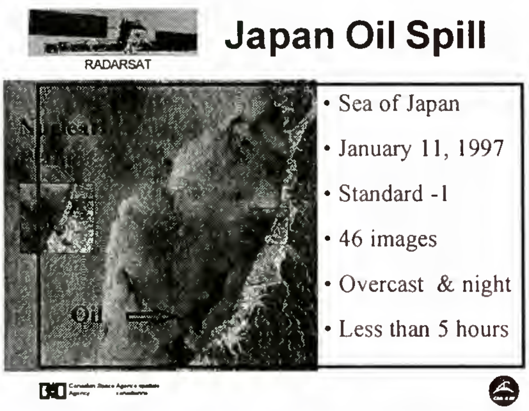

RADARSAT
Complementary
Resolutions & Coverage
AVHRR
1100 x 1100m
RADARSAT
Scan SAR
100 x 100m
RADARSAT
Standard Beam
LANDSAT TM,
ERS-1
30 x 30m
RADARSAT
Fine Resolution
SPOT
10 x 10m

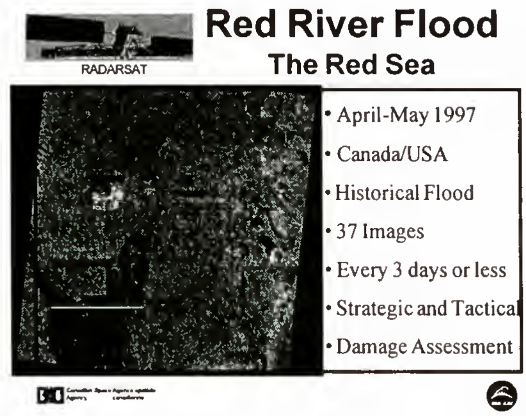

RADARSAT
SAR Advantage
Cloud Free: reliable

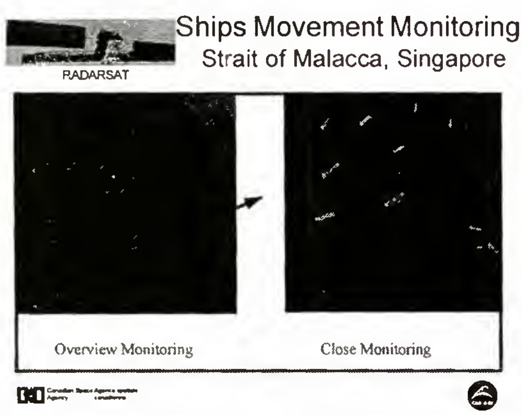

RADARSAT
Network Stations
Coverage, November 1997
ASF
Tromsø
PASS
GAT
W. Freugh
Singapore

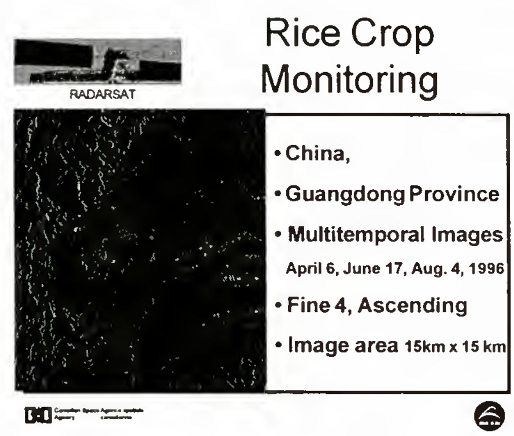

RADARSAT
EMERGENCY ACQUISITION
PROCESS
IMAGE
ACQUISITION
≤3 DAYS
≤24 DAYS
REQUEST
PROGRAMMING
24-48 HRS
PRE-
PROCESSING
≤2 HRS
VALUE
ADDED

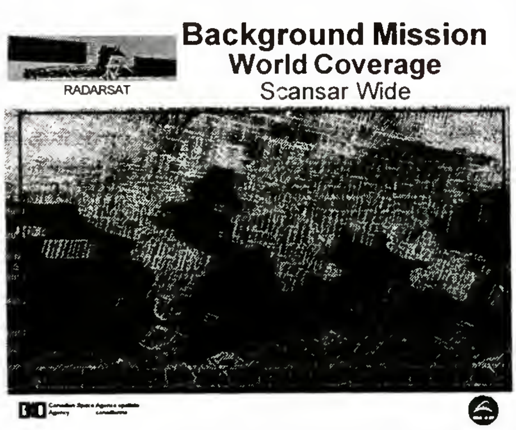

RADARSAT
DISASTER
MANAGEMENT
CHARACTERISTICS
• Short to Medium Duration
• Occur During Inclement Weather
• Often Seasonal or Cyclical
EVENTS
• Anthropogenic: Oil Spills
• Climatological: Flooding, Wind/ Storm Damage
• Geological: Mass Movement, Tectonic Activity

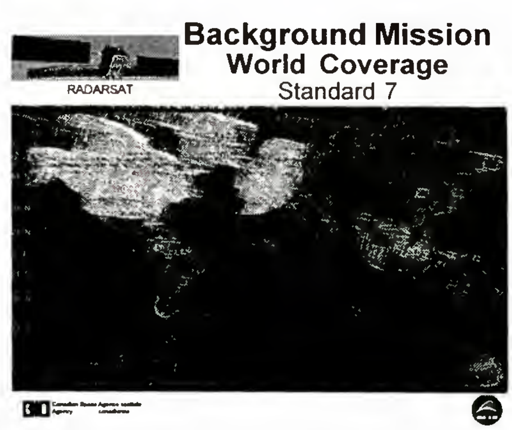

RADARSAT
Japan Oil Spill
Oil
• Sea of Japan
• January 11, 1997
• Standard -1
• 46 images
• Overcast & night
• Less than 5 hours


RADARSAT
Red River Flood
The Red Sea
• April-May 1997
• Canada/USA
• Historical Flood
• 37 Images
• Every 3 days or less
• Strategic and Tactical
• Damage Assessment


RADARSAT
Ships Movement Monitoring
Strait of Malacca, Singapore
Overview Monitoring
Close Monitoring

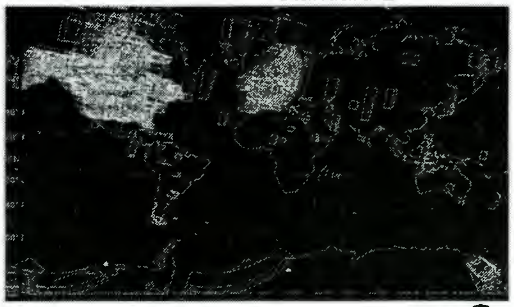

RADARSAT
Rice Crop Monitoring
• China,
• Guangdong Province
• Multitemporal Images
April 6, June 17, Aug. 4, 1996
• Fine 4, Ascending
• Image area 15km x 15 km


RADARSAT
Background Mission
World Coverage
Scansar Wide


RADARSAT
Background Mission
World Coverage
Standard 7

RADARSAT

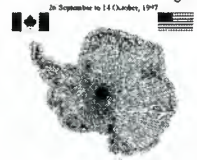
Background Mission World Coverage
Standard 2



RADARSAT

Antarctic Mapping Mission

Radarsat Antarctic Coverage



- First Coverage at High Resolution
- Near Real Time Snapshot
- One Satellite in 18 Days Compared to 13 Satellites & 6 years
- Full Mosaic in 1 1/2 years

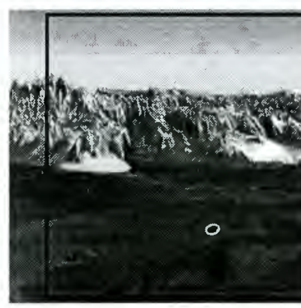
RADARSAT

Fastscan System

- Efficient Data Acquisition Planning
- Validation of Data Reception
- Preliminary Mosaic

RADARSAT

Flying In McMurdo, looking at the Transantarctic Mountains



- RADARSAT S2 Data Laid Over a DEM.
- Bowers Ice Piedmont and Blue Glacier. (On the left)
- The Ferrar and Taylor Valleys
- Wilson Ice Piedmont (on the right)
- Sea ice

RADARSAT

The Commercial Distributor

- RADARSAT International Inc.(RSI)
- Worldwide Data Distribution Rights
- Station Reception & Distributor Network
- Royalties to CSA on Data Sales

EDUCACION Y ENTRENAMIENTO

Un punto llave por el desarrollo de las aplicaciones de la Percepción Remota

Jean-Pierre PARIS - GDTA
Administrador Adjunto

INTERES DE LAS TECNICAS DE TELEDETECCION Y DE LOS SIG

arios puntos llave son de interés por el desarrollo del uso de la Teledetección y de los SIG.

. ***Actividad de cooperación nacional y internacional***
- ✓ *desarollo de proyectos interdisciplinarios*
- ✓ *promoción, relaciones y red de expertos.*

Uso de nuevas herramientas
- ✓ *muchas diferentes experiencias, sistemas base de datos*
- ✓ *intercambios necesario : estandardización de las proceduras.*

Rol de los varios partenarios :

Sector privado :
- *. apoyo a la creacion y desarollo de PME*
- *. relación continua con grandes organismos de producción cartografica o tematica.*

Rol de sumo interés de las universidades :
- *. introducción de percepción remota y SIG en la enseñanza*
- *. cursos de postgrado.*

PUNTO LLAVE :
EDUCACION Y ENTRENAMIENTO

- *Elemento de sumo interés por el uso sostenible de la teledetección y de los S.I.G.*
- *Las aplicaciones de la teledetección son cada vez construidas por profesionales entrenados.*
- *Educación y entrenamiento no son limitados a un unico rol pedagogico.*
- *Capacitación profesional debe ser parte integrante de cada uno de los planes de trabajo c la industria*

☞ *Todo en la linea de capacitación del GDTA.*

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

INTERES DE LAS TECNICAS DE TELEDETECCION Y DE LOS SIG

- *Nuevos sensores y datos de teledetección se han incrementado en las dos ultimas decadas.*

- *Se demostró su interés evidente, no unicamente para los païses en via de desarrollo si no para todos.*

- *Nuevas tecnologias están en desarrollo continuo.*

  - las tecnicas de los S.I.G.

  - el uso complementario de los datos de fotos aereas como de los satelites con sensore de radar o de optica en modo multispectral y multifechas.

GRUPO PARA EL DESARROLLO DE LA TELEDETECCION AEROSPACIAL

G.I.E. creado en 1974

4 MIEMBROS : grandes organismos publicos franceses

cnes		BRGM	IFREMER
Centre national d'Etudes Spatiales	Institut Geografique National	Bureau de Recherches Géologiques et Minières	Institut français de Recherche pour l'Exploitation de la Mer

Personnal : *31 personas*
Docentes : *Personal GDTA y mas de 400 expertos en varios campos de actividades*
Presupuesto : *24 MF ~ 4M $ US*

De 1980 hasta 1997, mas de 3200 profesionales capacitados

Ubicuación : *en el entorno espacial de Toulouse :*

GDTA
8-10 rue Hermès - 31526 Ramonville Cedex
tel. 33-(0)5 61 39 49 50 - fax : 33-(0)5 61 39 49 50

ACTIVIDADES DE CAPACITACION EN EL GDTA

Producción y distribución de productos pedagogicos.

- *Apuntes de cursos y cuadernos pedagogicos*
  - *Bases Fisicas*
  - *Visualisación de Imagenes*
  - *Modelo Digital de Elevación*
  - *Urbanismo*
  - *Riesgos geologicos, ...*

- *Kit de demostración sobre estudio de casos concretos - CD ROM.*
  - *SIG y manejo urbano*
  - *Desvio de carretera*
  - *Perimetro de riego*
  - *Catastro.*

- *Software de Iniciación del Ministerio Frances de Educación Nacional : TITUS.*

Dirigidas a profesionales (Ingenieros, Tecnicos) como a jefes de proyectos, investigadores, formadores como a decisores y administradores.

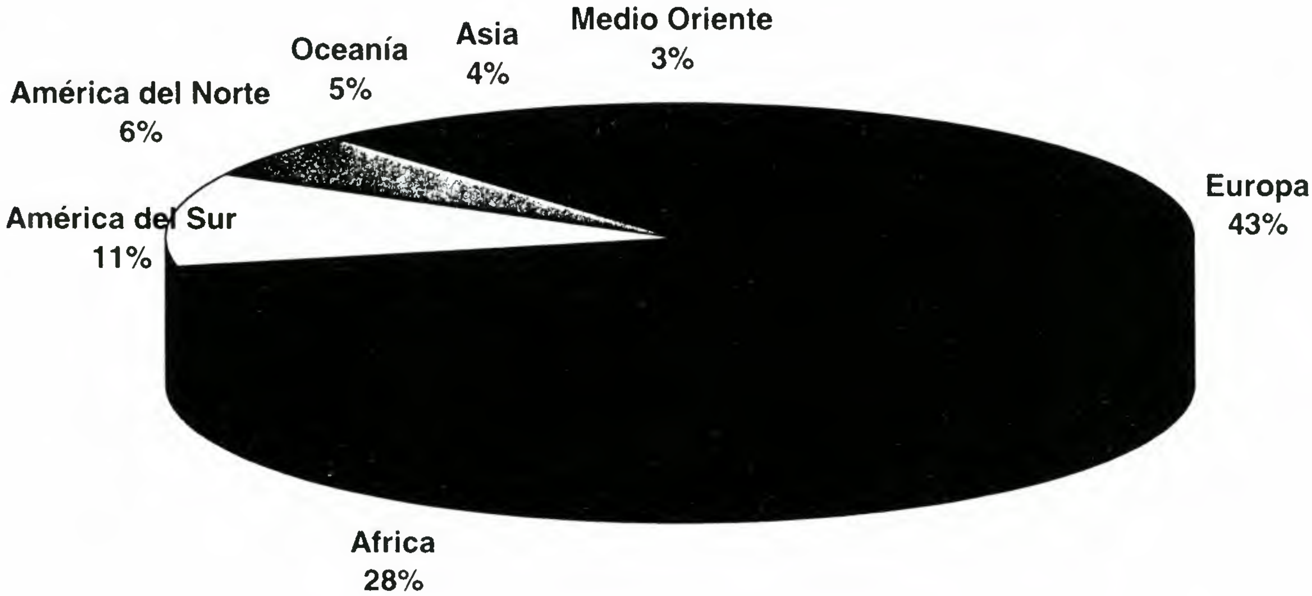
- *CURSOS REGULARES EN FRANCIA :*

* Un diplomado profesional : CETEL /	Frances
* Una amplia gama de cursos y modulos de 2 dias a 5 semanas	Frances
✓ cursos introductivos : SITEL - RSC - SIG	Ingles
✓ cursos especificados y tematicos	Español
. cartografia espacial	
. agricultura	
. manejo teritorial y urbanismo	
. riesgos y exploración geologica	
. radar, GPS...	

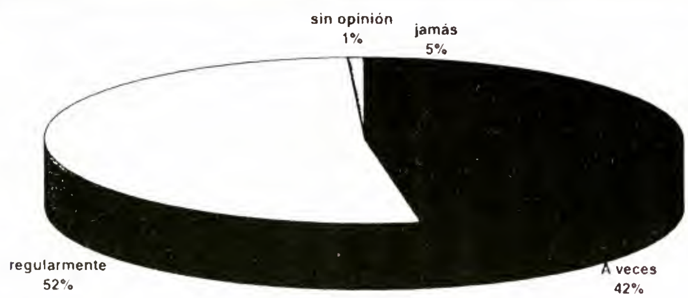
- *CURSOS A SU MEDIDA EN FRANCIA O EN SU SITIO*

- Cursos y modulos ya existente	Frances
- Programas especificos	Ingles
- Formación sobre proyectos	Español

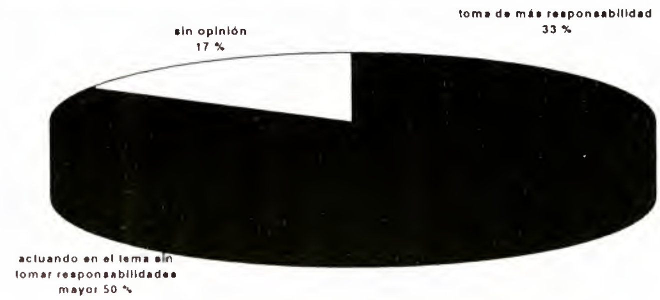
Repartición de los cursantes por regiones, 1980 - 1997



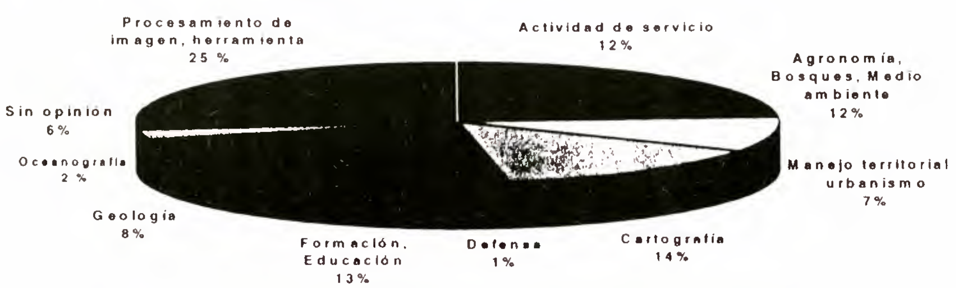
Evaluación de la capacitación



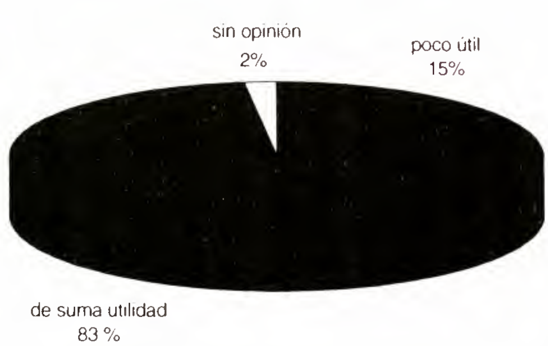
Uso de los conocimientos adquiridos



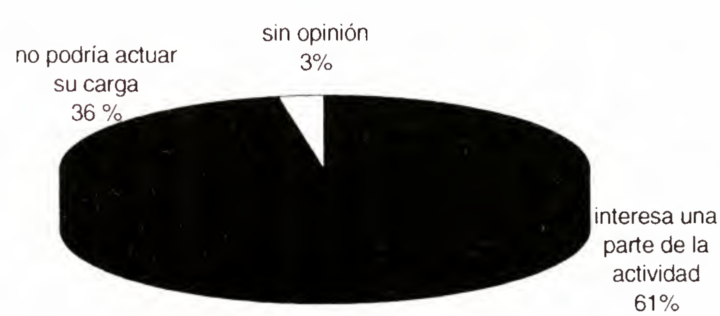
Toma de responsabilidad

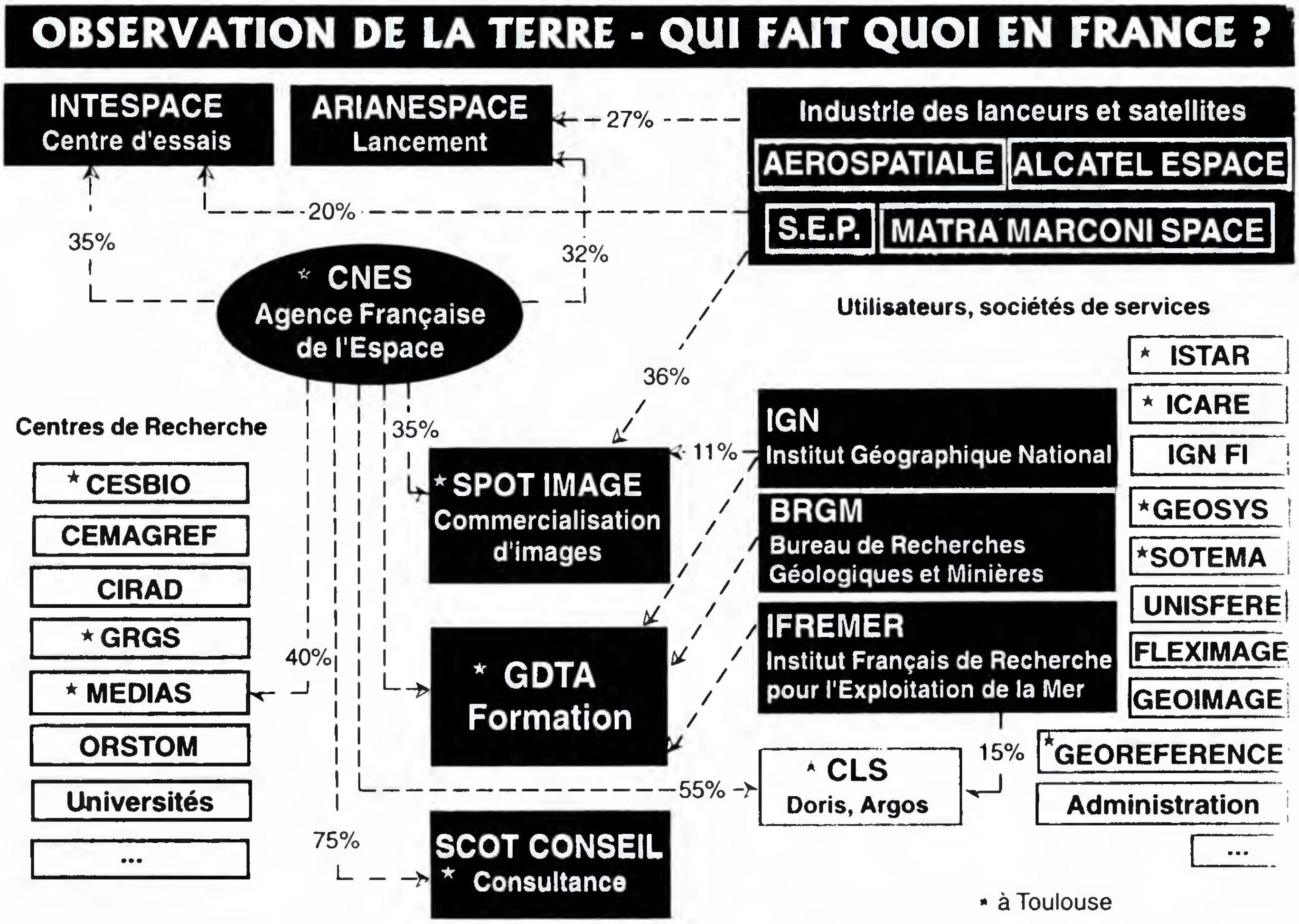


Utilidad de la capacitación en general



Utilidad en la actividad de los previos cursantes





EDUCACION Y ENTRENAMIENTO

CONCLUSION

MAÑANA : *La capacitación va ser muy diferente.*

** nuevas tecnicas numericas de transmisión de datos*
** rapidez de comunicación*

NECESIDAD DE VIGILENCIA

** coherencia de la capacitación*
** una nueva estructura de formación no se improvisa*

NECESIDAD PARA UNA ADAPTACION PEDAGOGICA CONTINUA

** poner al dia y actualizar la enseñanza*
** contestar así a los nuevos requesitos de los profesionales.*

OCEANOGRAPHIC AND ATMOSPHERIC STRUCTURES DETECTED IN THE SEA SURFACE BY THE SAR OF THE ERS-1 IN THE WESTERN MEDITERRANEAN

Dr. Bernardo Shirasago
Interdisciplinary Center of Marine Sciences (CICIMAR-IPN)
Instituto Politecnico Nacional S/N, La Paz 23000, Baja California Sur, Mexico.
Phone (112) 2-53-44 and 66 – Fax (112) 2-53-22
e-mail: shirasag@servidor.unam.mx

ABSTRACT
Three cases of marine and atmospheric structures manifested on the sea surface and detected in the SAR/ERS-1 scenes are presented in this study of the Alboran Sea western sub-basin. The first example shows a partial detection of a warm anticyclonic gyre imaged in the SAR scenes by means of the high values of backscattering recorded in the interior of the gyre as well as the delineation of the eastern border of this structure by dark lines of low backscatter intensities. The presence of the gyre was corroborated by on site measurements. In the second case, atmospheric internal wave trains are shown in the SAR set of images which appear to be related to bad meteorological conditions specially to a cold front detected to the South of the study region. The third case corresponds to an eddy (small gyre) imaged in a SAR scene, whose marine or atmospheric origin was not possible to determine.

1. INTRODUCTION

It has been demonstrated the capability of the active microwave sensor SAR (Synthetic Aperture Radar), in the detection of oceanographic and atmospheric features that affect the roughness of the sea surface. An important variety of phenomena occurring in the oceans and the atmosphere are detected by SAR sensors because of their manifestation on the sea surface such as surface waves, internal oceanic and atmospheric waves, marine currents, wind and oceanic fronts, warm and cold eddies and gyres, bathymetric features, storms, etc. [1, 3, 7, 8, 10].

These phenomena are distinguishable by SAR sensors due to the fact that the capillary and short gravity waves, generated by wind stress, are modulated by them [2, 9, 10, 13]. The interaction of these waves and the SAR electromagnetic wave are responsible of the so-called Bragg Resonance, main contributor to the SAR imaging of oceanic and atmospheric features at incidence angles from 20° to 70° [5, 15].

Other factors responsible for the detection of the marine features are the presence of surfactants, surface films of organic origin associated with marine currents [11] as well as the stability perturbation of the marine atmospheric boundary layer. This perturbation is generated by differences in air-sea temperature and it is accompanied by an increase in the surface drag coefficient and Bragg spectral energy density and therefore, an increase in the radar backscattering [1, 3]. In the event of atmospheric processes detected by SAR, gravity waves are a case of internal waves that produce variations in wind speed over the ocean surface affecting the local roughness of the sea and in turn, detected by this kind of sensor [12]. The generation mechanisms are often uncertain but they are associated with orographic interactions, frontal disturbances, or convective instabilities.

The oceanographic relevance of the Alboran Sea is attributable to its strong relation to the Atlantic Ocean, maintaining an interchange of water in two layers with this ocean (upper layer entering to the Mediterranean and the lower one exiting it) [4]. The Alboran Basin is the first Mediterranean sink encountered by the incoming Atlantic waters entering through the Gibraltar Strait. Mesoscale structures are very important in this sea being the most important features two large and warm anticyclonic gyres, surrounded by colder waters [6]. One gyre is located in the western sub-basin and presents quasi-permanent characteristics whereas the other one, detected in the eastern sub-basin, is sometimes present. If not there, a current along the African coast is seen. The diameters of both gyres are about 100 km and have coupled to them a thermal front associated with a strong jet responsible for transporting 1Sv (one million of cubic meters/second) into the Mediterranean [14].

The aim of this work is to present the results obtained during a survey made in the Alboran Sea in 1992, in the detection of marine mesoscale structures and their ways of manifestation in the SAR scenes. An important set of daily wind data, oceanographic measurements, and SAR scenes were collected. During the data analysis atmospheric features were detected in the SAR images but one of the most exciting structures observed was a well-shaped, probably cyclonic, eddy, with an uncertain origin.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

2. DATA AND METHODOLOGY

Nine ERS-1 FDC.SAR scenes were used for this study as part of a set of forty five images obtained from ESA under the AO project "*Evaluation of ERS-1 microwave sensors capability in the study of oceanic fronts*". The images corresponded to the western Alboran Sea with dates 15 September and 1 and 4 October 1992. The images were reduced from their original 16 bite 5000x6300 pixels to 8 bite 500x525 pixels through an 10x12 average pixel window. All images were geo-coded and vector overlaid with the image processing system GEOJARS.

Marine data were acquired aboard the Spanish Research Vessel 'Garcia del Cid' of the Institute of Marine Sciences, Barcelona, during Cruise FE92 made from 22 September to 7 October 1992. This cruise included 134 oceanographic stations obtaining at each one profiles of conductivity and temperature versus depth using a CTD Sea Bird model SBE 25. Additionally, continuous along track measurements of marine currents were made with a Vessel Mounted 150 RD Instruments ADCP (Acoustic Doppler Current Profiler) during the path of the cruise. Meteorological information including isobaric charts at 10^5 Pa and wind fields with a spatial resolution of 54 km were obtained from the National Meteorological Institute of Spain. The isobaric charts are at 12:00 or 18:00 GMT and wind fields at 0:00 or 12:00 GMT. All of these meteorological conditions were selected to be close to the ERS-1 passing time.

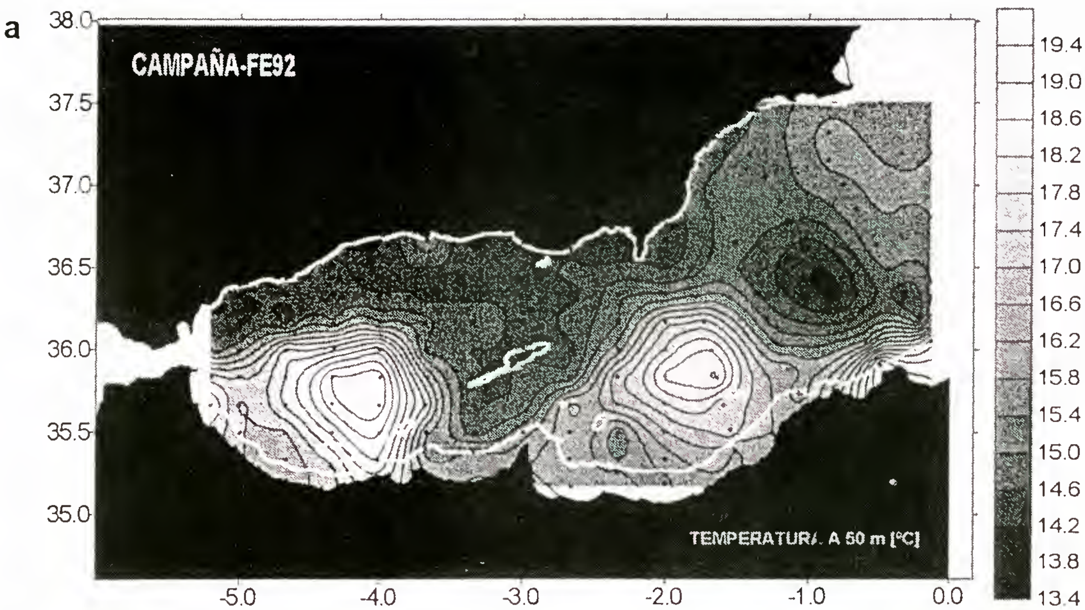
3. RESULTS

Oceanographic data obtained during the cruise revealed the presence of important mesoscale structures. Figure 1a shows the temperature distributions at 50 m depth obtained from the CTD data. The surface temperature is very similar but perturbed by the sun warming. The two warm anticyclonic gyres are easily detected in this figure. The air temperature in the area was 17°C and water temperature inside of both gyres reached about 23°C with the surrounding areas at 19°C. This temperature difference between the water inside and outside the gyres gave as a result the formation a wave-like temperature front (haline as well, from the cruise data) around the gyres. Geostrophic velocities calculated from the CTD data (fig. 1b) also show the presence of both gyres with a strong jet associated with the wave like temperature-haline front. The jet continues flowing to the east of the Alboran Sea forming an important along shore coastal current named the Algerian Current.

Meteorological conditions prevailing during September and October 1992, were characterised by a high spatial variability. The presence of high and low atmospheric pressure cells dominating alternatively the Iberian Peninsula and the Alboran Sea produced wind fields in different directions and magnitudes with the same variability, a situation clearly reflected in the SAR images. Near midnight 15 September a high-pressure cell to the north of the Alboran Sea and a low-pressure cell to the south were observed, with the corresponding wind field shown in figure 2a (0:00 GMT, 16 September). In this figure, the winds are blowing from the southwest in the western part of the sea with magnitudes of 5 to 6 m/s. Figure 2b shows the corresponding SAR set of three images (22:00 GMT, 15 September) with the western anticyclonic gyre detectable by means of an important area of high backscattering values. The border of this gyre is delineated on the eastern and northern sides by dark lines, possibly caused by the turbulent interaction of the gyre with the surrounding waters or the SAR signal damping because of the surfactants. This image is overlaid with ADCP marine current vectors showing the velocities at many points of the image, corroborating the gyre location and sense of spin. This latter was confirmed by dark areas in the southern part of the gyre.

During 4 October, meteorological conditions were severe in the Alboran Sea because of the presence of atmospheric low-pressure cells with considerable gradients and a cold front at the southern border of the sea at 18:00 GMT (fig. 3a). The wind field appears roughly homogenous with winds blowing almost from the north at 12-14 m/s (0:00 GMT, 5 October). The three SAR scenes obtained from ERS-1 at 22:30 GMT of October 4 (fig. 3b), revealed high values of backscattering as a result of the strong winds in the entire Alboran Sea. In spite of this, atmospheric internal wave trains are detected in the right part of the set of images with a wave length varying between 10 and 15 km travelling in different directions. The western gyre is not clearly detectable because of the high backscattering values but in some areas it is possible to see lines of relatively low returned signal, delineating the water flow entering from the Gibraltar Strait (west) and the African coastal current generated because of the gyre spin (south). All of these seawater flows are corroborated by overlaid ADCP current vectors.

The combination of low and high atmospheric pressure cells influencing the Iberian Peninsula on 1 October (18:00 GMT) gave a wind convergence zone centred mainly in the western Alboran Sea sub-basin (fig. 4a) with magnitudes of 2-3 m/s in the north and up to 8 m/s in the south (0:00 GMT 2 October). In addition to these



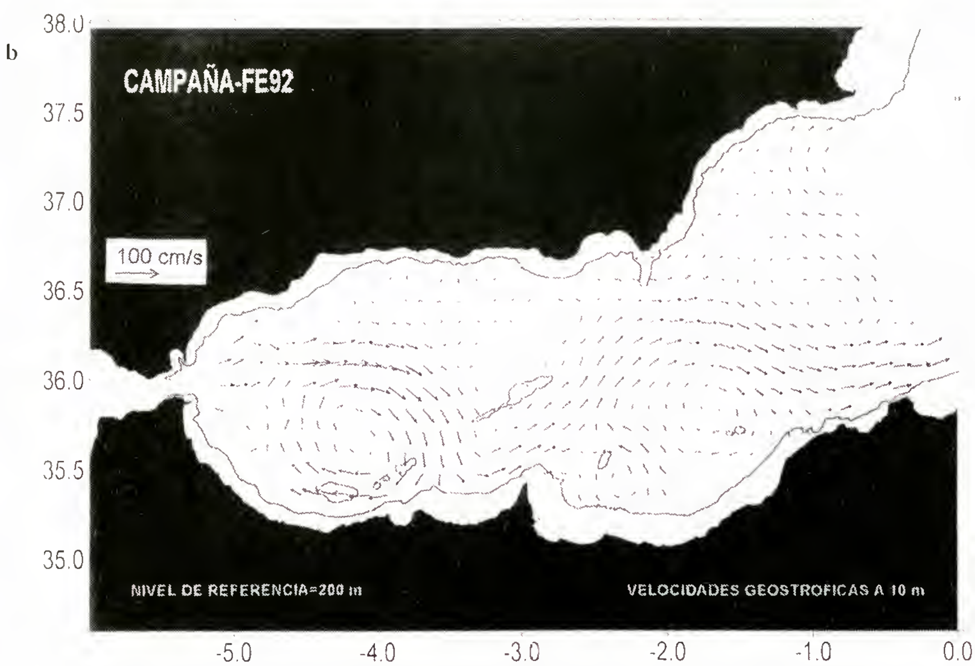
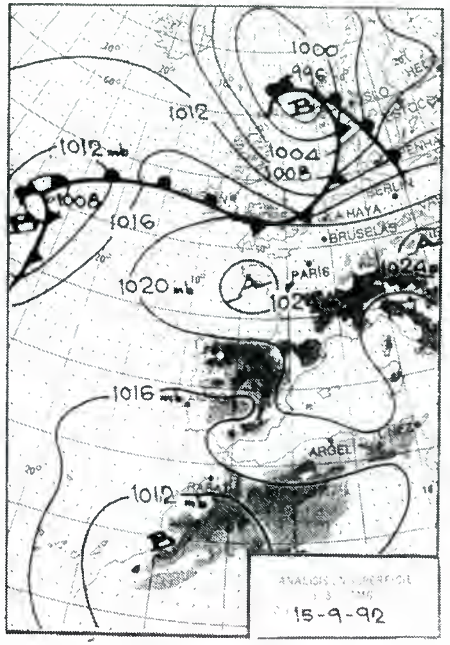
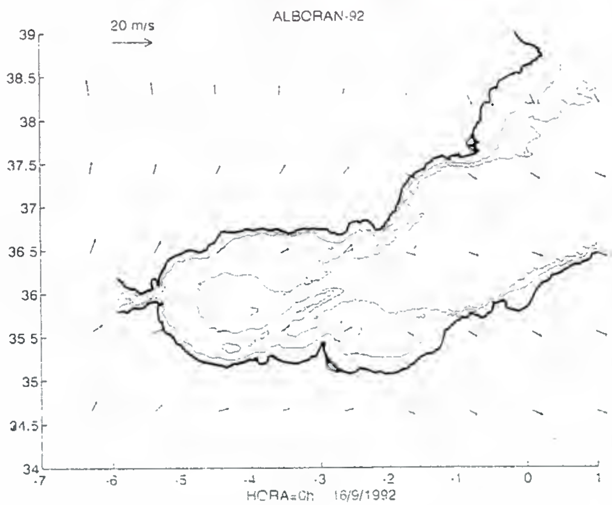


FIGURE 1. Distributions obtained from CTD data. a) Temperature Field at 50 m depth. b) Geostrophic velocities at 10 m with a 200 m

a





b

FIGURE 2. Meteorological conditions and SAR set 15 September 1992.
a) Isobaric chart at 18:00GMT and wind field at 0:00 GMT 16 September
b) SAR set of images at 22:00 GMT showing the anticloclonic gyre with ADCP vectors.

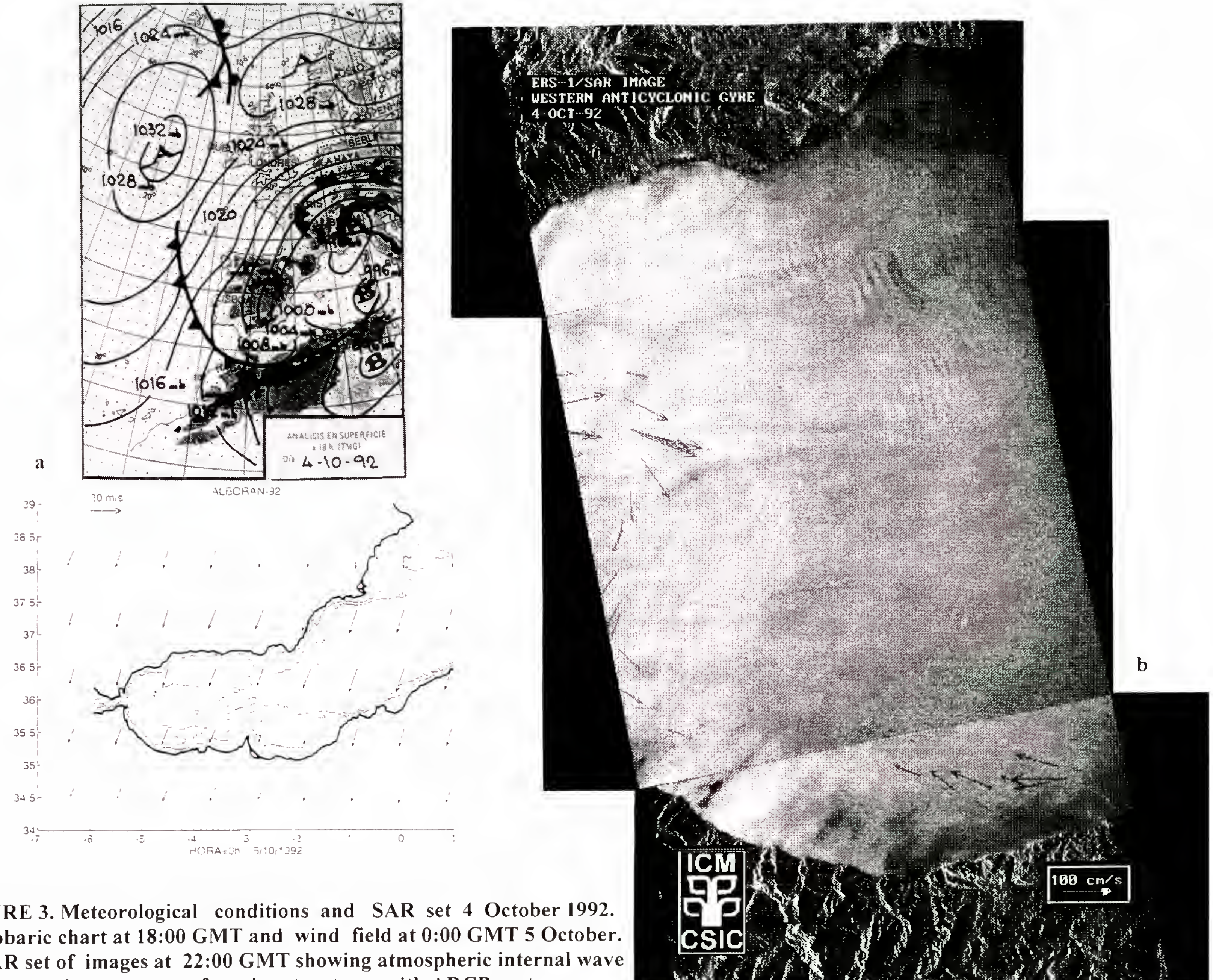
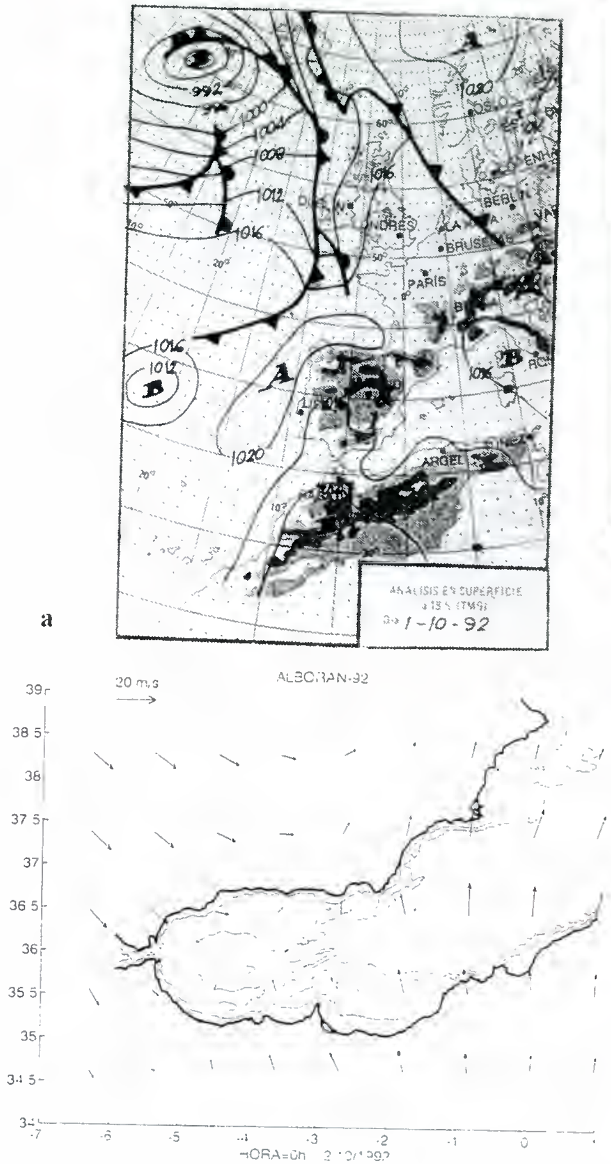


FIGURE 3. Meteorological conditions and SAR set 4 October 1992.
a) Isobaric chart at 18:00 GMT and wind field at 0:00 GMT 5 October.
b) SAR set of images at 22:00 GMT showing atmospheric internal wave trains and some traces of marine structures with ADCP vectors.



a

b

FIGURE 4. Meteorological conditions and SAR set 1 October 1992.
a) Isobaric chart at 18:00GMT and wind field at 0:00 GMT 2 October
b) SAR set of images at 22:00 GMT showing the small gyre intruding into the western anticyloclonic gyre.

wind conditions, a cold frontal zone was present to the northwest of the peninsula. The set of ERS-1 SAR scenes obtained at 22:30 GMT 1 October of the western sub-basin (figure 3b) shows an important feature consisting of a 20km diameter eddy (small gyre), probably cyclonic, intruding into the big western anticyclonic gyre at its eastern side (center left of the set). This structure is imaged in the SAR scene by means of black lines of low backscattering. It was impossible to determine its marine or atmospheric origin. The eddy is superimposed with black and diffused lines showing atmospheric internal wave trains, also present in some other parts of the set. Dark zones to the north (top of the set) are caused by low wind magnitudes recorded in these areas.

4. DISCUSION AND CONCLUSIONS

The first two sets of ERS-1 SAR scenes revealed important mesoscale marine and atmospheric features with different manifestations. The marine aspects were corroborated by on-site measurements. The big anticyclonic gyre was detected in the SAR images (first set of scenes) because of the high backscattering values recorded in the interior of the gyre as well as the border delineation of this structure by dark lines of low backscatter intensity. This high values of the returned signal are related to the differences between water and air temperature (gyre waters 23 °C and air ~19 °C), a situation producing instability in the marine atmospheric boundary layer. Such instability increases the wind-drag coefficient and therefore causes the generation of capillary waves on the sea surface, the main contributors of the Bragg resonance.

For atmospheric internal wave detection on SAR images (second set of images) and in spite of the high levels of backscattering because of the strong wind, these kind of waves were possible to detect as trains in different directions. The trains appear to be related to bad meteorological conditions, especially to the cold front detected to the south of the study region. Some traces of the big anticyclonic gyre and also the water entering through the Gibraltar Strait are detectable by lines of relatively low backscattering.

The marine or atmospheric origin of the features observed in the SAR scenes could be determined in the firts two cases. This was not the same for the third set of images. If it were marine, it could be generated because of instabilities of the wave-like front and its associated jet, or the interaction of this front with the one of the two anticyclonic gyres. If it were atmospheric, it may be a manifestation of a whirlwind on the sea surface, generated by the wind convergence zone observed in the wind distribution chart or caused by the bad meteorological conditions, including the presence of a cold front near the study area.

It is remarkable that all of the structures, marine or atmospheric, were detected by the SAR of the ERS-1 under bad meteorological conditions and cloudy days, representing a powerful tool for marine research.

This study is part of the ESA OA project E1 "Evaluation of ERS-1 microwave sensors capability in the study of oceanic fronts" and EUROMODEL MAST Project No. MAS2-CT93-0066. My thanks to Dr. Jordi Font from the Institute of Marine Sciences of Barcelona, principal investigator of the ESA OA project and Dr. Ellis Glazier for editing the English-language text.

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PROCESAMIENTO DE IMÁGENES DE SATÉLITES DE ÓRBITA BAJA

Dr. Roman E. López Bonilla
Centro de Investigación y de desarrollo de Tecnología Digital
Instituto Politécnica Nacional
Av. del Parque #1310 Mesa de Otay, Tijuana, B. C. México 22500
Tel. (66) 231344 ext. 119 Fax (66) 231388
e-mail rlopez@citedi.mx

ABSTRACT

The trends attained throughout the last three decades in the remote sensing fields, especially in the image detection, that have offered to the science community other means of detecting determinates changes that are produced on the surface of our planet. The methods of remote sensing are used in great way by biologists, geographists, agronomists, and engineers dedicated to the evaluation of natural resources. With the purpose of counting with a system that process and analyses satellites images from LEOS, programs and routines in high level language as well as assembly has been developed. For the reduction of the processing time a specialized hardware has been implemented. The result of this work is shown in this paper.

RESUMEN

Los avances conseguidos en el transcurso de las tres ultimas décadas en los campos de los sistemas de detección a distancia particularmente en la detección de imágenes han puesto a disposición de la comunidad científica medios con los que es posible conocer y registrar determinados cambios que se producen en la superficie de nuestro planeta. Los métodos de detección a distancia son utilizados en gran medida por biólogos, geólogos, geógrafos, técnicos agrónomos y forestales e ingenieros dedicados a la evaluación de los recursos naturales. Con el propósito de contar con un sistema de análisis y procesamiento de imágenes de satélites, se ha desarrollado un de paquete de rutinas en C++ y circuitería especializada para disminuir el tiempo de procesadores la captura, acondicionamiento e interpretación de imágenes digitales, estas rutinas se han implementado en una estación de trabajo. El desarrollo de este paquete es presenta en este articulo.

1. INTRODUCCIÓN

La órbita utilizada con mas frecuencia en satélites de comunicación es la órbita geoestacionaria (GEO), esta es una órbita circular en el plano ecuatorial a una altura de 35,786 km. Los satélites geoestacionarios pueden cubrir grandes áreas del planeta con lo cual permiten el uso de antenas terrestres de punto fijo. Sin embargo, requieren de altas potencias de transmisión y antenas de gran apertura. No cubren regiones de la tierra de alta latitud. Producen largos retardos de comunicación, y requieren de lanzamientos del satélite de alto costo y alto riesgo [1,2,3 y 3].

1.1 Órbitas de los Satélites

Las órbitas no geoestacionarias se encuentran agrupadas como *órbita bajá* (LEO), *órbita mediana* (MEO) u *órbitas altamente elípticas* (HEO). Las órbitas bajas son aquellas que se encuentran en el rango entre 200 y 3000km entre la llamada altitud de densidad atmosférica constante y los cinturones de radiación Van Allen. Las órbitas medianas empiezan después de los 3000km y se extienden hasta una distancia GEO. Los satélites en estas órbitas siempre cruzan los cinturones de radiación, y de esta manera se encuentran con niveles muy altos de radiación [1-4].

Las órbitas altamente elípticas se aproximan a la superficie terrestre a unos cuantos cientos de kilómetros, y después alcanzan y sobrepasan la distancia GEO. La alternativa para una órbita satelital óptima se determina frecuentemente por la cobertura de la tierra requerida.

2.0 Adquisición e interpretación de imágenes de satélites

Por medio de la detección a distancia, los datos necesarios son tomados desde satélites puestos en órbita alrededor de la Tierra. Seguidamente, estos datos son procesados y elaborados por medio de la computadora y correlacionados con la ayuda de instrumentos de medida instalados en tierra. Procesos tales como el agotamiento del ozono, la formación de dióxido de carbono y la lluvia ácida han puesto de manifiesto la necesidad de una cooperación internacional para conseguir resolver estos sistemas, ya que la contaminación ambiental desconoce la existencia de fronteras nacionales.

2.1 Sensado remoto

Cuando un objeto situado sobre la superficie terrestre infiere con la radiación electromagnética emitida desde el satélite, puede tener lugar uno o varios de los siguientes

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

fenómenos: reflexión, refracción, dispersión, absorción o remisión. Cuando dicha radiación electromagnética es reflejada o remitida, deberá atravesar de nuevo la atmósfera para que pueda ser captada por los senderos instalados en el satélite. No obstante, dado que la atmósfera contiene partículas tales como polvo, hollín y aerosoles, así como vapor de agua, dióxido de carbono y ozono, puede resultar alterada la intensidad y composición de la radiación reflejada que llegue a incidir en los senderos instalados en el satélite. En la mayoría de los casos, el sensor consiste en un dispositivo electro-óptico que transforma las radiaciones electromagnéticas en impulsos eléctricos, los que, a su vez, son convertidos, por medio de un compuatador, en valores digitales que se almacena en discos o cintas magnéticas.

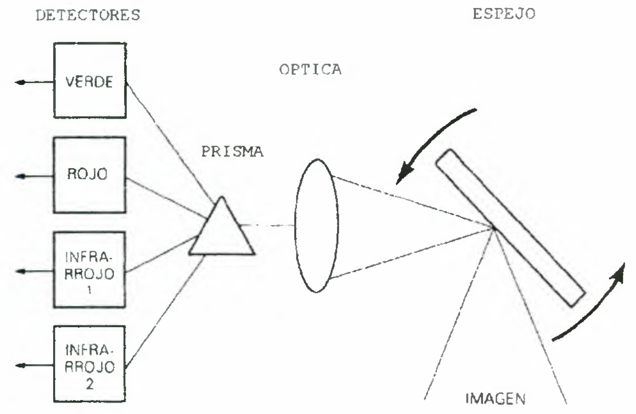

Figura 1 Principio de funcionamiento del sistema de barrido multiespectral.

La mayoría de los sensores electro-ópticos son dispositivos de barrido multiespectral que registran simultáneamente la energía procedente de las diversas regiones del espectro electromagnético.

En estos dispositivos de barrido puede utilizarse un espejo que, con su rápida oscilación, dirige la radiación a través de un sistema óptico en donde un sistema de filtros apropiados la divide en bandas espectrales individualizadas (fig. 1). También se utilizan a veces conjuntos lineales de detectores que realizan el barrido electrónicamente, a medida que el satélite se desplaza en su órbita. Con el sensor MS (Multispectral Scanner) instalado en los satélites Landsat se han obtenido imágenes en dos bandas del espectro visible y en dos del infrarrojo cercano. El explorador de barrido TM (Thermatic Mapper) ha posibilitado la obtención de imágenes en tres bandas visibles y cuatro del infrarrojo cercano. Cada una de estas bandas es concentrada sobre detectoras individuales que poseen sensibilidades especificas, en donde se produce la transformación de las radiaciones electromagnéticas en energía eléctrica. Los sensores barren la superficie terrestre bajo estudio, en el sentido oeste-este. La anchura de la zona barrida (fig. 2) viene determinada por el campo visual del correspondiente sensor, que para el Landsat es de 184 km. y para el **SPOT** es de 59 km [2-3].

La resolución de un sistema sensor viene determinada por sus capacidad para poder distinguir las diferencias existentes en la información procedente de la superficie en estudio o en sus características espaciales. Se denomina pixel, contracción de *picture element* (elemento de imagen) a cada una de las porciones en que se puede dividir una imagen para poder así digitalizarla y manipularla o también al elemento pictórico mas pequeño de las imágenes que es susceptible de ser procesado.

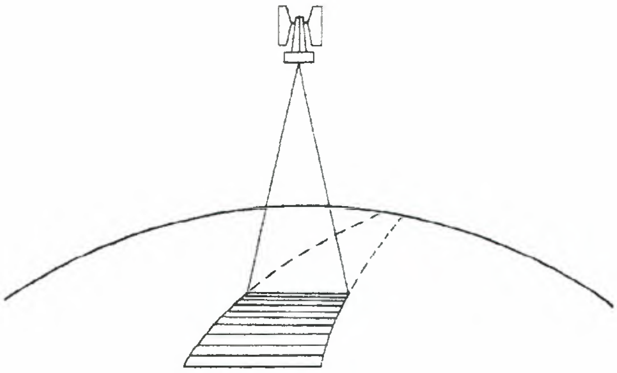

Figura 2 La capacidad de barrido de un satélite viene determinada por el campo visual del sensor.

Los pixeles constituyen a modo de millares de pequeñas piezas rectangulares del rompecabezas gigante en que consiste una imagen completa. Para el Landsat 5, la resolución de cada pixel es el *nadir*, posición correspondiente a la vertical bajo el satélite, es de 82 m con el MMS y de 30 m con el Thermatic Mapper. Estos valores podrían parecer muy grandes, pero hay que tener en cuenta que los objetos son observados desde un satélite situado a mas de 640 km. por encima de la superficie terrestre y que la amplitud del campo visual equivale a una anchura de 184 km. Toda mejora que se logre en la resolución de los sistemas sensores se traducirá en un mayor detalle, lo que, a su vez, redundara en una mejor calidad de las imágenes obtenidas.

El nivel energético correspondiente a cada pixel individualizado se registra en forma digital sobre la cinta magnética. En el Landsat MMS, a cada pixel se le asignan cuatro valores digitales, uno por cada banda espectral, los que, a continuación son transmitidos directamente a las estaciones de recepción situadas en diversas partes del globo. Los datos así obtenidos no son tratados para corregir los efectos de origen atmosférico, de iluminación, de calibración de los sensores o de distorsiones debidas a las características geométricas de la Tierra, todos los cuales introducen errores en la altitud del satélite. Las diversas correcciones se realizan, normalmente, en una posterior etapa del proceso de datos. Para poder restablecer los pixeles a fin de obtener la imagen de un determinado escenario del terreno, los valores digitales son convertidos en las correspondientes tonalidades de gris. Estas tonalidades pueden pasarse a un negativo fotográfico o pueden visionarse en un monitor de vídeo en blanco y negro o en color. Para cada una de estas bandas espectrales o combinación de relaciones o diferencias entre ellas puede obtenerse una de estas imágenes.

La ventaja de la recogida de datos en distintas bandas espectrales estrechas reside en que, al proceder al revelado de las pautas la respuesta espectral, es posible diagnosticar determinadas características del terreno y variaciones experimentadas por los recursos naturales. El tratamiento de los datos espectrales digitalizados supone la identificación de dichas pautas y resaltar al máximo los contrastes entre sus diversas clases o categorías. La transformación de los datos espectrales mediante el calculo de relaciones o diferencias entre bandas espectrales hace posible la *cuantificación* de ciertos parámetros o su representación numérica, que puede ser tratada por métodos matemáticos en las computadoras.

2.2 Adquisición y acondicionamiento de las imágenes

Variedad de sensores están siendo evaluados en aplicaciones ecológicas especificas. La identificación directa de materiales que forman parte de la superficie terrestre, basándose en la información proporcionada por un pixel, se consigue realizando un muestreo de las características de absorción de las bandas espectrales. A mayor numero de bandas espectrales, mayor será la cantidad de información que es proporcionada en cada pixel. Existen materiales en la superficie terrestre cuyas características de absorción, mediante las cuales es posible su diagnostico, tienen únicamente de 20 a 40 nm de ancho. Por tanto, los equipos de barrido multiespectral de los Landsat, cuyos anchos de banda varían entre 100 y 200 nm, son inadecuados para poder llegar a resolver muchas de estas características espectrales.
El espectro infrarrojo cercano de la vegetación contiene información acerca de la pigmentación de las plantas, de la estructura celular de las hojas y de su contenido de humedad.

Cuando una planta esta sometida a estres debido a enfermedades, plagas, condiciones climáticas o desequilibrio en minerales, se modifica la estructura interna de sus hojas. A pesar de que algunos de estos cambios no sean observables a simple vista, es posible su detección con equipos de barrido de infrarrojo. La vegetación sana presenta dos intensidades de infrarrojo casi iguales, que se corresponden con dos valores distintos de longitud de onda. Es posible la identificación de diferentes especies vegetales mediante los que se denomina su relación espectral, la cual se obtiene dividiendo entre si las intensidades correspondientes a la primera y a la segunda crestas espectrales y multiplicando el resultado obtenido por una constante. Cuando la vegetación se encuentra sometida a estres, una de las crestas podría ser mas baja que la anterior. Recogidos estos datos en forma adecuada, es posible la detección temprana de enfermedades, la discriminación a distancia y la confección de mapas de especies o de comunidades de plantas, así como el conocimiento de la cantidad total de biomasa o de la bondad de las cosechas.

2.3 Bandas espectrales

La mayoría de las sustancias aparecen con diferentes aspectos cuando son observadas con bandas de distintas longitudes de onda y poseen, por tanto, diferentes rangos espectrales. Las sutiles diferencias existentes en las características de las superficies en estudio se hacen mas evidentes cuando las bandas espectrales individuales se combinan para conseguir una composición en pseudocolor. Los colores son *falsos*, ya que representan bandas espectrales en las regiones del verde, del rojo y del infrarrojo cercano.

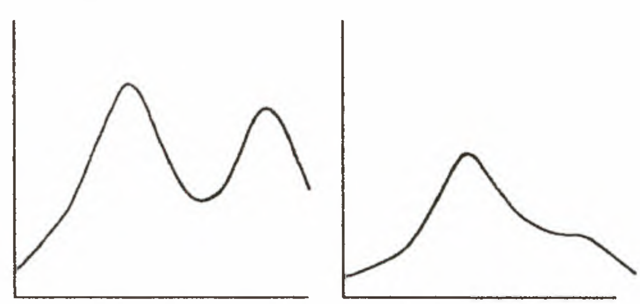

Figura 3 Los dos máximos consecutivos de intensidad de la radiación infrarroja.

Por medio del procesamiento de las imagenesy una técnica llamada falso color se puede asignarse cualquier color a las bandas espectrales, de modo que aun cuando la imagen continúe teniendo color falso, puede hacerse que la vegetación aparezca de color verde.

Con el proceso denominado de *intervalos de densidad* pueden obtenerse contrastes en valores que cambian de modo constante como, por ejemplo, profundidades de masas de agua. A determinados rangos de valores se asignan distintos pseudocolores (colores falsos), a fin de obtener imágenes que hacen mas fácil a las personas encargadas de interpretarlas la apreciación de sus diferencias esenciales.

La característica observada sobre el terreno puede verse afectada por varios factores. Dado que el 70 por ciento de la superficie terrestre esta cubierta por vegetación, los factores ambientales mas comunes que influyen sobre la radiación especifica del objetivo son la cantidad y la orientación de la vegetación y la magnitud de la reflectancia comparada con la del suelo.

3.0 Desarrollo del trabajo de procesamiento de imagenes de LEOS

Con el propósito de simular una imagen adquirida por un satélite de órbita bajá, se acondiciono una cámara de vídeo comercial de bajo costo con los cambios pertinentes al caso.

3.1 Cámara de vídeo

la cámara seleccionada fue una cámara de ccd de Polaris Industrie Modelo MB-912C con las características mostradas en la tabla 2.

Tipo de sensor	CDD
Resolución del ccd	510 (h) por 492 (v)
Entrelazado	2:1
Frecuencia	15.734Kh (h), 59.94Hx (v)
Señal de salida	1 v.p.p.
Resolución	350 X 350
Tipo de vídeo	NTSC
Y	0.54
Control de ganancia	Automático (-6 + 18dv)
Iris	Automático (1/60-1/100,000)
Alimentación (v)	+11v a +15v
Alimentación (mA)	menor que 200 mA
Aceleración	65g máxima

TABLA 1. Características de la cámara empleada.

Este tipo de sensor se selecciono por ser una de las mas usadas en la actualidad en los satélites de órbita baja por su tamaño, bajo consumo de energía y inmunidad al ruido.

4. 0 El almacenamiento de imágenes digitales

La compresión de imágenes consiste en almacenar las imágenes de tal forma que están ocupen menor espacio de almacenamiento que las originales. Para considerar que un sistema de compresión es eficiente es necesario que este contenga los siguientes elementos:

4.1 Formato de archivos gráficos

Los programas gráficos pueden ser clasificados por su forma de almacenarlos y desplegarlos. Estas son: Formato de rastreo y formato vectorial. Los formatos de rastreo son compuestos por una serie de elementos de imagen o pixeles. Los monitores de rastreo son generados por el barrido periódico de electrones de emisión sobre la superficie de imagen (por ejemplo, una cámara de vídeo). Las imágenes de rastreo a menudo son usados como una representación gráfica, donde consideraciones artísticas y la calidad de la imagen son importantes.

Las principales ventajas de los formatos de rastreo son:

a) El fácil manejo de los datos de salida de un dispositivo de rastreo de entrada (por ejemplo un digitalizador de vídeo o un "scanner") a un dispositivo de rastreo de salida tal como un monitor o impresora.

b) El desplegado de los datos de rastreo son más rápidos que el desplegados de datos vectoriales. Por que los dispositivos de rastreo hacen el desplegado directo y los datos vectoriales tienen primero que pasar por un rastreo y después ser desplegados.

Los formatos de vector se basan en los segmentos de línea en vez de pixeles en la formación de una imagen. Una imagen vectorial esta compuesta de formas que son hechas de segmentos de línea. Los formatos de vector son muy limitados en aplicaciones de procesamiento de imágenes digitales. Los formatos de rastreo más comunes son el PCX/PCC, TIFF, GIF, BMP y MPEG [5-12].

5.0 Paquete de procesamiento de imágenes desarrollado

Debido a la gran cantidad de procesamiento requerido en el acondicionamiento de las imágenes, se desarrollo un paquete para el procesamiento de imágenes en el CITEDI-IPN. Toda la programación se llevo a cabo utilizando el lenguaje "C++ por objetos" con el fin de ser compatibles con el software generado por los otros proyectos que integravan el programa de investigación **"Estaciones Terrenas".** Durante la primera parte del proyecto se trabajo en el ambiente del sistema operativo windows 3.1 y posteriormente con windows 97.

Se desarrollaron las rutinas necesarias para la adaptación con la interfaces de vídeo y el sistema de captura, así como también se implementaron los programas necesarios para la tarjeta del TMS320C51 el cual se encarga de las tareas de procesamiento digital de la imagen. Esta ultima interfaces se desarrollo en el lenguaje "C" paralelo con algunas rutinas en ensamblado para acelerar algunos procesos muy particulares [12-13].

5.1 Imágenes utilizadas

Con el sistema de captura implementado, se adquirieron imágenes en forma indirecta, es decir se coloco una imagen tomada por algún satélite y se digitizo la imagen para luego comprimirla, adaptarla al formato de trabajo (RAW, PCX o TIFF). Otras fuentes de datos fueron las imágenes proporcionadas por el "Centro de Tecnología Espacial de la Universidad de Weber Uthat y el Instituto de Ingeniería de la UNAM.

6.0 Experimentos y resultados.

Los experimentos realizados consistieron en digitalizar las imágenes con la ayuda del sistema de captura (si estas no están digitalizadas) y luego transformarlas a un formato estándar (RAW, PCX y TIF). Se encontró que los formato tipo GIF, JPEG, MPEG están teniendo mas auge por lo que incluirá en un futuro dichos formatos para almacenamiento de imágenes. Los pasos a seguir fueron los siguientes.

Sistema de captura.

- *Captura (simulación).*
- *Transmisión (Puerto serial RS232, 9600 baut).*

Sistema de procesamiento

- *Captura (por puerto RS-232C).*
- *Despliegue de la imagen "cruda"*
- *Generación del encabezado del archivo de la imagen.*

Compresión/descompresión de las imágenes

- *Empaquetado de la imagen (RAW, RLL).*
- *Generación del archivo de clasificación de la imagen.*
- *Almacenamiento de la imagen (datos crudos y clasificados).*
- *Procesamiento de la imagen (histograma, modificación del contrate, acotamiento, filtrado y segmentación de regiones en la imagen.*

6.1 Trabajo experimental

Las siguientes imágenes se adquirieron en diferentes formatos y se transformaron en forma "cruda" para simular que son captadas por la imagen de WEBERTSAT de tamaño 552 por 240 pixeles.

NOMBRE DEL ARCHIVO	FORMATO original	LUGAR DE CAPTURA
PERUM68	datos crudos	Peru
BRAZILMM2	datos crudos	BRASIL
ANDAMAM	datos crudos	Andaman
PHILIPO	datos crudos	Filipinas

Tabla 3 Imágenes usadas para los experimentos.

7.0 Conclusiones

La estación de trabajo implementado consiste en una computadora IBM PC "Pentiun" con una trajeta TMS320C5X para el procesamiento de datos, un monitor de vídeo de color, así como tres cámaras de vídeo con sus respectivas tarjetas de adquisición de imágenes. El software desarrollado fue implementado en Borland C++ versión 4.52. Se desarrollaron rutinas en lenguaje ensamblador para diminuir el tiempo de procesamiento procesamiento. El paquete incluye demás de los formatos de descompresión y almacenamiento, rutinas para el filtrado de las imágenes. Actualmente se están desarrollando programas para ser implementados en un sistema de procesamiento paralelo utilizando "Transputers". Se desarrollaron experimentos consistentes en la descompresión de imágenes con diferentes formatos de almacenamiento, haciendo énfasis en la calidad y rapidez de la descompresión de las imágenes. Además se realizaron experimento consistentes en el realce, acotamiento, brillantes filtrado, segmentación y clasificaciones de regiones de las imágenes tratadas.

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UTILIZACION DE UNA RED DE ESTACIONES UNIX PARA MEJORAR LAS PRESTACIONES DE UN PROCESADOR SAR

A.Martínez. F.Fraile
Dep.Teledetección, INDRA Espacio
C/ Mar Egeo s/n. 28850-S.Fernando de Henares, SPAIN
Tlf.+34 1 396 3911. Fax+34 1 396 3912
e-mail: amar@mdr.indra-espacio.es

J.J.Mallorquí, L.Nogueira, J.Gabaldá, A.Broquetas, A.González(*)
Dep.Teoría de la Señal y Comunicaciones, U.Politecnica Catalunya
(*)Computer Architecture Dep., U.Politecnica Catalunya
C/Sor Eulalía de Anzizu s/n, Ed. D-3. 08071-Barcelona, SPAIN
Tlf.+34 3 401 7229. Fax+34 3 401 7232
e-mail:mallorqu@voltor.upc.es

ABSTRACT

A parallel SAR processor is presented in this paper. The target configuration is a cluster of UNIX workstations, available in most user sites. This fact allows to obtain an increased computing performance without the need of dedicated hardware investment.

1. INTRODUCCION

El Radar de Apertura Sintética, SAR, es un instrumento de teledetección capaz de obtener imágenes de alta resolución de la superficie de la tierra [1]. El objetivo del proceso SAR es la trasformación de los datos brutos (raw data) en una imagen. La generación de imágenes SAR involucra gran cantidad de datos y un complejo algoritmo de enfoque. Estas razones lo hacen atractivo para la aplicación de las tecnologías HPCN (High Performance Computing and Networking).

El objetivo del proyecto PARSAR es llevar un procesador secuencial SAR a una arquitectura en paralelo. La configuración base es un cluster de estaciones de trabajo UNIX intentando explotar los beneficios de la paralelización sin la necesidad de inversiones en hardware.

Este articulo describe la estrategia de paralelización del procesador basada en un proceso multiblock usando PVM (Paralel Virtual Machine) como interface entre procesos.

2. DESCRIPCION DE DATOS Y ALGORITMO

Los datos SAR usados en el proyecto corresponden a la escena completa (100 x 100 km^2) del satélite europeo ERS[2]. Los datos brutos son una matriz de 26800 lineas por 5616 columnas o pixels. Los pixels son números complejos, codificados en 1 + 1 bytes, y el tamaño total es de aproximadamente 300 MB. Los cálculos son llevados a cabo en formato de punto flotante, resultando una matriz de proceso de 1.2 GB. La imagen SAR obtenida tiene 25000 líneas por 4912 columnas. Los pixels son complejos y codificados en 2 + 2 bytes, resultando cerca de 500 MB.

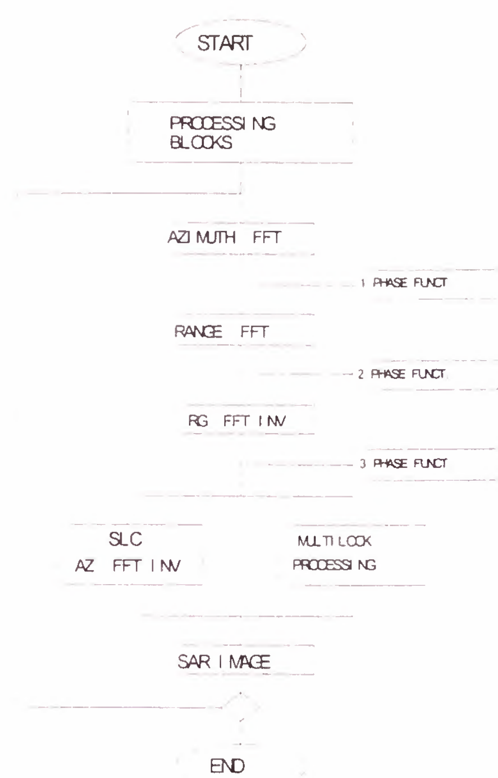

Fig.1.- Diagrama de flujo del procesador secuencial CSA

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

El enfoque de los datos brutos SAR es esencialmente una correlación en 2D de la señal de entrada con la Función de Respuesta del Impulso SAR[3]. Los métodos clasicos de proceso SAR implementan la compresión de la señal en el dominio de las frecuencias. El proceso SAR usado en éste proyecto es llamado Chirp Scaling Algorithm, CSA [4]. El CSA solo conlleva FFT y multiplicaciones. La estructura del CSA es relativamente simple, consistiendo en una secuencia unidimensional de trasformadas de Fourier (FFT) y productos matriciales elemento por elemento (ver figura 1). El número de operaciones y ciclos es constante ya que el CSA no utiliza procedimientos iterativos.

3. DISEÑO DE LA PARALELIZACION

La estrategia de paralelización es llamada Multi- Block Approach, MBA. Esta consiste en dividir los datos entrantes en bloques independientes a procesar; cada bloque es completamente procesado en una estación (proceso hijo) resultando una pequeña porcion de la imagen final. El MBA puede ser visto como una estrategia de paralelización de alto nivel. El PVM se usa para controlar todo el proceso. El PVM es un sistema de software que permite que una red de estaciones de trabajo UNIX heterogeneas sean usadas como una sola gran máquina en paralelo [5].

La principal ventaja del MBA es la completa independencia entre las diferentes labores llevadas a cabo en las estaciones disponibles. Cada proceso hijo es autónomo y no necesita información de otros procesos. Consecuentemente, pueden coexistir estaciones de trabajo lentas y rápidas en la misma red sin afectar ésto a todos los procesos. Otro punto interesante del MBA es la reducción de operaciones I/O y de la cantidad de datos transferidos en la red.

La implementación de la paralelización del MBA es relativamente sencilla, ya que el procesador CSA no tiene divisiones. Cada computador en la red tiene un procesador CSA, muy similar al secuencial. Consecuentemente, las mejoras en el codigo secuencial son inmediatamente trasferidas al software paralelo. Por otro lado, el punto débil del MBA es la relacion de eficiencia, que depende fuertemente del tamaño de los bloques de datos y de la RAM disponible en cada computador.

El diagrama de flujo del procesador SAR paralelo se muestra en la Figura 2. Hay un proceso principal, o proceso padre, que se encarga de lanzar las diferentes tareas en las estaciones de la red y controlar su ejecución. Hay tres tipos de tareas o de procesos.

- Cortador: Esta labor es responsable de la lectura del fichero de datos brutos, y generar los diferentes bloques de datos que serán enviados a los nodos.
- Hijo . Este es una versión simplificada del procesador CSA, que lee un bloque de datos y produce una pequeña porción de la imagen final.
- Constructor: Este proceso lee las diferentes porciones de la imagen y compone la imagen SAR final.

Tanto los bloques de datos brutos como los trozos de imagenes generados por los procesos son almacenados en ficheros temporales. A primera vista, el uso de ficheros temporales puede ser visto como un inconveniente, debido al incremento de operaciones de I/O y a la utilizacion del disco duro que ello conlleva. Sin embargo, las pruebas realizadas sin ficheros temporales mostraron importantes conflictos de acceso al disco cuando diferentes procesos hijo leen y escriben los mismos ficheros de grandes dimensiones. Es más, las operaciones sobre disco de los procesos hijo han de ser realizadas por acceso directo, implicando altos niveles de ineficiencia.

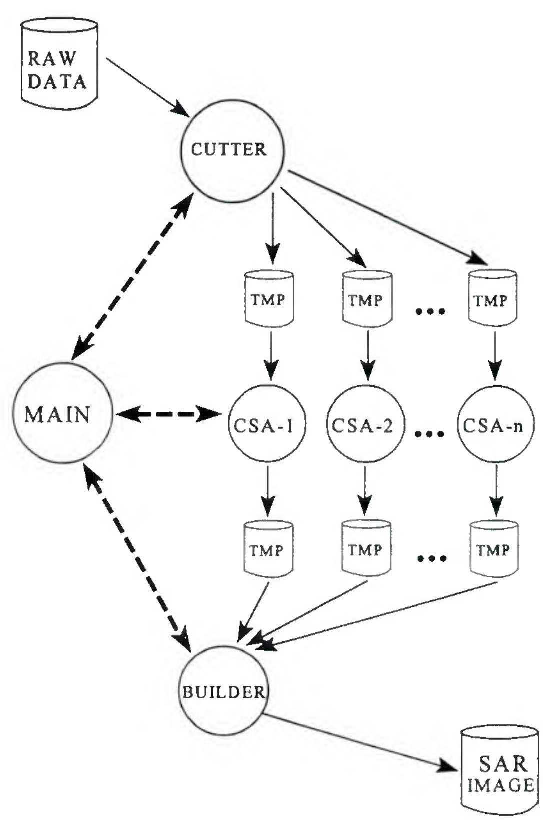

Fig.2.- Diagrama de flujo del proceso en paralelo.

El código paralelo comienza generando un conjunto de bloques de datos que son asignados a las estaciones disponibles. El proceso padre continuamente examina el estado de los diferentes nodos en la red. Cuando uno está libre, el padre le asigna un nuevo bloque. Las prioridades en el proceso padre son:

- 1.- Cortador: Es necesario para asegurar que habrá bloques de datos disponibles para los procesos hijos.

- 2.- Hijos: Una vez que una estación acaba el proceso de un bloque, el tiempo de espera es minimizado.

- 3.- Constructor: Cuando la porción de imágen correspondiente a un bloque de datos está disponible, la parte correspondiente del fichero final es colocado en un espacio libre de disco.

Con esta estrategia, los problemas de cuello de botella en el disco son prácticamente suprimidos haciendo que diferentes procesos nunca accedan al mismo fichero, y la mayoría de las operaciones de disco pueden ser llevadas a cabo utilizando un más eficiente acceso secuencial.

El numero de estaciones a utilizar en la "máquina en paralelo" puede ser seleccionado ya que las labores pueden ser llevadas a cabo por cualquier nodo.

4. RESULTADOS

Los parámetros clásicos para estimar el rendimiento del código paralelo, factor de velocidad (cociente del tiempo de proceso en un nodo entre el tiempo de proceso en N nodos) y eficiencia (factor de velocidad por el número de nodos), no son aplicables para una red heterogénea (cada nodo tiene su tiempo de proceso). Hemos utilizado una definición alternativa para estos parámetros que es intuitiva y tiene más sentido para un grupo de computadoras trabajando en paralelo:

- Eficiencia: la tasa del número de productos generados por el código paralelo en un tiempo dado frente al número de productos generados por el código secuencial corriendo en todas las máquinas de la red durante el mismo tiempo.

- Factor de velocidad: eficiencia por el número de computadoras de la red.

La siguiente tabla muestra los tiempos de proceso medidos para la generación de una imagen SAR estándar (100 x 100 km^2) con el procesador secuencial CSA en las estaciones UNIX disponibles en UPC-TSC (las dos primeras) y en INDRA (las cinco últimas).

Computadora	Código	Velocidad (Mhz)	RAM (MB)	Tiempo de Proceso (min)
HP 9000/720	HP-720	50	64	320
HP 9000/735	HP-735	99	96	150
HP C-160L	HP-160	160	128	75
Sun Sparc 10/40	SS-10	40	128	210
Sun Sparc 20/71	SS-20	75	128	135
Sun Ultra 1/170	SU-1	167	128	75
Silicon Graphics O2	SGO2	180	128	85

Tabla 1.- Medidas del Procesador Secuencial SAR CSA para una imagen de 100 x 100 km^2.

Los datos del proceso CSA SAR corriendo en un cluster de estaciones de trabajo UNIX se presenta en la Tabla 2. Las primeras seis columnas definen qué estaciones componen cada uno de los diferentes cluster probados (marcado por una X). Los códigos para las diferentes computadoras estan en la tabla 1. Los tiempos de proceso para la generación de una escena estandar completa están en la tabla 2, columna 7. Los factores de eficiencia y velocidad estan en las columnas 8 y 9 respectivamente.

La configuración del procesador SAR CSA en paralelo utilizada en los test es la siguiente:

- El proceso principal y el cutter y el builder de procesos hijo es llevado a cabo en el mismo host, que es el situado más a la izquierda en la tabla.
- Cada uno de las restantes computadoras del cluster tiene un proceso hijo CSA.
- El tamaño de los bloques de proceso es de 64 MB (4096 lineas por 2048 columnas).

ss 10	ss 20	su 1a	su 1b	hp 16o	sg O2	tim. mn.	Eff	Vel oc
X	X	X				58	0.65	1.96
	X	X	X			48	0.61	1.83
X	X	X		X		46	0.56	2.24
X	X	X			X	48	0.56	2.24
	X	X	X	X	X	40	0.55	2.18
	X	X	X	X		37	0.57	2.28
X		X	X	X	X	35	0.56	2.82

Tabla.2.- Medidas del procesador CSA SAR en paralelo en diversas redes de estaciones de trabajo para una escena estándar (100 x 100 km^2).

Aunque la estrategia de paralelización y el diseño fueron pensados para una configuración diferente, se han hecho pruebas adicionales sobre dos computadoras multi CPU disponibles en la UPC. Las principales características de estas computadoras son expuestas a continuación:

- La Silicon Graphics Power Challenge tiene 16 CPU's R10000, con una velocidad de 194 MHz. Cada unidad tieneun caché pimario de 32 + 32 kB y un caché secundario de 2 MB. La memoria RAM de la computadora es de 2 GB.

- La Silicon Graphics Origin 2000 tiene 32 + 32 CPU's R10000 (trabaja como dos computadoras separadas), con una velocidad de 195 MHz. Cada unidad tiene un caché primario de 32 + 32 kB y un caché secundario de 4 MB. Tiene 4 + 4 GB de RAM.

Aunque la configuración de hardware que fue utilizada en ambos tests es aproximadamente la misma, la Origin 2000 ofrece una mejor ejecución que la Power Challenge. La razón de este comportamiento está en la diferente carga de cálculo externo existente en las computadoras.

El tiempo de ejecución del codigo paralelo disminuye al aumentar el número de CPU's hasta que un número de procesadores es alcanzado (7 u 8 unidades). Este hecho refleja las partes no paralelizables del algoritmo: los procesos de entrada y salida de datos.

Children Proc	**Silicon Graphics Power Challenge**			**Silicon Graphics Origin 2000**		
	TI ME	**Eff**	**Spee dUp**	**TI ME**	**Eff**	**Speed Up**
1	77	1	1	65	1	1
2	39	0.99	1.97	37	0.88	1.76
3	28	0.92	2.75	23	0.94	2.83
4	20	0.96	3.85	17	0.96	3.82
5	17	0.91	4.53	15	0.87	4.33
6	16	0.80	4.81	12	0.90	5.42
7	14	0.79	5.50	11	0.84	5.91
8	14	0.69	5.50	9	0.90	7.22

Tabla 3.- Ejecución del proceso CSA SAR paralelo en estaciones multi-CPU. Para la imagen estandar 100 x 100 km^2.

El último punto a mencionar no es menos importante. Es la evaluación de los parámetros de calidad de los productos generados con el codigo paralelo. Se ha demostrado que la generación es totalmente equivalente a la procedente de codigo secuencial, y de hecho, cumple con las especificaciones ESA.

5. EPSIE: ENTORNO DE PROCESO SAR

El software paralelo de generación de imágenes SAR se ha integrado en un entorno completo de proceso de datos SAR denominado EPSIE (Entorno de Proceso SAR INDRA Espacio)[10]. Las principales funcionalidades de EPSIE quedan descritas a continuación:

- Lectura de cintas CEOS
- Cálculo de parámetros de proceso de datos brutos SAR
- Procesador de precisión CSA SLC y PRI
- Procesador SAR Quicklook
- Módulo de Interferometría SAR para la generación de DEM's
- Funciones de manejo básico de imágenes SAR
- Filtros de speckle
- Herramientas de análisis de calidad de imágenes SAR
- Visualización de imágenes
- Detección de bordes en imágenes SAR

El entorno de trabajo EPSIE ha sido desarrollado sobre una estación de trabajo UNIX, y está programado en ANSI C y OSF Motif 1.2.

6. CONCLUSIONES

Se ha llevado a cabo la paralelización de un procesador secuencial SAR sobre una arquitectura en paralelo, incluyendo la selección de estrategia de paralelización y la implementación del primer prototipo. El software paralelo es flexible y portable, así que puede ser instalado en la mayoría de los sitios.

Los resultados obtenidos con el código paralelo son prometedores y ofrecen una clara reducción en el tiempo de proceso con respecto al código secuencial.

Se están realizando nuevos trabajos para optimizar y afinar el código para que la eficiencia del código paralelo pueda ser mantenida constante al añadir más estaciones al cluster.

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8. RECONOCIMIENTOS

PARSAR is a project supported by PCI-II, ESPRIT IV.

SIGNIFICADO DE LA EXPANSIÓN URBANA EN LA ZONA METROPOLITANA DE LA CIUDAD DE MÉXICO.

Sergio Romero Vallejo* y Magnolia Orea Coria**.
*Profesor-Investigador del CIIEMAD-IPN., Becario de la COFAA-IPN, Investigación Financiada por la DEPI-IPN.
**Becario PIFI-IPN, del posgrado del CIIEMAD-IPN.

Centro Interdisciplinario de Investigaciones y Estudios sobre Medio Ambiente y Desarrollo Instituto Politécnico Nacional (CIIEMAD-IPN), Av. IPN Esq. Sierravista s/n Col. Lindavista, México, D. F. 07300, Tel. y Fax 754 02 06 e-mail svallejo@vmredipn.ipn.mx

RESUMEN

Se lleva a cabo un estudio sobre el efecto del crecimiento urbano con relación al resultado de la contaminación que causa un grupo de partículas denominadas PM10 generadas por fuentes naturales hacia la Zona Metropolitana de la Ciudad de México, con el empleo de imágenes multiespectrales manejadas a través del sistema EASY PACE.

La investigación se complementa con recorridos de campo y el apoyo de los reportes de la Red Automática de Monitoreo Ambiental del Departamento del Distrito Federal.

Se logra reconocer un comportamiento diferenciado entre los eventos provocados por factores climáticos y la movilización cotidiana de la población, la cual induce efectos significativos sobre los registros de este contaminante en la atmósfera de la Zona Metropolitana. Dicho fenómeno se explica mediante el significado que tiene la expansión urbana como causa indirecta de este tipo y comportamiento de la contaminación en metrópolis.

1. INTRODUCCIÓN

La actividad práctica que el hombre desarrolla en los procesos de transformación para acondicionar el medio a sus necesidades, con cambios recíprocos entre la naturaleza y la sociedad, suceden, a menudo, con expresión acelerada en y alrededor de las ciudades. Tal velocidad de cambio tiene que ser enfrentada al momento de investigar la cada vez más compleja problemática urbana, entre otros, la contaminación atmosférica.

De ahí que para hacer estudios de superficies extensas, entre otros los urbanos, como ejemplo de problemas complejos y de rápida modificación y en concreto el de una megalópolis, exige métodos de estudio que respondan a las preguntas intrincadas de los mismos; además, se requiere el empleo de herramientas precisas de bajo costo y que ofrezcan las mayores facilidades para el seguimiento de los fenómenos. Esta clase de estudios que conjugan las cualidades antes mencionadas, imbuídas de un enfoque metodológico no tradicional son escasos y representan un reto.

Lo anterior significa: en primer lugar, para realizar un trabajo con técnicas de bajo costo que faciliten su seguimiento manejando la información del problema complejo, se obliga teóricamente, a concebir con otra perspectiva la problemática histórica de los procesos y sus resultados; en segundo lugar, se hace necesario integrarlo dentro de un todo que explique los efectos del desarrollo dentro de una totalidad. Esta percepción incorpora lo urbano simultáneamente en el contexto de la relación medio-ambiente y desarrollo tal como queda planteado por Lhamas, C. (1997); así, se abren posibilidades a otros enfoques del conocimiento.

Propuestas como la anterior combinando el análisis e interpretación dialéctica (Romero y et al.,1997), en conjunto con el empleo de herramientas modernas como las que ofrecen las técnicas de los sensores remotos y sistemas informáticos como el EASY PACE, generan otras posibilidades de análisis para comprender los mencionados problemas complejos y encontrar elementos e interacciones esenciales que describan desde su origen los fenómenos y problemática ambiental en aras de generar propuestas de solución apegadas a la realidad.

De acuerdo con lo anterior, para comprender y plantear otra alternativa de solución para controlar un fenómeno como la contaminación en urbes por partículas respirables menores a diez micras de origen edáfico

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(Coordinación de Asesores DDF. 1990), hay que ir al origen y a su esencialidad, y no basta con calcular sus volúmenes, identificar su fuente, conocer sus trayectorias y demás cualidades de las partículas en el aire, en virtud de que el punto de partida con cualquiera de estos estudios, enfrentan al final el efecto de la descontextualización inicial, ya que planteado así, cualquiera de los estudios es fenoménico debido a la referencia teórica que caracteriza a las prácticas tradicionales de las ciencias departamentalizadas. En otras palabras, ordinariamente los resultados así obtenidos, conducen a visiones parciales de un fenómeno complejo cuyo tratamiento debe mantener la unidad del contexto desde que se inicia el abordaje y tratamiento del problema.

2. OBJETIVOS

Analizar e interpretar mediante una concepción integral medio-ambiente y desarrollo, el fenómeno de contaminación urbana por partículas PM10 de origen natural, denominadas fracción respirable (menores a 10 micrones), dentro de la problemática ambiental de la Zona Metropolitana de la Ciudad de México (ZMCDM), con el uso de sensores remotos e informática como herramientas; se utiliza como base metodológica la dialéctica.

La investigación parte de la siguiente suposición:

"La emisión de PM10 de origen natural a la ZMCDM procede de los campos arados y áreas desprovistas de vegetación circunvecinos, su presencia en el aire responde a la velocidad del viento, a la época de sequía y a la condición de desagregación de la estructura del suelo; por consiguiente, el comportamiento esperado de éstas partículas en la atmósfera de la zona urbana respondería con base a lo anterior, por lo que no se pueden considerar otras influencias distintivas en los efectos como el crecimiento económico y sus repercusiones sociales".

3.- ESTADO DEL ARTE

H. Bravo y A. Báez, en 1960 estimaron que en la Ciudad de México se depositan al rededor de 70 t/km^2/mes, provenientes de las tolvaneras del ex-vaso de Texcoco. L. Wilson (1975), mediante la aplicación de la ecuación de erosión eólica estimó el polvo suspendido en 225 000 t anuales para una región de Nuevo México.

E. Jáuregui en 1983 reportaba que la visibilidad en la Ciudad de México disminuía al rededor de las 10 A.M. durante los meses de invierno y esta aumentaba en el mes de marzo. El mismo autor en 1989 determinó que la zona nororiente de la Ciudad recibía el mayor número de tormentas de polvo, mientras que por el sur y sureste entre los meses de noviembre y abril también se presentaban tormentas afectando el sur de la Ciudad; en el mismo trabajo indicaba que las tormentas de polvo producían un total de 98 t al año sobre la Ciudad. Una actualización este autor, estima que los vientos del sector norte dominan en 56 % sobre los del sur, a los que corresponde el restante 44% de los vientos dominantes.

R. Kantamaneni et al en 1996, midieron el efecto que producen los vehículos en tránsito sobre caminos asfaltados y no asfaltados sobre la emisión de PM10 a la atmósfera el cual es relativamente significativo y que la humedad atmosférica disminuye los valores.
Por otra parte Mage y colaboradores (1996), discuten que la contaminación del aire en las megaciudades es la cuestión ambiental política más controversial ya que afecta a cada uno de sus habitantes y cada uno de ellos contribuye de manera diferencial a este problema el cual, para las 12 megaciudades del mundo, según dicho autor, es el fenómeno contaminante de mayor envergadura.

Al mismo tiempo se conoce que el problema de las PM10 de origen natural aunque sean relativamente inertes, dentro de las ciudades, incrementan el tiempo de residencia de las partículas tóxicas (NOx y SOx son adsorbidas produciéndose efectos sinérgicos), las mismas, adquieren mayor importancia en los pulmones debido a que en combinación con otros contaminantes potencionan su toxicidad.

Existen indicios de que las PM10 contribuyen al aumento de la hipersensibilidad pulmonar al menos en ratas expuestas a las condiciones de centros urbanos que se relacionan con tránsito vehicular y otros agentes contaminantes cuyos efectos son posible de revertir con el cambio de exposición a atmósferas no contaminadas (Pereira, Saldivia y et al 1995).

Las consideraciones anteriores ponen en evidencia la necesidad de incrementar los estudios relativos a los fenómenos de contaminación, en una urbe de más de 20 millones de habitantes, donde el fenómeno de concentración del desarrollo da como resultado la mayor tasa de densidad de población con 3 mil habitantes/Km2.; cuenta, además, con un saldo migratorio negativo igual a 8.3 % de su población, éste es el más significativo del país. Máxime que de acuerdo a los datos censales del 90, existían ya 14 ciudades con más de un millón de habitantes en el país cuyo crecimiento poblacional alcanza una tasa del 9.6 (INEGI, 1994).

Por su parte S. Romero et al (op. cit. 1997), consideran que el crecimiento económico de grandes metrópolis actuando como polo de atracción para los trabajadores, repercute en un efecto importante sobre la contaminación de PM10 al desplazarse diariamente entre su hogar y el centro de trabajo.

4. MÉTODO

Se utilizó la imagen Landsat Temathic Mapper 26/047 plataforma 5 del 2 de febrero de 1993 a través del hardware del Silicon Graphics con el sistema EASY PACE para obtener imágenes clasificadas mediante fases de entrenamiento y método supervisado y llegar a seleccionar las zonas edáficas emisoras de partículas, cumpliendo requisitos estadísticos con mayor resolución, aislando variables analíticas apoyadas con recorridos de campo, para una posterior identificación por similitud o distancia entre los casos y posteriormente reagrupar, seleccionar, discriminar y aislar áreas típicas y representativas de pixeles tanto estadísticamente como sus representantes con verdad de tierra.

Para el trabajo de campo y apoyo en gabinete, se interpretaron visualmente imágenes impresas SPOT multiespectrales escala 1: 500 000 de marzo de 1986; 1: 100 000 de noviembre de 1986 y diciembre de 1988; y, el espaciomapa INEGI 1995 de la Ciudad de México escala 1: 75 000 elaborado con imágenes SPOT de marzo de 1994 complementado la zona bajo estudio con la imagen de diciembre de 1988.

Las aplicaciones estadísticas se realizaron sobre nueve frentes de viento previamente seleccionados bajo el criterio de dirección, velocidad y componente fisiográfico del Valle de México. La longitud distal del frente se considera en 20 k, medidos a partir de un cuadrante central de la ciudad arbitrariamente de 13 k por 13 k, en cuyo centro se localiza el Zócalo metropolitano; dicho cuadrante incluye la isla de calor más importante en la urbe, hacia este cuadro de referencia confluye el efecto potencial de cada uno de los frentes de viento cuya anchura o frente varía según las limitaciones orográficas de la cuenca.

La sistematización de la información geográfica para su posterior despliegue en ARCINFO, fue apoyada en 32 puntos de georeferenciación distribuidos espacialmente para evitar distorsión. En el campo fueron ubicados 12 puntos de observación mediante un GPS Magellan NAV 5000 PRO con un promedio de tres a cinco lecturas por punto, cotejados con la cartas topográficas escala 1:50 000 de INEGI.

La información de más de 12 000 datos provenientes de los registros de la Red Automática de Monitoreo (RAMA), fue trabajada en plataforma Excel versión 7,0 y únicamente fueron consideradas 10 estaciones dándole tratamiento a más de nueve millones de los registros desde el registro más antiguo de la toma de PM10 hasta septiembre de 1996, éstas fueron: Tlalnepantla (TLA), Tultitlán (TLI), La Villa (LVI), Xalostoc (XAL), Netzahualcoyotl (NET), Coacalco (VIF), Merced (MER), Pedregal (PED), Cerro de la Estrella (CES), y Tláhuac (TAH).

Para los censos de viento se consideraron cuatro millones de datos de las estaciones: Tacuba (TAC), Ecatepec (EAC), San Agustín (SAG), Tlalnepantla (TLA), Xalostoc (XAL), Merced (MER), Pedregal (PED), Cerro de la Estrella (CES), Plateros (PLA), y Hangares (HAN), en fechas equivalentes a las estadísticas anotadas de PM10.

A partir de los datos obtenidos por la RAMA fueron agrupados los resultados por meses, días y horarios; con ellos se compararon entre sí las gráficas de PM10 con las velocidades de vientos.

Para complementar la información fueron revisados las estadísticas socioeconómicas 1990 de INEGI; los Anuarios Estadísticos para el Distrito Federal y para el Estado de México de 1994. Así como las Estadísticas de 1994 del Medio ambiente en México del INEGI.

Para la interpretación contextual, el estudio considero dialécticamente como categorías centrales: totalidad, proceso de contaminación como movimiento, desarrollo, crecimiento urbano en su efecto de borde, transporte en la relación urbano-rural y ocupación histórico social del espacio.

5. RESULTADOS

De acuerdo con los datos estadísticos sintetizados de más de 2000 gráficas, los meses de mayor concentración de partículas PM10 corresponden a los meses de enero, febrero, marzo y abril para las estaciones Tlalnepantla, Merced, Coacalco, Tultitlán, Cerro de la Estrella y

Netzahualcoyotl, con registros máximos que van de 400 a 800 µgramos/m^3 al día. Al mismo tiempo los vientos registrados mayores a 4 m/s para los mismos períodos tienen coincidencia. Sin embargo, en zonas populares como Tlalnepantla, Cerro de la Estrella, Xalostoc, Netzahualcoyotl y Tultitlán, se aprecian incrementos de concentración de partículas hasta de 500 µgramos/m^3 al día, durante la época de lluvias y con vientos sin potencia para elevar partículas.

En este último caso, se procedió a un análisis horario de los registros de la RAMA, encontrándose que los días con tales valores, correspondieron a días sin lluvia coincidiendo el comportamiento de las partículas con los horarios de las horas pico matutinas, vespertinas y al movimiento habitual de la población de sitios populares, como las horas de mercado o salida de las primarias.

Para la condición de efectos por vientos y la época de estiaje, se comprobó que existen nueve frentes de viento capaces de generar contaminación a la Ciudad de México, éstos son: los frentes norte, noreste, este, sureste, sur 1 y 2, suroeste y noroeste, cada uno con una anchura específica dadas las condiciones orográficas que inciden en la ZMCDM.

De acuerdo con la interpretación de las imágenes y los recorridos de campo, se constató que mientras en las imágenes de 1986 existía un anillo urbano con asentamientos carentes de pavimento en sus calles, para 1996, se encontraba dicha trama vial pavimentada en un 95 % (Ciudad Netzahualcoyotl, norte, nororiente, sureste, sur y norponiente de la Zona Metropolitana). Sin embargo para el mismo 1996, periféricamente se había conformado una nueva estructura urbana repitiéndose la presencia de calles sin pavimento y precariedad, dichos asentamientos "nuevos", correspondían en el pasado a zonas agrícolas o terrenos desnudos de suelos salinos del vaso seco del ex-lago de Texcoco.

Por otro lado las contradicciones que se originan por la relación urbano-rural, junto a las promovidas por los efectos de polo de atracción de oportunidades de trabajo en un centro donde en 1988, 23 millones de habitantes utilizaban el 56 % de 44,4 millones de litros diarios para el transporte y movilización de 3,2 millones de vehículos (CMPCCAVM, 1988).

La ZMCDM ha crecido 2,6% de 1970 a 1990, es decir, paso de 2 090,42 km^2 a 4 652,53 km^2 (Romero op. cit). Y de acuerdo con las estadísticas de 1994, se registraron casi cuatro millones de vehículos para todo la ZMCDM, con 132 042 centros de trabajo en la ciudad y 9 159 en la periferia (INEGI 1994a, b). Además, de una población económicamente activa de 2 154 475 (INEGI, idem), los municipios adyacentes contribuyeron con más de 2 millones de trabajadores movilizándose en la periferia y hacia la ciudad.

En tanto que el INEGI en 1987, registra la cifra de 40 098 ha erosionadas, actualmente mediante el análisis de una imagen con el sistema EASY PACE, en este trabajo se calculó que la superficie para la fecha de toma de 1993 era de 22 590 ha, es decir casi el 50 % menos que la superficie anteriormente calculada.

6. DISCUSIÓN

Conforme a los resultados de este trabajo, se observa que se cumple la primera parte del postulado inicial, ya que aparece una correlación entre factores del medio como son: el viento, tierras en descanso o barbechadas, las condiciones del suelo y la época de sequía, así, durante los meses secos y con viento los valores de registro por la RAMA recogen datos en el sentido esperado. No obstante esta situación a partir de los meses lluviosos, el postulado no se cumple, en virtud de la presencia de humedad y la ausencia de vientos o en su caso los campos agrícolas están cultivados, los registros de la RAMA señalan presencia de PM10 aún bajo estas condiciones, lo cual podría llevar a interpretar la propuesta inicial como falsa o bien, que existen otras variables no consideradas. La visión departamentalizada conduce a una búsqueda sistematizada más amplia. Aquí es donde se requiere un postulado teórico no convencional como la contradicción dialéctica.

Así, con una aprehensión más amplia de la realidad contemplada mediante una visión totalizadora y guiada por el principio de la contradicción, es procedente otro postulado que explique la manifestación de PM10 en condiciones no esperadas. Esta postulación responde al efecto de la actividad práctica de la sociedad en particular de su movimiento cotidiano, y esto solo sucede en condiciones del medio social urbanizado, por lo que las PM10 en el aire, se presentan independientemente de los factores del medio natural.

Tomando este punto como eje conducente, se obtuvieron gráficas horarias de los registros, encontrando una correlación entre las horas pico: matutinas, vespertinas e intermedias, que coinciden con los movimientos cotidianos de la población, debido a sus hábitos y transporte, que durante los días intermedios de lluvia cuando calienta el sol seca los lodos arrastrados por las lluvias precedentes en el transcurso del día, acelerado por el paso de vehículos y peatones, provocándose condiciones para suspender partículas al aire que son diseminados por vientos ligeros.

Los frentes de viento radialmente, son los responsables iniciales de la presencia de partículas en la atmósfera urbana en lo general y de las zonas populares periféricas en lo particular, mismas que son las que reciben las mayores cantidades de partículas por encontrarse cercanas a las fuentes emisoras. Inclusive sufren mayores embates de la problemática por recibir los efectos de las PM10 emitidas tanto durante la época seca como en el período lluvioso sobre todo por el movimiento de los vehículos rodando sobre calles no pavimentadas, siendo esta una de las causas por la que se llegan a suspender las partículas secadas por el sol, inclusive en vialidades asfaltadas cubiertas de capas de suelos previamente depositadas por los arrastres de las lluvias o del lodo que se desprende de los automotores provenientes de zonas sin asfalto.

A excepción de las estaciones Merced y Pedregal, todas las demás que fueron seleccionadas, se localizan en el segmento norte, este y sur de la rosa de los vientos, coincidente con los frentes de viento más importantes que arrastran partículas PM10 a la ZMCDM. Dicho segmento predominantemente es el asiento de zonas habitacionales de recursos económicos limitados y se les denomina populares, ocupan una zona periférica a la mancha urbana dotada de todas las facilidades.

Se caracterizan por ser familias con más de cinco miembros, donde el padre y los hijos mayores contribuyen a los gastos del hogar, habitan zonas de rentas bajas y, sobretodo, los asentamientos más periféricos son irregulares carentes de servicios públicos, en particular drenaje y calles pavimentadas. Unos corresponden a campos agrícolas anteriores que por la baja rentabilidad cambiaron de uso. Otros sitios pueden corresponder a terrenos no productivos afectados por la salinidad, ambos tipos de suelos son presa de fraccionadores que especulan con la escasez de vivienda, dominada por la ocupación social del espacio al rededor de un polo urbano de atracción por la oferta de desarrollo.

En los casos de poblaciones rurales circunvecinas a la metrópoli, ante la oferta de trabajo asalariado, las actividades primarias del medio rural donde la incertidumbre de la agricultura de temporal son causas de abandono dejándose incultas las tierras, favoreciendo la erosión eólica de terrenos desnudos que generan partículas a la atmósfera convirtiendo tales campo de cultivo fuera de uso en una posibilidad para obtener ganancias sobre su venta.

Este proceso de expansión anillada de la urbe que materialmente enguye al medio rural circunvecino, se mantiene a lo largo del proceso; manteniendo una permanente presión sobre el recurso suelo, quedando involucrado el papel de la administración pública y el papel controversial del componente político, social y electoral en muchos casos. Sin dejar fuera los intereses económicos y la especulación de los terrenos para vivienda.

7. RECOMENDACIONES

Dentro de una perspectiva más amplia, el problema de la contaminación puede quedar comprendido dentro de los efectos del libre mercado y los efectos de la escasez; de las fallas del gobierno al aplicar leyes y reglamentos; y entre otros, de lagunas en los instrumentos jurídicos. Lo que lleva a pensar en otras dimensiones al problema relativo de las PM10 y que su abordaje no es suficiente mediante el estudio de sus propiedades como partículas o de su cinética en virtud de que por esa vía la esencialidad no se toca siendo este un problema complejo.

Todo hace indicar que pronto, algunos centros urbanos de grandes magnitudes evidenciarán en cierta medida, problemas similares.
Siendo el caso del crecimiento de los asentamientos humanos el papel que juega el uso del suelo en la perspectiva social y económica como factor de regulación o fuente de agentes contaminantes, cobra especial atención. Por lo tanto, su manejo o mejor dicho su administración, contribuirá al mejor control de los efectos provocados por la emisión de PM10.

Por la importancia que representan los datos anteriores, es importante tener disponible más detalles sobre formas alternas de poder controlar la emisión de partículas provenientes de fuentes naturales, que alimenten criterios para el mejor manejo del problema durante la toma de decisiones, incluso el de aportar criterios de regulación no contemplados todavía.

Este tipo de fenómenos que engloban la relación sociedad-naturaleza en su expresión concreta de lo urbano y el campo, no deben disociarse para su comprensión, sino, desde el planteamiento inicial, debe tenerse como premisa el contexto ambiental que los envuelve. Lo anterior conduce a otra perspectiva y enfoque de abordaje de este tipo de problemas complejos del desarrollo.

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CARTOGRAFÍA DE OCUPACIÓN DEL SUELO MEDIANTE ANÁLISIS DE IMÁGENES ERS-1

[1]J.Gutiérrez del Olmo y [2]V. Moreno
INDRA ESPACIO
C/Mar Egeo,4. Pol.Ind.nº1. San Fernando de Henares.28850.Madrid.España
[1]Tf: +34 1 3963936. Fax: 3963912. e- mail: jgut@mdr.indra-espacio.es
[2]Tf: +34 1 3963955. Fax: 3963912. e- mail: vmor@mdr.indra-espacio.es

ABSTRACT

In Spain, the agriculture is one of the main basis of the economy. For the last forty years the cultivated area has been almost duplicated. However, the main determinant factor is the water availability and distribution. In this context, to have a specific, updated and controlled mapping is fundamental for this agricultural development.

In this way, we have tryed to develop a soil occupation mapping methodology through ERS-1 images analisys. From three ERS-1 SAR images we have obtained a multitemporal image, and from this one we have got two new information layers: Addition and Max. Variation. The images filtering has been performed by the FFT method. We have superposed two diferent delimitations and through classes assignment by photointerpretation, we have obtained a final land cover classes map.

The study reveals great potential of SAR in labours as crop control, phenological evolution stages, soil evolution condition and harvest characterization. We have concluded that it is posible to get soil ocupation maps with an acceptable precission level from ERS-1 SAR images analisys.

1.- INTRODUCCIÓN

La agricultura es uno de los principales pilares de nuestra economía. En los últimos años han variado mucho las superficies agrícolas en nuestro país. Hemos pasado de 1,7 millones de hectáreas de regadío en 1957 a casi 3 millones en la actualidad. La meta de transformación de secano en regadío está en 4 millones de hectáreas.

Sin embargo, el agua es el gran factor limitante de esa transformación agraria en nuestro país. También influyen nuestra acusada orografía y otros factores. Es por tanto, fundamental a la hora de realizar una previsión de demanda de nuevos regadíos, contar con cartografía específica, la cual ha de mantener una constante actualización y control, ya que la transformación se deja notar en el sector día a día.

2.- MARCO FISICO

En el presente trabajo se ha desarrollado una metodología de clasificación de usos del suelo a partir de imágenes ERS-1 SAR. La zona elegida se sitúa al sur de la ciudad de Sevilla. Incluye las marismas del Guadalquivir y sus alrededores. Su actividad es principalmente agrícola. Surcan la zona los ríos Guadalquivir y Guadaira. Actualmente es un área de aluviones cuaternarios, margas y calizas. Destaca la casi ausencia de relieves topográficos.

Hay una fuerte irregularidad hídrica estacional e interanual. Los cultivos que se dan en la provincia con mayor extensión son: arroz, maíz, girasol, algodón, cítricos y olivar. Hay una alta rotación de cultivos, con bruscas fluctuaciones entre un año y otro, lo cual convierte a esta zona en la típica que necesitaría una constante actualización cartográfica.

3.- DATOS DE PARTIDA

Hemos dispuesto de tres imágenes SAR banda C del satélite ERS-1. Éstas eran de diferentes fechas ya que el estudio ha sido de carácter multitemporal. Las fechas son:

- 3 de Marzo de 1993
- 16 de Junio de 1993
- 25 de Agosto de 1993

También hemos utilizado la escena 202-34 de Sevilla del satélite Landsat sensor TM. Asimismo también se ha contado con la ayuda auxiliar de diversas fuentes bibliográficas de la zona: mapas topográficos y de usos del suelo. Se ha utilizado la digitalización de la zona del proyecto RMO.

Por último se han tomado datos de las estaciones evaporimétricas y de aforos más próximas para ver el estado de humedad de las imágenes.

4.- ERS-1 SAR

El ERS-1 fue lanzado por la Agencia Espacial Europea (ESA) el 17 de Julio de 1991 como el primer satélite europeo con sensores remotos. Entre otros sensores, contaba, dentro del AMI (Active Microwave Instrument) con un SAR (Synthetic Aperture Radar).

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

El SAR es un sensor activo: porta su propia fuente de iluminación. La principal característica del SAR es la simulación de una antena de grandes dimensiones por medio de la adecuada combinación de pulsos basándose en el efecto Doppler (la frecuencia recibida por un objeto en movimiento depende de la trayectoria de éste con respecto al foco de emisión). La posibilidad de producir imágenes de alta resolución con independencia de la iluminación solar y de las condiciones meteorológicas, son importantes ventajas con las que cuenta el SAR. Son destacables sus aplicaciones en oceanografía, vegetación, geología, cartografía y estudios polares.

5.- ESTADO DE LAS IMAGENES

Recibimos las imágenes en formato FDI. Hemos creído importante saber las condiciones del terreno que estamos interpretando. Por ésto se ha realizado un estudio de estado de humedad de las imágenes en el que se han tenido en cuenta la precipitación y los caudales como entradas al sistema y la evapotraspiración como salida, como principales parámetros. Al final, como se muestra en la tabla, el estado de humedad que se puede esperar es el normal para las fechas de toma:

Datos al %	Q	Prec.	ETO
3 Marzo 93	90	100	28
16 Junio 93	100	90	81
25 Agosto 93	54	0	100

6.- AJUSTE ENTRE IMAGENES

Para realizar el estudio multitemporal es necesario superponer las imágenes para obtener una sola con varias capas. Este ajuste se realiza mediante puntos de control del terreno (GCP´s). Es importante que estos GCP´s no tengan dinamismo temporal. Para facilitar su localización se ha aumentado el contraste. Con éstos GCP´s se calcula una ecuación de trasformación que se aplica a la imagen fuente para ajustarla contra la destino.

Se ajustaron Junio y Agosto contra Marzo (ECM = 0,2 y 0,4). Una vez ajustadas se hace una superposición de capas (Layer Stack) mediante intersección.

7.- FILTRADO

Las imágenes presentan un moteado típico denominado speckle. Este tipo de dispersión es característico de las imágenes SAR debido a las múltiples orientaciones de los objetos que son iluminados dentro de un mismo pixel.

Para reducir el speckle hemos probado varios filtros en pequeñas parcelas de prueba, quedándonos al final con el más efectivo: un filtro de paso bajo mediante la Trasformada Rápida de Fourier. Primero se aplica la Trasformada Rápida de Fourier (FFT) para convertir la imagen al dominio de las frecuencias o de Fourier. Así se puede visualizar y se le aplica el filtro de paso bajo mediante una ventana de Hanning. Éste elimina las altas frecuencias, en las que está el speckle, dejando las bajas, en las que se encuentra la mayoría de la información. Una vez filtrada la imagen, para volver al dominio espacial se le aplica la Inversa Trasformada Rápida de Fourier (IFFT).

8.- GEORREFERENCIACION

Con la georreferenciación se dará validez cartográfica a las imágenes y en consecuencia al mapa final generado. La georreferenciación la realizamos contra una imagen TM ya georreferenciada. El procedimiento es bastante similar al del ajuste entre imágenes. El error cuadrático medio aquí ha sido de 0,6 píxeles. Éste ECM es mayor debido a la diferente naturaleza de las imágenes origen y destino.

9.- GENERACION DE NUEVAS CAPAS

Para obtener información adicional hemos generado dos nuevas capas: la media y la máxima variación:

a) Media: es una capa en la cual el valor de intensidad o nivel digital (ND) de cada píxel es la media aritmética de los píxeles que ocupan la misma posición en las imágenes de Marzo, Junio y Agosto. La función aplicada es sencilla:

$$ND_{Media} = \frac{(ND_{Marzo} + ND_{Junio} + ND_{Agosto})}{3}$$

El aspecto de esta capa es una mezcla representativa de las otras tres.

b) Máxima Variación: esta capa trata de representar la máxima variación temporal posible en cada punto entre las tres originales. Para esto se construye un modelo que nos combine las capas de dos en dos de todos los modos posibles, se restan los valores de los pares obtenidos, se ponen en valor absoluto y se escoge el de valor máximo. El algoritmo que se aplica es el siguiente:

$$Nd_{final} = MAX(|ND_{marzo} - ND_{junio}|, |Nd_{marzo} - ND_{agosto}|, |Nd_{junio} - ND_{agosto}|)$$

El aspecto de esta nueva capa nos resalta los puntos de alta variabilidad temporal y deja con ND´s muy bajos los puntos con escaso dinamismo temporal.

10.- COMBINACIONES EN FALSO COLOR

La escala de trabajo elegida fue de 1:100.000 Las bandas disponibles eran:

- Banda 1: Imagen 3 Mayo 1993
- Banda 2: Imagen 16 Junio 1993
- Banda 3: Imagen 25 Agosto 1993
- Banda 4: Imagen Media
- Banda 5: Imagen Máxima Variación

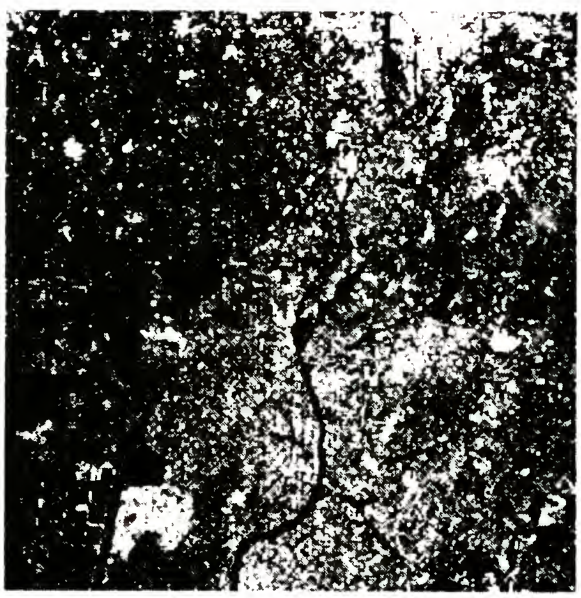

Fig 1.- Imagen SAR multitemporal (1,2,3)

Se probaron múltiples combinaciones, en las que se realizó ecualización automática de histogramas en algunos casos y expansión manual en otros. También en algunos casos se realizó un filtrado de realce de estructuras previo a la salida por el plotter. Al final las combinaciones elegidas para la fotointerpretación fueron: RGB: 1,2,3 y RGB: 3,1,5

11.- FOTOINTERPRETACION

Para la fotointerpretación se ha hecho una delimitación independiente para cada una de las dos combinaciones en falso color elegidas. Las delimitaciones se hicieron atendiendo a criterios de tono- saturación, textura y estructura. Se obtuvieron 23 y 17 clases respectivamente. Se cruzaron y dieron 146 tipos de terrenos diferentes, los cuales fueron agrupados en 16 categorias.

12.- RESULTADOS

Entre las ventajas del SAR frente a otro tipo de sensores, pudimos observar: gran abanico de tipos de cultivo así como una buena descripción del estado y del estadio dentro del ciclo de cultivo. También se observó una gran capacidad para localizar y delimitar núcleos urbanos.

Entre los puntos a mejorar están: definición de bordes un tanto defectuosa, pérdida de información de textura en algunas zonas debido al speckle y menor capacidad de discriminación en terrenos con menor contenido de humedad como pastizales, matorral o masas forestales.

La metodología seguida se muestra en el siguiente esquema:

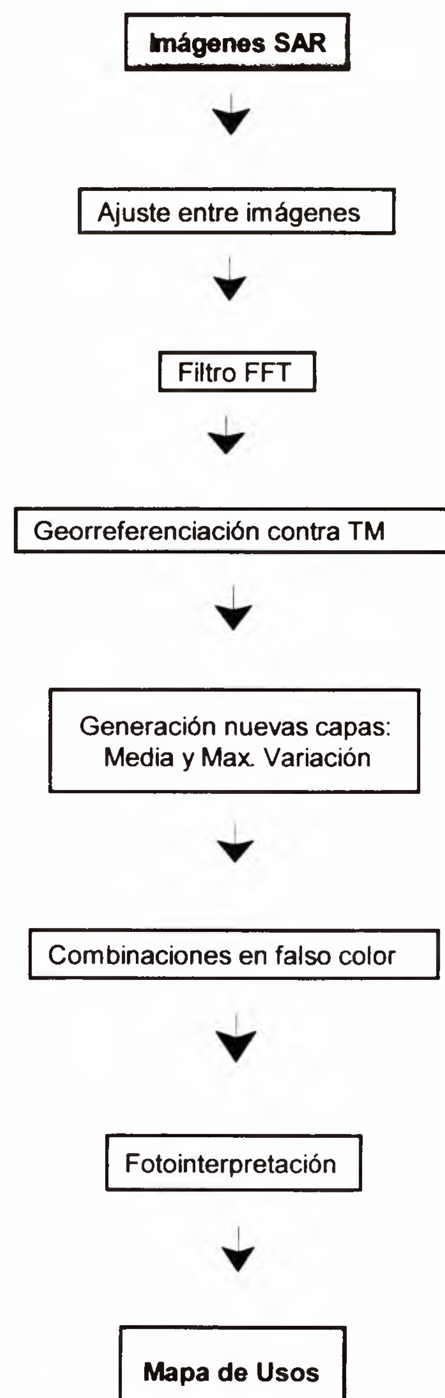

Figura 2.- Imagen SAR

Figura 3.- Imagen SAR multitemporal.

Figura 4.- Imagen SAR con delimitaciones

Figura 5.- Mapa de usos del suelo

13.- CONCLUSIONES

Como conclusión, queda claro que se puede realizar un mapa de ocupación del suelo con imágenes SAR multitemporales con un aceptable nivel de precisión.

Aun a falta de mejorar los aspectos antes mencionados, el SAR se revela como una interesante herramienta de cartografía, siendo independiente de las condiciones atmosféricas. Es fácil, pues, vislumbrar un futuro muy prometedor para este tipo de sensor.

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Estimation of oceanic primary production from space

J.R. García[1], L. Mayo[1] and C. Rodríguez[2]

[1]GMV. S.A. c/Isaac Newton 11, Tres Cantos 28760, Madrid. Spain
[2]Instituto Canario de Ciencias Marinas. Apdo 56, Telde 35200, Gran Canaria. Spain
e-mail: jrgarcia@gmv.es / lmayo@gmv.es / crodriguez@iccm.rcanaria.es

ABSTRACT

Oceanic biology has always been limited by the scarce and expensive data obtainable by ship campaigns or offshore stations. Space-borne sensors greatly help to solve this problem by providing global coverage, continuous and repetitive observations which, properly calibrated using some few in-situ measurements, can replace expensive data gathering campaigns. Moreover, a whole new generation of color sensors makes available the global and frequent coverage required for new analysis of local phenomena and the study of global cycles and long term variations.

Computation of primary production is one of the areas where space data has proven more useful. GMV, under contract to the European Space Agency (ESA) has developed a tool for this purpose, named OPPP (Ocean Primary Production Processor). This tool paves the way for the use of data from MERIS sensor on ENVISAT.

The OPPP tool, besides the computation of primary production, provides a complete environment for pre-processing of auxiliary data, format conversions, mosaicking of images and data visualisation and analysis. The models and algorithms have been calibrated and exhaustively validated using in-situ measurements taken in the area surrounding the Canary Islands and existing CZCS archives.

MERIS will ensure the continuity of raw ocean colour data availability to the European user community well into the next century. However, it is necessary to ease the access to data to the end-user. Data centres, such as the Spanish CREPAD, will play an important role in this respect and in promoting the further use of EO data in other disciplines.

INTRODUCTION

Besides the oceanic bio-geophysical parameters directly derived from ocean colour sensors radiometric measurements, several models have appeared which allow to estimate oceanic primary production from these derived parameters and regional characterisations. Primary production has a crucial role in the global bio-geochemical cycles as a major component in the CO_2 absorption, and later in the deposition of carbon as marine sediments.

Based on the model of Platt & Sathyendranath (1988) GMV has developed a flexible, multi-sensor prototype tool for the estimation of primary production, its application around the Canary Islands being presented. Major conclusions show the large potential of these applications, presently limited by the lack of accurate regional properties.

Plans for the future include the OPPP extension to process MERIS data. GMV is presently developing for ESA the MERIS Processing Facility to be implemented within the Envisat Payload Data Segment (PDS). Moreover, GMV has already implemented and delivered to INTA the first version of the Spanish Data Acquisition, Processing, Archiving and Distribution Centre (CREPAD). CREPAD V2.0 is intended to become the Spanish Processing and Archiving Centre (PAC) for Envisat, mainly devoted to MERIS.

OPPP METHODOLOGY

Several algorithms for the computation of production have been published, ranging in complexity and theoretical background from purely empirical correlation of annual primary production with chlorophyll to analytic descriptions of productivity with photosynthetic or quantum yield parameters. An empirical component, however buried in theoretical models, is present in all of them.

From this available range of options, the algorithm proposed by Platt & Sathyendranath (1998) was chosen as the cornerstone of the processor, along with the surface irradiance model described by Gregg & Carder (1990). Primary production is computed as a function of available light and chlorophyll, other second order factors being taken into account in regionally valid parameters. The spectral and depth variation of productivity is computed and integrated along the photosynthetic active range, the photic depth and finally throughout the day in order to retrieve daily water column primary production, the basic output of the processor.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

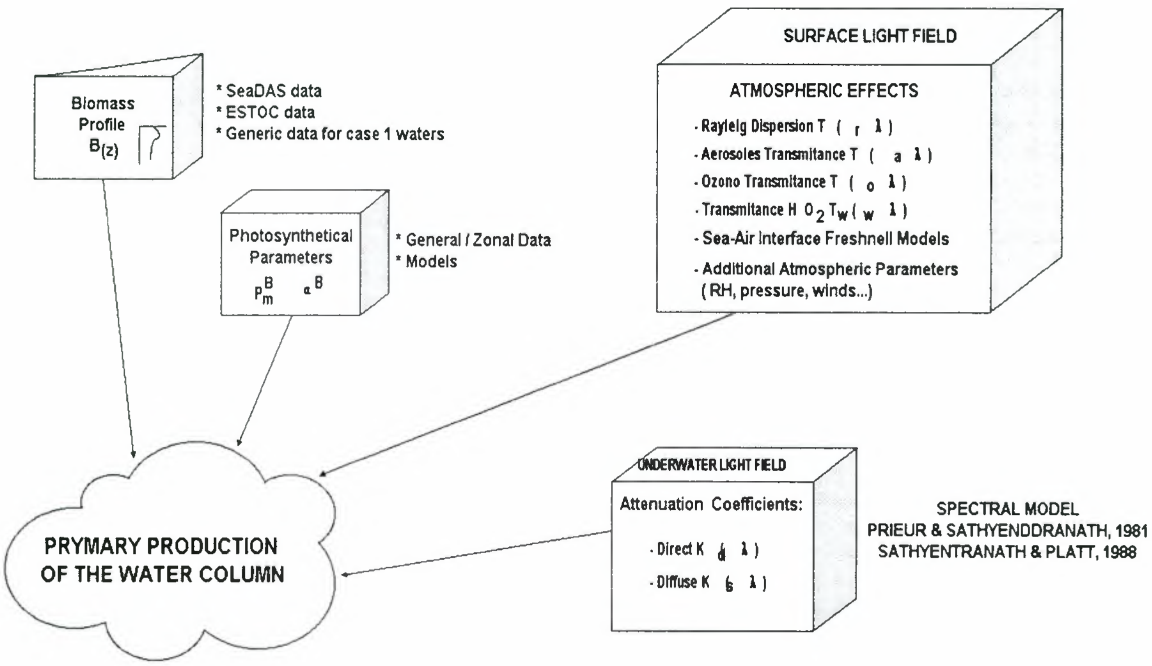
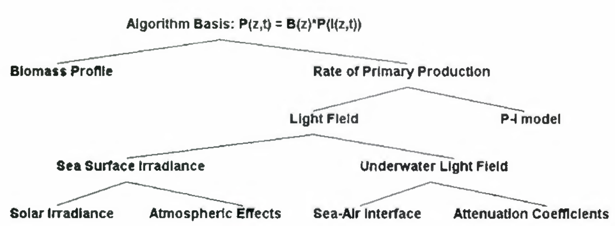


Fig 1. Identification of input data and processing parameters.



The spectral dependence of light and its resolved attenuation by the atmosphere and the water column, along with the variation of phytoplankton with depth require a large computational effort which may be too bothersome for very large images.

The oceans are divided in regions of uniform bio-geochemical characteristics (provinces) for which the required parameters need to be known with seasonal variability. The implemented model is valid only in open ocean (case I waters) of low concentration (<2 mg/m^3).

For the application in the Canary Islands area, in-situ data collected by the ICCM (Instituto Canario de Ciencias Marinas) as well as historic data of the same area from different publications were used. CZCS ocean color images were retrieved from ESA OCEAN project and NASA GSFC archives.

MOS DATA

Required OPPP inputs are standard level 2 products (containing water leaving radiances and chlorophyll maps) and regional characterisation parameters. In order to input MOS data to the OPPP processor, a level 2 file processor is being developed for ESA/ESRIN by GMV and GKSS (GKSS Forschungszentrum Geesthatch GmbH). This processor implements a Neural Network based inversion of the radiative transfer equations, a procedure whose testing will also serve as a validation of similar MERIS algorithms.

OPPP RESULTS

Though implemented as a multi-platform tool, it could only be tested initially using CZCS data as the only available source. MOS and SeaWiFS level 2 images are becoming available nowadays and they will be used soon.

The chosen model requires a relationship between the satellite estimated chlorophyll and the vertical profile, dependent as the profile itself on the province and season. This relationship was performed using data from the same epoch of CZCS images available at ICCM. Also biomass profiles for the area were improved from the Platt & Sathyendranath proposed province parameters using local data.

Extension calibration of the algorithms and validation of the implementation was performed against data given by Carla Caverhill (from Bedford Institute of Oceanography), historic data (Braun et al.,, 1985; Fdez. de Puelles, 1986) with CZCS images and new measurements of primary production (Neuer pers.

comm.). Main results showed differences between estimated and measured production generally less than 50%, within the input data error range.

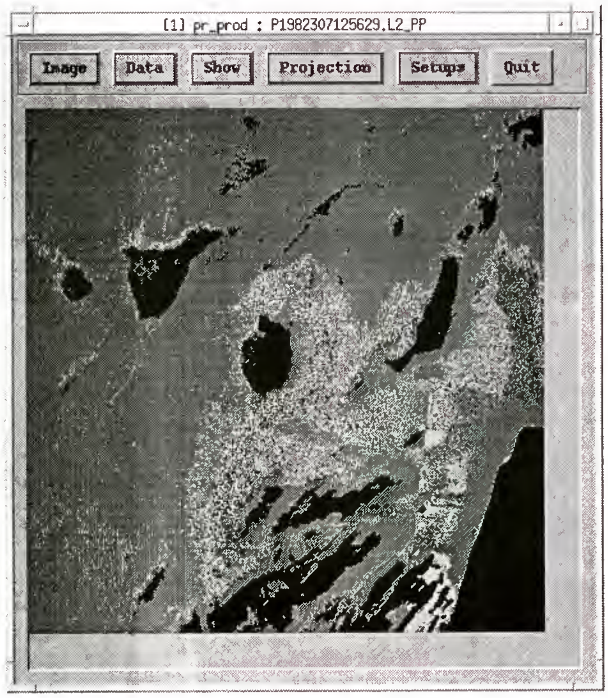


Fig 2. Sample of a primary production image

Validation of parts of the algorithm such as the surface and underwater light models were performed against data from Oldenburg University showing a good agreement with a slight tendency to underestimate attenuation.

The model has proved to be very sensitive to the definition of the biomass profile and specially to the photosynthetic parameters, unfortunately the input parameters subject to the largest uncertainty in their measurement.

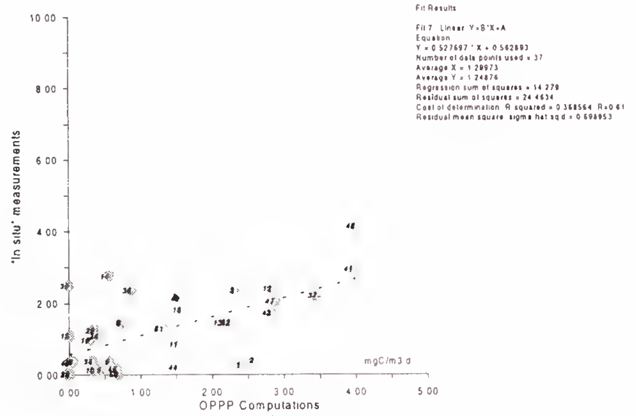


Fig 3. Correlation of measured and estimated production

Comparison of in-situ measurements with satellite data offers some difficulties due to the different spatial scale (comparing a point data with a 1 km^2 averaged value) and sometimes also the different times. Also the large variability in the sampled levels when bottle measurements are employed sometimes introduce a large bias in the observations of the vertical distribution.

CONCLUSSIONS FROM OPPP EXPERIENCE

The lack of accurate input and output reference data does not allow a clear conclusion on the model validity and accuracy. It should be expected that the new sensors in operation (MOS and SeaWiFS, soon also MODIS and MERIS) and their on-going calibration campaigns will bring new data and allow a much better insight in these models performance. However this preliminary results have confirmed the possibilities of this approach and the good results obtained with this model and the implemented tool in the Canary Islands area.

Nevertheless, the application with existing data has shown the major problem to be in the inaccurate knowledge of provinces and their parameters, specially the photosynthetic ones, so a great improvement should be expected when new, more accurate, ocean color data is known. Application in other areas may depend on the knowledge of this data. Another desirable improvement would be to incorporate new algorithms to solve the cloudless assumption made in the surface irradiance model which greatly limits the range of application of the tool.

Also the large computational effort required makes the selected model not optimum for mass image processing. A simpler modelling (not necessarily a purely empirical model) should be better used to obtain global and long term estimations of primary production, though this highly resolved models are very useful to characterise the phenomenon and for local estimations.

MERIS PROCESSING ON-GROUND

The planned launch of ESA's ENVISAT-1 by mid-1999 will ensure the continuous availability of ocean colour data into the next century.

MERIS (MEdium Resolution Imaging Spectrometer) has 15 selectable bands and a spatial resolution of 300 m (FR mode). The instrument has been developed by an industrial consortium led by Aerospatiale of Cannes, with GMV developing the on-board instrument control unit application software.

With a higher spectral and spatial resolution than most of their predecessors (OCTS mission was lost after a debris impacted on ADEOS-1 and NASA's MODIS has not yet flown), MERIS will bring substantial advantages with respect to the currently available colour sensors.

MERIS gathers data at a constant 300 m resolution. However, data is pre-processed on-board and downlinked to ground in either low resolution or full resolution mode. The low resolution data is used for the global change mission. The full resolution data can, among other uses, be applied for ocean colour studies.

The MERIS stream of data in full resolution mode will be down linked at 24 Mbps via ARTEMIS over the ESRIN Ka-band ground station, which is part of the Envisat Payload Data Handling Station (PDHS-E). The data processing and archive of the data however will be distributed. Low resolution data will be processed at PDHS-E and archived in the Envisat Low Reference Archive Centre (LRAC) in Kiruna. Full resolution data - which will only be acquired and processed on user request - will be processed and archived at national Processing and Archiving Centres (PAC) provided by the United Kingdom, Italy and Spain. These three PAC's will be allocated a geographical area over the Earth surface to serve the requests of the users.

Based on the lessons learned from ERS missions, ESA has put a strong emphasis on standardising the payload data processors through all the ground segment centres. Thus, even though PAC's will be funded and developed by national entities, they will incorporate a number of Generic Elements (GE's) which will be developed centrally under contract to the Agency.

The MERIS Processing Facility (MERIS-PF) will be one of these GE.

MERIS-PF is currently being developed by GMV. The software processor accepts level 0 products and can generate:

- Browse products;
- MERIS Level 1b products;
- MERIS Level 2 products.

The processor can ingest both low resolution and high resolution input data.

The processor has been designed to Open Systems standards. It can run on any implementation of Unix Sytem V POSIX standard, but it will be optimised for IBM AIX.

Among the level 2 products generated by MERIS-PF there is a Water Leaving Radiance data set. There are already plans to feed OPPP with this product as input.

THE SPANISH DATA ACQUISITION, PROCESSING, ARCHIVING AND DISTRIBUTION CENTRE: CREPAD

As already mentioned above, Spain will host one of the ENVISAT Payload Data Segment PAC's devoted to MERIS. Aiming to prepare this future centre, the Regional Government of the Canary Island, with the cooperation of the Spanish National Institute of Aerospace Technology (INTA), launched in 1995 a preliminary study to investigate the requirements of the Spanish Earth observation data users and to define the concept and architecture of the future centre. Two parallel contracts were awarded for this study, GMV being responsible for one of them.

The outcome of this preliminary study was a semi-distributed concept for a Spanish data acquisition, processing, archiving and distribution infrastructure. This was based on a central facility implementing all the required functions for data handling up to level 2 and distributed thematic centres for level 3 processing and archiving. The central facility should make use, as far as possible of the existing national infrastructure. It was named CREPAD (Centre of REception, Processing, Archive and Distribution).

Another important conclusion of this initial study was that the user was not very much concerned about which mission or instrument was supplying the raw data in so far as he could have regular access to equivalent geophysical data products. Thereby the idea of creating a central facility which is suitable to support different missions.

Looking at promoting the future use of MERIS data, INTA decided in 1996 to let a contract to set up an initial version of CREPAD (so called CREPAD V1.0) which would provide similar services and products to those expected for MERIS for its precursor missions, namely AVHRR, SeaWiFS, MOS and OCTS. Again, the pilot system implementation contract was placed with GMV following an open tender action.

Following the conclusions of the preliminary study, the site selected for the installation of CREPAD was the INTA's Maspalomas ground station. INTA was already receiving and pre-processing data from several missions at this station, under agreement with ESA and other organisations. Two antennae, providing data acquisition capabilities in both the L and X-bands are available, as well as data ingestion, recording and preprocessing facilities.

The contract started in the late Summer 1996 and the system was installed and delivered to INTA by June 1997 and it is operational since that date.

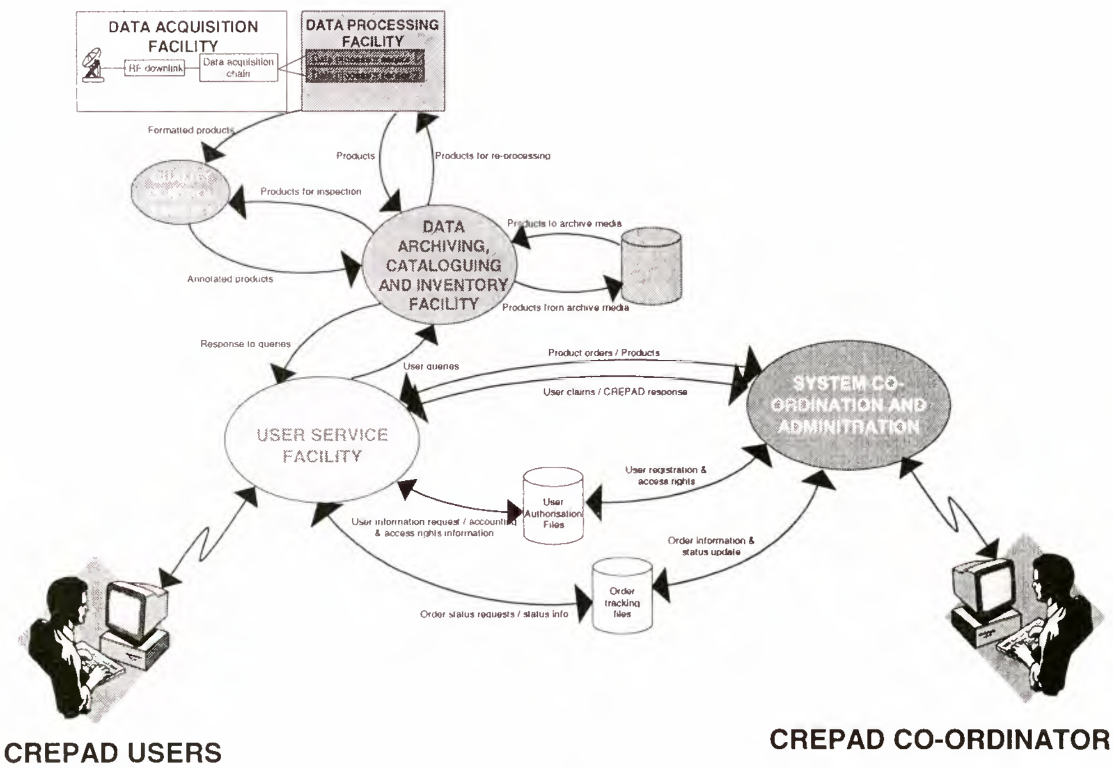


Fig. 4. High level logical architecture of CREPAD V1.0

CREPAD V1.0 provides the following functionality:

- Data acquisition for AVHRR, SeaWiFS and MOS (data acquisition for OCTS was also originally planned, but obviously cancelled after the lost of this mission).
- Data processing to level 0, 1a and 1b, for all the raw data received.
- Data archiving and cataloguing for the three sensors.
- User services, including provision of general information on EO missions, data browsing, preparation and submission of product requests, registration and subscription services.
- Distribution of data products.
- System administration and co-ordination as required to support the rest of the functions.

User services are rendered through a WWW interface which provides two different types of accesses to registered or unregistered users. The Internet address is http://www.crepad.rcanaria.es.

CREPAD V1.0 started acquiring and cataloguing AVHRR images by July 1997. SeaWiFS images are also received following the launch and commisioning of SeaStar. MOS data is received but not yet available in the centre catalogue.

Because of the selection of missions to be supported in CREPAD, it is obvious that the centre has drawn some attention from the oceanographic community. In the future, the services and products to be distributed from the centre may include OPPP products obtained from the different raw data available.

The pilot system implementation contract also included the preparation of a specification of requirements for a CREPAD V2.0 which includes also MERIS acquisition, processing, archiving and distribution, as well as an analysis of the plan and budget for the implementation of these additional functions.

The implementation of CREPAD V2.0 is expected to start in 1998, when the ENVISAT PDS generic elements will become available. The system is expected to be fully operational by mid-1999, when the launch of ENVISAT-1 is planned.

The second version of CREPAD will bring a new thrust to the development of ocean colour applications of space data in Spain. We expect this to even push further the development of ocean primary production estimation techniques in the Spanish user community.

ACKNOWLEDGEMENTS

The authors wish to thank Peter Regner, Eduardo Duato, Felipe Martín and other ESRIN staff for the many useful comments and helpful reviews conducted on GMV's work in the development of OPPP and of CREPAD V1.0.

Moreover, we also want to thank Octavio Llinás, from ICCM, for his enthusiastic support to the CREPAD initiative and his endeavour to the development and validation of OPPP.

We are finally in debt with José Ortiz and Miguel A. Martín from INTA, who contributed with their constructive criticism to the development of CREPAD V1.0.

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OBTENCIÓN DE INFORMACIÓN MEDIOAMBIENTAL BÁSICA MEDIANTE TELEDETECCIÓN

Victoriano Moreno[1], Carmelo Alonso[2], Carmen Martín[3]

Departamento de Teledetección, INDRA ESPACIO
Mar Egeo nº 4, Pol. Ind. nº 1. 28850 San Fernando de Henares. Madrid. España.
[1] Tf: +34 1 3963955. Fax: 3963912. E-mail: vmor@mdr.indra-espacio.es
[2] Tf: +34 1 3963934. Fax: 3963912. E-mail: calo@mdr.indra-espacio.es
[3] Tf: +34 1 3963942. Fax: 3963912. E-mail: cmar@mdr.indra-espacio.es

ABSTRACT

This paper describes the methodology for obtaining the evolution of the environmental basic cartography for the management of the natural resources in a country scale.
This methodology has been used in a project supported by the European Community, being the Spanish Ministry of Environment the final user.
The goal of this project, developed during 1996, was to obtain a complete land uses cartography of the Spanish country for 1984, 1991 and 1995 years based on Landsat TM images.

INTRODUCCIÓN

Entre las funciones que corresponden al organismo público de un país con competencias en materia de medioambiente, se encuentra el análisis y la evaluación de las decisiones estratégicas para el desarrollo de políticas sectoriales que muestren una influencia específica sobre la ordenación del territorio y el medioambiente. Dicho análisis no puede ser posible sin el apoyo de una información completa y actualizada del medio físico a escala nacional. Si tenemos en cuenta que los mapas de uso del suelo reflejan la interacción del hombre con el medioambiente que le rodea, se hace especialmente imprescindible cuando se trata de gestionar un recurso natural tan importante como es el agua.
Esta importancia de los recursos hídricos está plenamente reconocida por todos los organismos encargados de la gestión de los recursos en cualquier país, en particular España: "El agua constituye un recurso natural básico en la gestión estratégica del territorio, hasta el punto de que en algunos territorios españoles se configura ya como un factor limitante para su desarrollo". En el caso del litoral mediterráneo español, la mayor parte de sus regiones tienen hipotecado su desarrollo a la dependencia del agua, escasa e insuficiente para la demanda actual y futura.
En estas condiciones, es evidente la necesidad de contar con una información objetiva, precisa y sobre todo oportuna, de las variaciones tanto geográficas como temporales de los recursos hídricos del país.
Además, en España los datos de las distintas comunidades, administrativas, científica o de usuarios, involucradas coinciden en evaluar en un 80%, sobre el total disponible, la demanda de agua de las explotaciones agrícolas. Si añadimos a esta cifra que la reutilización del agua es muy alta para otros usos y poco significativa en el caso de los regadíos, podemos asegurar que hay una relación directa entre la gestión del agua como bien económico, social y ambiental y el control de las superficies utilizadas para regadíos.

El objetivo principal, por tanto, bien puede ser el análisis de la evolución temporal y geográfica de los cultivos en regadío a escala nacional durante un período determinado de tiempo. Junto a este objetivo principal, otro no menos importante aunque restringido a un ámbito menor, puede ser el seguimiento de la evolución de las "zonas de interés medioambiental" excepcional, tales como humedales, lagos, bosques, etc.
La necesidad de alcanzar estos objetivos con oportunidad, es decir, en plazos que permitan actuar sobre problemas incipientes, es crítica para establecer las políticas nacionales de ordenación de recursos tan altamente interrelacionados como los hídricos y los agrícolas.
En este sentido, la teledetección espacial es, quizás, actualmente la única herramienta que, con precisión razonable, permite obtener una información sintética, rápida y barata.

METODOLOGÍA

A grandes rasgos, la metodología a seguir para abordar la realización de un proyecto cuyo objetivo sea la generación de una cartografía dinámica medioambiental a escala nacional a partir de datos de teledetección espacial, puede constar de las siguientes etapas:

- Selección e identificación de imágenes (áreas, época del año, fechas idóneas sin nubes, etc.).
- Corrección geométrica y georreferenciación a escala según la cartografia nacional.
- Generación de índices de vegetación del tipo NDVI.
- Evaluación general de la imagen sobre combinaciones en color.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

- Fotointerpretación supervisada sobre dichas imágenes y delimitación de las coberturas fijadas.
- Digitalización de los polígonos delimitados en el caso anterior.
- Estratificación de las coberturas más relevantes y estracción de las de regadíos.
- Clasificación por índices de vegetación aplicada al estrato "regadíos" exclusivamente.
- Encuestas de campo.
- Evaluación global de los resultados de la fotointerpretación convencional y de la clasificación por índices.

Esta metodología fue puesta en práctica para la realización de un proyecto, desarrollado a lo largo de 1996 y 1997, y que consistió en la obtención de información medioambiental básica que sirviera de base para la gestión racional de los recursos hídricos. En lo que sigue la desarrollamos, utilizando el proyecto español como ejemplo descriptivo.

La correcta selección de las imágenes es determinante para asegurar la calidad de los resultados, especialmente en el caso de los cultivos de regadíos en los que la elección de una época del año incorrecta para las imágenes puede hacerlos indetectables, durante la fotointerpretación y clasificación.

Durante la etapa de selección se consideraron las siguientes variables:

a.- Selección de tres aniversarios entre 1984 y 1995.

- Disponibilidad de escenas (limitaciones impuestas por el uso de las imágenes Landsat).
- Determinación de los años pluviométricos, hidrológicos y agrícolas "normales" (series temporales pluviométricas, evolución del volumen de agua embalsada, series temporales de producción agrícola).
- Revisión de hitos que puedan tener impacto en los planes agrícolas (entrada en vigor de la Ley de Aguas, política agraria común).

b.- Determinación de los meses de selección de imágenes más adecuados.

- Delimitación geográfica de España (Características y divisiones climáticas, áreas biogeográficas similares, propuestas de áreas homogéneas según la distribución de imágenes Landsat).
- Distribución de las zonas regadas en relación a los límites de las escenas Landsat.
- Calendarios de siembra y recolección de las principales variedades agrícolas en regadío (arroz, algodón, maíz, etc).
- Distribución de los bosques caducifolios, marcescentes y perennifolios.

Como resultado de este proceso de análisis se seleccionaron fechas comprendidas entre mayo y septiembre de los años 1984, 1991 y 1995. Esto es, tres coberturas completas de España adquiridas por el sensor "Thematic Mapper" del satélite Landsat 5.
La escala de trabajo prevista era 1/100.000 y todas las imágenes (en total 129 escenas) se geocodificaron con "puntos de control" obtenidos de la cartografía militar española a escala 1/50.000 en proyección UTM, elipsoide de Hayford, utilizando polinomios de transformación de segundo grado y errores medios cuadráticos de los puntos de control inferior a 1 píxel.
El remuestreo de los píxeles de las imágenes se realizó por dos métodos: vecino más próximo y convolución cúbica. Con un tamaño de píxel de 30 m * 30 m.
En esta fase se tuvo en cuenta que España está incluida en cinco husos UTM, los 27, 28, 29, 30 y 31. De manera que la georreferenciación de las imágenes se realizó según el huso UTM en que se encuentra ubicada.

Las escenas remuestreadas por vecino más próximo se utilizaron para la elaboración de los índices de vegetación (NDVI) y las remuestreadas por convolución cúbica para la impresión en papel de todas las imágenes según la distribución de las hojas 1/100.000 (en total más de 850 hojas). Estas últimas sirvieron de base para la fase de fotointerpretación.
El parámetro medido que sabemos caracteriza las superficies cubiertas por vegetación es la reflectividad. La posibilidad de disponer de datos homogéneos tanto en el infrarrojo como en el rojo del visible nos permite observar el contenido de humedad de las plantas y su biomasa, sensibles a estas ventanas espectrales y que recogen las bandas correspondientes del satélite Landsat. De esta forma, podemos llegar a establecer el vigor de la vegetación comparando la banda roja del visible (los pigmentos de la hoja absorben la luz que reciben y, en consecuencia, ofrecen valores bajos de reflectividad) y el infrarrojo cercano (que ofrece valores altos de reflectividad). El NDVI (Normalized Difference Vegetation Index) es función de la diferencia normalizada del infrarrojo cercano y el rojo. En el caso del Landsat TM las bandas correspondientes son la TM4 y la TM3, respectivamente. Por tanto

$$NDVI = (TM4 - TM3) / (TM4 + TM3)$$

El valor del índice establece una serie de rangos comprendidos entre 1 y - 1. El agua y la nieve, por ejemplo, presentan valores negativos debido a la ausencia de vegetación; las rocas y el suelo desnudo tienen valores próximos a 0, ya que tienen reflectancias similares en el rojo y en el infrarrojo cercano. Solamente la vegetación tiene índices positivos, siendo mayor este valor cuanto mayor sea el vigor y la biomasa de la misma o los cultivos en regadío.
En rigor, los valores a incluir en el cálculo de estos índices son las reflectancias deducidas a partir de los valores digitales en cada banda, ya que son las únicas

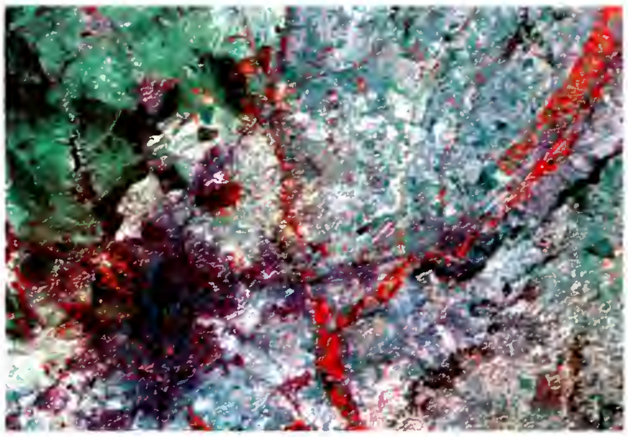


Figura 1: Imagen Landsat TM del área metropolitana de Madrid y sus alrededores. La combinación de bandas es la 4, 5, 3 en RGB, esta es la másadecuada para realizar la fotointerpretación.

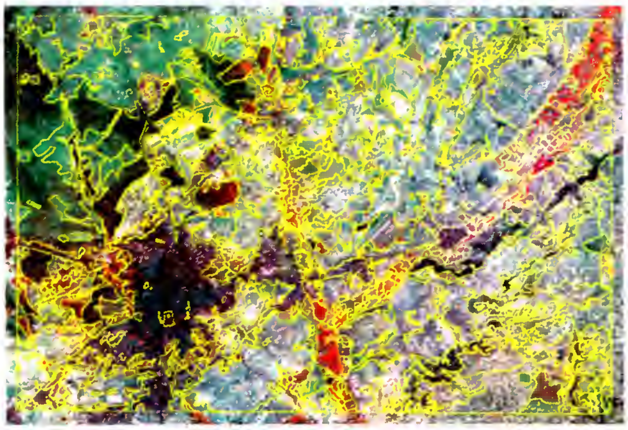


Figura 2: La fotointerpretación a partir de imágenes de satélite consiste en delimitar las diferentes clases de usos del suelo que pueden distinguirse en la imagen. Para ello se superpone un acetato transparente sobre la imagen y se dibujan los polígonos que posteriormente serán digitalizados.

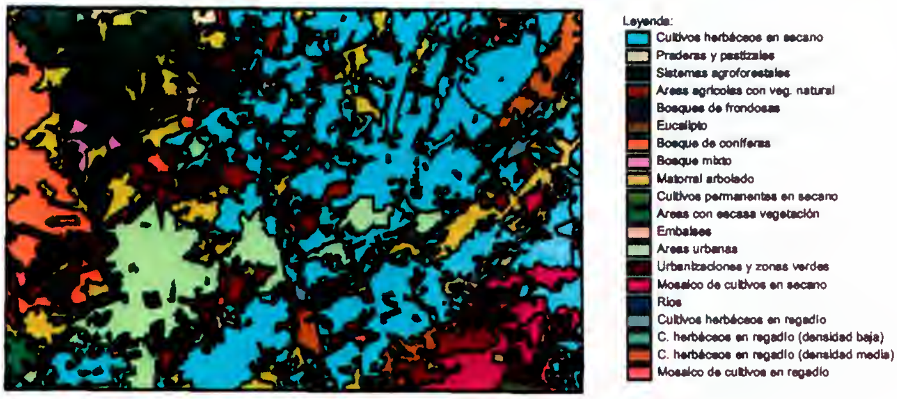


Figura 3: La información medioambiental digitalizada puede manipularse a través de un Sistema de Información Geográfica. Se puede analizar así, de manera sencilla, la evolución temporal y la distribución geográfica de cualquier cobertura de interés medioambiental.

cantidades estables y reproducibles obtenidas a partir de una imagen de teledetección. Sin embargo, la dificultad de calcular con precisión la reflectancia, especialmente debido a las interferencias atmosféricas, justificó el empleo de una magnitud más simple como es la radiancia, obtenida a partir de los coeficientes de calibración incluidos en la cabecera de las imágenes originales del Landsat.
Para la selección de áreas-tipo y cálculo de los umbrales de segmentación para la estratificación de los NDVI se comenzó por estudiar las imágenes a escala 1/1.000.000 en combinación de color 4,3,1 en RGB para identificar las escenas relevantes y establecer dichas areas-tipo que incluyeran situaciones de cobertura vegetal muy diferentes. El estudio de las imagenes finalmente seleccionadas permitió adoptar una segementación que identifica cinco clases bastante homogeneas:

- Classe 1: Valores del NDVI entre -1 y 0 (ausencia total de vegetación: Láminas de agua, ciudades, roquedos, nubes, nieve, etc).

- Clase 2: Valores del NDVI entre 0 y 0,1 (suelo expuesto con muy poca vegetación).

- Clase 3: Valores del NDVI entre 0,1 y 0,3 (vegetación escasa: barbechos, eriales, etc).

- Clase 4: Valores del NDVI entre 0,3 y 0,5 (zonas en las que la vegetación no cubre el 100% del suelo: regadios de frutales, olivos, vides, matorral, bosque de baja densidad, etc).

- Clase 5: Valores del NDVI mayores que 0,5 (totalmente cubierto de vegetación: cultivos de herbaceos en regadio, bosques densos, especiamente frondosas, etc).

Esta fase de los trabajos permite evaluar rápidamente de forma global la situación de la cobertura vegetal (densidad y estado de salud) de todo el territorio nacional en los tres años de estudio. Estos índices permiten comparar cualitativamente, y en cierta medida cuantitativamente, la situación, por ejemplo, en relación con la sequía o la desertificación, en los diferentes años.

La fotointerpretación se realizó a partir de las imágenes Landsat TM georreferenciadas y remuestreadas por convolución cúbica. Se extendió a toda la cobertura española y a los períodos y años mencionados anteriormente. Como resultado de esta etapa del proyecto se generó la cobertura vectorial de España digitalizada en ficheros según la distribución de las hojas 1/100.000 del SGE (más de 290 hojas), en formato ARC/INFO.
La identificación de las superficies regadas en el momento de la toma de cada imagen por el satélite, es relativamente sencilla, salvo factores de escala si se utiliza la combinación de bandas espectrales y colores adecuada.

Para la realización de los documentos sobre los que se realiza la fotointerpretación se ha utilizado la siguiente metodología:
. Determinación de la combinación de bandas mas adecuadas para la fotointerpretación. Dicha combinación es, en principio, la misma para todas las hojas, lo que permite al fotointérprete la familiarización con la respuesta de cada categoría en esa combinación determinada. Se utilizó la combinación 4,5,3 en RGB. A la vista de las pruebas realizadas se confirmó la idoneidad de esta combinación, en especial para la discriminación de regadíos. No obstante, los casos más complejos se estudiaron directamente en pantalla con realces locales que ayudaron a la interpretación.

. Determinación de la base topográfica a la que adecuar la fotointerpretación. Dicha base se obtiene del trabajo de georreferenciación realizado, es decir de las imágenes corregidas conforme a las hojas 1:50.000 del mapa topográfico nacional.

. Para la obtención del documento de trabajo se imprimieron las imágenes en papel de calidad fotográfica. Este método permite también la posibilidad de realizar salidas en papel en otras combinaciones de bandas o a diferentes escalas, de una forma rápida. La escala de trabajo en este caso fue 1/100.000 y se utilizaron las mejoras de contraste estándar basadas en la desviación típica de cada hoja-imagen.

La delineación se realizó en un acetato superpuesto sobre dichas imágenes, utilizándose el mismo para las tres fechas. Esto sirvió para facilitar la labor de digitalización y además evitar los problemas de falta de coincidencia en las zonas comunes. Se comenzó por la imagen del año 1984, a continuación se delinearon los cambios sobre la imagen de 1991 y, por último, los cambios de la imagen de 1995.
Para subsanar los problemas de delimitación de los regadios dispersos, y de poca superficie, mezclados con otras clases, con algunos secanos por ejemplo, se utilizó una sobrecarga de densidad del regadio añadida al codigo, densidad media (c) y baja (b). Se entiende que, en este estudio, la clase regadios es prioritaria frente a las otras y, por tanto, se clasifica una zona como superficie regada, utilizando una envolvente que incluye todos los regadios y otras clases mezcladas con ellos.
En general, un regadio sin sobrecarga indica una densidad superior al 75% en superficie, la densidad media, "c", indica una cobertura entre el 50 y el 75%, y una densidad baja, "b", indica menos del 50 % cubierto. En algunos casos se modificó este criterio (estos intervalos), para introducir información sobre el sentido de la evolución de las zonas regadas, es decir, en algunas áreas la disminución o el aumento de superficie realmente regada se producia dentro del mismo

intervalo de densidad. En estos casos una cubierta del 70%, por ejemplo, se incluyó en densidad alta , para incluir la información sobre el aumento de regadio en la zona con respecto al año anterior estudiado, que tenía una cubierta del 60%. En casos especiales también se utilizaron otras sobrecargas como ocurre en grandes zonas de olivares con riego disperso (sobrecarga R).
La fotointerpretación se adecuó en cada caso a las clases más representativas en cada zona. Es decir, se tuvieron en cuenta las características de ocupación del suelo de cada región y su impacto en las demandas hídricas. Los campos de golf serían relevantes, por ejemplo, en el sur de España y no lo serían en el norte. Las posibles confusiones en la identificación de arrozales serían relevantes en las zonas en que estos ocupan una gran superficie; en el norte, por ejemplo, no se tuvo en cuenta la identificación de estos cultivos por ser prácticamente inexistentes.

La unidad cartográfica utilizada es la unidad espacial delimitable en las imágenes de satélite. Puede tener una composición homogénea o heterogénea pero siempre reconocible como una unidad en la imagen. Si su contenido es heterogéneo tendrá estructuras identificables (por ejemplo aeropuertos, polígonos industriales, etc). La unidad cartografiable mínima era de 25 ha. Esto supone, a una escala 1/100.000, un polígono de 5 mm * 5 mm, o un círculo de 2,8 mm de radio en el mapa. De todas formas esta unidad mínima se utilizó únicamente para los cultivos de regadío, en el resto de los casos dependía del contexto.
Considerando la limitación que supondría el área mínima delineada y para no dejar sin contabilizar en regadios los polígonos menores de 25 ha, que en algunas zonas podian llegar a cubrir áreas significativas se delimitaron envolventes que los incluyeran. Estas envolventes sirvieron para mejorar las estadísticas de superficies regadas mediante el uso de los índices de vegetación, y que permiten obtener la superficie real regada incluyendo áreas menores de 25 ha.
En cuanto a los objetos lineales (carreteras, vías férreas, canales) se cartografiaron solo aquellos de mas de 100 m de ancho (en principio nudos de comunicación) englobándolos en la categoría zonas urbanas, por ejemplo.
Los problemas en la asignación de categorías, sobre todo en el caso del año 1995, que no se resolvieron con la consulta de la documentación auxiliar se corrigieron mediante trabajo de campo. En el trabajo de campo se determinaron las características de grandes zonas geográficas en cuanto a las pautas de ocupación del suelo y se resolvieron dudas puntuales que surgieron en la fase de fotointerpretación. Evidentemente las visitas, realizadas en 1996, sólo han sido efectivas para aquellas categorías que no cambian de un año para otro y también han resultado muy útiles para determinar las características y las pautas de cambios en la ocupación del suelo de cada zona.

La leyenda utilizada en la fotointerpretación de las imágenes incluía 31 clases diferentes de usos de suelo que podían discriminarse facilmente a partir de las imágenes.

LEYENDA: CLASES DE USO DEL SUELO

codigo	**descripción de la clase**
	1. SUPERFICIES ARTIFICIALES
28	1.1 ZONAS URBANAS, INDUSTRIALES Y DE SERVICIOS.
29	1.2 ZONAS VERDES: CAMPOS DE GOLF Y URBANIZACIONES.
30	1.3 ÁREAS DE EXTRACCIÓN MINERA
	2. ÁREAS AGRÍCOLAS
	2.1 TIERRAS DE LABOR EN SECANO
1	2.1.1 Cultivos herbáceos
2	2.1.2 Cultivos permanentes
3	2.1.3 Asociación/mosaico cultivos herbáceos y permanentes
	2.2 CULTIVOS DE REGADÍO
4	2.2.1 Cultivos herbáceos
5	2.2.2 Arrozales
6	2.2.3 Cultivos permanentes
7	2.2.4 Mosaico cultivos herbáceos y permanentes
8	2.2.5 Cultivos bajo plástico
9	2.2.6 Policultivos regados tradicionales
10	2.3 PRADERAS Y PASTIZALES
11	2.4 SISTEMAS AGROFORESTALES
12	2.5 ÁREAS AGRÍCOLAS CON VEGETACIÓN NATURAL
	3. BOSQUE Y VEGETACIÓN NATURAL
13	3.1 BOSQUES DE FRONDOSAS
	3.2 FRONDOSAS DE PLANTACIÓN
14	3.2.1 Eucaliptos
15	3.2.2 Choperas
16	3.3 BOSQUES DE CONÍFERAS
17	3.4 BOSQUES MIXTOS
18	3.5 MATORRALES Y MATORRALES ARBOLADOS
19	3.6 F. SUPRAFORESTALES
20	4. ROQUEDO Y ESPACIOS CON ESCASA VEGETACIÓN
	5. CURSOS Y LAMINAS DE AGUA
21	5.1 LAGOS Y LAGUNAS NATURALES INTERIORES
22	5.2 LAGUNAS COSTERAS
23	5.3 MARISMAS
24	5.4 ÁREAS INTERMAREALES, DELTAS Y ESTUARIOS.
25	5.5 EMBALSES
26	5.6 OTRAS LAGUNAS ARTIFICIALES
27	5.7 AGUAS MARINAS
31	5.8 RIOS

El control de la bondad de la fotointerpretación se realizó de la siguiente manera:

- Selección de una serie de zonas a analizar sobre la hoja fotointerpretada.
- Asignación por otro miembro del equipo de categorías a las zonas seleccionadas.
- Determinación de la diferencia entre la asignación original y la realizada en la comprobación.

Estrictamente hablando, con esta primera verificación se comprueba la homogeneidad de la fotointerpretación de los diferentes equipos que participan en el proyecto.
En paralelo se realizó otro proceso de verificación que utiliza el trabajo de campo y lo compara con la fotointerpretacion realizada. Esta comprobación se realizó sobre más de un diez por ciento del total de las hojas 1/100.000 (sobre las que previamente se habían señalado los problemas locales) y sobre, practicamente, el cien por cien de las hojas que presentaban problemas de identificación en zonas relevantes.

Para mejorar la evaluación de la superficie real dedicada a regadíos se utilizaron como máscaras sobre los índices de vegetación antes calculados las envolventes de todas las clases incluidas en el estrato "cultivos de regadío" y finalmente se utilizó una clasificación supervisada sobre dicho estrato.
La clasificación sobre los índices evita la sobrevaloración de las superficies regadas y la utilización de las máscaras evitan que puedan clasificarse como regadíos otras coberturas vegetales con respuesta similar, tales como choperas o bosques de coníferas silvestres.

CONCLUSION

El resultado final del estudio representó más de 100 gigabytes en datos de teledetección, más de 250 ficheros vectoriales (con una media de 900 polígonos cada uno) y más de 400 CD-ROM's entre originales y procesados.
El informe final incluyó las superficies de las clases más importantes desde el punto de vista medioambiental por hojas 1/100.000, por cuencas hidrográficas y por Comunidades Autónomas.
En el caso de los regadíos, este informe incluía dos cifras para cada uno de los tres años: la primera, siempre igual o mayor, la obtenida del cálculo del área de los polígonos digitalizados; la segunda, más precisa, obtenida de la clasificación de los índices de vegetación sobre el estrato de regadíos.

Toda esta información generada, tanto gráfica como numérica, puede integrarse en un Sistema de Información Geográfica (GIS) para la manipulación temática y espacial de los datos. Estos sistemas constituyen el verdadero soporte en la labor de gestión que realizan los organismos públicos relacionados con el medioambiente.
Mediante la manipulación y el análisis de las distintas capas de información, se pueden establecer procedimientos que generen nuevos datos tales como determinación de zonas de influencia, cuantificación, relación entre elementos, medidas lineales y superficiales, etc.; que permiten la elaboración conjunta de información (inventario de superficies de regadío, bosques, etc.), mapas temáticos y consultas interactivas, en tiempo real, así como la actualización permanente de los datos.

CESAR: UN PROGRAMA ARGENTINO ESPAÑOL DE OBSERVACIÓN DE LA TIERRA

L. ACEDO, F. GONZÁLEZ, M.A. SERRANO

Departamento de Programas y Sistemas Espaciales, Subdirección de Investigación y Programas, **Instituto Nacional de Técnica Aerospacial**

Crta. de Ajalvir km 4 - 28850 Torrejón de Ardoz, Madrid ESPAÑA

Resumen

El Programa de Pequeños Satélites del INTA, ha sido estructurado en tres etapas. La primera de ellas culminó con la puesta en órbita del satélite MINISAT el pasado mes de abril. Este satélite llevaba embarcadas cargas útiles de carácter científico.

La segunda etapa del Programa, se inició en 1995, fecha en que comenzaron a realizarse estudios, con el propósito de utilizar la plataforma MINISAT para embarcar cargas útiles de observación de la Tierra.

Fruto de estos estudios, nace el Programa CESAR, como un programa de colaboración internacional entre España y Argentina, que utilizará un pequeño satélite para realizar misiones de cartografía y estudios temáticos.

Introducción

Tras la experiencia alcanzada en España, en el desarrollo del Programa Minisat y la también alcanzada en Argentina con el desarrollo del SAC-B, ambos países se plantearon la posibilidad de desarrollar conjuntamente un Satélite de Observación de la Tierra, que diese respuesta a las necesidades concretas de su comunidad de usuarios.

El programa MINISAT nace en el INTA en el año 1991 con el objetivo de diseñar en un corto periodo de tiempo una plataforma multipropósito de bajo costo. En la primera fase del programa se ha desarrollado la plataforma MINISAT 01, que llevaba como carga útil tres experimentos científicos y uno tecnológico. Esta fase tuvo su punto culminante en el lanzamiento exitoso del satélite MINISAT el 21 de abril del presente año.

La segunda fase del programa, iniciada en el año 1995, tiene como objetivo el desarrollo de una plataforma orientada a misiones de observación terrestre en general , y en particular todas aquellas que nos permiten evaluar el impacto humano en el ecosistema. En esta fase se encuadran entre otros el programa CESAR.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

En efecto, al objeto de concretar las diversas iniciativas planteadas en la Segunda Conferencia Espacial de las Américas, se mantuvo una reunión especifica en 1995 en Cartagena de Indias entre diferentes países latinoamericanos y España. En la misma se concluyó que los sistemas existentes (Landsat, SPOT, NOAA, ERS...), no eran los mas idóneos para la comunidad de usuarios de sus respectivos países, bien por problemas en su sistema de distribución (los periodos de tiempo para disponer de una imagen determinada a veces pueden ser de meses), bien por problemas de disponibilidad (la imagen no ha sido tomada en las condiciones necesarias para realizar el estudio: época del año, iluminación, cobertura nubosa, etc..).

Al objeto de concretar los intereses de los usuarios se realizaron diversos talleres de trabajo con los mismos, que permitiesen realizar la definición concreta de la misión entre un abanico de posibilidades. Finalmente España y Argentina decidieron abordar el desarrollo de un sistema para realizar misiones de Cartografía y Estudios Temáticos.

Objetivos y características del Programa CESAR

Así nace el CESAR, como un programa de colaboración internacional española argentina, cuyo propósito es satisfacer la demanda de las comunidades de usuarios de ambos países relativas a cartografía, topografía, catastro (fundamentalmente rural)evaluación de cultivos, predicción de cosechas, conocimiento de la calidad de las aguas, detección de depósitos subterráneos de agua, evaluación de masas forestales, recursos oceánicos y mineros, evaluación de la contaminación en suelos y aguas así como de los daños ocasionados en incendios y otro tipo de catástrofes que afectan al ecosistema.

Para poder realizar las misiones especificadas, el satélite contará con la siguiente instrumentación:

UNA CÁMARA PANCROMÁTICA: en el espectro visible de 450-700nm, con la posibilidad de extenderla a 800. Esta cámara se utilizará para cartografía digital y además como el satélite tendrá la posibilidad de tomar imágenes fuera de nadir , tanto a lo largo de la traza como transversalmente a la misma, se podrá utilizar para obtener imágenes topográficas del terreno.

La resolución final (5-10m), y el ancho de la traza (30-60 Km) se decidirán durante la primera etapa de la fase de viabilidad en la que se elaborarán los Requisitos de Misión consolidados.

UNA CÁMARA MULTIESPECTRAL: con las bandas y aplicaciones que se detallan a continuación (Tabla 1) y con un ancho de barrido de 480 x 480 Km.

Banda	Rango nm	Resolución m	Aplicaciones
B1	500 - 520	40 - 80	Mapas de productividad primaria en aguas costeras. Monitoreo de la contaminación y mareas rojas
B2	540 - 560	40 - 80	Monitoreo de sedimentación y polución en aguas costeras
B3	620 - 660	40 - 80	Índice de vegetación. Monitoreo productividad agrícola
B4	780 - 820	40 - 80	Índice de vegetación. Límite tierra-agua. Corrección atmosférica
B5	1600 - 1700	200 - 240	Mapeo de hielo y nieve. Monitoreo de la vegetación.

Tabla 1

El satélite se situará en una órbita circular heliosíncrona, con el propósito de tomar imágenes en las mismas condiciones de iluminación que puedan ser comparables, La altura de la órbita se decidirá finalmente en función del ciclo orbital elegido, del tiempo de contacto con las estaciones de recepción para poder volcar imágenes en tiempo real, y del combustible para mantener el heliosincronismo de la órbita. En la Tabla 2 se incluye un cálculo del retraso en la hora local respecto al nodo ascendente por latitud para diferentes alturas.

RETRASO EN HORA LOCAL RESPECTO NODO ASCENDENTE POR LATITUD

Latitud \ Altura	450	475	500	525	550	575	600	625	650
0	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00	0:00:00
10	0:05:07	0:05:11	0:05:15	0:05:19	0:05:23	0:05:27	0:05:32	0:05:36	0:05:40
20	0:10:34	0:10:42	0:10:50	0:10:59	0:11:07	0:11:16	0:11:25	0:11:33	0:11:42
30	0:16:46	0:16:59	0:17:12	0:17:26	0:17:39	0:17:53	0:18:07	0:18:21	0:18:35
40	0:24:23	0:24:42	0:25:02	0:25:21	0:25:41	0:26:01	0:26:21	0:26:42	0:27:02
50	0:34:42	0:35:09	0:35:37	0:36:05	0:36:33	0:37:02	0:37:31	0:38:00	0:38:29
60	0:50:39	0:51:19	0:52:00	0:52:41	0:53:23	0:54:05	0:54:48	0:55:31	0:56:14
70	1:21:23	1:22:30	1:23:38	1:24:46	1:25:55	1:27:05	1:28:16	1:29:27	1:30:40
80	3:03:28	3:06:35	3:09:46	3:13:02	3:16:24	3:19:51	3:23:23	3:27:02	3:30:48
80	8:56:32	8:53:25	8:50:14	8:46:58	8:43:36	8:40:09	8:36:37	8:32:58	8:29:12
70	10:38:37	10:37:30	10:36:22	10:35:14	10:34:05	10:32:55	10:31:44	10:30:33	10:29:20
60	11:09:21	11:08:41	11:08:00	11:07:19	11:06:37	11:05:55	11:05:12	11:04:29	11:03:46
50	11:25:18	11:24:51	11:24:23	11:23:55	11:23:27	11:22:58	11:22:29	11:22:00	11:21:31
40	11:35:37	11:35:18	11:34:58	11:34:39	11:34:19	11:33:59	11:33:39	11:33:18	11:32:58
30	11:43:14	11:43:01	11:42:48	11:42:34	11:42:21	11:42:07	11:41:53	11:41:39	11:41:25
20	11:49:26	11:49:18	11:49:10	11:49:01	11:48:53	11:48:44	11:48:35	11:48:27	11:48:18
10	11:54:53	11:54:49	11:54:45	11:54:41	11:54:37	11:54:33	11:54:28	11:54:24	11:54:20
0	12:00:00	12:00:00	12:00:00	12:00:00	12:00:00	12:00:00	12:00:00	12:00:00	12:00:00
-10	12:05:07	12:05:11	12:05:15	12:05:19	12:05:23	12:05:27	12:05:32	12:05:36	12:05:40
-20	12:10:34	12:10:42	12:10:50	12:10:59	12:11:07	12:11:16	12:11:25	12:11:33	12:11:42
-30	12:16:46	12:16:59	12:17:12	12:17:26	12:17:39	12:17:53	12:18:07	12:18:21	12:18:35
-40	12:24:23	12:24:42	12:25:02	12:25:21	12:25:41	12:26:01	12:26:21	12:26:42	12:27:02
-50	12:34:42	12:35:09	12:35:37	12:36:05	12:36:33	12:37:02	12:37:31	12:38:00	12:38:29
-60	12:50:39	12:51:19	12:52:00	12:52:41	12:53:23	12:54:05	12:54:48	12:55:31	12:56:14
-70	13:21:23	13:22:30	13:23:38	13:24:46	13:25:55	13:27:05	13:28:16	13:29:27	13:30:40
-80	15:03:28	15:06:35	15:09:46	15:13:02	15:16:24	15:19:51	15:23:23	15:27:02	15:30:48
-80	20:56:32	20:53:25	20:50:14	20:46:58	20:43:36	20:40:09	20:36:37	20:32:58	20:29:12
-70	22:38:37	22:37:30	22:36:22	22:35:14	22:34:05	22:32:55	22:31:44	22:30:33	22:29:20
-60	23:09:21	23:08:41	23:08:00	23:07:19	23:06:37	23:05:55	23:05:12	23:04:29	23:03:46
-50	23:25:18	23:24:51	23:24:23	23:23:55	23:23:27	23:22:58	23:22:29	23:[illegible]:00	23:21:31
-40	23:35:37	23:35:18	23:34:58	23:34:39	23:34:19	23:33:59	23:33:39	23:33:18	23:32:58
-30	23:43:14	23:43:01	23:42:48	23:42:34	23:42:21	23:42:07	23:41:53	23:41:39	23:41:25
-20	23:49:26	23:49:18	23:49:10	23:49:01	23:48:53	23:48:44	23:48:35	23:48:27	23:48:18
-10	23:54:53	23:54:49	23:54:45	23:54:41	23:54:37	23:54:33	23:54:28	23:54:24	23:54:20

Tabla 2

En la Figura 1 se ve de forma gráfica el retraso horario en función de la latitud para alturas de 450Km y de 650Km. En la Figura 2 se representa la traza de un dia para una altura de 600Km.

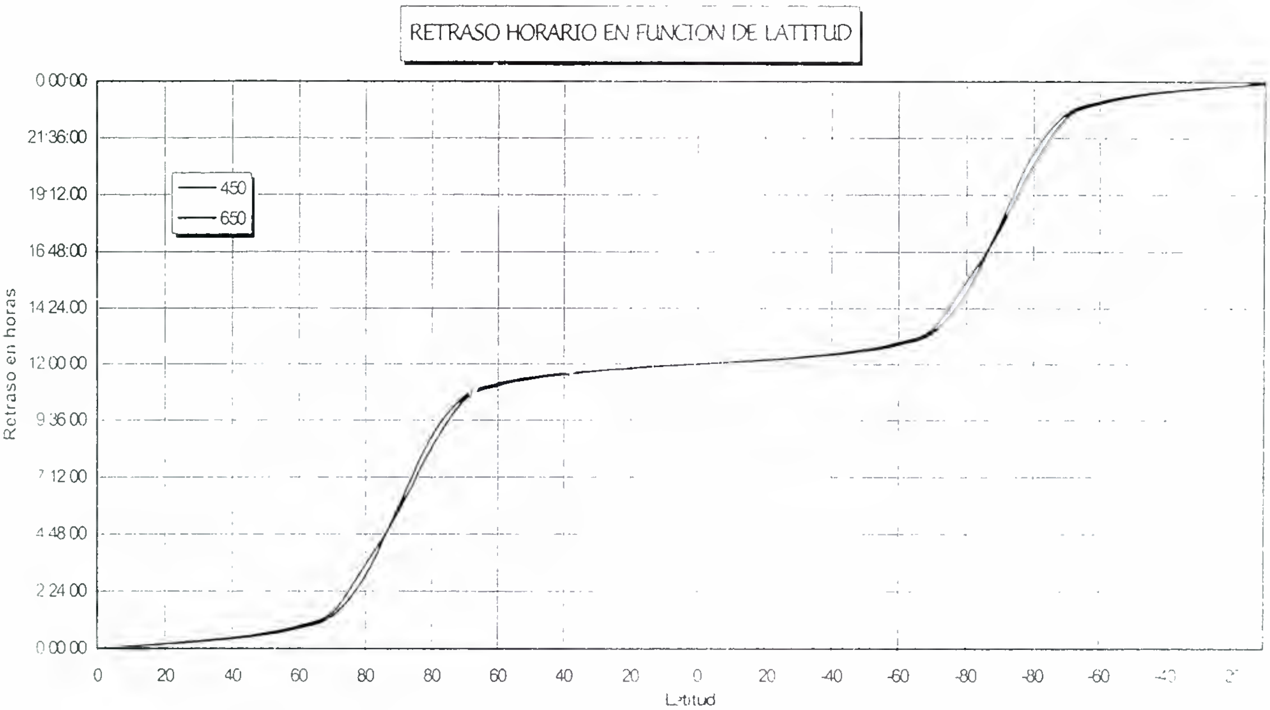


Figura 1

TRAZA DE UN DÍA

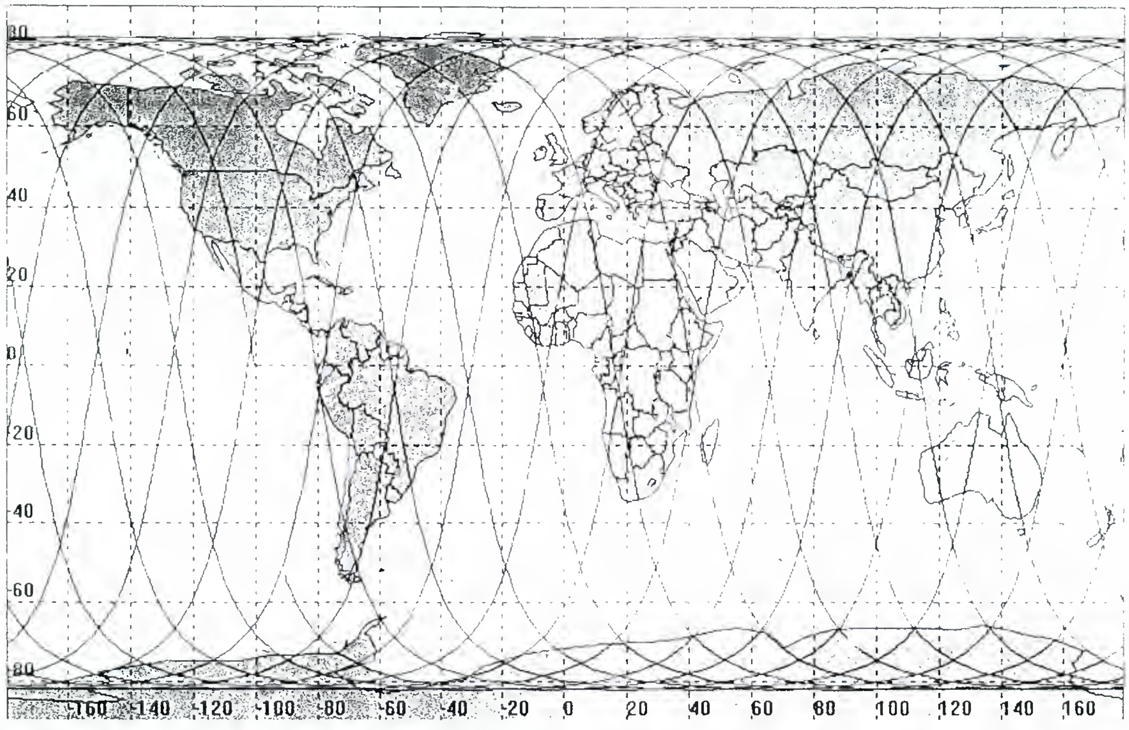


Figura 2

La digitalización se realizará a 8 o 10 bits, la decisión final se tomará durante la fase de viabilidad en función de diferentes factores entre los que el prioritario será la explotación de la información por el usuario final (niveles de gris).

El satélite contará con un sistema de almacenamiento de datos a bordo con capacidad de al menos 60 Gbits, será una memoria de estado sólido con capacidad de lectura y escritura simultáneas.

Características del Segmento Terreno

La transmisión de los datos se realizará en banda X a una velocidad de 80Mbps. El volcado de datos se realizará sobre las estaciones de recepción existentes actualmente en los dos países Maspalomas (España), Falda del Carmen (Argentina), además desde estas estaciones se realizará TTC. En la Figura 3 aparece representado el circulo de cobertura.

ESTACIONES DE RECEPCION / TTC

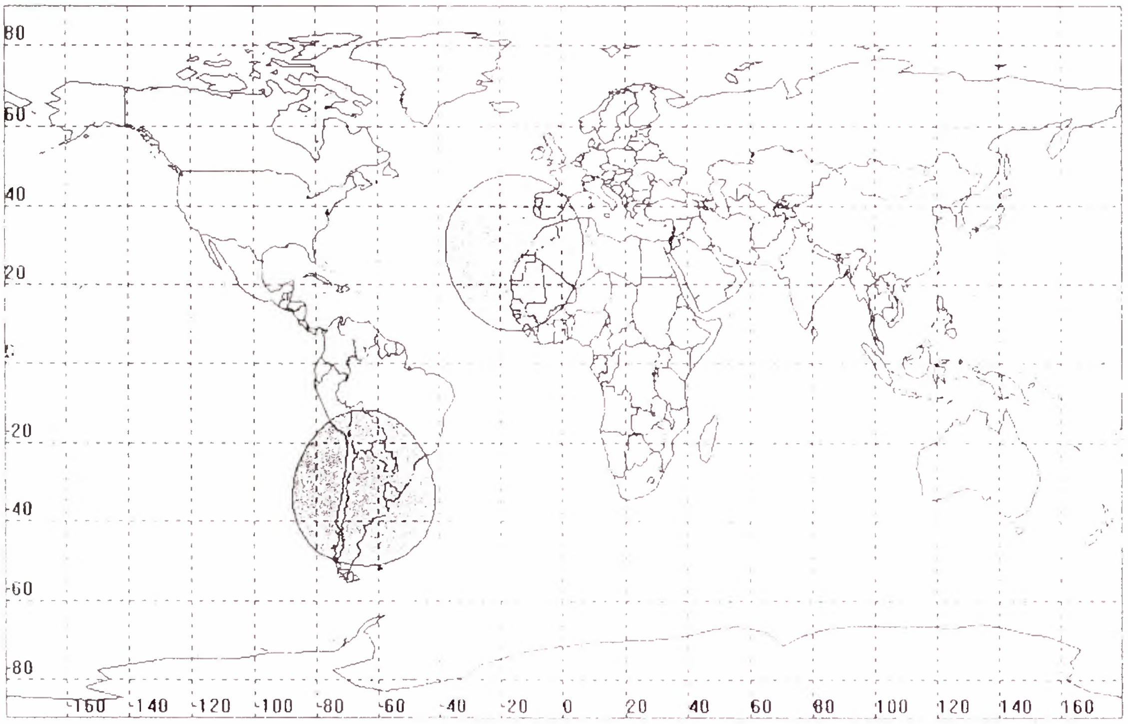


Figura 3

Existe la previsión de que tanto España como Argentina cuenten con una estación mas de recepción de datos, que en el caso español estaría situada en Madrid y en el caso argentino en Usuhaia (Tierra del Fuego).

Evidentemente, este hecho aumentaría enormemente el número de imágenes que se pueden volcar en tiempo real, y la comunidad de usuarios de ambos países podría disponer en un tiempo muy corto (horas) de imágenes del territorio cubierto por el círculo de cobertura de las estaciones. Seria de especial interés contar con la estación de recepción de Usuhaia por su posición estratégica en el globo terráqueo (Figura 4).

ESTACIONES DE RECEPCION DE DATOS

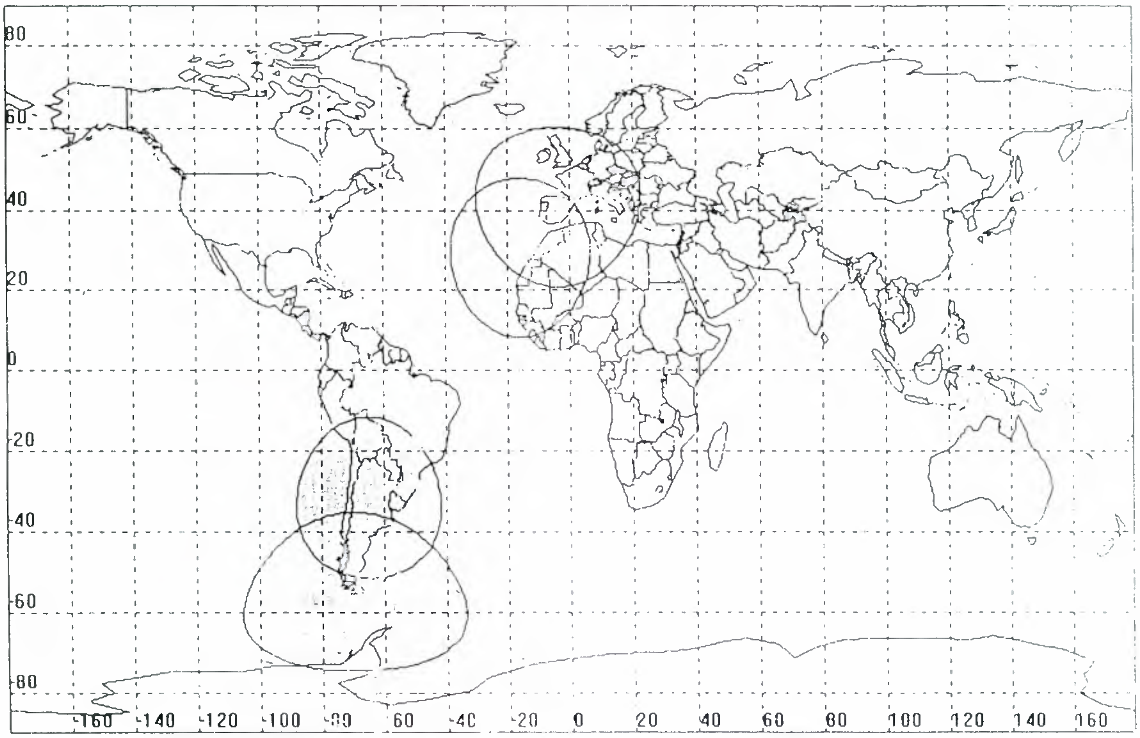


Figura 4

Programática

Para abordar el programa, INTA (España) y CONAE (Argentina) realizarán una fase de viabilidad, en la que se pretende contar con unos escenarios de misión que nos permitan consolidar los requisitos y con una concepción preliminar del sistema que nos permita evaluar su viabilidad económica y técnica. Si el resultado de la misma es satisfactorio se abordará su desarrollo para el que inicialmente hemos previsto un periodo de cinco años, atendiendo mas a factores presupuestarios que técnicos, ya que consideramos que técnicamente este programa se puede desarrollar en un tiempo considerablemente menor.

Telecommunications

THE ESA MULTIMEDIA PROGRAMME

A. Pinglier
Directorate of Applications
European Space Agency

INFORMATION REVOLUTION

Digitalisation of all types of information
(audio - video - data)
into unified bit streams
has brought about

MULTIMEDIA

Information in a digital form

- may be readily processed
- will need to be transmitted over new or greatly improved NETWORKS in order to benefit from the full potentiality of Multimedia

INTERNET is a good example of

- the huge capabilities in terms of services to users offered by an

  Interactive Multimedia Network

- the shortcomings and restrictions imposed by existing networks

Exponential growth of Internet users require large bandwidth

Typical telephone connection lasts 3 minutes

Internet access via PSTN increase mean call duration to several 10 to 100 minutes

➡ PSTN will shortly be overloaded
Users will experience higher blocking than today

Ultimately FIBRE OPTIC CABLE in each home and associated with SWITCHING in the network is considered to be the solution.

This process is long and expensive and may not be the optimal solution in all cases.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

SATELLITES FOR INTERACTIVE MULTIMEDIA

Satellites can help ease the situation
in the short term and also
in many instances in the long term

Satellites "see" a large user population

large capacity satellites
&
low cost user stations
&
unrestricted connectivity

can complement terrestrial networks

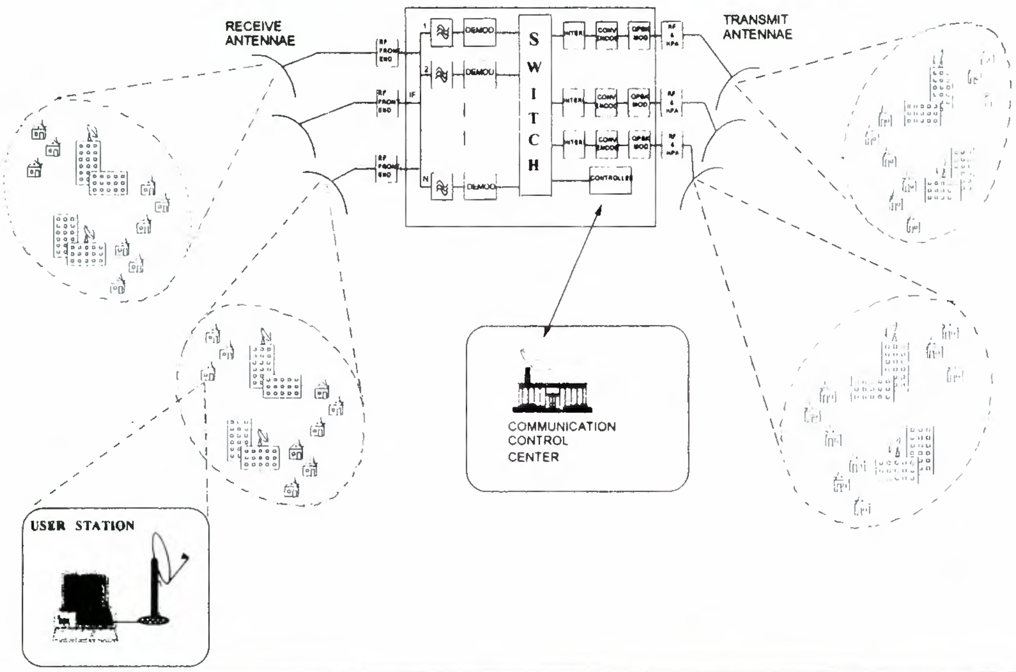
ON-BOARD PROCESSING

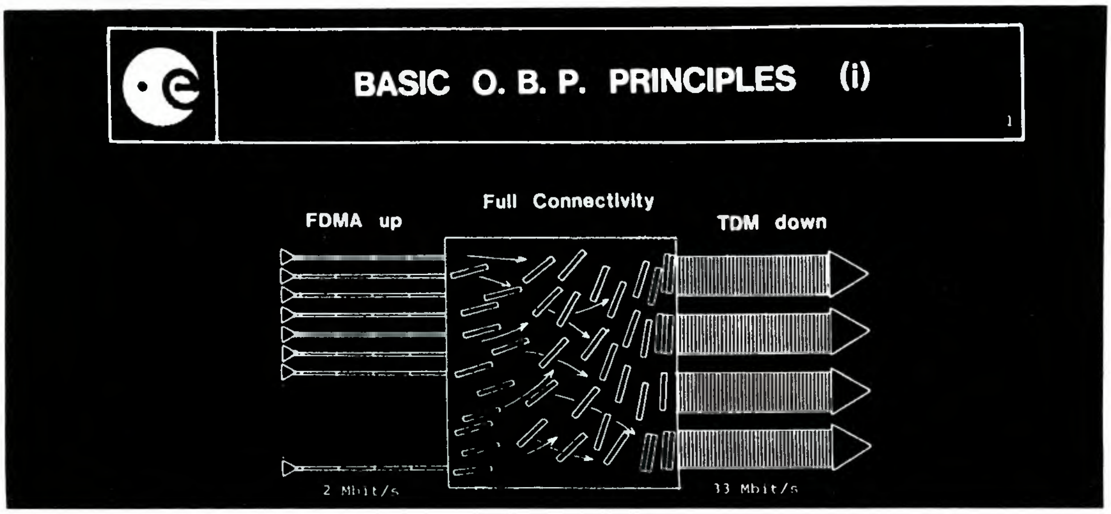
The use of a <u>non transparent satellite payload</u> with on-board processing of the incoming information is a very <u>efficient</u> approach to interactive multimedia systems.

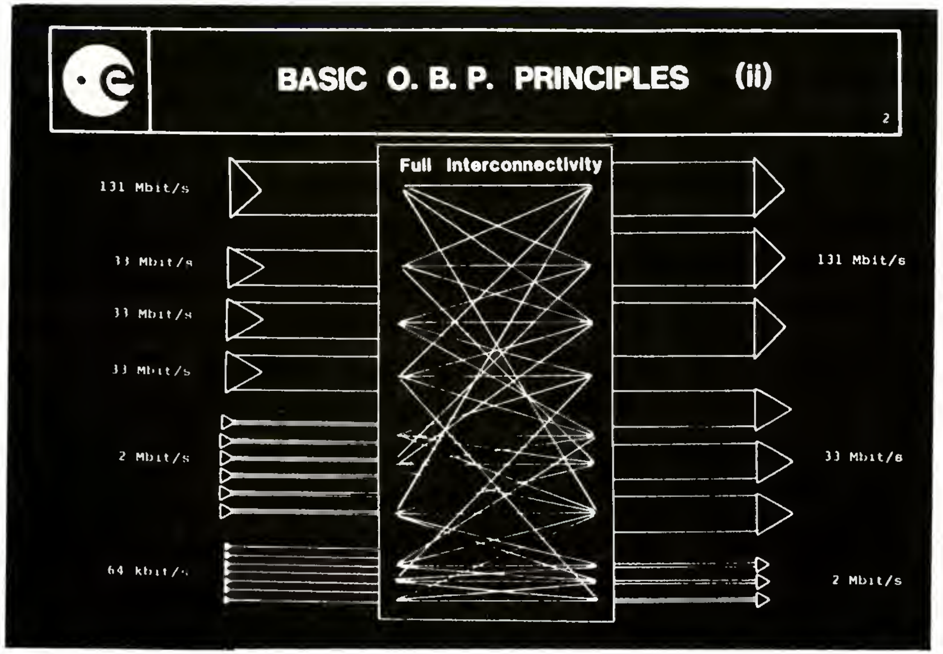
OBP associated with multibeam operation provides

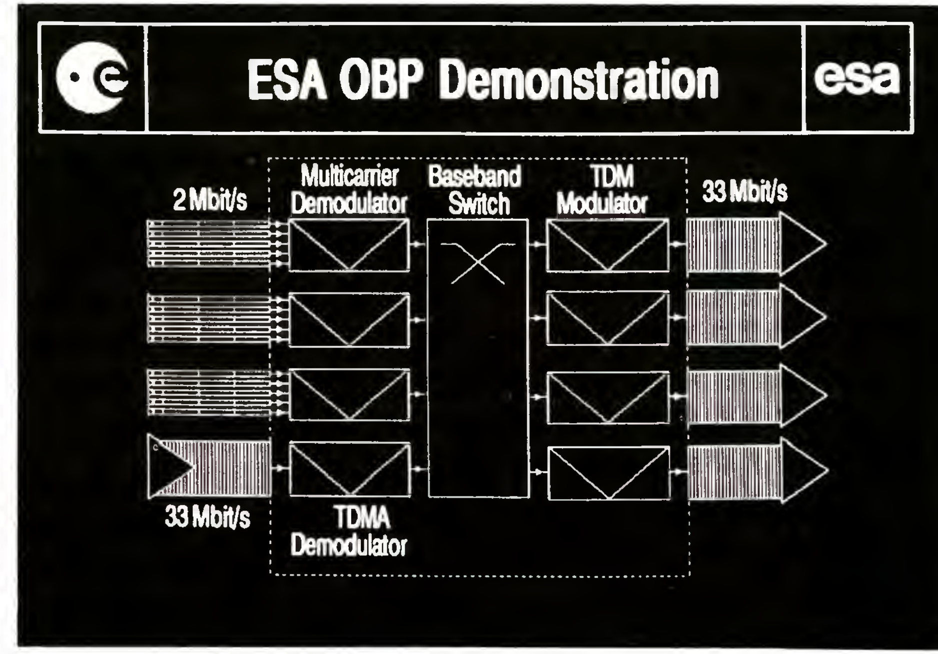
- full connectivity
- bandwidth on demand

OBP:INTERACTIVE MULTIMEDIA









ESA OBP DEVELOPMENTS

Within its telecommunications framework programme, ARTES (Advanced Research in Telecommunications Systems), ESA has sponsored European industry to carry out a study of an OBP system and the development and testing of a breadboard model.

USER SERVICES REQUIREMENTS

- ISDN basic rate & primary rate access
- Extended network services
  ISDN based (multi)-point-to-multi point services
- Packet switched services
  TCP/IP services

REQUIREMENTS FOR INTERACTIVE MULTIMEDIA SATELLITE SYSTEMS

Low cost user station

→ very small spot beams

Large satellite capacity

→ multiple frequency reuse

INTERACTIVE MULTIMEDIA SATELLITE: SOLUTION

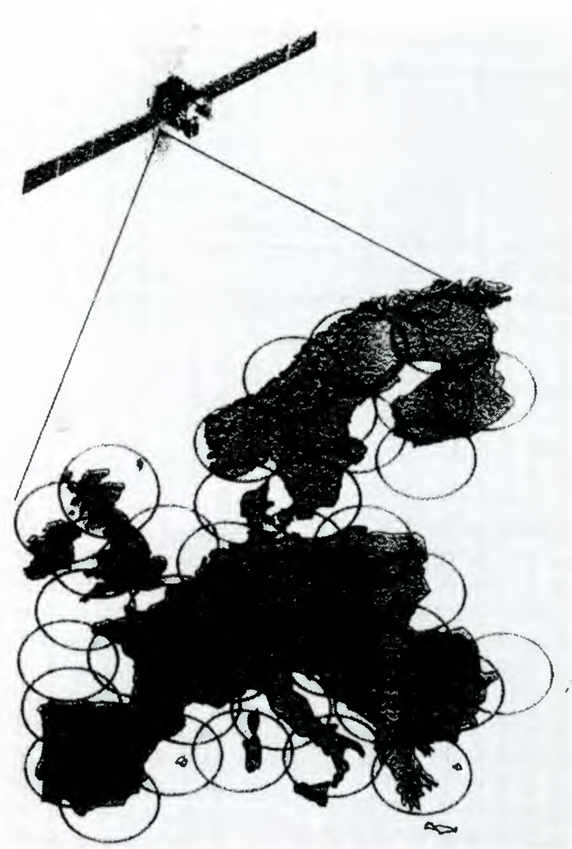
Operation at highest possible frequency band

→ Ka-band

Multiple spot beams to cover large area

On-demand on-board switching

MULTIPLE SPOT BEAMS



OBP COMMUNICATION SCHEME

How is the communication established?

Basically two types of operations:

- circuit switched mode (ISDN and ISDN related) via the on-ground Master Control Station
- packet switched mode via the On-Board Request Handler

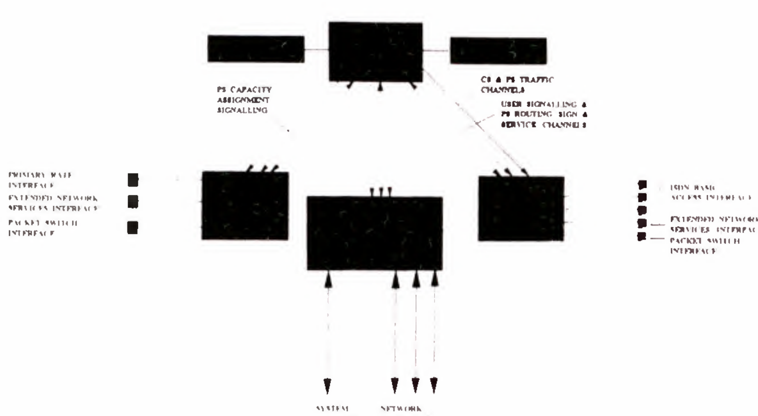
PACKET SWITCHING IN GEO SATELLITES

Large on-board memories are needed

One concept:

buffering on ground
switching on board

OBP COMMUNICATION SCHEME

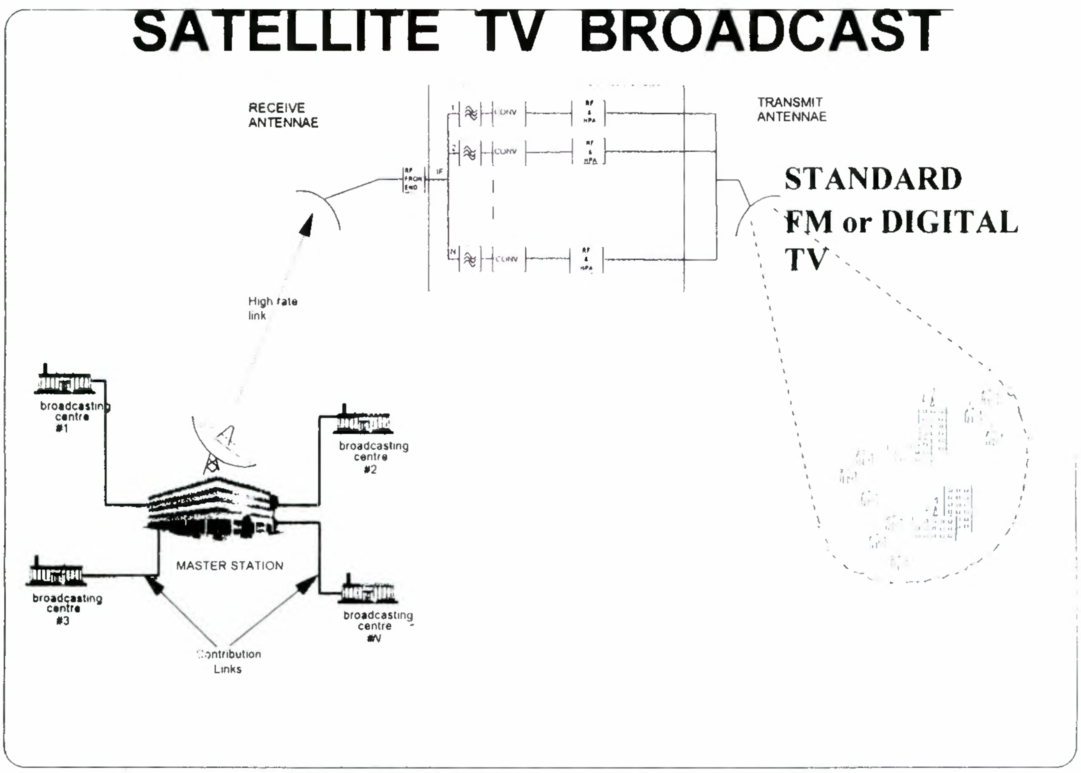


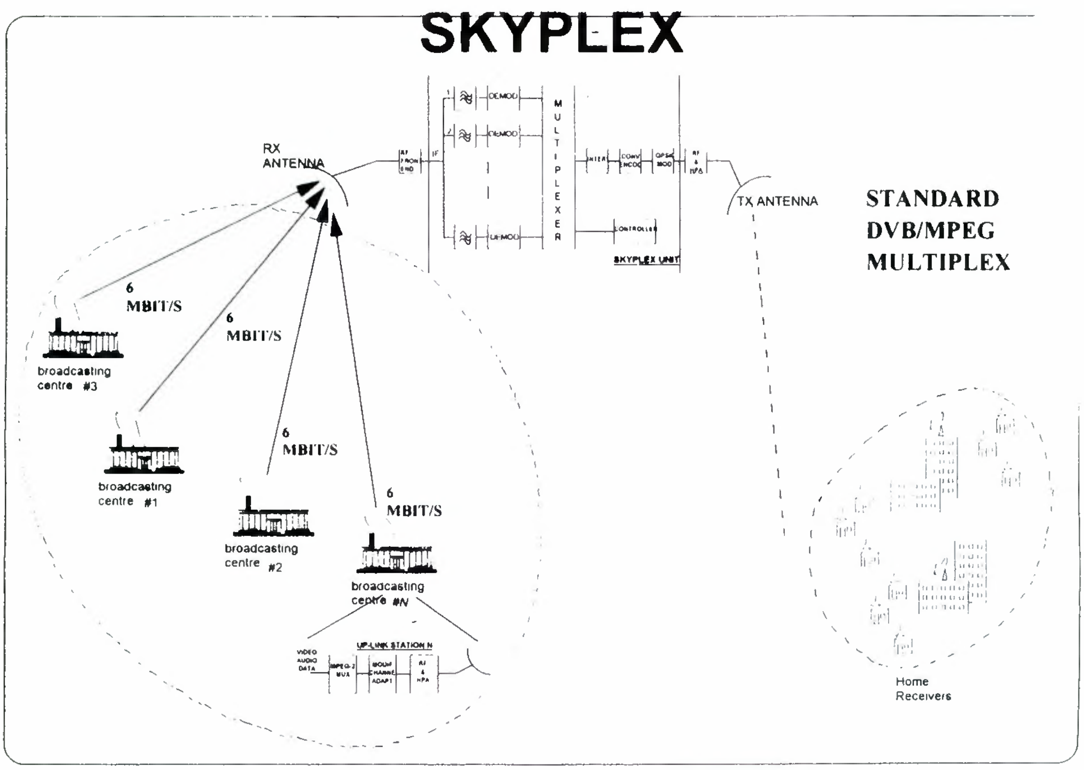
SATELLITE TV BROADCAST

Uplinking several TV programmes

Classical method: multiplexing on the ground

New approach: onboard multiplexing in the case of digital TV (Skyplex)


SATELLITE TV BROADCAST
RECEIVE ANTENNAE
TRANSMIT ANTENNAE
STANDARD FM or DIGITAL TV
High rate link
broadcasting centre #1
broadcasting centre #2
broadcasting centre #3
broadcasting centre #N
MASTER STATION
Contribution Links


SKYPLEX
RX ANTENNA
TX ANTENNA
STANDARD DVB/MPEG MULTIPLEX
MULTIPLEXER
SKYPLEX UNIT
6 MBIT/S
6 MBIT/S
6 MBIT/S
6 MBIT/S
broadcasting centre #3
broadcasting centre #1
broadcasting centre #2
broadcasting centre #N
UP-LINK STATION N
Home Receivers

INTER SATELLITE LINK

To extend the system coverage, two or more satellites needed which should be interconnected.

Interconnection via the ground or directly via a satellite to satellite link (ISL)

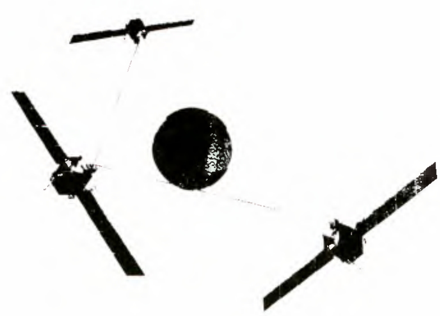
Multimedia satellites will require interconnectivity and many systems will use ISL.

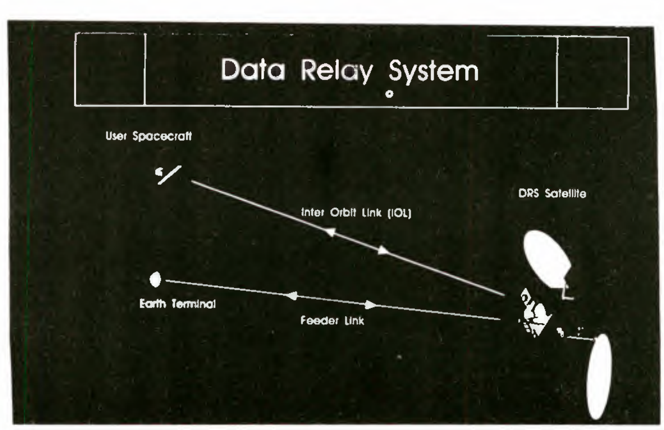
INTER SATELLITE LINK

GEO to GEO
LEO to LEO (ISL is particularly relevant here as the coverage of individual satellites is limited)
GEO to LEO (for data relay applications)

Technical approach
1. Microwave (Ka-band and 50/60 GHz)
2. Optical

GEO GEO INTERSATELLITE LINKS





OPTICAL ISL

Is still at the experimental stage. ESA has been very active in this field.
A proof concept-demonstration optical ISL payload (SILEX) is onboard the ESA technology satellite ARTEMIS to be launched in early 2000.
The system will be tested with ARETMIS and the French SPOT-4 Earth observation low earth orbit satellite also equipped with a Silex terminal.
Similar tests will be carried out between ARTEMIS and OICETS, a Japanese LEO technology satellite.

Wavelengths	- 0.8 micron	As Ga
	- 1 micron	Nd YAG
	- 1.5 micron	Iridium Ga (used in fibre optic cable)

Silex:	wavelength:	0.8 micron	low power diodes
	ISL data rate:	50 Mbit/sec	
	Terminal mass:	150 kg.	
	Terminal power:	200 W	
	Telescope diameter:	25 cm	

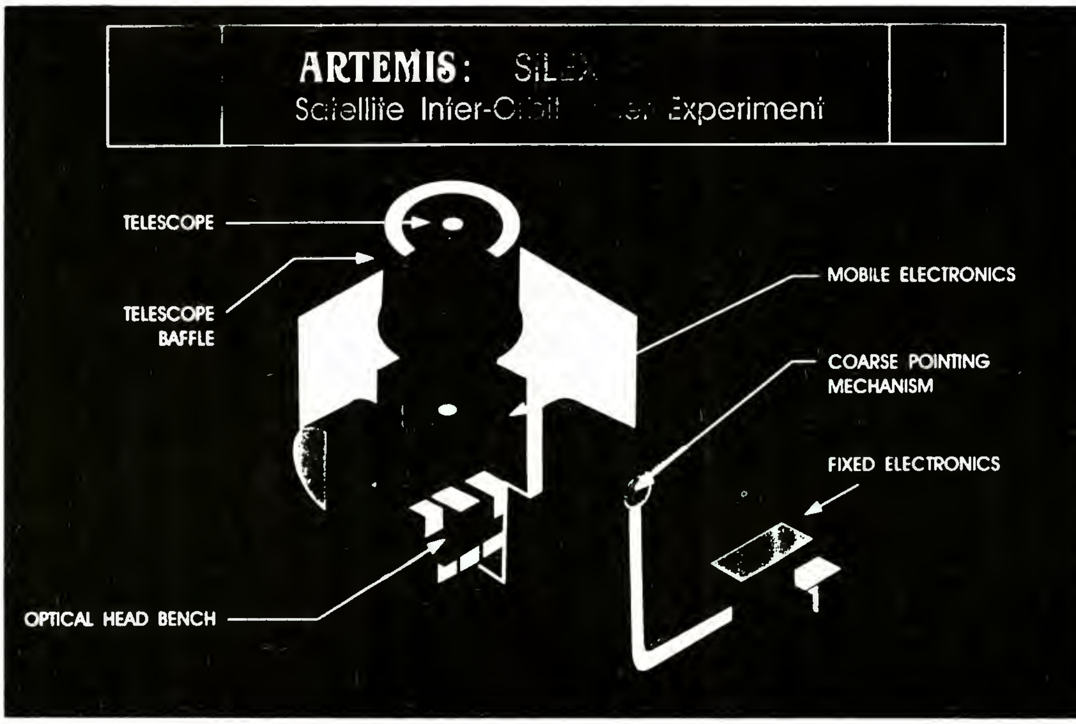
Since Silex was designed substantial progress has been made, particularly on laser diode : output power x 10.

The ISL data rate can be substantially increased: 1.5 GHz or more

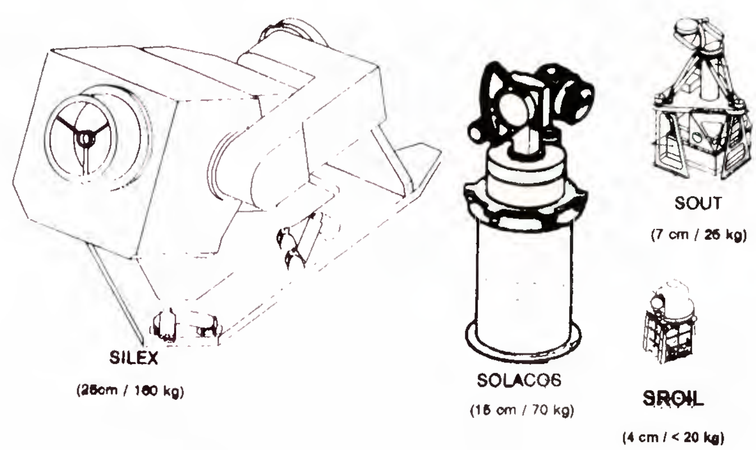
The size of the telescope reduced: 10 cm.

As a consequence weight and cost will be considerably lowered.

Optical ISL will soon be a very attractive approach (much more so than the microwave solution with its large antenna).



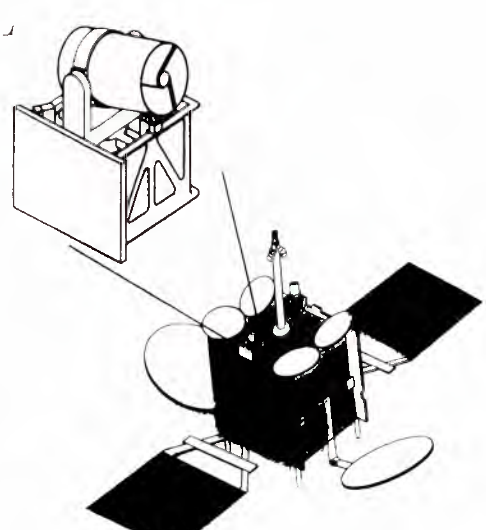
TERMINAL SIZE EVOLUTION



SOTT TERMINAL

MASS 50 Kg

POWER 100 W



THE NEW ESA MULTIMEDIA PROGRAMME ARTES-3

Considering the rapid evolution of multimedia worldwide, ESA is adopting a new approach:

- The scope of the programme will be broader. Up until now efforts on a few key aspects (OBP, ISL etc.). From now on all facets of Multimedia via satellite will be potentially covered.
- The ESA-Industry relationship will evolve from a customer to supplier situation to a partnership.

ARTES-3 MISSION

- to put Member States' industry in a position to acquire as large a share as possible of the world market in satellite based communications services
- to promote advanced applications and thereby assist with the development of new markets

OPPORTUNITIES IN GLOBAL BROADBAND INFORMATION SERVICES

- Explosive growth in the Internet has increased public awareness of the power of low cost multimedia technology
- Worldwide pressure for deregulation coupled with migration to digital standards for the broadcast community has stimulated an enormous market for broadband interactive services
- Delivery of low cost services using satellite technology offers Europe the opportunity to capitalise on expertise in this field and increase its share in the international market place.

THE GLOBAL MARKET: THE NEED TO BE PRESENT

- Global market estimates for broadband satellite services indicate between 30-50 million subscribers in the next decade
- In that time frame Europe will have approximately 52 million computers which will represent a major portion of the global market for multimedia products and services
- The challenge is either to import these products and services or to improve the competitiveness of our industry so that it can establish a strong export position in the international market place towards the end of the next decade

ARTES-3 LINES OF ACTION

To serve the whole spectrum (from SMEs to large Space Companies and Consortia, as well as Satcom Operators, Service Providers and others) three major lines of action will be pursued:

- Line 1: Development of Satcom Multimedia Markets
- Line 2: Development of Satcom Multimedia System Elements
- Line 3: Pioneering Novel System

DEVELOPMENT OF THE SATCOM SYSTEM ELEMENTS

- System building blocks such as on-board processing technology, intelligent antennas, inter-satellite links and communications control techniques
- Ground systems such as low cost user terminals and those elements of satellite infrastructure which are necessary to support the interfaces with service providers

DEVELOPMENT OF THE SATCOM SYSTEM MULTIMEDIA MARKET

ARTES-3 will support the development of applications to promote early market start up in:

- tele-medecine
- tele-education
- public administration
- Intranets
- high speed Internet

DEVELOPMENT OF THE SATCOM SYSTEM MULTIMEDIA MARKET

- Promotion of open standards for interactive satellite terminals
- Active involvement from European satellite operators is planned to help create strategic links with manufacturers and applications teams

PIONEERING NOVEL SYSTEM

- The pace at which the present generation of systems is evolving constitutes a revolution for the satellite communications industry
- Global players are actively initiating new systems, maintaining an active R&D strategy will be an essential feature for survival of manufacturing companies
- ARTES-3 will harmonise development projects to enhance the market position of those companies having the long term vision both to identify and exploit the critical technologies for the 21st century.

ARTES-3 FUNDING

Activities will be co-funded by ESA and contractors on a 50% basis. (Higher ESA funding levels for SME and universities and institutes.)

ESA has requested from its Member States 350 MECU (390 M$) over a five-year period.

Initial contributions are being received and the programme has started in October 1997.

CONCLUSION

Fascinating times are ahead in the Multimedia area. Satellites will play a major role. There will be competition between:

- service promoters
- system manufacturers, and for
- technical solutions
  - LEO versus GEO mixed systems
  - OBP versus transparent transponders
  - ISL or not, etc.

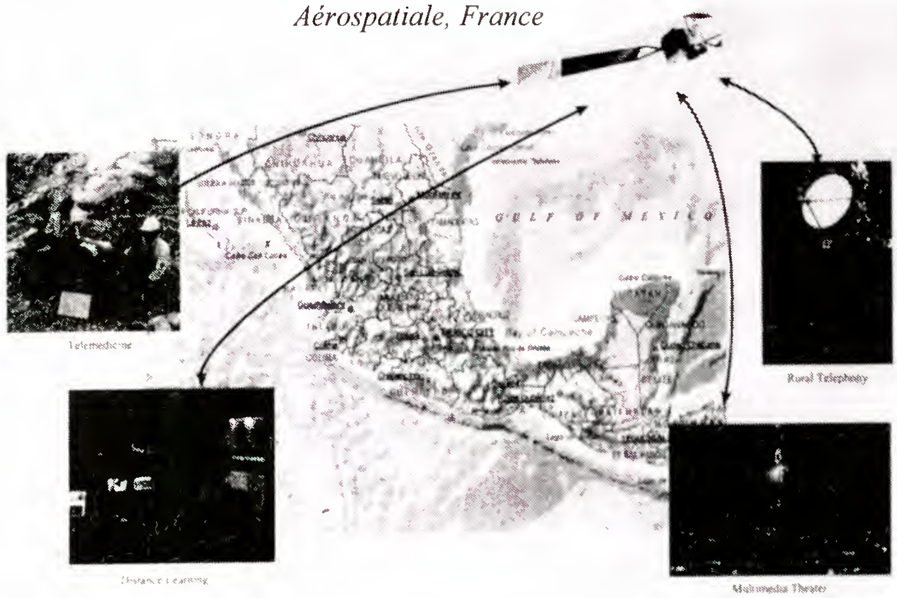
ESA and European industry are taking the necessary steps to meet the challenge.

Some of our initiatives could greatly benefit from the cooperation of partners outside Europe.

HIGH-SPEED MULTIMEDIA SERVICES FOR LATIN AMERICA

G. Deveau & P. Eymar

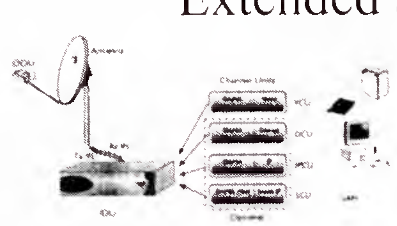
Aérospatiale, France



Typical architecture

- A VSAT rural telephony system includes :
  - A hub with a control center and a gateway to the Public Switch Telephone Network (PSTN)
  - Up to many thousands of terminals able to provide many telephone circuits to deliver toll quality voice, fax and data (modem) as required. Antenna diameter from 60 cm (Ku band) to 1,2 m (C band). DAMA (Demand Assigned Multiple Access) technoloy is used

Extended applications



ODU = OutDoor Unit
(Antenna and RF module)
IDU = InDoor Unit

- Possible extensions for small business applications
  - Interfaces with a PABX (up to thirty lines)
  - Groupe III fax
  - Dial up data (modem with data rate up from 2,4 kbits/s) for PCs
  - Interfaces with Local Aera Networks (LAN) with different protocols
  - Internet connection

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

Economy of a typical system

- Simulation is done for a system with :
  - 1000 VSAT with 2 two-ways compressed telephone circuits (16 kbits/s) per site serving two pay phones (no business applications)
  - 15 minutes per day use for each pay phone (standard hypothesis for pay phones in developped countries ; real usage could be much higher in isololated villages
  - five years amortization
- Monthly cost per site is 90 US$
- Communication cost/minute (from VSAT to VSAT or Gateway to PSTN : 5 cents/minute

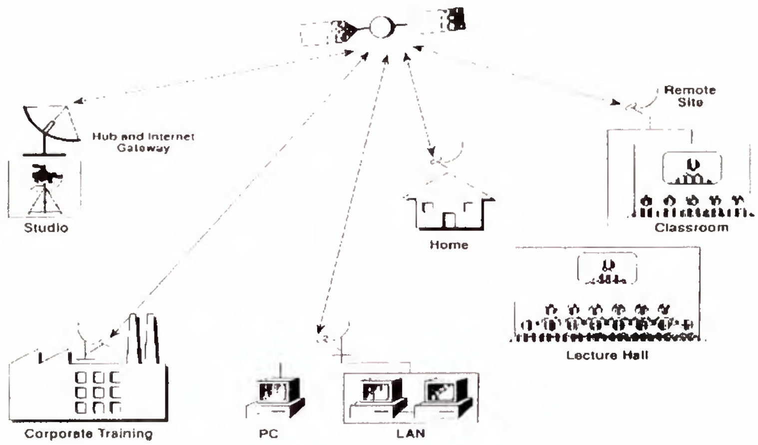
Renewed Importance of Interactive Distance Learning

- Distance learning is now able to realize its full potential due to two kinds of factors
- Technical Factors :
  - New digital technologies for low-cost and high quality broacasting of lessons from central studios in Universities, Institutes or dedicated distance education organisations
  - New very low-cost terminals (one-way or two-ways Very Small Antenna Terminal - VSAT) for classrooms
  - Efficient low data rate return links for interactivity between teachers and distant students

Evolution of Pedagogical Tools for Interactive Distance Learning

- The second factor renewing the interest of distance learning is the availability of very simple interactive processes enabling an efficient interaction between teachers and students. These processes rely on the use :
  - multimedia studios teachers with return of personal and statistical data on the students and their skills
  - very simple interactive keypads at the student level to ask questions and answer questionaries
  - tailoring of classical courses for interactive distance learning by «education engineering» techniques

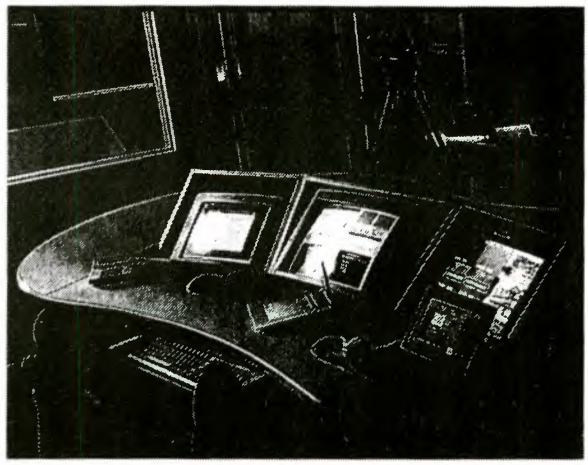
Scheme of Interactive Distance Learning System by Satellite



The Production and Broadcasting Studio for Distance Learning

- It is a small TV production studio where the teacher is able to mix its own video image with different multimedia sources (VCR, Laser Disc, video from computer screen, video of objects)
- The teacher has many screens in front of him :
  - screen from the master computer showing the plan and the viewgraphs used for the teaching
  - control monitor with touch screen enabling choice of video sources and showing questions from the students
- At any time questionaries can be sent

The Teaching Working Place



The Satellite Link

- The best solution is now digital broadcasting using DVB (Digital Video Broadcasting) - MPEG2 (video compression) standards
- The studio uses a 2.4 m (Ku band) or 6 m (C band) antenna for the uplink and the downlink (if two-ways VSAT are used ; the return link can also use the telephone network in case of one-way VSAT)
- Data rate is about 7 Mbits/s for the uplink
- Size of VSAT antennas are about about 0.6 m (Ku band) to 1.2 m (C band)

Cost Elements for Interactive Distance Learning via Satellite

- One-way VSAT : less than 1000 US$
- Two-ways VSAT : about 3000 US$ (the return link has a low data rate since no video signals are downlinked toward the studio)
- Classroom equipment : about 5000 US$ for a medium size classroom (30 students)
- Studio cost : about 50 000 US$
- Satellite bandwitdth leasing : about 300 000 US$ per year for a single DVB/MPEG2 channel

Some Examples of Interactive Distance Learning via Satellite

- The largest education network is «Channel One» in the US which serves :
  - 350 000 classrooms in 12 000 schools
  - 8 millions pupils
- Another exemple for professional training is the Interactive Distance Training Network (IDTN) which operates 45 facilities across the US and is used by such corporate customers as :
  - Silicon Graphics ; Intel ; IBM ; Microsoft Corp.
  - 3Com ; 3M ; GE Capital ; Days In ; Bristol-Myers Squibb ; DHL
  - FAA ; Sun Microsystems ; Oracle ; Ernst & Young ; Glaxo Wellcome

Advantages of Interactive Distance Learning via Satellite

- The experience in developped countries (mainly the US) proves than Interactive Distant Learning via Satellite is :
  - very good for pedagogical results (results are often better than with classical learning) very good use of the best teachers
  - very cost effective (for 300 classrooms and 10000 students the initial investment is about 200 US$ per student and operating cost after that are very low)
  - useful from first grades to university level and professional training

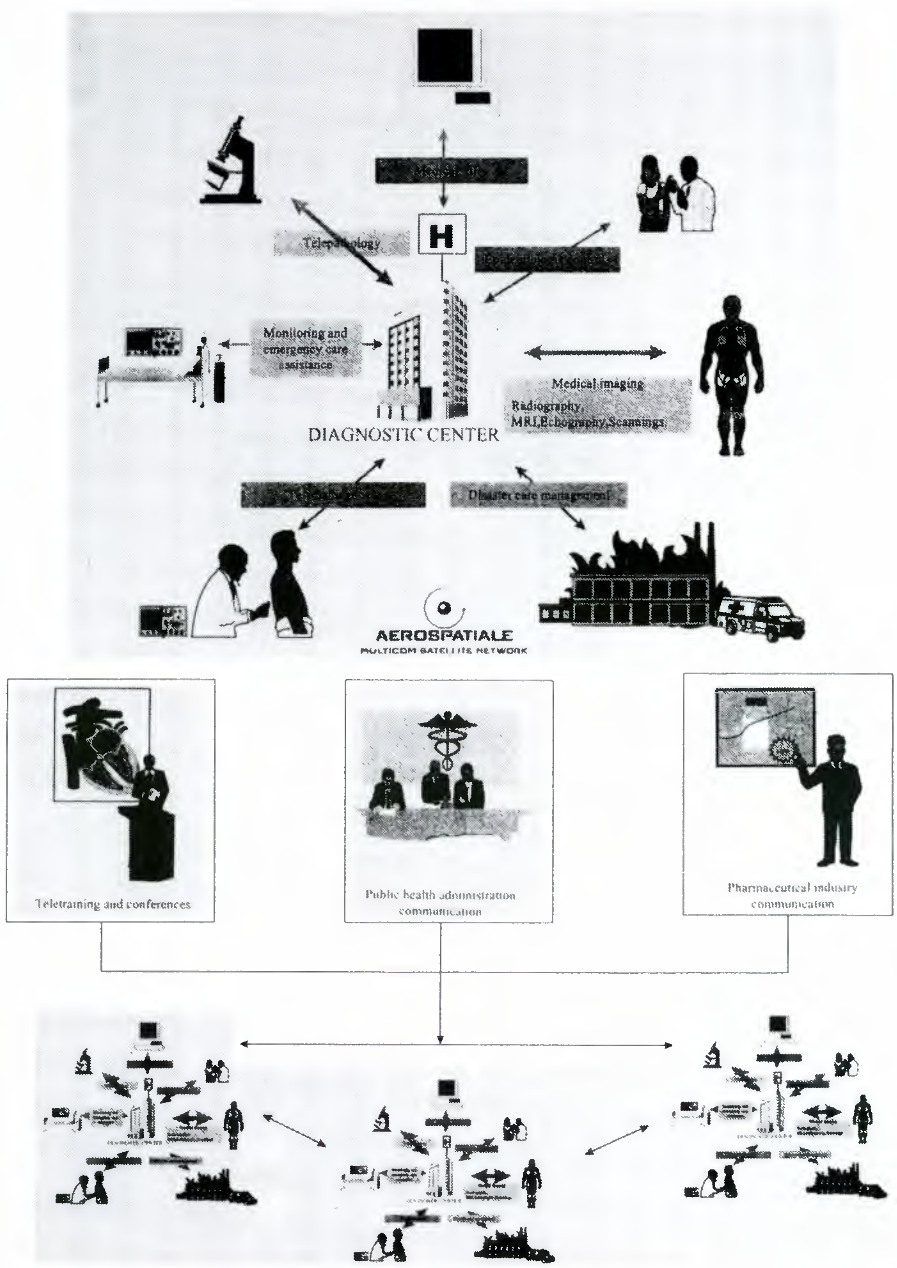
High bitrate telemedicine satellite systems specificities

- **Fast transmission of datas**
  - 1 Neuroradiology image = 23 Megabytes
  - Transmission time with telephone modem : App 20 min
  - Transmission time using satellite link:30 sec
- **Rapid access to hospitals information systems**
  - Patient file (Medical records, drug interaction and overdosage ..).
  - Patient monitor datas.
  - Medical library ressources (electronic reporting of communicable diseases, medical databases)
- **Real time video-conferencing**
  - Video consultation linkage with diagnostic centers.
  - Specialists meetings.
  - Public health conferences.
  - Pharmaceutical research communications.
- **Extensive coverage .**
  - Rapid potential coverage of 14000 hospitals ; 22000 primary health centers even in remote area (independant from phone infrastructure)

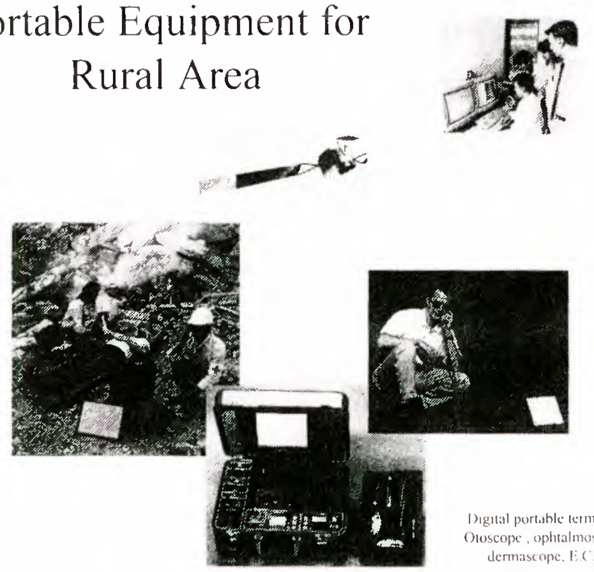
Technical specifications

- Primary health centers equipment ;
  - 1.8 meter dish + Up/down Converter +Modem
  - PC : Pentium 166, 32 MB RAM, 2 x 2.5 GB hard drive
  - High Resolution Scanner + Software for acquisition, display and transmission
  - Videoconferencing equipment : software, cards and camera
- Rural dispensaries
  - Portable ECG, dermascope,ortoscope...
  - Small antenna for simplex or duplex transmission from 9.6 to 64 kb/s
- Satellite transmisions
  GEO satellite
  Ku band transponder
  Hub for bandwidth assignemt and management
  Temporary high bitrate link between Primary Health Center and Diagnostic Center (4Mb/s)
  Temporary low bitrate link between Rural Dispensary and Primary Health Center (9.6 to 64 kb/s)

Telemedicine Basic Network



Portable Equipment for Rural Area



Digital portable terminal : Otoscope , ophtalmoscope, dermascope, E C G

Aerospatiale Multicom Satellite Network

Who's Multicom

- Subsidiary of the AEROSPATIALE Group, European leader of turnkey satellite telecommunications systems,
- Developing unique expertise as multimedia integrator, based on its competence in three areas:
  - architect of hardened telecom systems
  - specialist in high speed satellite communications
  - expert in «content»

How and in What Fields Works Multicom

- MULTICOM proposes solutions based on the use of high speed satellite networks,
- In partnership with professionals of data processing technologies and their content:
  - Training and educational programming
  - Medical Science
  - Films
  - Software & data
  - Advertising
  - Press
  - Meteorology

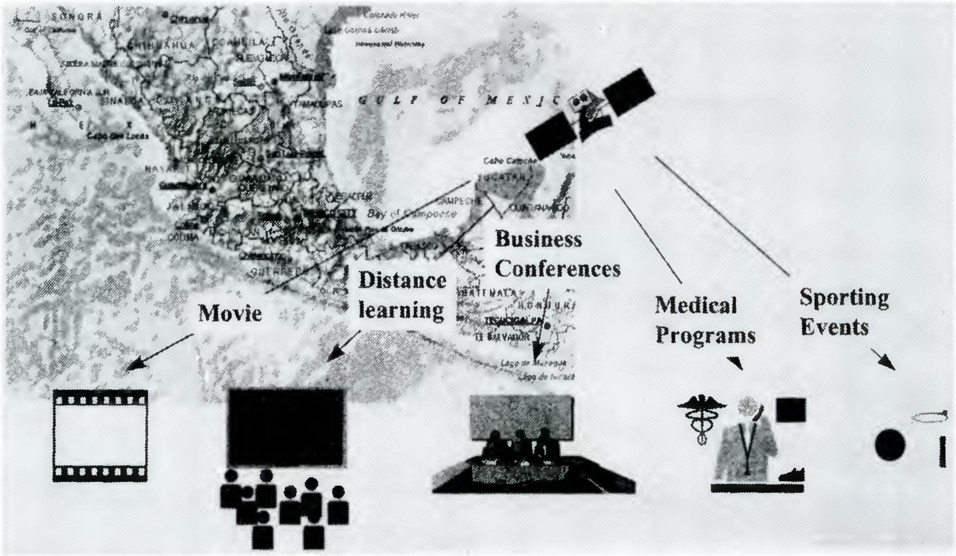
What's Multicom Offer

- MULTICOM SERVICES INCLUDE:
  - Market Studies & Business Plans
  - Strategy Consultancy
  - Prospective analysis of technologies and services
  - Turnkey delivery of technical solutions
  - Implementation and operations of systems
  - Services Operation

Where's Multicom Located

- MULTICOM headquarter and main office is located in PARIS, France
- 30 rue d'ORLEANS 92200 Neuilly/Seine
- PHONE: 33 (0) 1 41 92 91 00
- FAX: 33 (0) 1 47 22 02 83
- Central e-mail: contact@multicom.aerospatiale.fr

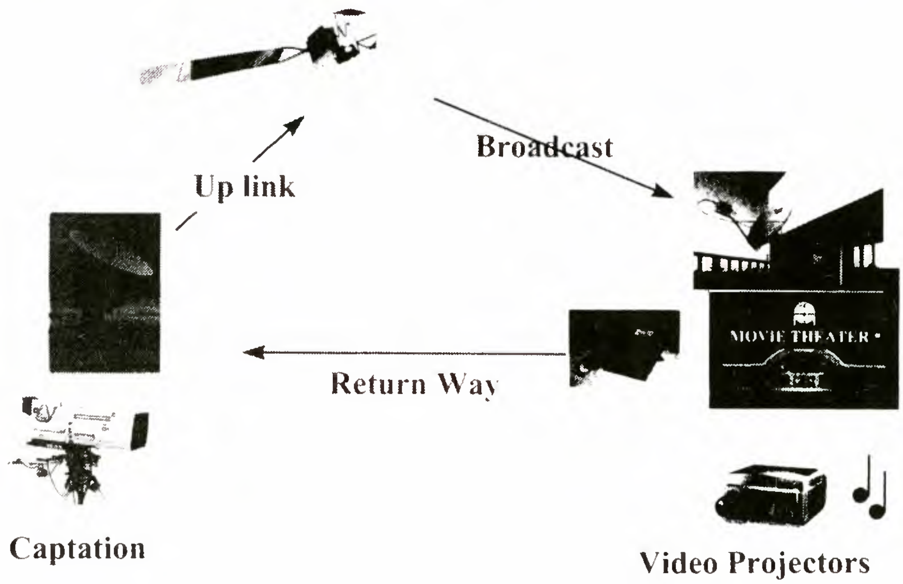
Mexican Multimedia Theaters Network
Multi-applications System



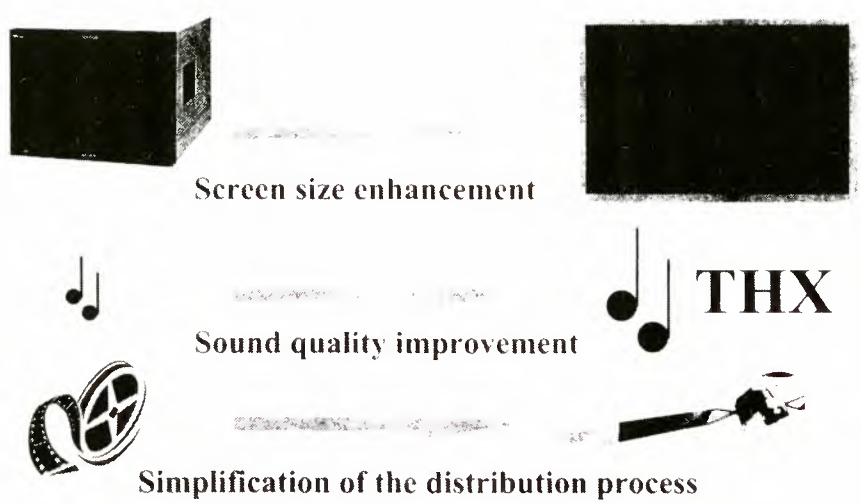
Advantages

- Merging business opportunities and public goals
- Universal access to Information Society
- Increase attendance and revenues of movie theaters
- Organisation of regional conferences and meetings (possibly political) with popular attractions
- Saving money by sharing investments beetwen miscellaneous applications
- Large opportunity of cooperation with Mexican partners
- Enjoy an independant partner : Aerospatiale, highest expertise in Europe as system architect

Logical Chain



Technical advantages



Economic Overview

- Assuming that main theaters would invest 20% per ticket sold to acquire video projector and downlink equipment, break even point could be reached in a 4 year term
- Distribution expenses should be reduced by 20% because film prints would be replaced by satellite transmissions
- Better release flexibility would allow theaters to have a better selection of movies, show more films, with a better sound and picture quality
- Theaters would be able to diversify their programs and their sources of revenues (theater plays, conferences, sporting/political events)...

AEROSPATIALE
MULTICOM SATELLITE NETWORK

SATELLITE-BASED NON-FORMAL ENVIRONMENTAL EDUCATION
A case in Guyana

Authors:
Helena Landázuri [1] & Danilo Piaggesi [2]

ABSTRACT

In remote rural areas, educational opportunities are extremely limited due to a lack of communication avenues; particularly, lack of electricity limits the audio and visual components that are otherwise found in developed areas; print materials are rare and expensive. This situation is particularly acute in a country like Guyana, where existing demand for educational, health, and other basic services cannot not be reasonably expected to be met within the next decade or longer.

In order to eliminate the handicap imposed by remoteness in Guyana, a project has been designed by a team lead by the authors; the project is currently being considered for funding. The project design calls for the use of satellite telecommunications equipment to allow the transfer of data via satellite from an acquisition and dissemination center to a number of remote sites.

A first phase covering two years would implement a telecommunication system using small portable antennas and audiovisual terminals. Participating communities would have access to each other, as well as to the central program unit, in order to exchange information and experience relating to environmentally sound natural resource management and environmental protection.

The primary recipients of this program are mainly Amerindian communities, located in remote areas within Guyana, and selected urban conglomerates in Georgetown and other main urban centers. While the official language of the program would be English, the telecommunication network will naturally be capable of sustaining exchanges in other native languages.

The authors also discuss current trends and opportunities for the implementation of an environmental information & telecommunications system in the Inter-American Development Bank, and the potential connection with telecommunication systems set-up in the Bank's member countries, such as the one designed for Guyana.

1/ Senior Environmental Specialist, Inter-American Development Bank, Washington D.C.
2/ Information Strategy Specialist, Nuova Telespazio, Rome, Italy

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

I. INTRODUCTION

Guyana has an important natural resource base. More than 80% of the country is covered with tropical forests and woodlands belonging to the Amazon basin and associated systems; these hold a rich biodiversity of flora and fauna. Likewise, underlying the forests and along the water courses, Guyana harbors mineral deposits, mainly gold, bauxite, and diamonds. These resources constitute major sources of foreign exchange to the country.

Under the current liquidity constraints faced by the country due to its external debt burden, the Government is committed to enlarge the country's exports over the next few years. For that purpose, its strategy includes the expansion of investment in both forestry and mining activities, with participation of national and international interests.

Prospects for rapid development of Guyana's natural resources may represent a threat to their sustainable yield over time. In order to avert undesirable impacts of imminent investment decisions, efficient environmental organizations capable of generating policies that would strike a sound balance between profit and careful natural resource management are needed, supported by a strong program to enhance public awareness and promote community participation in decisions pertaining to environmental/resource management.

The present operation is addressed towards enhancing environmental awareness among the Guyanese society in general, and particularly among communities involved directly in the management of its natural patrimony.

II. PROJECT OBJECTIVES AND ACTIVITIES

A. Specific objectives

The project would: (i) implement an innovative environmental awareness and educational program designed to reach specific audiences in major population centers in the remote interior of Guyana and main urban centers; (ii) strengthen the governmental and non-governmental organizations in charge of project implementation, to prepare them to continue the execution of environmental education and awareness activities once project funding ceases; and (iii) enhance data and information dissemination among the general public, schools, and specialized interest groups.

B. Principal activities

Due to the experimental nature of the program, a first phase covering two years was considered appropriate. The first phase would cover the following activities:

a. Participatory development and implementation of an environmental education and awareness strategy, to facilitate the exchange of information on community development and environmentally sound resource management, via educational methods outside of the schooling system --thus the title of "non-formal".

b. Implementation of a telecommunication system to reach selected urban conglomerates and remote rural villages, using small portable antennas and audiovisual terminals. The signal would be transmitted from the originator of information and data to participating communities and back, utilizing a satellite connection.

c. Operation of the telecommunication network allowing participating communities and groups to access each other, as well as the central program unit, in order to exchange information and experience relating to environmentally sound natural resource management and environmental protection.

d. Operation of a demand-driven information and resource center, at the central program unit, which would allow participants' access to science-based factual data and information through which to better inform the network's discussions. The unit will also act pro-actively to develop material to fit specific intended audiences.

e. Facilitation of the exchange of information on health and nutrition, or other contents deemed priority by the communities, through the program's telecommunication network.

f. Intensive field work, so as to generate opportunities to discuss the information shared and to find means to implement changes in attitudes and behaviour on the part of participants.

g. Institutional strengthening of participating organizations.

C. Thematic coverage

It is expected that a wide range of issues relevant to community sustenance would be addressed, in search for environmentally sound means to ensure the long-term sustainability of the community's income, resource base and environment. Communities consulted during project preparation suggested the following as priority areas for the program: (i) value, condition, fragility and other traits that characterize Guyana's natural resource endowment; (ii) trends in the utilization of natural resources and the deterioration of the human environment; (iii) impacts upon the lives of urban and rural communities in Guyana derived from unsound natural resource management and environmental deterioration; (iv) opportunities for sustained utilization of those resources and for the conservation of the country's biodiversity and natural ecosystems; (v) means to engage community efforts in improved resource management and environmental conservation; and in general, environmentally sound means to increase and sustain the flow of economic benefits from productive activities.

D. Project beneficiaries

The primary recipients of this program are Guyanese, mainly Amerindian communities, located in remote areas within Guyana, and selected urban conglomerates in Georgetown and other main urban centers.

In the remote rural areas, educational opportunities are extremely limited due to a lack of communication avenues; particularly, lack of electricity limits the audio and visual components that are otherwise found in developed areas; print materials are rare and expensive. This handicap will be eliminated through the use of satellite telecommunications equipment which will allow the transfer of data via satellite from an acquisition and dissemination center to a number of remote sites. In addition to the many obvious benefits of this system, such as mobility and overcoming the lack of electrical networks, it allows the transfer of the most recent information on a given subject. In contrast, the information presented in standard print materials, such as textbooks, is usually six to ten years old when published.

To ensure success, the program has been designed to promote environmental awareness and appreciation at the community level. A major emphasis is placed upon cooperative problem solving, and data retrieval systems will be provided to supply needed information. This program promotes both environmental awareness and sustainable development, as neither element can be achieved for the long term as a completely separate entity.

The audience to be served by this informal education program is quite diverse. The cities and coastal areas are inhabited by people of East Indian, African and European descent while the interior parts of the country are inhabited primarily by people of Amerindian ancestry. Tremendous differences exist between the lifestyles of urban dwellers and people living in the remote areas. Georgetown, the Capital of Guyana, has electricity, automobiles, and most modern conveniences. Of the sites selected in the remote areas, the Rupununi, Moruka and Mazaruni Regions, two have a few automobiles and most have only enough electricity to cool and preserve medications.

The geographical separation between the major populations in Guyana, coupled with a lack of communications devices, has led in many areas to apathy and withdrawal. People in the southern portions of the country are more likely to have close ties to Brazil, while those in the western parts of the country are often more closely allied with Venezuela. This is to be expected, considering the advantages of shorter distances and decreased transportation costs. However, these selected areas within Guyana are interdependent, and should share and work together in such areas as economical and educational development to improve the welfare of all Guyanese people.

Considering the differences in lifestyles between the selected areas, plus the fact that many environmental problems are localized, providing a standardized informal environmental education program to cover all the participating areas is not possible. In fact, taking what works in the cities and applying it to the remote areas could do irrevocable harm, and lead to the abandonment of methods developed over hundreds of years that work without being obvious. See the table below for an illustration of existing differences between urban and rural communities and their respective environments.

While the official language of the program would be English, the telecommunication network will naturally be capable of sustaining exchanges in other native languages. Successive phases would consider the generation of materials in such languages, if deemed necessary.

Comparisons of Urban and Rural Communities

ELEMENT	URBAN AREAS	RURAL AREAS
ENVIRONMENT	Greater isolation from nature. Predominance of man-made environment over natural	Predominance of nature over human activity
SIZE	Larger	Small
POPULATION DENSITY	Higher	Low
POPULATION	More heterogenous than rural communities	Compared with urban populations, rural communities are more homogenous in racial and cultural traits
MOBILITY	More mobility in all categories	Less moving, in and out, of the community and less job mobility
INTERACTIONS	More numerous contacts. More impersonal short-lived relationships	Fewer contacts per person. Contacts are more personal and with familiar people
BELONGING	Individuals frequently have a sense of being cut off from meaningful group associations	Individuals have a sense of belonging to significant, meaningful groups
GOALS	Individuals frequently have a sense of pursuing divergent goals and feel no sense of oneness with other residents of the city	Individuals have a sense of pursuing common goals and frequently feel a oneness with other community members, particularly in a time of crisis
INDIVIDUAL WORTH	Urbanites frequently each other as means to an end and value individuals less	Individuals regard each other as worthwhile people

E. Social Linkages

To ensure that this program addresses environmental concerns and serves the needs of the Guyanese people, the program will emphasize problem solving in a truly unique, "bottoms up" approach. Problems will be identified at the local level and the participants in all areas will take part in the research and resolution stages. Information will also be acquired from sources internationally. Teleconferencing will be used to promote communications between government officials and other experts with knowledge pertaining to a specific issue. Informal chat lines and bulletin boards will be established to promote continued communications, and data banks will be established in each participant area for use by future generations and the surrounding communities.

Thus the program will promote problem solving at the local level; provide problem solving capabilities to areas where information is extremely limited; establish databases at each site to insure long-term success; promote interaction and cooperation between the participants in the selected areas; and provide the participants with the tools and information needed to improve their general living conditions and at the same time protect and improve their environment.

III. SATELLITE BASED DISTANCE LEARNING STRUCTURE

A. Distance learning telecommunications systems

Traditionally, teaching or training is a process by which an expert instructor uses different tools to deliver messages to an audience. The content of the messages is assembled from a pre-existing body of knowledge and is delivered on a schedule pre-planned by the instructor in order to achieve, as the pre-determined goal, a defined state of knowledge in the students. The training, then, is essentially a normative process in the control of the instructor.

It has been found that the desired state of knowledge is achieved sooner if the student has opportunities to feed back to the instructor any imperfections of understanding which necessitate repetition or explanation. Interactivity is therefore accepted as enhancing the learning process in so far as as it permits relevant questions to be asked by the student.

This extension of the traditional process, permitting feedback, still leaves the procedure highly asymmetrical: a large amount of information flows from the teacher to the student, while a small amount of information, and that only in the form of questions relevant to the lesson, flows from the student to the teacher. This asymmetrical procedure is the most efficient in situations of large classes and fixed curricula to be covered on a pre-determined schedule, such as exists in most formal education settings.

Telecommunication systems designed to serve distance education have usually followed the asymmetric model, partly because the high investment demands efficient methods which show quick quantitative return, and partly because technology designers, not being education specialists, have tended to follow conservative educational approaches. As a result, a variety of technical solutions already exist, and are in use in several parts of the world, which emphasize delivery of information in text and audio-visual form from a central studio, with opportunities for interaction limited to voice links in the return direction.

A non-formal education system is likely to benefit from a less asymmetric model of training. Outside the formal system, the teacher/student ratio is likely to be lower; the time constraints are not set by fixed schedules or examinations; the curriculum is not strictly regulated but may leave openings for exploration; and, perhaps, the content is not all pre-defined or even known by the instructor. In such a situation, a greater flow of information from student to teacher can enhance the learning process. This may happen because the student can more easily extend his/her knowledge by induction from the already known; because training is transformed from an unequal didactic mode into a collaborative investigation; and, above all, because the student does not remain passive but is able to direct the investigation into areas which truly interest him/her, unconstrained by a formal curriculum. It is clear that the subject-matter most easily learned is that which attracts the interest and spontaneous attention of the voluntary learner. In this way a deeper understanding of the subject, and a greater likelihood of positive action resulting from the new knowledge, will be allowed by an increase in interactivity.

The area of environmental education is one example of a situation where the goal is not simply the transfer of existing knowledge from the instructor to the student. The intent of the non-formal environmental education program is to help to nurture a countrywide environmental ethic in Guyana, a synthesis of values and actions that suggest a wise stewardship of the national and global patrimonies.

For the particular case of a non-formal environmental education program, the design of a Distance Learning Telecommunication System, therefore, is best guided by criteria relating to the provision for feedback from the student to the teacher.

B. Telecommunication systems for signal transmission

It is convenient here to examine the characteristics of the different systems available, classified according to the technical means of signal transmission.

a. UHF/ VHF - (Ultra High Frequency / Very High Frequency) The large amount of audio-visual information is easily distributed as terrestrial TV using the standard network of TV radio-repeaters; interactive communication between audience and instructor is additionally provided by low-cost Personal Computers with modems connected to the public switching telephone network (PSTN).

b. CATV - (Cable TV) The distribution of audio-visual information is possible not only by TV repeaters, but is usually done also by cable networks. Metallic coaxial cables or optical glass fibers may be used for this distribution system. Advanced CATV computer controlled systems are interfaced to the PSTN and the interactive data capacity of the network is available for such services as teleconferencing, data communications, electronic mail, etc.

c. MMDS - The cost-effective alternative to cable delivery is the multichannel microwave distribution service. This radiolink system allows coverage up to 30 Km and uses the 2.5 Ghz band to transmit signals from local sources to users, provided that a line-of-sight path exists. Advanced MMDS computer controlled systems are interfaced to the PSTN and the interactive data capacity of the network is available for such services as teleconferencing, data communications, etc..

d. WLAN - The wireless local area network is a low-cost and high-speed information telecommunication system that is being used in a variety of computer network applications. WLAN is a flexible and easily installed radiolink solution for internetworking in geographical regions where cabling doesn't exist or would be prohibitively expensive to install. High capacity (2 Mbps full duplex and higher) fully interactive networks allow coverage up to 30 Km and uses the 2.4 Ghz radiofrequency band.

e. Satellite - In spite of the high costs involved, the flexibility and advantages provided by satellites constitute a valuable alternative when big areas with large scale problems are involved. Satellite communications interconnect remotely located regions with service routes where no cables exists. Every part of the globe is covered, no terrain is inaccessible. The network topology is flexible (point-to-point and point-to-multipoint) and suitable for emerging applications like distance learning, multimedia, telemedicine, wireless local loop. The high quality and reliability of the service is unmatched. The rapid deployment and the ease of expansion are service advantages.

C. Operation of a Distance Learning System (DLS)

The operation of an advanced Distance Learning System, devoted to non formal education, includes the following primary functions, that have to be considered together with the particular requirements relevant to the life conditions and the culture of the country eligible for the implementation.

a. Design and production of educational core programs;
b. Transmission of educational materials to the audience;
c. Stimulation and collection of the feedback from the participants;
d. Interactions between participants and instructors;
e. Stimulation and development of non formal activities;
f. Design and production of new educational and information materials;
g. Interactions with external information resources.

The core educational programs are designed, produced and delivered to the remote audience following a predefined schedule, according to the participant needs. The content production staff assembles existing and new educational materials in print and audio-visual media in order to create a framework of basic information. The production process (design, editing, etc...) requires studios and suitable video equipments. The delivery process of audiovisual information requires the transmission from the studios to the audience located in the remote sites.

Therefore, any Distance Learning System may utilize different transmission media, depending on the local availability of telecommunication infrastructures. As seen in the previous section the choice of transmission system ranges from the conventional TV broadcasting to the high-speed Intranet (Internet-like computer network) running on a telematic highway. The quality of the feedback, collected from the distant participants, plays a crucial role in the Telecommunication-Information System design and drives the choice of the equipments needed at each of the remote sites.

The truest benefits of an advanced and very flexible Distance Learning System, devoted to non formal education, is realized through the interaction process between the participants. School aged children, young people, adults, operators, instructors, educators may be involved in cooperative work for the development of non formal activities, demand driven by the audience and, therefore, suggested by the educators experience. The collaborative work may be extended to students outside the project sites and may involve information sharing or other kind of interactions with the general public, with decision makers or with the international community.

The interactions between participants and the work methodology are the critical elements for enhancing the initial framework of the core curricula. Actually, the production staff may act as an information resource to answer questions coming from the remote sites and to stimulate direct access of participants to the production of new documentary and information materials. This aspect is one of the key features of the system applied to non formal education programs.

The electronic storage of the educational and documentary materials developed during the system operation is an other important aspect. It provides the capability of sharing with all the participants any kind of multimedia information (video, audio, images, text), even for worldwide dissemination by means of the internet.

Similarly, information gathering and documentary research internationally via the internet or on-line data banks are allowed; the data collected after these accesses can be easily stored and shared with participants.

The use of advanced telecommunication and information systems for educational purposes is not so new. Many examples of system implementation exist in developed countries (e.g. student projects, curriculum development support, home instruction, access library services, special programs) that share design solutions typical in other applications fields: business and professional (e.g. databases, medical, home financial services, distribution of information for retail and service business, general office use, telecommuting), civic (e.g. informal communication with town leaders, conferences for information and discussion, distribution of civic information), and quality of life (e.g. social, cultural, recreational and entertainment uses).

Also in developing countries there are several examples of Distance Education Systems implemented in the past years, as shown in "Telecommunications Policy Recommendations on Distance Education and Health Care", Feb.'93, IDB.

The operation of a Distance Learning System, particularly in the case of non formal education, cannot be simply transposed from other examples of application, but should be carefully designed according to the particular requirements that have been identified.

The design of the telecommunication and information components of the System should also consider very carefully the exploitation of the emerging technologies in order to make the project sustainable.

D. Requirements

The Non Formal Environmental Education Program has to provide interactive training and audio-visual information relevant to different environmental problems. Such non-formal education sessions will have an estimated total duration of about six hours per week with a high degree of feedback from the audience and of interaction between all the participants.

The participants identified during the survey activities performed in Guyana are the following :

a. Audience (school aged children, young people, adults)
b. Staff (community facilitators-operators, instructors, educators)
c. external audience (general public, teachers, decision makers, researchers, international community)

The activities to be developed in these non formal environmental education sessions will require treatment, recording and interactive exchange of many audiovisual information having different characteristics and complexities:

a. audio information (news, talks, music, telephone calls)
b. video-graphical information (still images, movies, drawings, maps, WWW pages)
c. text and database information (fax, email, data collections, chatlines, bbs)

There is also the need for a methodical gathering and dissemination of the audiovisual information on a regional and geographical base.

Finally, the DLTS should be integrated with other telecommunication networks and information resources already available or planned in Guyana (Public Switching Telephone Network, Internet, educational and public utility networks) and has to be designed for actual sustainability, taking into account the conditions of Guyana, one of the poorest developing countries of South America.

The site selection activity performed envisages four regional areas of Guyana, where audiovisual and telecommunication equipments should be installed to set up the Distance Learning Education System :

a. Upper Mazaruni region (Kamarang), Lat. N. 5 ° 52' and Long. W. 60 ° 37'.
b. Moruka region (Santa Rosa);Lat. N. 7 ° 39' and Long. W. 58 ° 57'.
c. Rupununi region (Annai), Lat. N. 3 ° 57' and Long. W. 59 ° 09';
d. Urban area (Georgetown), Lat. N. 6 ° 49' and Long. W. 58 ° 10;

These four regional areas have been investigated in detail and four design sub-options have been envisaged for the coverage of multiple sites (up to seven) per region:

Design Sub-options				
Region :	(1)	(2)	(3)	(4)
Rupununi	1 site	3 sites	4 sites	7 sites
Moruka	1 site	3 sites	4 sites	5 sites
Upper Mazaruni	1 site	3 sites	5 sites	5 sites
Georgetown	1 site	3 sites	5 sites	6 sites
TOTAL SITES	**4**	**12**	**18**	**23**

Each of the sites for the DLTS has to be equiped with basic audiovisual and telecommunication equipments. The front line workers of the project are the community facilitators, of whom two are stationed at each site. These persons have to be recruited from within the village which hosts the site. The community facilitators have to be trained in the operation and maintenance of all the equipment of the project, but their most important function is to allow the people of the village to contribute to the work of the project and to benefit from it. These persons therefore serve the exchange of local knowledge between their own environments and all the others in the project and beyond. They will be trained in skills on information handling using the most modern computer and multi-media tools, but their role is to facilitate social use of the technical solutions and to promote the non formal and collaborative activities in the project. They will share the use of a multimedia computer and a set of audio-visual equipment.

More sophisticated studios for audiovisual production are even required in each regional center site, where they can be established in the relevant administrative centre. In addition to the community facilitators, there will be stationed one additional local worker, whose function is more concentrated on audio-visual production. Designated videographers, these operators will have a deeper training on the computer and video technology, so as to support their LAN sites (up to seven in each area depending on funding availability) in preparing presentations on local environmental situations. A centre site is equipped with an additional computer for use by the videographer, and additional pieces of audio-visual equipment to be deployed in turn among the remote sites.

The following table describes the site locations of the four design sub-options envisaged.

SITE LOCATION / n. TOTAL	Subop 1 4 sites	SubOp 2 12 sites	Subop 3 18 sites	Subop 4 23 sites
RUPUNUNI				
Annai	#	#	#	#
Surama		*	*	*
Wowetta				*
Aranaputa			*	*
Massara		*	*	*
Yakarinta				*
Kwataman				*
MORUKA				
Santa Rosa			*	*
Kumaka	#	#	#	#
Akwero				*
Kwebanna		*	*	*
Waramuri		*	*	*
MAZARUNI				
Kamarang	#	#	#	#
Waramadon			*	*
Paruima		*	*	*
Jawalla		*	*	*
Kako			*	*
GEORGETOWN				
IDCE, QC Compound		*	*	*
UG Campus		*	*	*
NCERD	#	#	#	#
St. Stanislaus College			*	*
St. Margaret Primary Sch.			*	*
ZOO Nature School				*

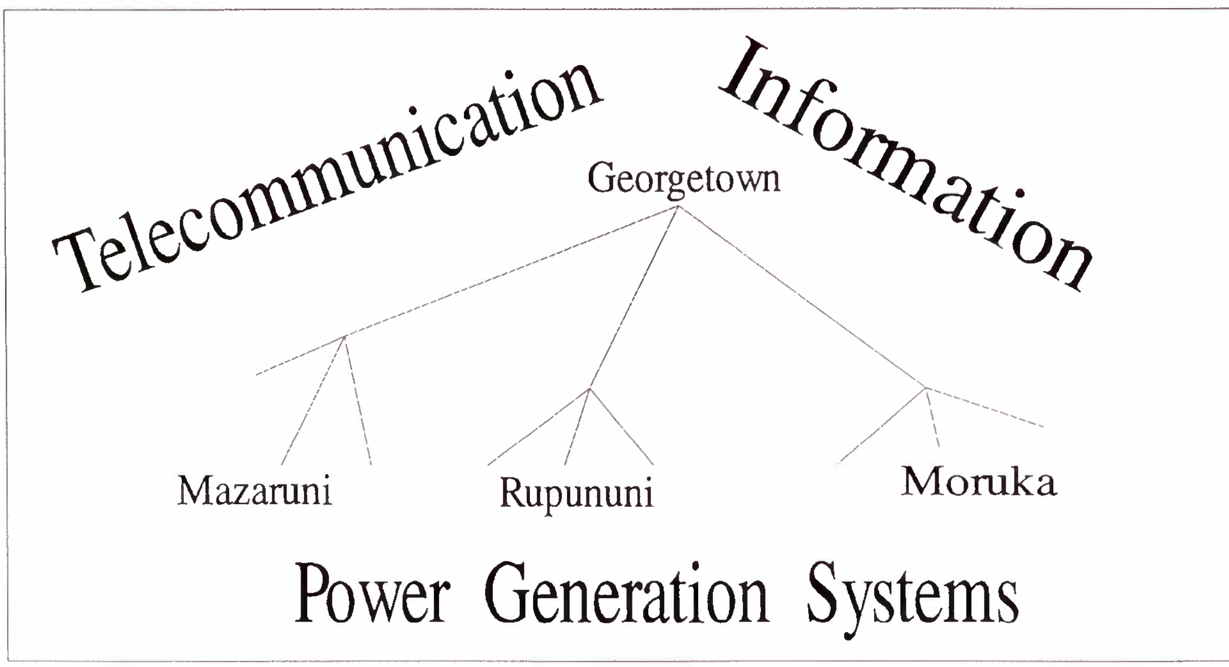
- Standard site, equipped with basic audiovisual and telecommunication facilities.

Centre site, equipped with enhanced audio-visual production facilities.

E. DLTS components

The Distance Learning Telecommunication System has to be viewed as a Wide Area Network (WAN) for distance education in Guyana. This community private network includes the following functional components :

a. Telecommunication systems for audiovisual and data information transmission;
b. Information systems for Distance Learning and for interactive sessions extended, on demand, to external networks or information resources;
c. Power generation systems.



F. Telecommunication system design

The total lack of telecommunication, transportation and electric power infrastructure in the remote regions of Guyana, the large distances involved between the selected regions, the high costs related to any new installation of terrestrial radiolink for long distance communication, have suggested to consider only the VSAT satellite technology options for the telecommunication system design.

In a previous study (see: Telecommunications Policy Recommendations on Distance Education and Health Care, Feb.93, IDB) the cost comparison of telecommunication technologies, (VSAT, radio, microwave and cable) has been conducted. The analysis indicates that the use of VSAT is always the most cost effective solution to providing new connection to geographically dispersed locations, especially when a large number of dispersed sites (more than 20) are involved.

1. Satellite Network Design Options

In big areas where there are no alternative ways (cables or terrestrial radiolinks), satellite technology provides the best available infrastructure to create the proper "highways" for delivering and conveying information : video, audio and data or texts.

Compared with all conventional, terrestrial technologies, the satellite option has the advantage that a network can be deployed in a very short time for providing long-distance two-way communication links between remotely located VSAT (very small terminal aperture) ground stations.

In spite of the high equipments cost involved, the flexibility and advantages provided by VSAT systems make satellite technology the most cost effective for the implementation in Guyana of a Wide Area Network (WAN). The cost per node decreases significantly when an extension to more than 20 distant sites is planned.

To provide the capability to utilize distance education at a minimum cost, the adoption of the modern technologies for digital compression of audiovisual information is the practical way for minimizing the satellite channel capacity needed for transmission of videos over a telecommunication channel to its remote destinations.

Indeed, the cost of the satellite channel lease is independent on the number of sites, but is proportional to the capacity required or, in other words, to the digital bit rate (or to the bandwidth) leased on the satellite considered.

In the equatorial and tropical regions the satellite up-link and down-link are usually allocated in the C-band of microwave frequencies (4-6 Ghz), because the small effect of heavy rains and atmospheric humidity on the radio-propagation at these low frequencies.

The alternative choice of K-band (11-14 Ghz) for the satellite links would provide advantages in terms of antenna size, considering clear-sky operation of the system, but the quality of the link would be severely limited by heavy rain events.

On the other hand, besides the technical aspect relevant to the radio-propagation advantage, also the availability of many C-band transponders from Intelsat and Panamsat organizations has been one of the key elements considered in the decision of operating the satellite channels in this microwave band.

For management purposes a master ground station (HUB) is always defined in the VSAT network and two different satellite link architectures, STAR and MESH can be envisaged.

a. *STAR network* providing direct and low cost HUB-to-VSAT connectivity with a single telecommunication "hop" by means the satellite transponder. Large capacity (wide band and high data rate) connections are viable with quite reasonable investment costs. The large sized HUB antenna dish diameter is several times that of VSATs. The HUB ground station includes a Network Management System (NMS) that centralizes and controls the operation of the telecommunication network. The VSAT-to-VSAT connectivity is available too, but always passing through the HUB: "double hop" connections (VSAT1-to-HUB and HUB-to-VSAT2) are therefore needed in this type of link.

b. *MESH network* providing direct VSAT-to-VSAT connectivity (all "single hop" links). This type of network do not require a large HUB: the mini-HUB dish has usually the same dimension of a VSAT and it provides the NMS function. Due to the current limitations of the power available on the satellite and of the VSAT antenna size, limited capacity (narrow band and low data rate connections) are usually provided with this type of architecture.

In principle, a full meshed network would be very attractive and preferable, but is viable at reasonable costs only for narrow band channels (voice or slow data-rates) considering the power performances of the latest satellites in service.

Satellite telecommunication networks

Features	**STAR**	**MESH**
channels capacity (bandwidth or bit rate)	large	limited
connectivity type (with "single hop" link)	HUB-to-VSAT	VSAT-to-VSAT
HUB antenna size	larger than VSAT'	same as the VSAT'

The VSAT link budget calculations provided in Annex 1 demonstrate how the STAR network configuration is the most viable and cost effective, as far as the large capacity satellite link required for audiovisual interactive transmission is considered, while the MESH network can support all the narrow band communication channels (control and network management data, voice). Therefore, STAR and MESH architectures may coexist. In detail, let's note how the quality of the audiovisual data requires a very low occurrence of errors in the digital communication process with a typical bit error rate of 10e-7, while a much less severe figure of 10e-4 is accepted with the narrow band operation for voice channels or slow data rates.

The unmatched quality and reliability of the satellite service are key elements of long distance and large capacity communications; therefore, VSAT technology is particularly well suited for circumventing practical implementation problems in Guyana, due to the lack of reliable infrastructures and of human resource skills. In other words, the VSAT network is the best candidate option for the immediate deployment of a Wide Area Network (WAN), that is the audiovisual information highway required in an advanced Distance Education System with a high degree of interactivity.

Finally, the VSAT network topology is very suitable for extensions and inter-networking with wireless local loops, the emerging technology of Wireless LAN (WLAN). Therefore, due to the high cost of VSAT equipments, local connectivity should be provided by means of the low cost WLAN technology whenever is possible and, particularly for :

a. Multiple site networking in the metropolitan area of Georgetown;
b. Multiple site networking in hinterland local areas.

The indoor unit of a modern VSAT is modular and provides any type of low-frequency or "baseband" processing of digital signals, according to the most common communication and networking standards. It may be interfaced directly with any type of local area network and equipments, according to the most popular standards (Token ring, RS232, Ethernet, telephone, fax, etc..)

The VSAT indoor unit usually provides connections to:

a. Low-speed serial lines via asyncronous RS232 port;
b. Voice channel for telephone and fax communication;
c. LAN connected by ethernet or token ring interfaces.

2. Complementary systems for extended connectivity

The countrywide audiovisual connectivity between remote regions requires a satellite link in order to provide enough channel capacity over the whole geographical network. Therefore, additional extensions of the satellite network could be considered for improving terrestrial connectivity at regional and local level. These extensions lead to the design of a multilevel telecommunication network, where the top level (WAN) is provided by the satellite STAR network for long distance communications, while the bottom level provides local terrestrial connectivity by means of wireless local area networks (WLAN). Each wireless local loop is connected to a VSAT stations by means of proper equipments that bridges the LAN to the geographically extended WAN.

VSAT ground stations are designed for digital data exchange according to the X.25 or Frame Relay packet switching standards and are provided with the most popular physical interfaces for LAN (Ethernet\IEEE802.3 interface). The WLAN equipments available on the market meet compatible requirements (IEEE802.11) and are designed for operation with TCP/IP networks.

An intermediate telecommunication level could eventually exist when the connections between two or more areas, belonging to the same region, is provided by terrestrial radiolink trunks in alternative to the installation of additional VSAT stations, every time the latter is more expensive.

For the sake of trade-offs and feasibility evaluation, a simple two-levels network, the VSAT/WLAN design option, will be presented as baseline candidate in comparison with the pure VSAT network design option already introduced in the previous section. Both provides connectivity of the same sites, envisaged in the four design sub-options.

The cost per node relevant to the WAN/WLAN telecommunication network is much lower than the pure VSAT one as shown in the following figure, but the intrinsic limitations associated with the WLAN are: line-of-sight propagation, range of less than 30 Km.

Therefore, these WLANs are autonomous from the satellite telecommunication system and can be independently operated to provide connectivity at local level, without engaging the satellite channel or even in case the satellite connection were not available for any reason.

A pure-VSAT network requires one satellite station per site, even in case many sites are very close each other. The main disadvantages of this design approach are the high cost per node and the high power consumption per site. The channel capacity of the WLAN is 2 Mbps, with the current state-of-the-art; new products with enhanced data rates, up to 10 Mbps, are expected in this year. Advantage of the VSAT/WLAN over the pure-VSAT design option is that any local area network is operated independently from the satellite channel at 2 Mbps (or even more). Advantage of the pure-VSAT system is that the network deployment is straight forward, without special constraints of installation to be considered (obstacles like: hills, trees, mountains, buildings).

Telecommunication network design options

Features	VSAT \ WLAN	pure VSAT
terrestrial links (WLAN) at local level	yes	no
operation at local level	autonomous as LAN	depends on HUB-NMS
channel capacity at local level	2 Mbps or higher	limited by VSAT channel
power consumption per site	lowest	highest
initial cost per site (18 sites)	lowest (70,400 US$)	highest (144,000 US$)
local level connectivity limitations	line-of-sight range < 30 Km	no terrain is inaccessible no limitations

The Figure below shows the principle of operation of the VSAT\WLAN network : the VSAT network layer provides the long distance (countrywide WAN) interconnection of remote regions or sites, while each WLAN terrestrial network provides the connectivity at local level, for instance between several villages (or between several buildings in urban area) in a maximum range of about 30 Km.

The terrestrial wireless links are large capacity connections (namely 2 Mbps) and allow reliable audiovisual networking of several villages within the same rural region, provided that a clear line-of-sight path exists. Up to eight adjacent villages could be interconnected in such a WLAN and, through the wireless access to the satellite VSAT station (properly located at the centre of the Local Area Network), they are connected countrywide to any other remote region and village which belongs to any other similar WLAN (see figure 2 here below).

In case the satellite link were unavailable, the WLAN can operate autonomously at local level without limitations. Therefore, a WLAN requires the installation of guy towers for the radio equipments in each of the site belonging to the area. The guys require inspection and some maintenance one time per year. The installation costs of these towers have been included in the previous figures.

The emerging technology of digital spread-spectrum communication made the success of the WLAN for wireless local loop applications. One of the most important factors of success is the low power consumption of these telecommunication equipments.

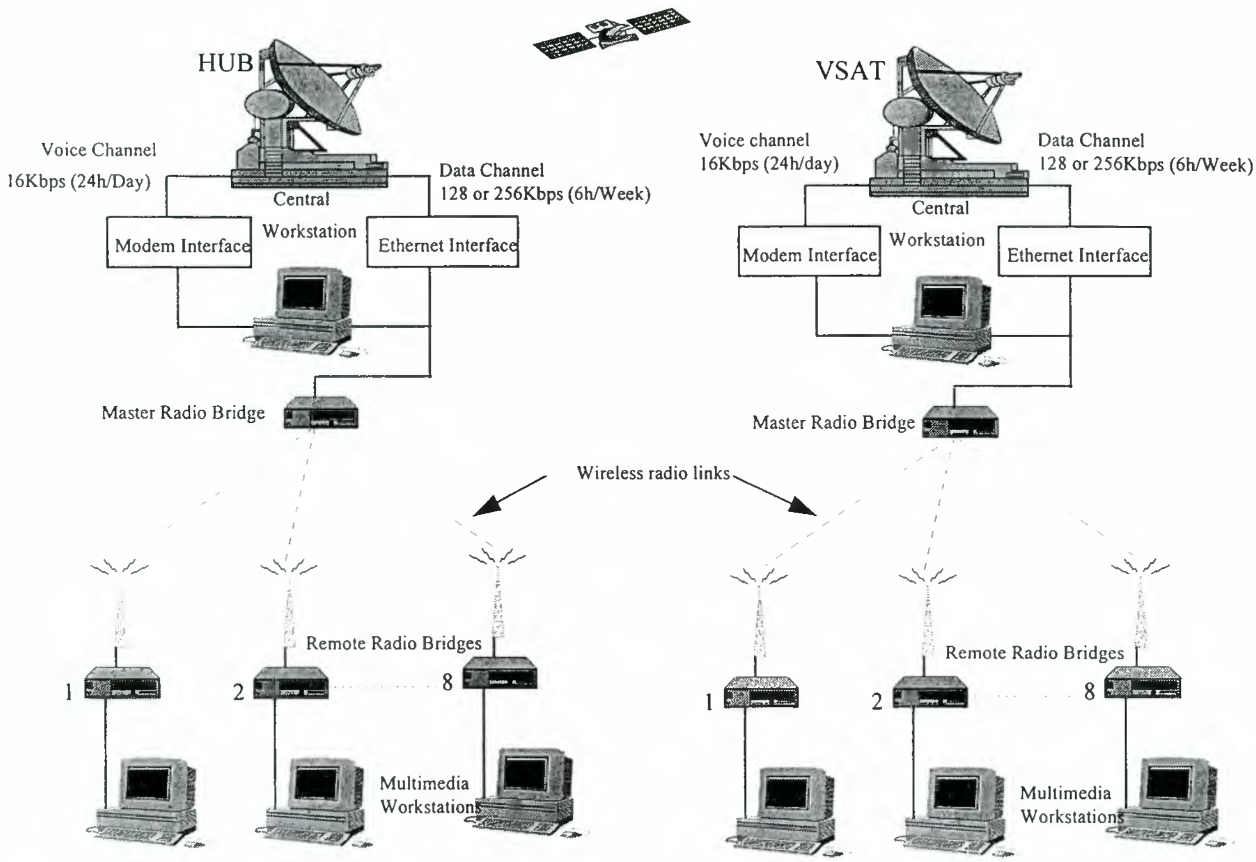


Figure 1 - Distance Learning Telecommunication System

G. Information system design

The Distance Learning System requires not only a telecommunication network, to provide the WAN connectivity between sites, but also an information system designed for data-gathering by all participating sites, for sharing by means of audiovisual interactive sessions between users. The system must allow for data to be gathered not only from local informants at each site but on demand from remote information resources (databases, BBSs) accessible through external public networks (PSTN, Internet.)

The telecommunication system therefore has to provide the technical means for information flows between participants which will optimise the sharing of data from diverse sources and in diverse formats, including audiovisual. Different technical solutions offer different possibilities for these information flows, at different costs; the choice which offers a cost-effective balance of features will define the optimal information system.

Two different concepts of information system architecture can be proposed:

a. Distributed architecture WAN/WLAN
b. Centralized architecture WAN

The former envisages a central information system at the headquarters in Georgetown, but also many autonomous information systems at regional-local level.

The characteristics of this architecture are summarized in the following table.

Distributed Architecture **WAN / LAN**	
Advantages	Disadvantages
Enhanced regional-local authonomy and connectivity (network service availability)	Higher complexity of management
Local expertise growth by training	Higher training costs
Lower initial cost	Higher operation costs

On the other hand, a full centralized architecture could also be proposed: this option envisages a stand alone central information system at the headquarters, where all the communication and information functions are concentrated. The interaction of the remote users with the educational information and data are controlled by the central organization. This centralized architecture has the following characteristics :

Centralized Architecture **WAN**	
Advantages	Disadvantages
Lower complexity	Lower flexibility at regional-local level
Simpler network management	No network services available at local level
Lower operation and training costs	Higher initial costs

Four Information System Design options have been analyzed and proposed in the frame of the feasibility study for design trade-offs purposes:

OPTION A : Intranet System with proprietary HUB satellite station
OPTION B : Intranet System with GT&T (Guyana's telecommunications company) shared-HUB satellite station
OPTION C : Teleconference System with proprietary HUB satellite station
OPTION D : Teleconference System with GT&T shared-HUB satellite station

The information systems relevant to the options A and B have the same distributed architecture. They differ only in the telecommunication systems, in that the former has a dedicated HUB satellite ground station located in Georgetown, while the latter shares the existing GT&T HUB in Thomas Lands - Georgetown.

Option A foresees higher initial costs for the HUB, with the exclusive availability and private ownership of this facility; on the other hand, the option B allows some saving in the implementation of the HUB station, but requires the lease of the facilities owned by GT&T.

The information systems of the options C and D have the same centralized architecture. The same distinction relevant to the HUB system applies also to options C and D.

IV. CONCLUDING REMARKS

The program described in this paper is currently being considered for joint funding by multi-lateral international agencies. It is expected that the program would become operative during 1998, after additional consultations with local communities and authorities.

Similar operations are being considered in other countries within the region served by the Inter-American Development Bank. There is a need felt at the Bank to establish mechanisms that would facilitate connections among projects that generate valuable information, such as the one described here, as well as to permit communication between those projects and the Bank. Additionally, there is also need to better utilize the products of the numerous geographic information systems being established and operated with financing from the Bank throughout the region.

Recently, the Bank undertook a study [3] aimed at defining specific needs in terms of environmental information generation and exchange, as well as at identifying appropriate means and mechanisms to improve such flows within the Bank and towards its member countries. A proposal to establish an environmental information system for the IDB was presented and is under consideration.

Among the fundamentals of the proposal are the introduction of a Bank-wide standardized procedure, allowing the user to follow the same guidelines for the identification and storage of data and information sources as well as for the retrieval and dissemination of environmental information. The system would rely on computer and communication technology (telematics) for the optimization of such procedures. Through the system, the Bank would substantially strengthen its knowledge-based environmental information system by improving the linkages among the main environmental information areas, and by establishing a common procedure for feeding and retrieving from the system.

Main objectives of the proposed system include increasing efficiency and lowering the costs of environmental information exchange, through fostering standardization in routine procedures, technical methods, and formats. A more harmonized network would offer opportunities for easier co-operation among IDB staff, facilitating trans-regional information exchange between departments. A sequential process of system's development is recommended, consisting of immediate, medium and longer term

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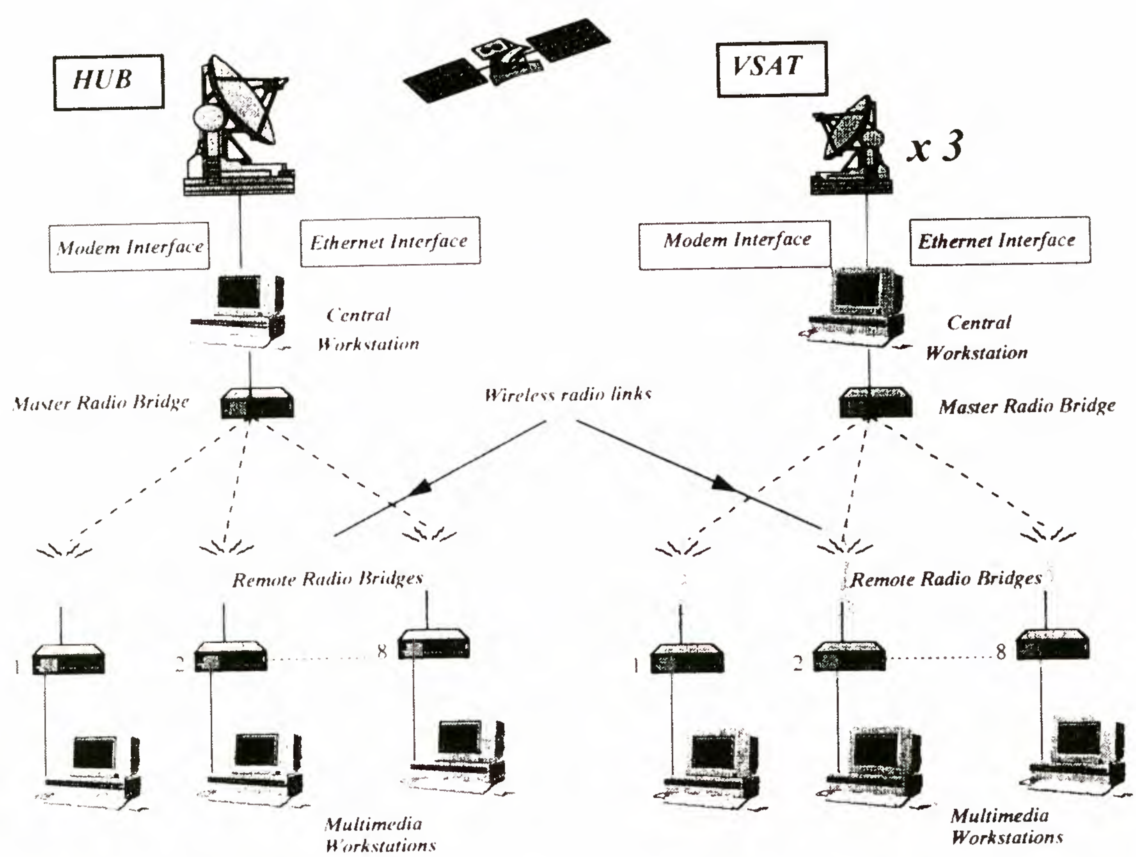
3/ Piaggesi, D. & Hooten, A. Environmental Information and Telecommunications Needs Assessment., September 1997.

actions. This process would begin with consolidating existing structures and functions, gradually moving in the direction of a long-term goal integrating and connecting system components.

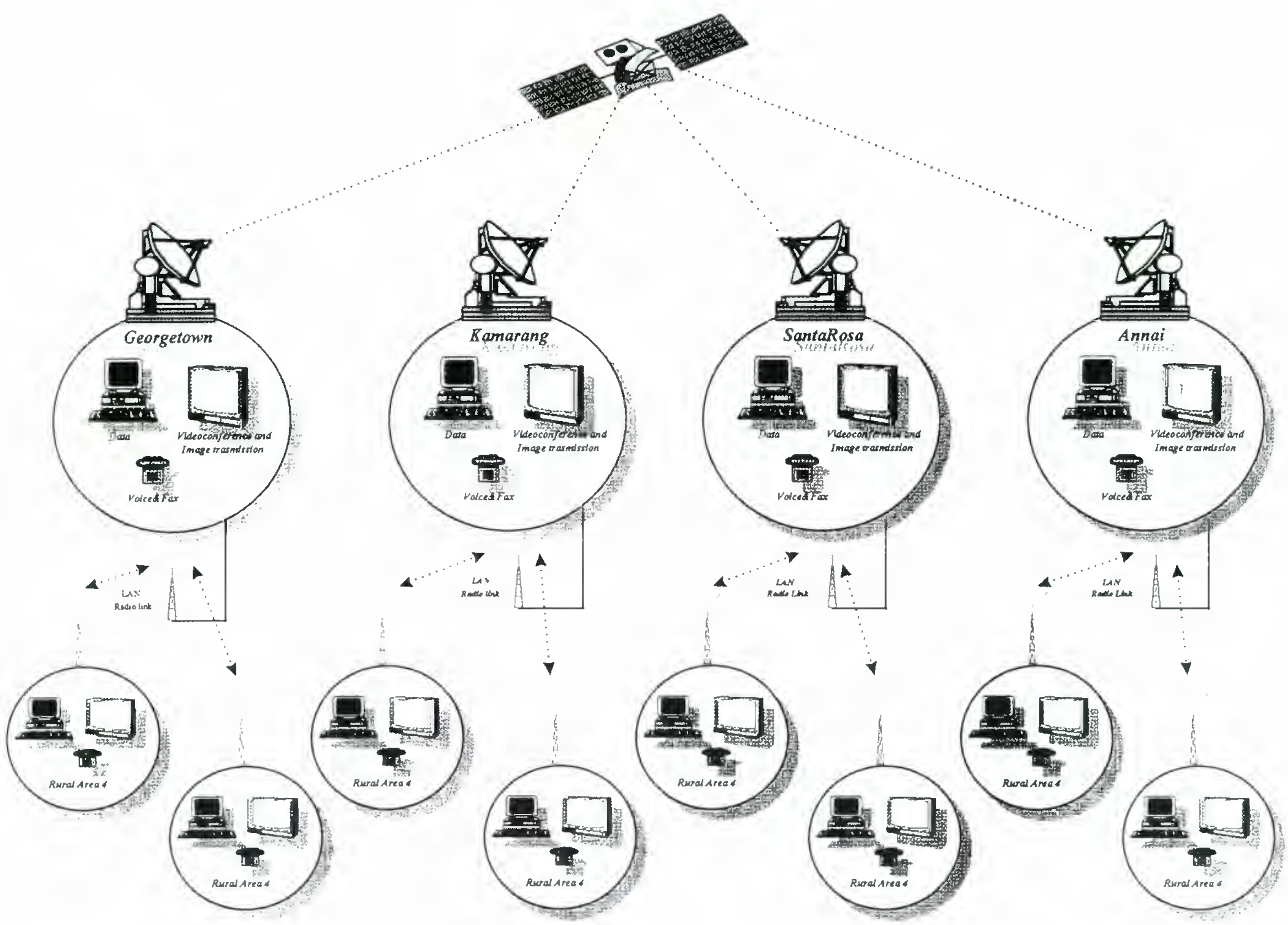
The long-term goal would consist of a telematics architecture, that will make use of IDB computers and telecommunications tools, but which would entail their aggregation into a network, linking together the different existing specialized sub-systems/components, and optimizing their performance for environmental information management purposes. Such architecture would be accompanied by customized solutions for environmental information management, which in turn would consist of standardized procedures for accessing and retrieving information from the main areas of the environmental information system.

While this proposal is being studied, a parallel analysis will be undertaken in order to assess potential linkages with country-based information systems, for the environmental field and other associated areas. A group of countries would be selected for the first implementation phase, where the required telecommunications and information systems would be installed and operated.

Projects containing significant information management components, such as the one described in this paper, would be suitable candidates to join the regional network, thus increasing benefits for all participants.

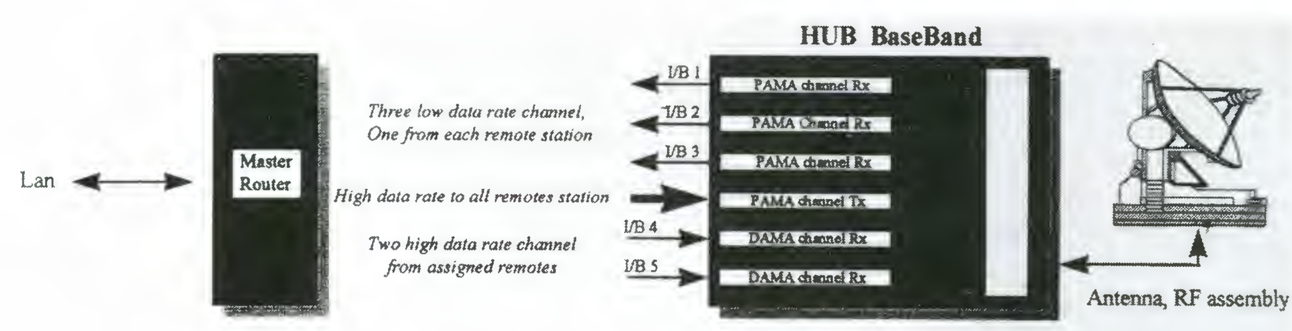


Distance Learning Telecommunication System

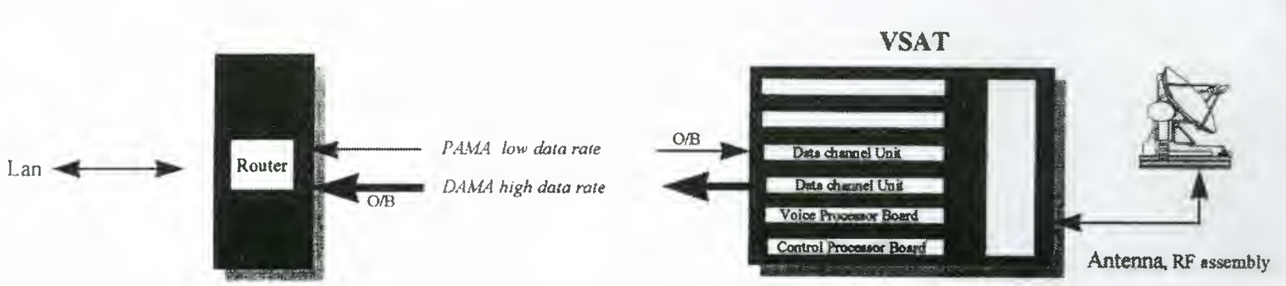


DLTS for remote sites interconection

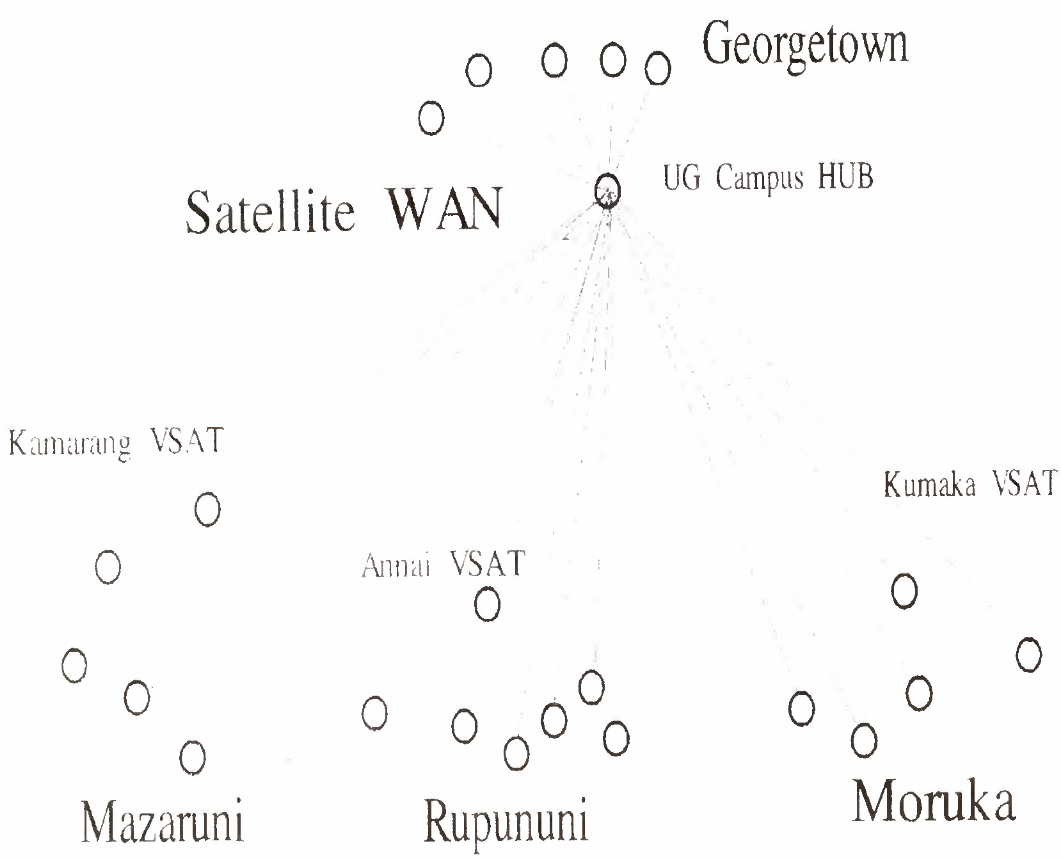
HUB and REMOTE Site Configuration

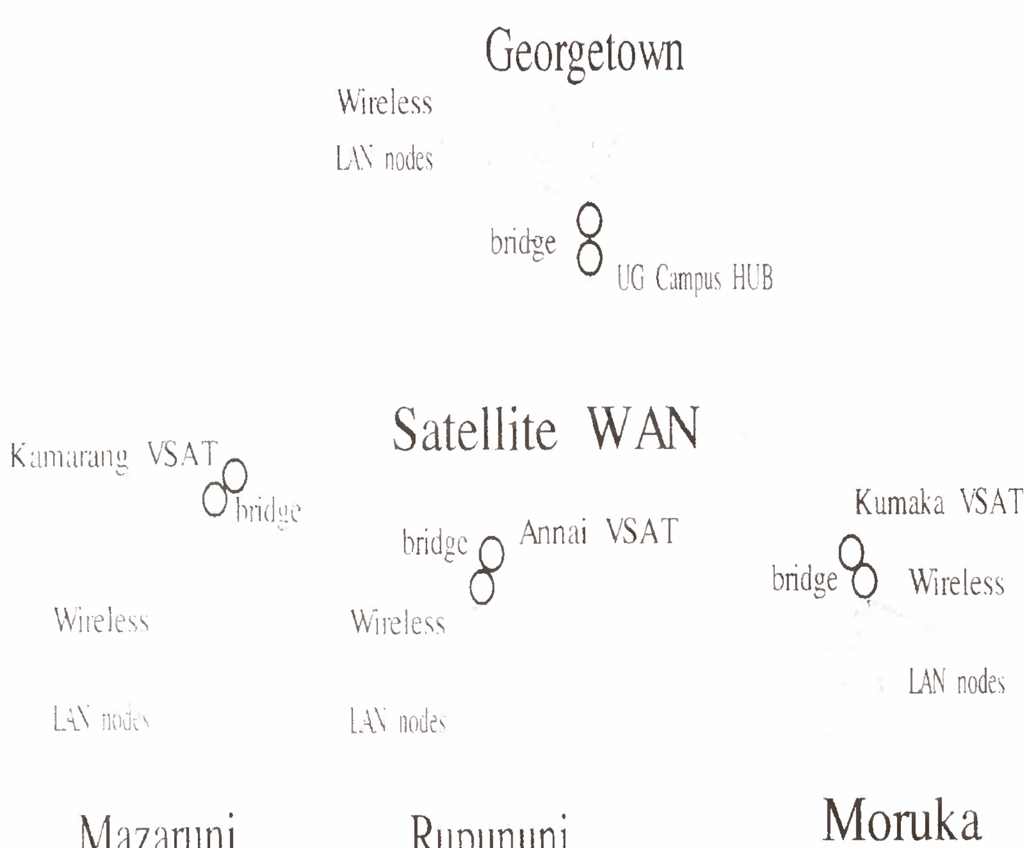


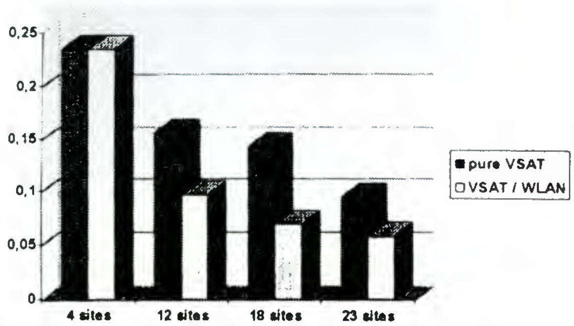
HUB site configuration

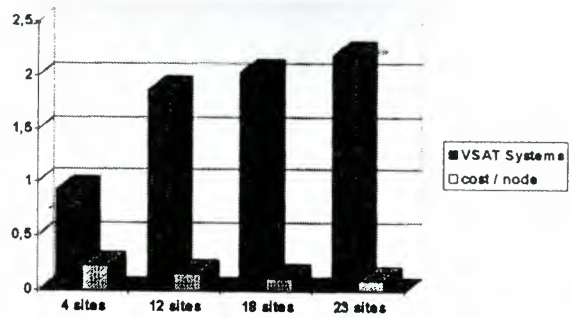


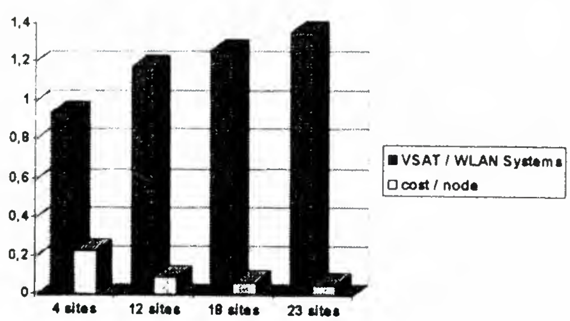
Typical remote site configuration


Georgetown
UG Campus HUB
Satellite WAN
Kamarang VSAT
Annai VSAT
Kumaka VSAT
Mazaruni
Rupununi
Moruka

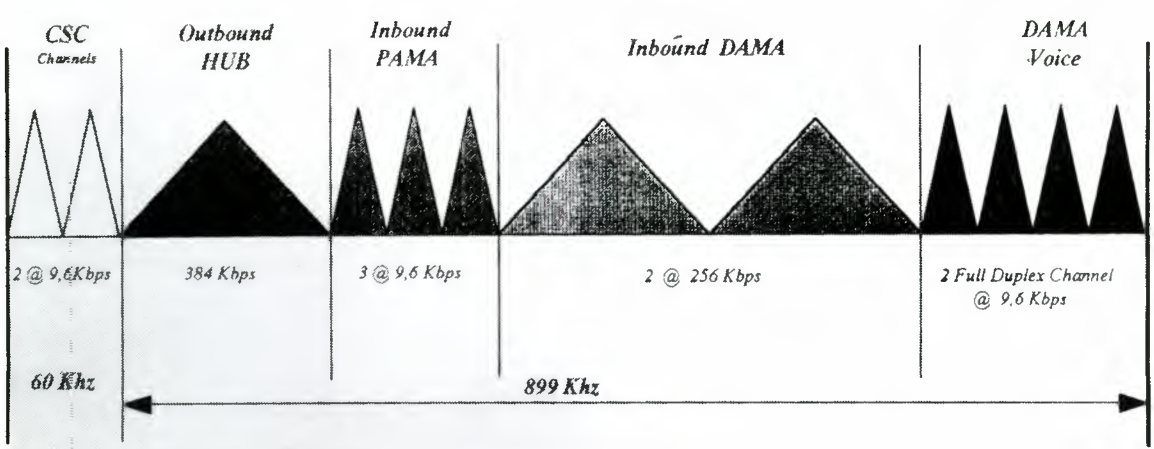

Georgetown
Wireless
LAN nodes
bridge
UG Campus HUB
Satellite WAN
Kamarang VSAT
bridge
bridge
Annai VSAT
Kumaka VSAT
bridge
Wireless
Wireless
Wireless
LAN nodes
LAN nodes
LAN nodes
Mazaruni
Rupununi
Moruka







Satellite Bandwitdth Requirement



Signal Type	*Qty (simplex)*	*RATE (Kbps)*	*Modulation*	*FEC*	*Carrier Spacing*	*Bandwidth per Carrier (Khz)*	*TOTAL Bandwidth*
CSC-I/B	1	9,6	Bpsk	0,50	1,56	30	30
CSC-O/B	1	9,6	Bpsk	0,50	1,56	30	30
Hub O/B	1	384	Qpsk	0,75	1,4	358	358
PAMA I/B	3	9,6	Qpsk	0,75	1,4	9	27
DAMA I/B	2	256	Qpsk	0,75	1,4	239	478
DAMA Voice	4	9,6	Qpsk	0,75	1,4	9	36
TOTAL							959

PRIMER SISTEMA SATELITAL DOMESTICO ARGENTINO-UNA SOLUCION ORIGINAL-

Miguel Sánchez-Peña

Asociación Argentina de Ciencias Espaciales
phone/fax: (54-1) 792-3418
Universidad Nac. de Lujan ,e-mail: miguel@unlu01.edu.ar

RESUMEN

Mencionamos los primeros proyectos de satélites domésticos y la formación de personal para encarar este tipo de emprendimientos (DOMSAT), por parte de la CNIE (Comisión Nacional Investigaciones Espaciales) desde 1979.Su presentación al gobierno Nacional 1981 posteriores revisiones y pedido de asignación de los puntos orbitales adecuados para Argentina.
El proceso de desregulación y apertura hacia la actividad privada. Llamado a una licitación pública internacional para instalación y operación del sistema satelital. Concepto de uso de un "Sistema Transitorio". Creación de empresa PARACOM-SAT, constitución original, tratativas con posibles oferentes. Negociación con TELESAT Canada y adquisición de satélites ANIK C-1 y C-2. Integración de capital en Paracom, socios y nuevo directorio. Adjudicacion licitación a la U.T.E. y contrato a Nahuelsat S.A. Reposicionamiento de los ANIK y rebautizo,sus características. Cobertura del pais y estación para control de tráfico. Usuarios del sistema y aplicaciones. Aspectos económicos. Sistema definitivo y nueva estacion T.T.y C. Transferencia del tráfico. Conclusiones.

1.INTRODUCCION y ANTECEDENTES

La idea de contar con un Sistema Satelital Doméstico de Comunicaciones se fué gestando en Argentina durante la década del 70 y principalmente dentro de la Comisión Nacional de Invetigaciones Espaciales (CNIE), como organismo rector de la actividad espacial. Dicha idea se sustentaba, también en algunas personas dentro de la Secretaría de Comunicaciones, aunque en algunas oportunidades no siempre entre sus autoridades. A efectos de contar con personal idoneo en la materia,la CNIE creó en 1979 un curso de postgrado en tecnología espacial en el Centro Espacial San Miguel, con profesores de Argentina, de U.S.A y de Francia. El objeto era el de capacitar a profesionales argentinos que pudieran participar con solvencia, por ejemplo, en la confección de pliegos de especificaciones para la licitación internacional que se debería convocar, para manejo de la estación de T.T.y C. y otras tareas en el segmento terrenal que se debería instalar. Así la CNIE contrató con la empresa Hughes un trabajo de consultoría, para la implementación de la arquitectura del sistema satelital que serviría de base para confeccionar el pliego de especificaciones. En dicho trabajo participaron además profesionales de la CNIE y de la Secretaría de Comunicaciones. Los requerimientos principales del sistema fueron: 1) Cada comunidad argentina deberá recibir por lo menos una transmisión local o regional de televisión con más de un canal, 2) Cada comunidad argentina deberá recibir una radiotransmisión local, otra regional y otra nacional. Otros requerimientoa fueron: 3) Proveer una red telefónica rural que incorpore estaciones del plan de la Secretaria de Comunicaciones y del Plan Soberania de ENTEL, 4) Proveer comunicaciones para la red de control del tráfico aéreo, 5) Proveer equipos transportables de telecomunicaciones para la explotación de recursos terrestres y socorros en catástrofes naturales, 6) Proveer comunicaciones para servicios educacionales y médicos, 7) Proveer las comunicaciones para un servicio telegráfico.
En el proyecto se previó un satélite Hughes HS-376 en banda C, sin perjuicio de prever otros en una licitación internacional con varios oferentes, en el caso de que el proyecto hubiera avanzado.Se estimó un punto orbital a los 65°. de longitud W y 3 opciones de cobertura.
El dia 31 de marzo de 1981, el Comando en Jefe de la Fuerza Aérea entregó oficialmente a la Secretaría de Planeamiento de la Presidencia de la Nación el proyecto "Sistema Satelital Doméstico para Argentina", el cual no se concretó. En la figura 1 se indica la cobertura.

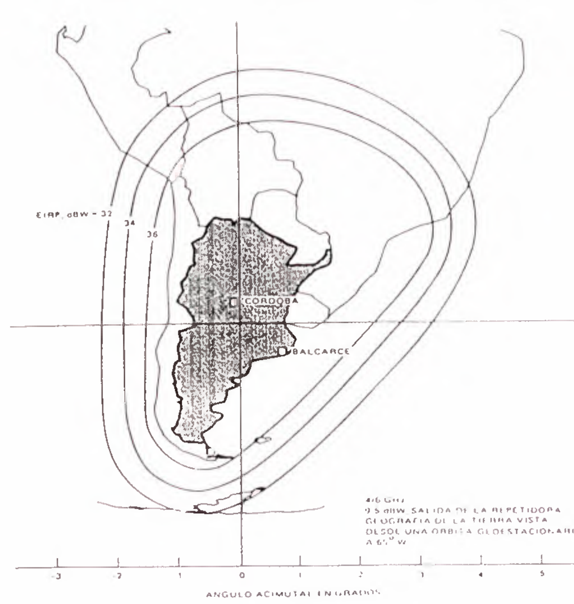


Figura 1

Cabe acotar que se realizaron presentaciones y estudios por otras empresas interesadas en participar en este proyecto, ejemplo: de Alemania Dornier, de Francia Aerospatiale y Satel Conseil entre otras.La CNIE realizó en Noviembre de 1983 las Jornadas sobre Satélites de Comunicaciones. Canada realizó jornadas sobre el tema interesada en reactivar el interés nacional en este asunto. Satel Conseil en Septiembre de 1986 preparó para el Banco Francés del Rio de la Plata un estudio sobre "el interés económico de un sistema de telecomunicaciones por satélite para la Argentina". Ya en esa fecha se habían hecho ante la UIT, las reservas de las posiciones orbitales para el pais en 72°. y 75°. de longitud Oeste, pero en general como proyecto del Estado. Se venía trabajando para impulsar la desregulación en telecomunicaciones, tema en el cual CADAS (Cámara Argentina de Actividades Satelitarias) junto a otras Cámaras impulsaron fuertemente esta idea.

Recien a partir de 1990 primaron las ideas de desregulación y privatización y que condujeron finalmente a producir un llamado a licitación internacional para la implementación y operación de un sistema satelital doméstico, emprendimiento totalmente privado y a riesgo empresario. El estado fijó las especificaciones del llamado a licitacion y esto sirvió para consolidar la reserva de los puntos orbitales gestionados ante la UIT.

2.PARACOM-SATELITES

Durante 1992 algunos profesionales constituyeron el llamado "Grupo Promotor", quienes impulsaron las tareas inherentes a la licitación que se había convocado. Asi en Junio de 1992 se establece por escritura la sociedad PARACOM S.A. constituida en su directorio por los señores: Curi, Urueña, Maranzano, Sánchez-Peña, Goldenberg y A. Garcia. El grupo promotor trabajó en varios objetivos: a) ante la C.N.T (Comisión Nacional de Telecomunicaciones) para consolidar la opción de utilizar un "sistema interino" b) obtener la participación en PARACOM de empresarios del pais para integrar el capital societario de la empresa.

c) Negociar con TELESAT- Canada la adquisición de los Satélite ANIK, únicos, prácticamente, que podian satisfacer requerimientos adecuados al pliego de la licitación y d) Negociar con posibles empresas interesadas en participar de la licitación, un acuerdo a fin de que ellas utilizaran el sistema interino formado por los satélites ANIK, en caso de ganar la misma.

Estos objetivos se fueron cumpliendo en general, luego de trabajosas tratativas. Asi por ejemplo en Noviembre de 1992 Paracom S.A firmó un acuerdo con Deutsche Aerospace AG (DASA) referente al uso del "Sistema Interino", ya en tratativas de adquisición por parte de Paracom. DASA a su vez actuó representando además a Aerospatiale de Francia y Alenia de Italia, las cuales en forma de U.T.E (Unión Transitoria de Empresas), se presentarían a la licitación internacional. El 19 de Noviembre de 1992 PARACOM S.A. firmó un acuerdo con Telesat Canada para la adquisición del 90% del valor de los dos satélites ANIK C-1 y C-2 y la estación de T.T.y C, que seguiría operando desde Canada. Mientras tanto se negociaba con empresas y bancos de Argentina para integrar el capital necesario a dicha adquisición. La licitación se abrió en Diciembre de 1992 resultando adjudicatario el consorcio encabezado por DASA y que luego se transformó en NAHUELSAT S.A

El 14 de Enero 1993 se constituye el nuevo directorio de Paracom S.A. en base a los nuevos integrantes de la misma, las empresa: diario S.A La Nación, Victorio Curi S.A, Loma Negra C.I.A.S.A, Extrader Capital Market, Ormas S.A.I.C.I.C, Tevycom Fapeco S.A., Rodafin S.A, y luego Unibanco. Telesat Canada participó con un 10%. Presidió el directorio el Dr. B . Mitre y lo integraban personas de las otras empresas.

En el primer semestre de 1993 se firmó con el Estado Nacional el contrato correspondiente y perfeccionaron lo acuerdos de PARACOM con el grupo ganador, constituido como Nahuelsat S.A. Asimismo se trabajó para reposicionar lo dos satélites en los puntos orbitales correpondientes a la Argentina. Se instaló el "up-link" en el telepuerto TIBA de Buenos Aires, para control del tráfico de comunicaciones a brindar a los diferentes clientes. Se efectuaron las mediciònes del PIRE (potencia irradiada isotrópica equivalente) en Mendoza y Buenos Aires y otras pruebas de aceptación. Una tarea muy importante fué la de ir concretando contratos de alquiler de facilidades satelitales con los futuros clientes

En mayo 1993 se realizaron transmisiones de ensayo y el 1°. de Junio de 1993 se realizó el acto inaugural y transmisiones experimentales; el 1°. de Julio/93 se subió la primera señal de un cliente utilizando este **primer** Sistema Satelital Doméstico de Argentina formado por estos dos satélites ANIK, rebautizados NAHUEL C-1 y C-2, constituyendo el llamado SISTEMA INTERINO.

El comando y control se siguió realizando desde Canada segun se había convenido en el contrato de compra. Cabe destacar que en seis meses se pudo disponer del sistema en forma operativa y con un costo entre 1/5 y 1/6 del valor de un sistema diseñado para el pais con la cobertura adecuada como el sistema definitivo Nahuel.

El satélite **NAHUEL C-1** poseía entonces combustible hasta Julio de 1997 , en órbita geostacionaria en el punto orbital de 71,8°. de longitud Oeste. Poseía 8 transpondedores en la polarizacion vertical (haz este) y 4 transpondedores en la polarización horizontal (haz oeste). El haz del Este cubre con gran potencia, 90% de Argentina aproximadamente, 80% de la población de Chile y 100% de la de Uruguay. El haz del Oeste cubre con buena potencia el Oeste de Argentina (Mendoza, San Juan, La Rioja, San Luis) y gran parte de Chile.

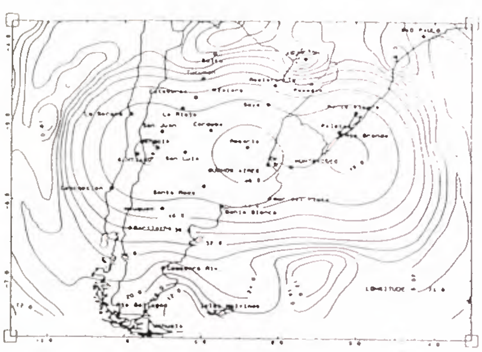
El satélite **NAUEL C-2** tenía entonces, combustible hasta Enero de 1998 en órbita inclinada en el punto orbital de 75,8°. de longitud Oeste. La inclinación a diciembre de 1996 era de 4,8 grados. El NAHUEL C-2 cubre con gran potencia todo el sur de Argentina y Chile Tiene 6 transpondedores en la polarización vertical para el sur deArgentina y Chile y 6 transpondedores en la polarización horizontal disponibles para el sur argentino

3.OPERACION y COBERTURAS

La cobertura de los satélites C-1 y C-2 no era la ideal para el territorio argentino y paises vecinos.Tengamos en cuenta que las antenas a bordo de los satélites habían sido diseñadas para Canada, país de gran extensión de Oeste a Este, mientras que Argentina tiene una gran extensión de Norte a Sur. De todos modos los satélites se posisionaron y se les dió la inclinación adecuada para que cubrieran un porcentaje del pais superior al 90%, ubicándose el C-2 para cubrir la parte Sur del pais.
En la figura 2 se indican los contornos del PIRE (EIRP) saturado en dBW para un transpondedor típico impar del haz Este y en la figura 3 se indican los contornos del PIRE de saturación del haz Este, spot global, para un transpondedor típico par.
Fig.2

NAHUEL-C1: HAZ DEL ESTE, Continúa

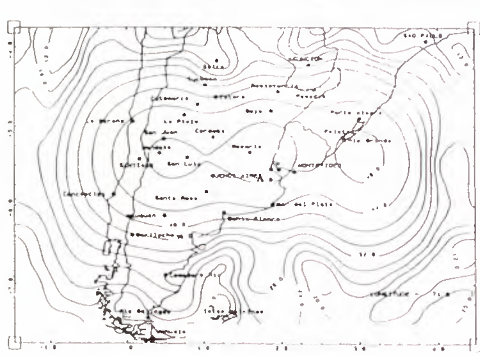
Contornos del PIRE Saturado



PIRE (dBW) de Saturación, HAZ ESTE, Spot Global, Transpondedor Típico Impar

NAHUEL-C1: HAZ DEL ESTE, Continúa

Contornos del PIRE Saturado



PIRE (dBW) de Saturación, HAZ ESTE, Spot Global, Transpondedor Típico Par

Figura 3

Vemos allí que la zona central del país y próxima a Buenos Aires era cubierta, en banda Ku, con una potencia de 48 dBW y la zona centro, centro-oeste y Uruguay con una potencia de 44 dBW, que son las zonas más pobladas de Argentina

En la figura 4 vemos algunos valores promedio del Pire en dBW y de la densidad de flujo de saturación (DFS) en dBW por metro cuadrado, para algunas ciudades de Argentina. Similares valores de PIRE y de DFS se indican en la figura 5 para algunas ciudades de Chile y de Uruguay.
Fig.4

NAHUEL-C1: HAZ DEL ESTE, Continúa

PIRE y DFS en Argentina

Algunos valores promedio del PIRE y de la DFS de saturación

Ciudad	PIRE (dBW)	DFS (dBW/m2)
BUENOS AIRES	48,0	-84,5
Mar del Plata	45,0	-79,5
Rosario	48,5	-84,0
Cordoba	46,5	-84,0
Mendoza	47,5	-86,5
Tucumán	34,3	-66,0
San Juan	47,0	-84,5
La Rioja	43,5	-81,5
Bariloche	33,0	-65,0
San Luis	46,3	-86,0
Posadas	34,0	-68,5

Nota: Los valores dados son NOMINALES, es decir, no incluyen posibles errores de apuntamiento de la antena terrena y/o del satélite

NAHUEL-C1: HAZ DEL ESTE, Continúa

PIRE y DFS en Chile y Uruguay

Algunos valores promedio del PIRE y de la DFS de saturación

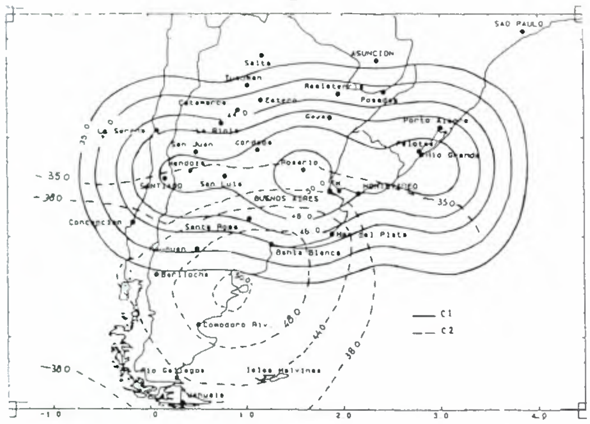
Ciudad	PIRE (dBW)	DFS (dBW/m2)
SANTIAGO	**48,0**	**-86,5**
Valdivia	35,0	-74,0
Temuco	41,0	-79,0
Concepción	43,0	-81,5
Linares	46,0	-84,0
San Fernando	47,0	-85,5
San Felipe	47,0	-85,5
La Serena	44,5	-84,5
Copiapó	36,0	-74,0
MONTEVIDEO	**47,0**	**-85,0**

Nota: Los valores dados son NOMINALES, es decir, no incluyen posibles errores de apuntamiento de la antena terrena y/o del satélite

Figura5

Habiamos indicado que el satélite NAHUEL C-2 cubría la parte Sur del país, de modo que entre ambos C-1 y el C-2, se logró una aceptable cobertura nacional y algo regional, sobre todo si se tiene en cuenta que el "Foot-Print" del diseño original de los satélites había sido para la configuración de otro país. En la figura 6 se indica la cobertura combinada de ambos satélites C-1 y C-2 con valores del PIRE de saturación, para la polarización vertical de un tranpondedor típico. Esto datos nos indican como pudo satisfacerse rápidamente un mercado ansioso de obtener facilidades satelitales, para ser utilizado por canales de televisión, empresas de TV por cable, para transmisión de datos, telefonía, uso ocasional, etc.

PIRE Combinado Nahuel C1 y Nahuel C2



PIRE (dBW) de Saturación, Polarización Vertical, Transpondedor Típico

figura 6

En la figura 7 se indican para algunas ciudades de Argentina, para Santiago de Chile y Montevideo de Uruguay, el diámetro (en metros) de las antenas receptoras de TV para señales analógicas asumiendo dos señales por cada transpondedor. Asimismo para TV digital asumiendo un sistema TDM saturando el transpondedor.

NAHUEL-C1: HAZ DEL ESTE, Continúa

Antenas Receptoras de TV

Ciudad	TV Analógica Diámetro (m)	TV Digital (TDM) Diámetro (m)
BUENOS AIRES	**1,8**	**0,6**
Mar del Plata	1,8	1,0
Rosario	1,8	0,6
Cordoba	1,8	0,6
Mendoza	1,8	0,6
Tucumán	5,0	2,4
San Juan	1,8	0,8
La Rioja	3,4	0,8
Bariloche	5,0	2,4
San Luis	1,8	0,6
Posadas	6,0	3,4
SANTIAGO	**1,8**	**0,6**
MONTEVIDEO	**1,8**	**0,6**

Nota: En TV Analógica se asumen dos señales de TV por transpondedor y en TV Digita se asume un sistema TDM saturando el transpondedor.

figura 7

4.APLICACIONES

La puesta en operaciones de este Sistema Satelital Doméstico, vino a llenar en forma rápida una demanda insatisfecha en comunicaciones de todo tipo. Desde la propuesta original al Gobierno por parte de la CNIE, en 1981, hasta la implementación de este sistema en 1993 habían pasado muchos años. Los varios intentos que hubo para implementar un sistema satelital propio para el país y que no prosperaron en su momento, se vieron concretados. Felizmente ahora se estaba en presencia de un segmento espacial, que si bien no era el ideal, pudo prestar servicio a numerosos usuarios en APLICACIONES, tales como: distribución de televisión, distribución de radio, redes telefónicas, transmisiones punto a punto (SCPC), "Broadcast" de datos, VSAT y USAT, Business TV y business radio, Educación a distancia, comunicaciones móviles y transportables,etc.

Las .empresas que utilizaron los servicios de estos satélites para diferentes servicios, entre otras, fueron:

<u>En transmisión de datos:</u>
IMPSAT, STARTEL, COMSAT, ARNET, bodegas Peñaflor, bodegas Santa Ana, bodegas Chandon, Baiwo, empresa 3M, Liquid Carbonic, Condarco electrodos.

<u>En Televisión:</u>
A.T.C. Argentina Televisora color, Argentinísima, Canal del Trabajo, Canal 9 de Rio Gallegos, Canal 7 de Rawson, Canal 8 de Mar del Plata, Canal Federal Satelital de La Rioja, Canales 4, 10 y 12 del Uruguay, Canal 7 de Neuquen, D.T.H. televisión directa al hogar, Canal 12 de Córdoba, T.V.A.-Big Channel. En T.V. para cable las empresas: Estrellas Producciones, Imágen Satelital y Telesistemas.

<u>En señales de Audio:</u>
Hilo Musical, Telefónica de Argentina y ANTEL de la República Oriental del Uruguay.

<u>Uso ocasional:</u>
Torneos y Competencias (T.y C.), TELEFE, América T.V., Canal 9 de Buenos Aires, Canal 26-Noticias, N.C.N. (Noticias Congreso Nacional), YINCA (Uruguay) T y C (Uruguay), KEY TECH (dueños del telepuerto Internaional. Buenos. Aires TIBA), SERSAT (Servicio Satelital).

TARIFAS:

NAHUEL-C1, HAZ del ESTE

TARIFAS MENSUALES EN MILES DE US$
SERVICIO NO INTERRUMPIBLE

MHz	1994	1995	1996
54	225,31	255,56	267,15
27	129,55	146,94	153,61
18	99,32	112,66	117,77
9	57,11	64,78	67,72
7	45,31	51,40	53,73
6	39,12	44,38	46,39
5	32,84	37,25	38,94
3	21,90	24,83	25,96
2	16,93	19,21	20,08
1	8,39	9,52	9,95
0,1	0,965	1,094	1,144
Uso Ocasional p/Hora		0,30	0,30

figura 8

Las tarifas ofrecidas por el alquiler mensual de un transpondedor de 54 MHz o fracciones del mismo, para el Haz Este del Nahuel C-1, se indican en la figura 8.

TELECOMMUNICATIONS MARKET EVOLUTIONS & SPACE TRANSPORTATION SUPPLY

Patrice LARCHER
Marketing Manager

ARIANESPACE - Boulevard de l'Europe
B.P. 177 - 91006 Evry Cedex - FRANCE
Tel. 33.1.60.87.62.33 - Fax. 33.1.60.87.62.70

For several years past, we have been witnessing numerous changes in the business world: mergers and other forms of the combination of interests, privatisation, internationalisation and in fact a globalisation phenomenon. This very substantial "movement", a term regarded by many as a euphemism for "upheaval" or even "revolution", applies to the space telecommunications market as much as any other.

Our present purpose is to review current activities in the space telecommunications domain as we see them at the dawn of the third millennium.

In the context of this new environment, in the creation of which we are all involved, satellite operators, platform manufacturers and space transportation operators alike, our aim is to show you that the European Ariane launch system is ready to meet the new needs which are emerging in the interest of our customers.

NOW LET US TAKE A LOOK AT THE SPACE TELECOMMUNICATIONS SECTOR

World communications involve the exchange of various forms of information which we can class, together with corresponding future user needs, in three types of activity:

- Voice transmission using fixed or mobile terminals. The end user need will be to talk to, or leave a message for any correspondent from any point on the globe, while choosing the operator at will, according to service quality and cost.
- Reception of TV and radio programmes. The viewer/listener will naturally be able to hook up to cable networks, or receive broadcasts direct via an individual or semi-community antenna. The viewer will not longer play a passive role, but will be able to compose the evening's programme from a catalogue. The viewer will thus be "interactive".
- Access to all data bases, to send and receive data to and from libraries anywhere in the world. The user will naturally be able to dialogue with the data base.

This information will be transmitted exclusively in digital form. Data will be compressed to reduce access time and the storage capacity required.

Whatever type of transmission channel is used, the telecommunications operator will have a strictly "megabit management" task. Whether involved in telephony, media, radio, TV or computer data transmission activities, the operator will inject data in megabit quantities into the virtual world of communications.

In our view, this means:

- The disappearance of clearly defined frontiers between these various activities, which we still tend to place in their separate telephony, TV and information processing compartments. This is by no means an "interactive multimedia" approach.
- Communication is not an end in itself, but merely a tool for distributing or broadcasting "information programmes". The communication tool operators consequently invest in the content of these programmes. A good example is to be found in the information processing sector with Microsoft and MacCaw, which are investing in a space telecommunications tool in the shape of the TELEDESIC project. Without going quite so far, TELEVISA, one of the world leaders in the media domain, and in fact the No. 1 Spanish language service provider, recently invested in the PANAMSAT satellite system, while continuing to use the SOLIDARIDAD Mexican national satellites.
- Space telecommunications will also make its contribution to universal communication capacity, in terms of "anywhere, at any time and with anyone".

SO WHAT IS THE POSITION OF THE SPACE SECTOR CONFRONTED WITH THIS MARKET DEMAND?

For purposes of simplification, we can consider three types of response according to application:

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

- Firstly, the space sector must meet the needs of the "**traditional market**". This market essentially corresponds to telecommunications satellites handling telephony traffic, TV programme distribution to the cable networks or DTH (direct-to-home) TV, and the transmission of information extracted from data bases.

  This initially governmental type market is in the process of privatisation. The operators are naturally structured to take positions in national markets, but also regional, and in some cases international markets.

  Satellites must be compatible with increasingly powerful and more intelligent payloads, and this in turn means increased satellite lift-off mass values. Likewise, the satellite antennas must cover even larger footprints, resulting in the design of even larger satellites.

  The typical unit mass of a telecommunications satellite has increased from 2 to 3.5 tonnes, and even more in some cases. Electric power has doubled to over 10 kW, and typical satellite lifetime is now 15 years.

  For the whole of 1995, only 17 commercial telecommunications satellites were successfully placed into orbit. By comparison, a minimum total of 30 satellite launches is scheduled for 1997, and demand for next year is also extremely strong.

  This "**traditional market**" is in good health, and the European Ariane launcher is ideally suited to meet market demand.

  A few figures readily prove this point. Did you know, for example, that out of a total of 164 commercial telecommunications satellites currently in operational service around the globe, no fewer than **96** were successfully placed into orbit by the Ariane launch system? This represents **58%** of available capacity in geostationary orbit.

  It is difficult to imagine in what condition the telecommunications world would find itself, if we could waive a magic wand and make these 96 satellites disappear – there would only be 68 left!

  This traditional market also includes a number of satellites for Earth observation, meteorological and scientific missions. However, applications in the telecommunications sector predominate, with nearly 80% of the total market.

- Secondly, we are witnessing the emergence of mobile telecommunications systems providing world-wide coverage. This corresponds to the "**constellation**" market. The initial constellation projects, such as Iridium and Globalstar, are being structured to provide services within the next ten months or so. These systems, each based on several dozen satellites with a unit mass of a few kilograms, will operate in low Earth orbit. Launch services for the first generation of these satellites will be provided by a number of different launchers. In view of the limited lifetime of the satellites (4.5 years), the new private operators are already looking towards a second generation. For reasons of profitability and efficiency, "satellite dispenser" designs will be optimised for incorporation in the new launchers such as Ariane 5.

  However, the low orbit sector will not have the prerogative for all constellation systems. A number of new projects favour intermediate orbits at altitudes of around 10,000 km, geostationary orbits or even a combination of the two. Other systems combine the advantages of low and geostationary orbits.

  While the number of satellites comprising these new "mixed" constellations is smaller, corresponding satellite unit mass values exceed 1 tonne, or go as high as 3 to 5 tonnes in some cases. On the other hand, satellite lifetime will double by comparison with that of the low-orbit-only constellations.

  At this stage of the study and design phase, it is still too early to assess the advantages and disadvantages of these various types of constellation, and so identify those projects which will still be operational in 2005.

  One thing is certain, all these activities will require large and medium-sized launchers.

- In addition, a third type of market will emerge by about the year 2000, to provide a response to globalisation needs for the "**multimedia**" and "information highway" concepts. Some operators currently favour geostationary orbits, using a limited number of very large satellites of over 5 tonnes, while others are looking at constellations of several hundred satellites with a unit mass of 1 tonne, operating in low orbits.

Faced with very high market demand, the satellite manufacturers are all trying to outpace their competitors with the ingenuity of their solutions, while investors feel confident in the promising future of space telecommunications. This is why Arianespace is already working on the "Ariane 5 Evolution" programme, in collaboration with all its European Industrial Partners, in order to provide an adequate response in terms of the performance, orbit injection flexibility, cost and services which it provides.

We are abundantly aware that the space transportation service activity makes a vital contribution to the satisfaction of this world market demand, and consequently to the harmonious development of national, regional and international economies.

Providing a space transportation service is a unique business activity, which demands a number of essential qualities: rigour, continuity, efficiency, availability and reliability. Our experience over the last 17 years has shown us that a launch system designer, manufacturer or operator is not an entity which can be pulled out of a hat. Real expertise in these fields can only be acquired by lengthy, intensive, hands-on experience.

With Arianespace, Europe possesses the industrial, financial, commercial and operational capacity to meet the market demands of the year 2000 and thereafter.

LOS PLANES TÉCNICOS FUNDAMENTALES DE TELECOMUNICACIONES EN MÉXICO

José Luis Peralta Higuera
Director de Planes Técnicos Fundamentales de Telecomunicaciones.

Comisión Federal de Telecomunicaciones
Bosques de Radiatas 44, 1er piso
Col. Bosques de las Lomas, México, D.F.
Teléfono: + 525 261 42 56, fax: +525 261 40 42.
Correo electrónico: jperalta@cft.gob.mx

RESUMEN

Debido a la apertura de las telecomunicaciones en México, se previó la necesidad de contar con planes técnicos rectores, los cuales asegurasen la interconexión e interoperabilidad de las redes de telecomunicaciones en el país, con el fin de permitir un amplio desarrollo y trato no discriminatorio de nuevos concesionarios y servicios de telecomunicaciones y fomentar una sana competencia entre los mismos, coadyuvando al cumplimiento de los objetivos establecidos en el Programa de Desarrollo del Sector Comunicaciones y Transportes 1995 - 2000.

Dichos planes tecnicos rectores son los planes técnicos fundamentales de numeración, señalización, conmutación, transmisión y sincronización, es decir, los planes técnicos fundamentales de telecomunicaciones (*Planes Fundamentales*).

En junio de 1996, debido al inicio de la competencia en telefonía de larga distancia previsto para enero de 1997, se publicaron en el Diario Oficial de la Federación, los planes técnicos fundamentales de numeración y señalización.

Actualmente, la Comisión Federal de Telecomunicaciones (*CFT*), entidad gubernamental responsable de la elaboración y administración de los *Planes Fundamentales*, está llevando a cabo reuniones de trabajo con representantes de la industria de las telecomunicaciones en México, con el objeto de elaborar los *Planes Fundamentales* de conmutación, transmisión y sincronización.

El presente texto tiene como fin el tratar de explicar el objetivo de cada uno de los *Planes Fundamentales* dentro un entorno de competencia, así como la relación existente entre ellos.

INTRODUCCIÓN

El lograr una mayor cobertura y penetración del servicio telefónico y elevar la calidad y diversidad de los servicios de telecomunicaciones, con el fin de aumentar la productividad de la economía, brindando precios más accesibles en beneficio de un mayor número de usuarios, es uno de los principales objetivos que establece el Programa de Desarrollo del Sector Comunicaciones y Transportes 1995 - 2000. Para cumplir con este objetivo, dicho programa propone, entre otras estrategias, el incentivar la evolución de la red telefónica, para convertirla en la columna vertebral de las carreteras de la información en México.

Los *Planes Fundamentales* ocupan un papel primordial en el cumplimiento de tal objetivo, ya que:

i) establecen la disponibilidad numérica suficiente para satisfacer la demanda presente y futura de los diferentes servicios de telecomunicaciones prestados a través de las redes telefónicas nacionales;

ii) aseguran la confiabilidad y disponibilidad de la red nacional de telefonía, conformada por las diferentes redes públicas concesionadas;

iii) definen los parámetros mínimos de calidad que deberán de cumplir las redes telefónicas interconectadas, y

iv) garantizan la eficiente interconexión e interoperabilidad entre las redes telefónicas en competencia.

Cada uno de los *Planes Fundamentales* tiene sus objetivos particulares. Sin embargo, existe entre ellos un factor común, el cual les da la flexibilidad y dinamismo que permite su actualización permanente ante los acelerados cambios tecnológicos, dentro del entorno del desarrollo nacional e internacional. Dicho factor es la

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

participación activa de la industria de telecomunicaciones, representada en los comités consultivos de los diferentes *Planes Fundamentales* (*Comités Consultivos*).

Los *Comités Consultivos* tienen como objetivo primordial, el coadyuvar en la realización de todas las actividades necesarias para lograr la eficiente administración de los *Planes Fundamentales*. Para ello, a través del análisis y evaluación de los requerimientos que el desarrollo nacional de las telecomunicaciones plantea, emiten las opiniones y recomendaciones pertinentes a la *CFT*, la cual, tomando en cuenta el interés nacional, determina la viabilidad de la incorporación de dichas recomendaciones a los *Planes Fundamentales*.

Con el fin de permitir la diversidad tecnológica, los *Planes Fundamentales*, a excepción del de numeración, definen parámetros a cumplirse en las fronteras de las redes, de tal forma que cada concesionario tenga plena libertad de diseño al interior de sus propias redes, de acuerdo a su tecnología y a sus planes de inversión y cobertura, debiendo cumplir en todo momento con lo establecido en sus respectivos títulos de concesión y con las Normas Oficiales Mexicanas vigentes.

CONTENIDO DE LOS PLANES FUNDAMENTALES Y SU INTERRELACIÓN

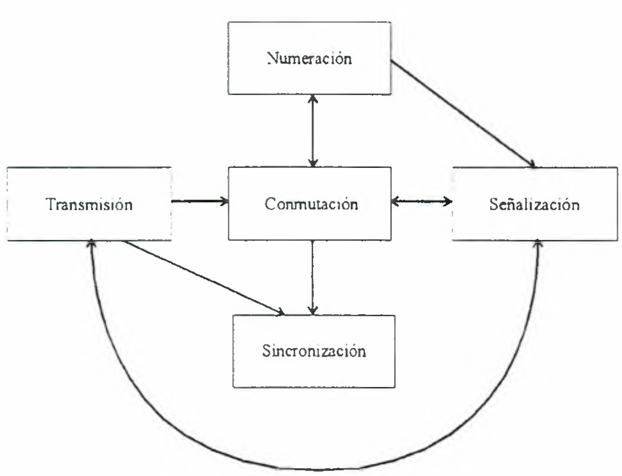


Figura 1.- Interrelación entre los *Planes Fundamentales*.

Como se puede apreciar en la Figura 1, existe una estrecha relación entre los diferentes *Planes Fundamentales*. Debido a que el plan fundamental de numeración es el único que debe de ser cumplido en su totalidad hacia el interior de las redes, es uno de los más importantes, pues de él depende que exista suficiencia numérica para poder identificar unívocamente a todas y cada una de las terminales de usuario conectadas a la red nacional de telefonía, permitiendo además un acceso ágil y uniforme en todo el país, para los diferentes servicios prestados a través de la misma.

A continuación, se presenta una breve descripción de cada uno de los *Planes Fundamentales*, explicando en cada caso la relación de cada uno con el resto de los planes.

Plan Técnico Fundamental de Numeración

El objetivo principal del Plan Técnico Fundamental de Numeración (*Plan de Numeración*), es el de establecer las bases para una adecuada administración y uso de la numeración nacional, con el fin de ofrecer una adecuada capacidad para identificar unívocamente todos los destinos y equipos terminales dentro del territorio nacional, al tiempo de cumplir con los objetivos en materia de ampliación de servicios y de competencia sana entre concesionarios, previendo las futuras necesidades de crecimiento, incluyendo aquellos servicios de telecomunicaciones diferentes al telefónico que requieran numeración.

El *Plan de Numeración* consta básicamente de 4 secciones principales: estructura de los números nacionales y códigos especiales; procedimientos y prefijos de marcación; evolución futura y, procedimientos de asignación de los números.

1) *Estructura de los números nacionales y códigos especiales.*

En esta sección se establece la longitud y formato de los números geográficos, compuestos por el número identificador de región (*NIR*) y el número local correspondiente. La longitud del número nacional será de 10 dígitos, con 8 y 7 dígitos en el número local, es decir, con formatos de 2+8 y 3+7 (Figura 2). El formato 2+8 se aplicará a redes locales de alta densidad, mientras que en el resto del país se aplicará el formato 3+7.

Número nacional (10 dígitos)	
Número identificador de región (*NIR*)	Número local
A B A B C	$cd_1efghij$ $d_2efghij$

$A \neq 0$, $c \neq 0$, $d_2 \neq 0$ y $B, C, d_1, e, f, g, h, i, j = 0, 1, \ldots, 9$

Figura 2.- Estructura del Número Geográfico Nacional.

Los números geográficos sólo pueden ser asignados a concesionarios de telefonía local.

Actualmente, la longitud del número nacional es de 8 dígitos, con 5, 6 y 7 dígitos en el número local, es decir con formatos de 1+7, 2+6 y 3+5, dependiendo de la densidad telefónica en los grupos de centrales de servicio local actuales. El *Plan de Numeración* plantea que los números irán extendiendo su longitud para cumplir con lo estipulado en el mismo, con base en consideraciones técnicas y de demanda.

Respecto a los números no geográficos, se conforman por una clave de servicio no geográfico de 3 dígitos más el número de usuario de 7 dígitos (Figura 3).

Clave de servicio no geográfico	Número del usuario
A0N	d e f g h i j

A ≠ 0 y N = 0, 1, ..., 9.

Figura 3.- Estructura de los Números No Geográficos

Las claves de servicios no geográficos son de la forma A0N, en donde A es diferente de cero (0) y N puede tomar cualquier valor. En la Figura 4, se muestran las claves de servicios no geográficos actualmente disponibles.

Clave de servicio no geográfico	Descripción
300	Servicios con cobro compartido entre el origen y el destino.
500	Números personales con transferencia de llamadas: el usuario que efectúa la llamada paga la tarifa de acceso local y la diferencia la paga el usuario que recibe la llamada.
700 (*)	Números de acceso a la red privada virtual de cada operador y a otros servicios de valor agregado.
800	Números no geográficos con cobro revertido.
888	Números no geográficos con cobro revertido.
900	Números no geográficos con sobrecuota por el servicio prestado.

(*) La administración de los números no geográficos correspondientes a este servicio la llevará a cabo, de manera independiente, cada operador.

Figura 4.- Claves de Servicios No Geográficos

Las combinaciones A0N no definidas en la Figura 4, están disponibles para asignarse a otros servicios no geográficos futuros.

El *Plan de Numeración* especifica que los números no geográficos sólo pueden ser asignados a los concesionarios de larga distancia, para prestar servicios de larga distancia y de valor agregado a nivel nacional, en sus diferentes modalidades.

Otra característica importante que se describe en el *Plan de Numeración* acerca de los números no geográficos, es su portabilidad. El usuario que tenga asignado un número no geográfico podrá cambiar de operador sin la necesidad de modificar su número, a partir de la fecha en que la *CFT* lo determine. Se han realizado diversas reuniones con los operadores de larga distancia, tendientes a definir la forma y tiempo en que podrá llevarse a cabo la portabilidad de estos números; estimaciones preliminares indican que podrá ser posible dentro de 2 años aproximadamente.

En cuanto a los códigos de servicios especiales, están conformados por 3 dígitos, y tienen el formato 0NX, en donde N no puede ser igual a cero (0) y uno (1) y X puede tomar cualquier valor.

Dado que estos códigos son una forma de marcación abreviada para servicios de emergencia, atención a la ciudadanía y atención a suscriptores, entre otros, es evidente la conveniencia de su corta longitud. Por otro lado, ya que son de aplicación nacional, el *Plan de Numeración* los agrupa en servicios genéricos, dentro de los cuales se definen los códigos de servicios especiales dependiendo del servicio específico a prestar (Figura 5).

Grupo de códigos	Tipo de servicios
02X	Servicios de larga distancia nacional vía operadora.
03X	Servicios del operador local.
04X	Servicios de información.
05X	Servicios de atención a suscriptores.
06X	Servicios de emergencia.
07X	Servicios gubernamentales
08X	Servicios de seguridad y emergencia.
09X	Servicios de larga distancia internacional vía operadora.

Figura 5.- Agrupación Genérica de las Claves de Servicios Especiales.

Los códigos de servicios especiales pueden ser asignados sólo a concesionarios locales y de larga distancia, así como a entidades gubernamentales y de servicio social.

En la Figura 6 se muestran los códigos de servicios especiales asignados actualmente.

Por último, en esta sección del *Plan de Numeración* se determina la estructura de los códigos de identificación de operador de larga distancia, los cuales están conformados por tres dígitos, ABC, en donde A no pude ser igual a cero (0), y B, C pueden tomar cualquier valor.

Código asignado	Servicio
020	Servicio de larga distancia nacional vía operadora.
030	Hora exacta (operador local).
031	Despertador (operador local).
032-039	*Reserva*
040	Información de números telefónicos nacionales (operador local).
041-049	*Reserva*
050	Recepción y atención de quejas (operador local).
051-054	*Reserva*
055	Servicios a clientes (operador de larga distancia).
056-059	*Reserva*
060	Emergencia.
061-069	*Reserva*
070	Información a la comunidad.
071	Servicios de suministro eléctrico.
072	Reportes y quejas de servicios públicos.
073-079	*Reserva*
080	Seguridad y emergencia.
081-089	*Reserva*
090	Servicio de larga distancia internacional vía operadora.

Figura 6.- Códigos de servicios especiales asignados actualmente.

2) Procedimientos y prefijos de marcación.

El *Plan de Numeración* especifica dos modalidades de acceso a los servicios de larga distancia que antes de enero de 1997 no existían en México. Nos referimos a la selección por presuscripción y selección por marcación.

La selección por presuscripción se implementó en las 60 ciudades que en 1997 se abrieron a la competencia de telefonía de larga distancia, y se irá implementando en forma paulatina en el resto del país, de acuerdo al calendario establecido en la resolución sobre el plan de interconexión con redes públicas de larga distancia, publicado en el Diario Oficial de la Federación en julio de 1994. Consiste básicamente en la preselección o presuscripción por parte del usuario, a la compañía de larga distancia de su preferencia. Cuando el usuario realiza una llamada utilizando la selección por presuscripción, el código del operador de larga distancia preseleccionado por el usuario es insertado automáticamente en la central local.

A partir de marzo de 1998, se habilitará la modalidad de selección por marcación a nivel nacional, la cual permitirá a los usuarios el realizar llamadas, eligiendo al operador de larga distancia en un esquema de llamada por llamada.

La Figura 7 muestra los prefijos de acceso al servicio de larga distancia y sus modalidades.

Los procedimientos de marcación por modalidad de acceso y tipo de servicio aparecen en la Figura 8.

Prefijo	Significado
01	Llamada de larga distancia nacional automática (para servicio de selección por presuscripción del operador de larga distancia).
00	Llamada de larga distancia internacional automática (para servicio de selección por presuscripción del operador de larga distancia).
010	Llamada de larga distancia nacional (para servicio de selección por marcación del operador de larga distancia).
000	Llamada de larga distancia internacional (para servicio de selección por marcación del operador de larga distancia).

Figura 7.- Prefijos de acceso al servicio de larga distancia.

3) Evolución futura

Cuando el proceso de crecimiento de 8 a 10 dígitos se haya completado, la *CFT* determinará la conveniencia de migrar hacia una marcación

Servicio	Modalidad	Dígitos a marcar
Larga distancia automática nacional.	Selección por presuscripción	01 + Número nacional
	Selección por marcación	010 + ABC + Número nacional
Larga distancia automática internacional.	Selección por presuscripción	00 + CC + Número nacional del país de destino
	Selección por marcación	000 + ABC + CC + Número nacional del país de destino
Larga distancia automática nacional con supervisión de operadora.	Selección por presuscripción	02 + Número nacional
	Selección por marcación	010 + ABC + 02 + Número nacional
Larga distancia automática internacional con supervisión de operadora.	Selección por presuscripción	09 + Número internacional
	Selección por marcación	000 + ABC + 09 + Número internacional
Número no geográfico nacional	(*)	01 + Número no geográfico
Número no geográfico internacional	N/D	00 + Número no geográfico internacional
Códigos especiales	Selección por presuscripción	Código del servicio
	Selección por marcación	010 + ABC + Código del servicio (**)

ABC = Código de identificación de operador de larga distancia

CC = Indicativo de país

(*) Para ciertos servicios no geográficos ofrecidos en competencia, existe la posibilidad de selección por marcación

(**) Sólo los servicios especiales que ofrezcan los operadores de larga distancia pueden ser seleccionados por marcación

Figura 8.- Procedimientos de marcación por modalidad de acceso y tipo de servicio

uniforme de 10 dígitos para todas las llamadas que se realicen dentro del territorio nacional, independientemente de si son locales o de larga distancia, implicando, entre otras cosas, la eliminación del prefijo de acceso 01.

4) Procedimientos de asignación de los números

En esta sección, el *Plan de Numeración* define los procedimientos de asignación de los números geográficos, los números no geográficos, las claves de servicios no geográficos, los códigos de servicios especiales y los códigos de identificación del operador de larga distancia.

Como ya se vio, el *Plan de Numeración* define los formatos de los dígitos que conforman la numeración utilizada en las redes telefónicas para prestar servicios al usuario final. Estos dígitos son intercambiados entre las diferentes redes, y es por ello que el *Plan de Numeración* tiene una estrecha relación con los planes de conmutación y señalización, de hecho, para elaborar estos últimos se requiere necesariamente del primero.

Debido a que un número identifica un destino único en la red nacional, las tablas de enrutamiento de los equipos de conmutación se construyen con base al análisis de dígitos de dicho número.

De igual forma, los números de origen y destino son enviados a través de la señalización intercambiada entre las redes telefónicas, por lo que el plan de señalización debe contemplar el formato y longitud de los mismos.

Plan Técnico Fundamental de Señalización

El Plan Técnico Fundamental de Señalización (*Plan de Señalización*), tiene como objetivo fundamental el establecer las bases para el adecuado uso y administración de los recursos asociados a la señalización entre redes públicas de telecomunicaciones, a fin de lograr la eficiente interconexión e interoperabilidad de las mismas.

Se conforma básicamente de 4 secciones fundamentales: códigos de puntos de señalización; procedimiento de asignación de los códigos; protocolos de señalización e, intercambio de información en la interconexión de las redes.

1) *Códigos de puntos de señalización.*

Esta sección define los formatos de los códigos de puntos de señalización nacional e internacional.

Respecto los códigos de punto de señalización nacional (*CPSN*), tienen una longitud de 14 bits, basada en la recomendación UIT PTM Q.704. Se conforman en tres estructuras diferentes, las cuales se muestran en la Figura 9.

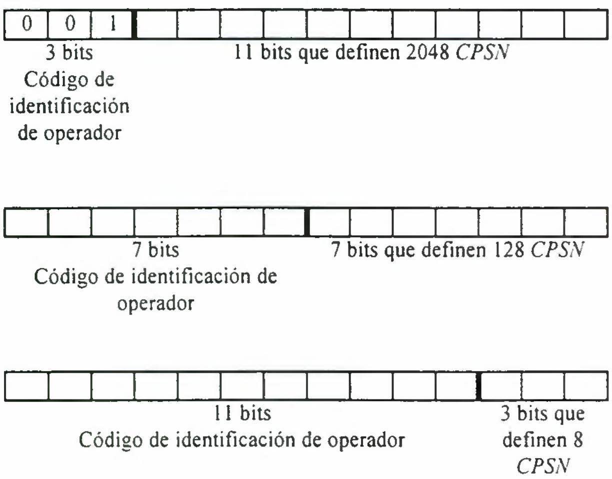


Figura 9.- Estructuras de los *CPSN*

Los *CPSN* con formato de la primera estructura, se reservan para uso exclusivo de Telmex, quien conservará para si mismo el código de identificación 001 binario que ha venido utilizando hasta la fecha.

Los *CPSN* con formato de la segunda estructura son asignados a los operadores de redes que, por su compleja topología, así lo requieren.

Los *CPSN* con formato de la tercera estructura, son asignados a redes que, por la simplicidad de su topología, así lo requieren o bien a conjuntos de puntos de señalización sin funcionalidad de punto de transferencia de señalización.

Por su parte, la estructura de los códigos de punto de señalización internacional (*CPSI*), está descrita en la recomendación UIT-T Q. 708 y se compone de tres elementos: un identificador de región de 3 bits, un identificador de red de 8 bits y un identificador de punto de señalización de 3 bits. Los dos primeros elementos conforman el código de zona de señalización/identificación de red (*CZRS*) y son administrados por la U.I.T. La estructura de estos códigos se muestra en la Figura 10.

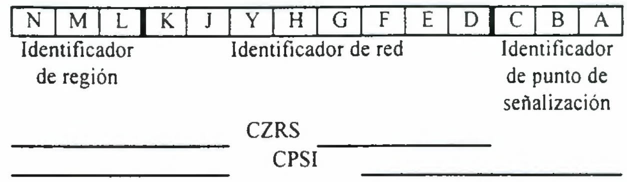


Figura 10.- Estructura de los *CPSI*

La asignación de *CPSI* se hace sólo a operadores con puerto internacional, y podrá ser en bloques de 8 códigos o código por código, dependiendo de la topología de las redes y de la disponibilidad de códigos.

La *CFT* es la entidad responsable de administrar la los *CZRS* que la UIT haya asignado a México.

2) *Procedimiento de asignación de los códigos.*

En esta sección se definen los procedimientos que se deberán seguir para la asignación de los *CPSN* y los *CPSI.*, incluyendo los requisitos que deberán de cumplir los operadores para ser sujetos de asignación de códigos.

3) *Protocolos de Señalización..*

En esta sección del *Plan de Señalización*, se establece que el protocolo PAUSI-MX (Parte de Usuario para Servicios Integrados-México), será el protocolo que deberán de usar las redes públicas de telecomunicaciones para su interconexión.

De igual forma se especifica que el sistema de señalización de las redes, deberá estar preparado para permitir la introducción de protocolos especializados, como los denominados Parte de Aplicación de Capacidad de Transacción (PACT) y el Parte de Control de Conexión de Señalización (PCCS), a fin de que puedan prestarse nuevos servicios de telecomunicaciones en el país.

4) *Intercambio de información en la interconexión de redes.*

Además de la información necesaria para establecer y liberar la llamada, la información mínima que deberá intercambiarse en tiempo real para la interconexión de redes será la siguiente:

a.- El número de "A" con formato de número nacional.

b.- La categoria de "A" conteniendo, al menos, la información que indique si se trata de una llamada realizada a través de un teléfono público o de abonado normal, así como si la llamada se realizó por operadora.

c.- El número de "B" indicando, cuando la red sea de destino, el número nacional y, cuando no sea la red de destino, el número nacional (geográfico, no geográfico o servicio especial) o el número internacional, según el caso.

d.- El estado de "B" incluyendo, al menos, la información que permita determinar si la llamada ha sido contestada o si la línea de destino se encuentra libre, ocupada o congestionada.

c.- Adicionalmente, la llamada deberá acompañarse de la información relativa al tipo de servicio, tipo de selección de red y la necesaria para su tarifación, de conformidad con las indicaciones señaladas por el usuario a través del procedimiento de marcación empleado.

d.- La información adicional para tasación de la llamada como el número para cargos (cuando sea diferente del número de "A" o códigos o prefijos de servicios cuando "B" paga).

La información para el establecimiento de la llamada arriba señalada se enviará en bloque completo en el Mensaje Inicial de Dirección y no en forma traslapada.

El *Plan de Señalización* tiene, como ya se vio, relación directa con el *Plan de Numeración*. Adicionalmente, guarda una estrecha relación con los planes de conmutación y transmisión. Respecto del primero, a través de la señalización se envía la información que utilizarán los equipos de conmutación para el establecimiento de las llamadas; respecto del segundo, requiere del establecimiento preciso de parámetros tales cómo la distorsión y la demora de propagación y el control de supresión y cancelación de eco, entre otros.

Planes Técnicos Fundamentales de Conmutación, Transmisión y Sincronización.

Como ya se dijo al inicio del presente texto, se están llevando a cabo reuniones con la industria para la elaboración de estos planes.

En forma preliminar, se puede esbozar en forma muy elemental el contenido de los mismos, tomando en cuenta que estos planes deberán de definir parámetros sólo en la frontera de las redes interconectadas. Es decir, mientras las redes cumplan con los parámetros establecidos en las fronteras, tienen plena libertad al interior de sus redes en cuanto a diseño y tecnologías a utilizar.

El *Plan de Conmutación* por su parte, deberá definir cuando menos los siguientes elementos:

- Elementos y niveles funcionales de conmutación.

- Delimitación de las redes de telecomunicaciones:
  - * Puntos de interconexión Local-Local.
  - * Puntos de interconexión Local-L.D.

- Esquemas de enrutamiento primario y alterno según tipología de tráfico:
  - * Tráfico local
  - * Tráfico nacional
  - * Tráfico internacional
  - * Tráfico de servicios no geográficos (con y sin portabilidad)
  - * Tráfico de desborde
  - * Tráfico de tránsito

Por su parte, en el *Plan de Transmisión* se deberán de establecer los valores mínimos a cumplir, de los parámetros característicos de los medios de transmisión en las fronteras de las redes (en interconexión y acceso), de tal forma que aseguren la calidad deseada de la red nacional de telefonía. Dichos parámetros son, entre otros:

- Atenuación

- Distorsión

- Propagación

- Eco

- Estabilidad

- Relación Señal/Ruido

- Diafonía

Por último, el *Plan de Sincronización* definirá los sistemas y métodos que se utilizarán para sincronizar la operación de las redes, buscando en todo momento la mayor disponibilidad posible de la red nacional, así como los métodos de sincronización alternos que se deberán de usar en caso de la pérdida de sincronía entre las diferentes redes interconectadas.

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SATELLITE-BASED TELE-EDUCATION NETWORK

Frank Franczyk & P. Eng

InfoMagnetics Technologies Corporation, IMT Communications Systems Inc., Canada
Tel: +1-204-989.4641 - Email: frank@infomagnetics.com - Web: http://www.infomagnetics.com

Summary

The drive to achieve a cost effective telecommunication infrastructure servicing educational and/or corporate communication needs, while minimizing the recurring charges associated with the satellite space segment utilization, has resulted in some unique implementations of systems based on open international standards. InfoMagnetics Technologies (IMT) and IMT Communication Systems (IMT ComSys) have developed two specific products which service the popular interactive applications including video conferencing and Internet by efficiently transporting such services via ATM (Asynchronous Transfer Mode) and MPEG2 - DVB (Motion Pictures Experts Group 2- Digital Video Broadcast) protocol carriage.

1. INTRODUCTION

The assumed network architecture which is addressed in this paper involves a central site, which is the focal point for the majority of information services and distant remote sites, which may not be serviced well by the existing telecommunications infrastructure. In this instance, the transport of service via satellite can be justified. The primary issue that confronts most potential users is the recurring satellite expenses for the desired applications.

In order to effectively support the delivery of such multimedia services, the satellite communications platform should consider the following:

- High bandwidth switching.
- Efficient transport of 'bursty' traffic.
- Voice/FAX functionality.
- Support of LANs over multiplexed access.
- Switching functions which minimize recurring operational costs.
- Compatibility with various network and telecommunications equipment, and
- Room for network growth and expansion.

Implicit in these requirements is the reliable transmission of the interactive information between the geographically remote users. The transmission system must therefore deliver error free information and route it to the correct destination in either direction.

The IMT solution which address these issues provides for the broadcast and bi-directional data transmission over satellite using the INFOCAST™ products which are based on a combination of the ATM telecommunications protocol combined with the MPEG2-DVB transport stream protocol.

The INFOCAST™ products include the AVENU ATM Bandwidth On Demand terminal which is unique in its multipoint ATM switching capabilities and in the use of ATM to multiplex the voice, video and data streams and the Asymmetric Multimedia Information (AMI) system which is unique in its delivery of IP datagrams over a broadband downstream MPEG2-DVB transport stream with a narrow band return channel.

The features in these two products and the flexibility inherent in the overall architecture make the IMT solution ideal for business, tele-education and telemedicine applications.

2. SYSTEM DESCRIPTION

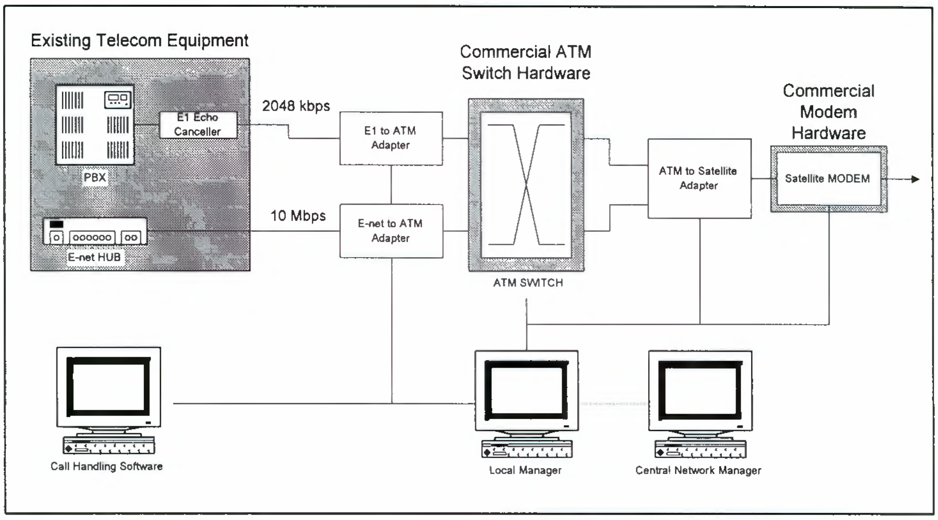
2.1. INFOCAST™ Avenu Switched VSAT (XVSAT) Overview

The IMT tele-education satellite network solution involves the use of a Switched VSAT system which was developed for the European Space Agency by IMT ComSys. The X-VSAT network provides real time demand based ATM over satellite services and can be used to carry all multimedia services including voice/fax, video conferencing and Local Area Network (LAN) traffic between remote site locations. The system provides a unique blend of conventional SCPC modems and ATM transport.

An Inter-Working Unit (IWU) provides legacy LAN network interfaces between Ethernet and E1 to ATM. The multiple media/traffic types are multiplexed using ATM switching with a conventional ATM switch which also provides for local ATM LAN interconnection and Direct ATM connections to existing ATM based terrestrial facilities. The IWU also performs satellite carrier switching and VSAT interface under control of the access control station.

Statistical multiplexing provides gains in the efficient use of the satellite resources, lowering queue delays and providing faster response times for LAN traffic. The inherent nature of satellite broadcasting makes multipoint video conferencing more efficient.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).



The system can also be configured with Bandwidth On Demand (BOD) system software which is capable of adapting to dynamic traffic requirements. Monitoring traffic flow, the system automatically closes idle satellite links thereby maximizing the satellite spectrum resource utilization. As traffic increases, the system automatically requests and sets up additional virtual circuits as needed.

A user interface allows customers/users to 'dial up' video conferencing and voice channels on demand. Capacity for LAN traffic is configured to vary between operating limits based on minimum acceptable and maximum cost circuit speeds.

A central management station provides the network operator with a full view of the network. In addition, usage records are generated and passed on for reports and individual subscriber usage and billing. The following Figure highlights the X-VSAT components described below:

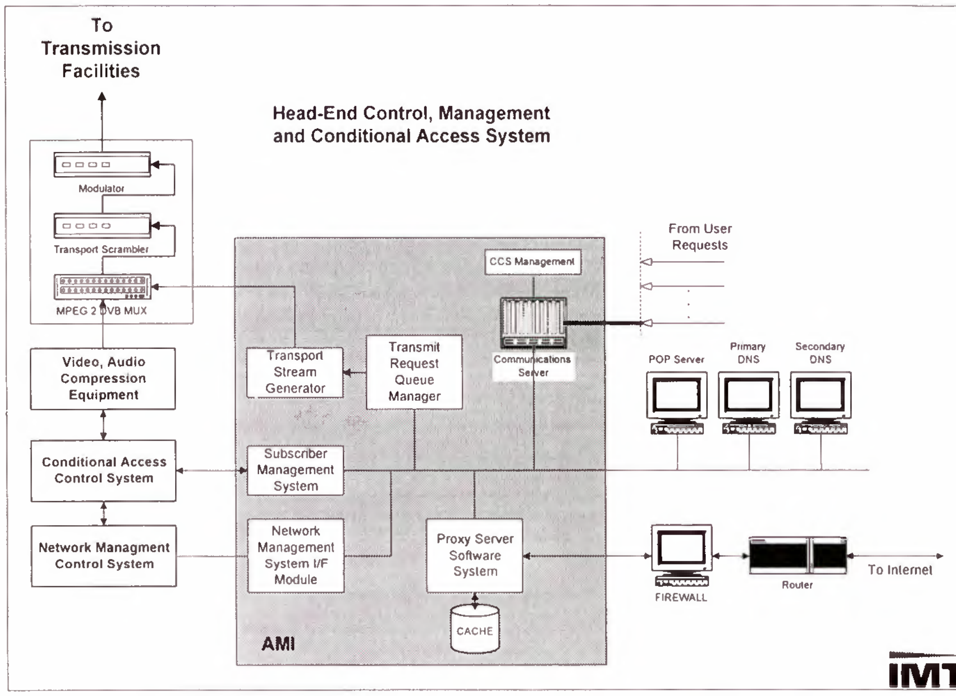
- CBOS (Connection Bit Orient Service) Adapter: terminates a 2048 kbps E1 framed synchronous data service and performs the AAL 1 adaptation in software prior to queuing the data in the ATM Network Interface card (ATM-155 Mbps fiber or UTP-5).
- CLPOS (Connection Less Packet Oriented Service) Adapter: terminates a 10 Mbps Ethernet LAN service, queues the IP datagrams according to a static routing table (it is a router), and passes the data on to the ATM Network Interface Card which performs the AAL 5 adaptation (ATM-155 Mbps fiber or UTP-5).
- STA (Satellite Transmission Adapter): terminates the ATM NIC (currently a single input from the output of the ATM switch via ATM-155 Mbps fiber), and performs rate adaptation and for an interface to a synchronous EIA 530 physical connection.
- Local Manager: based on a 10 Mbps Ethernet management LAN backbone, provides SNMP management and control of the terminal elements.

2.2. INFOCAST™ Asymmetric Multimedia Information (AMI) System Overview

The IMT tele-education satellite network solution also includes an Internet delivery system which can can be provided through an asymmetric communications architecture based on an MPEG 2 DVB broadcast Transport Stream (TS) outbound channel combined with a narrow band return channel. This concept and its implementation provides the tele-education network with the capability of enhancing the audio and video broadcast service with multimedia information services using an MPEG 2 DVB transmission system platform. The use of this platform provides for the implementation of low cost Integrated Receiver Decoders (IRDs) and/or PC Peripheral boards which are MPEG 2 DVB compliant.

The AMI system 'plugs and plays' into an existing MPEG 2 digital transmission system platform at a central head end with remote client gateway "routers" providing the return path communications channel through simple telephone modem connections or through the Avenu Ethernet LAN port. The AMI HUB components are shown in the following Figure and include:

- A Transport Stream Generator (TSG) which injects the Internet Protocol (IP) datagrams onto an MPEG 2 TS,
- A Network Management System (NMS) with a Proxy Server Software implementation,
- A Transmit Request Queue Management (TRQM) and capacity scheduling system,
- A Subscriber Management System (SMS), and



• A Communications Server System (CSS) which can be an SNMP managed standard ISP type modem bank for terminating the inbound return channels.

The client gateway system is comprised of an MPEG 2 DVB compliant receiver, client software, and a terrestrial dial up telephone line or a direct connection to the Avenu LAN connection. The receiver platform could be a conventional and existing Set Top Box (STB) with a high speed serial output or LAN interface, or it could be a PC plug in card. A receive only antenna plus Low Noise Block (LNB) converter are implicitly included.

Finally, the system is scaleable at the hub according to the required information processing computer platform to service the number of remote client gateway connections for the given system implementation

3. NETWORK DESIGN

A network involving a central site with 50 remote sites. Of these 50, four sites have been identified as important nodes requiring full bi-directional communications according to the following requirements:

- One way distribution of video, audio and Internet data services for distance learning applications to all 50 remote school sites. Return interaction for the distance learning broadcasts to be provided via telephone infrastructure or via Avenu terminals located in the four important nodes.
- Bi-directional video conferencing services with voice/fax capabilities between the central site and the four principal sites.
- LAN interconnection between the central site and the four principal remote sites.

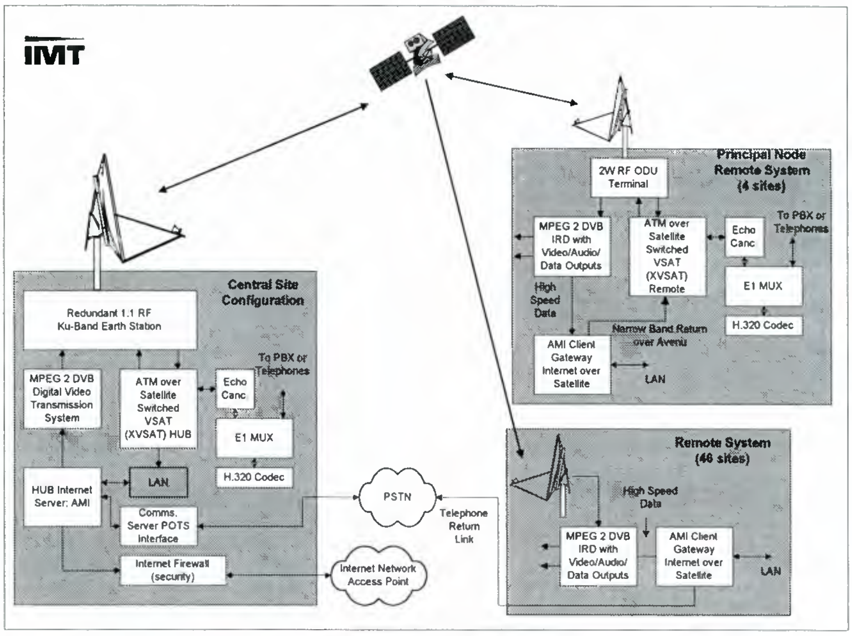
The network architecture based on the IMT Infocast solution is shown in the following Figure (next page).

3.1. Broadcast Video, Audio & Internet Data: Unidirectional Distribution

The broadcast services requirements call for a modest bit rate for the outbound distance learning application: the analogy to "VHS tape" quality could be provided with a 2.0 Mbps compressed data rate. The broadcast network implementation would thus consist of a single channel digital video uplink station including the MPEG 2 compression encoding equipment, the AMI information processing hub system, together with the reception and decoding equipment located at the 50 remote sites. The outbound Internet data rate to be available to the 50 remote sites has been determined as 500 kbps such that combined with the other MPEG 2 audio and SI table information, the occupied bandwidth of the system is no larger than 3.0 MHz. The system bit rate allocation table is shown in the Table (next page).

3.2. Bi-Directional Data Network Configuration

The tele-education network backbone between the central site and the four principal nodes, can be configured as a point to point trunking system with a fixed number of circuits allocated to each site to handle the voice/fax and video conferencing traffic. An alternative implementation using the Call-Handling and signaling system, can provide true Bandwidth On Demand (BOD) for maximum network flexibility and usage and will be discussed in this paper.



SCPC System Data Bit Allocation Example

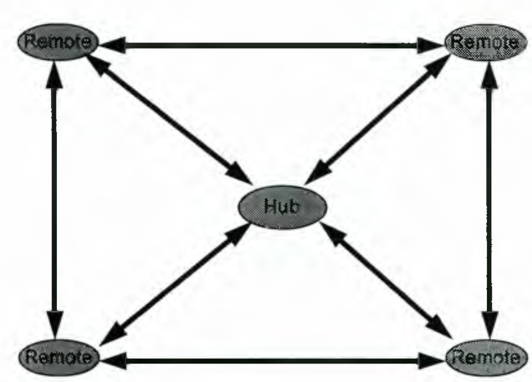
Total Information Bit Rate (kbps)	Inner Code:	Outer Code:	Total Channel Bit Rate (kbps):	Symbol Rate (ksps):	Alpha Factor (%)	Occupied BW (MHz):
2,806.45	R2/3	RS(204,188)	4,567.95	2283.97	35%	3.08

Number of Broadcast Video Services:	Number of PPV Video Services:	Number of Audio Services:	Number of HSD Services:
1	0	1	1

Number	Service	Bit Rate (kbps)	Overhead Bit Rate (2.5%):	PID	Resolution	Total Service Bit Rate	% of Total Information Bit Rate
1	VIDEO	2,000.00	50.00	0FF	480x576	2,050.00	73.05%
2	Stereo Audio Ch1, CH 2	128.00	3.20	100	-	131.20	4.67%
7	AMI Internet Data	500.00	12.50	1FF	-	512.50	18.26%
##	Service Info Tables	30.00	0.75	-	-	30.75	1.10%
##	Private Data	80.00	2.00	F00	-	82.00	2.92%
	TOTALS	**2,738.00**	**68.45**			**2,806.45**	**100.00%**

3.2.1. Trunking Network Configuration

The point-to-point case is the traditional SCPC (Single Channel Per Carrier) or TDM (Time Division Multiplexed) solution. One carrier is transmitted from the site to each site it communicates with. All traffic from site one to site two, for example, would be multiplexed with a TDM multiplexer and transmitted on a single carrier. In the SCPC scenario, each circuit would typically use an individual carrier for transmission via the satellite. In both cases the earth station HPA must be sized to allow for multi-carrier operation. The following illustrates the point to point trunking architecture.



Multi-carrier operation typically dictates that the total output power of the amplifier must be reduced by 3 to 4 dB to ensure that intermodulation interference specifications are met. This means that if an 8 watt amplifier is installed in an earth station, multi-carrier operation requires that the total maximum output power of the amplifier not exceed about 4 watts. On the other hand, if only one carrier is transmitted through the amplifier, most of the 8 watts could be used.

For the point to point SCPC configuration, the hub would require four modems, and each of the remotes would require three modems. The hub would continuously transmit four carriers (one to each remote) and each remote would transmit three carriers (one to the hub and one to each of its neighbors).

The INFOCAST Avenu point to point trunking configuration is much simpler as the hub will only require two modems (one active at a time), and two or three additional demodulators (one demodulator to receive each remote plus one additional demodulator to be used during carrier bandwidth changes). The cost of a demodulator is less than a modem so there are equipment savings with the Avenu terminal. Moreover, since only one carrier is normally active at one time, the amplifier does not need to be derrated for multi-carrier operation. Hence, either a smaller and less expensive HPA may be used, or more data may be transmitted through the same amplifier.

The basic Avenu system provides for control and command of the system using SNMP (Simple Network Management Protocol) network management from any SNMP management station. One central SNMP manager will be provided with some pre-configured functions and scripts to make routine operations easier to perform.

For the Bandwidth on Demand access, a signaling layer is provided to allow end users to set up and tear down "calls" or video conferencing sessions. This option is referred to as the Call Handling Software for Bandwidth On Demand. This signaling layer can be used to provide demand assigned telephone trunks. The signaling layer provides management of both, the bandwidth that is used in a satellite carrier that is already assigned, and where necessary, it can command additional satellite resources (that is, it can manage a pool of satellite bandwidth that is shared between a number of terminals).

The Call Handling for BOD can allow functions such as reconfiguring the system to provide for large data transmission such as in the transmission of databases from the hub to the remote during off peak periods. When the hub site is not using the main out-route bandwidth, remote to remote video conferences can be set up. The system can also dynamically monitor the data traffic from all the sites. When there is additional demand from one of the sites, and a corresponding lack of activity from other sites, the satellite resources could be reallocated automatically.

For full BOD, all traffic out of each site can be aggregated. The total traffic out of each site is summed, and the appropriate number of trunks to support that traffic load is calculated. The trunks required are calculated using Erlang B traffic tables. This assumes infinite sources and that blocked calls are lost. It is assumed that the traffic loading are symmetrical (equal number of calls originated and terminated).

For the BOD traffic configuration, each remote site will transmit a single 512 Kbps carrier (allowing for 64 Kbps of LAN data) and the hub would transmit at 1488 Kbps (allowing for 512 Kbps of LAN data). Total transponder utilization would be 10 MHz.

3.3. Overall Tele-Education Satellite Resource Utilization

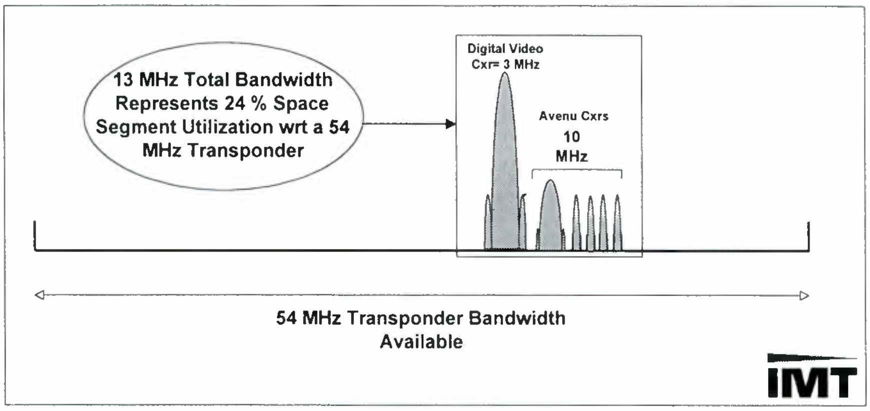
Based on the broadcast video, audio and Internet data allocation plus the traffic allocation for the dynamic Bandwidth On Demand configuration for the four principal remote stations, the following Table and Figure summarize the network telecommunications support to the 50 sites and the required overall satellite space segment requirements to support the services.

SITE	Bi-directional Data Rate	DSO Ccts.	Min. LAN data rate
Central Site	512 kbps	6	64 kbps
Sire 1	512 kbps	6	64 kbps
Site 2	1488 kbps	13	512 kbps
Site 3	512 kbps	6	64 kbps
Site 3	512 kbps	6	64 kbps
Other 46 sites	Broadcast Digital video & audio reception only: 2.2 Mbps information	-	500 kbps Internet data

4. CONCLUSION

The key highlights of the IMT system solution for a tele-education satellite based network include:

- Multi-point Avenu ATM over satellite traffic.
- Reconfiguration of satellite space segment according to traffic requirements with Bandwidth On Demand (optimizing space segment utilization).
- Distance learning uni-directional broadcast video and audio signals utilizing the MPEG2-DVB standard.
- High bandwidth Internet data services multiplexed into the MPEG2-DVB transport stream with asymmetric narrow band return path for requests and protocol acknowledgements.
- Network flexibility and expansion for future multimedia services based on international broadcast and telecommunication protocol standards.



5. CORPORATE OVERVIEW

InfoMagnetics Technologies Corporation (IMT) and IMT Communication Systems Inc. (IMT 'ComSys') specialize in hybrid satellite-terrestrial wireless technology development and its application to telecommunications networking solutions. IMT designs, develops and manufactures state of the art products for wireless applications in MMDS, LMDS, and advanced satellite communication systems. IMT complements these products with network operations and management software systems.

The IMT team builds on 30 years experience supplying microwave, VSAT, and Direct Broadcast Satellite systems to TELECOM, utility, space agency and military customers around the world. Our product legacy can be found in service on virtually every continent. IMT staff have earned an international reputation in electromagnetics, and a track record of innovation in antenna designs and in the commercial introduction of key technologies, including polylithic crystal filters, multi-function digital frequency synthesizers, constant-envelope modulation systems, TWT linearizers, image-enhancement mixers, satellite DAMA systems and Ka band RF terminals.

TELESALUD: EXPERIENCIA MEXICANA EN LA APLICACIÓN DE LAS TELECOMUNICACIONES A LA MEDICINA

AMANDA GOMEZ-GONZALEZ [1, 2]
JAVIER CASTELLANOS COUTIÑO [2]
MANUEL GONZÁLEZ VIVIAN [2]
JOSE LUIS AMARO HERNANDEZ [2]

Resumen: En el proceso de selección de un medio de transmisión para la atención médica y educación médica a distancia, se ven involucrados: la confiabilidad, viabilidad, respaldo, capacidad instalada, cantidad de señales tratadas, acceso y costos.

En el presente trabajo, los autores muestran la aplicación de un acceso real que actualmente se encuentra en operación con el enlace de ocho hospitales, y cuyo criterio de relación costo-beneficio ha sido válido para la ampliación de la red a una segunda etapa, la cual está por ser instalada con otras ocho estaciones más.

Se analizan los servicios que puede proporcionar un Programa Nacional de TeleSalud que incluya : Tele-Consulta, Tele-Diagnóstico, Tele-Radiologia, Tele-Educación y Tele-Administración.

Se exploran las opciones de señales mínimas requeridas para dar calidad de transmisión en la atención médica, directamente con los usuarios del sistema, esto es, los médicos, paramédicos y administrativos.

Por ultimo se evalúan los diversos medios de transmisión de los cuales bajo los criterios anteriores, se decide el idóneo para la aplicación expuesta y se muestran resultados de la aplicación.

I.- Antecedentes

La TeleSalud involucra además de la Video Conferencia convencional; la TeleConsulta con sensado de señales, la educación médica continua, educación para la salud y administración, por lo que requiere contemplar desde un principio el concepto completo.

En México los esfuerzos de la Tele-Enseñanza médica se dan desde los años 80 con la aplicación de la difusión de conferencias vía satélite de modo continuo en el Hospital Infantil de México a través del satélite Morelos, cabe mencionar que la Tele-Educación requiere interactividad con los usuarios, lo cual solo se logra con canales bi-direcionales, que en la actualidad el proyecto de la Universidad Médica Virtual de la UNAM representa la modernización del concepto al aplicar la RDI a teleaulas de escuelas de medicina (Hernandez,97).

En año 1991 se exploran las posibilidades de emplear la nueva generación de Satélites Solidaridad para atención médica (Gomez et al, 91) contando para tal efecto con un panorama global de la aplicación incluyendo los hospitales, clínicas y posibles hospitales móviles para atención rural.

En 1995 el Instituto de Seguridad y Servicio Social para los Trabajadores de Estado (ISSSTE) realiza una prueba piloto con el Hospital 20 de Noviembre en la Ciudad de México y una unidad remota en el Hospital Belisario Dominguez de Tuxtla Gutiérrez Chiapas, contando para tal efecto con enlaces vía satélite de 384 Kbps con capacidad de enviar video, audio, datos y rayos X en ambas direcciones. Los resultados después de 4 meses mostraron que una reducción en traslados desde los hospitales remotos a la Ciudad de México en un 50%, en comparación con el año precedente, quedando incluidos en el Programa los de control e interconsulta a distancia, los cuales representan en la relación costo-beneficio un autofinanciamiento de la inversión, dado que siendo conservadores con el 30% el proyecto se pagaba en dos años. (González,95). Con esta relación costo/beneficio real, el ISSSTE inicia en 1996 el proceso

[1] Comisión Federal de Telecomunicaciones, Radiatas #44, Bosques de las Lomas, tel. 525 261-42-60, fax: 525 259-13-61, e-mail:amandag@verona.fi-p.unam.mx
[2] Instituto de Seguridad y Servicio Social de los Trabajadores del Estado,San Fernando #547, Tlalpan D.F., tel: 525 606-54-09, fax: 525 606-30-02

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

de implantación de la primera etapa de la Red Nacional de TeleSalud.

II.- Infraestructura requerida:

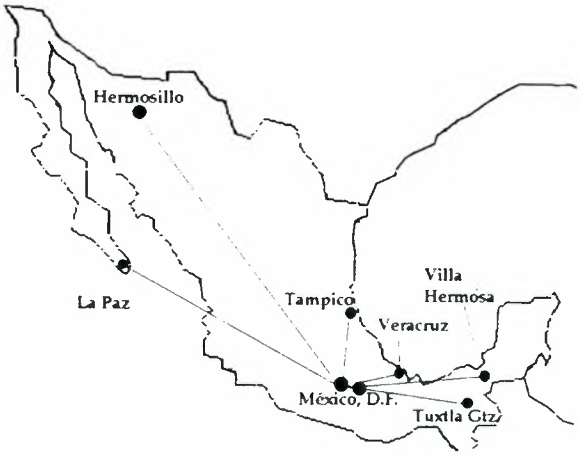
De acuerdo a la división de educación por una parte y atención médica por otra, los requerimientos de infraestructura varían, en el primero al ser una videoconferencia en teleaulas y equipo de transmisión de video y audio a velocidades que van desde 128 Kbps(calidad mala) a 384 Kbps (excelente calidad) y equipo de videograbadora para envío de cursos pre-grabados; en la prestación de atención médica a distancia, para ser un servicio confiable desde el punto de vista de los médicos, deben incluir además del video y audio de muy buena calidad, un grupo de señales sensables a distancia como son: sonidos provenientes de un electro-estetoscópio, imágenes de rayos x, tomografías y fotografías,diagnóstico electrocardiográfico, lo cual implica que el control de la estación de TeleSalud, deba ser manipulada desde una estación de trabajo que cuente con la capacidad de variar las funciones (velocidades, tipos de señales,etc) de acuerdo con las necesidades de la consulta, además de tener un expediente electrónico con la información aportada por los sensores anteriores, de los médicos interconsultantes y capacidad de grabado en algún dispositivo de almacenamiento.

La selección del medio de transmisión variará de acuerdo a las condiciones que se analizarán mas adelante.

III.- Selección de los hospitales:

Para que el programa de Telesalud pueda ser redituable, las unidades remotas deben ser aquellas que por lejanía o falta de poder resolutivo de la ciudad donde se localiza, a la estación central para que esto signifique un gasto elevado de traslados y subrogaciones médicas a hospitales de concentración. En la aplicación real se inició la primera etapa con un estudio de campo de costos en relación a traslados y subrogaciones médicas, destacando en ella unidades médicas que fueron las de mayor gasto para la Institución por este concepto, tal es el caso de los hospitales seleccionados: Chiapas, Tabasco, Veracruz, Tamaulipas, Sonora y Baja California Sur (hospitales de segundo nivel), tomando como unidades centrales dos Hospitales en la Ciudad de México (tercer nivel) , que son los de mayor afluencia de traslados.

Figura 0-1



IV.- Tipo de señales requeridas para TeleConsulta

Al seleccionar las señales mínimas requeridas para una TeleConsulta se consideró especialmente a el tipo de usuario de las unidades. Tradicionalmente, los médicos requieren atender al paciente personalmente; sin embargo, al modificar la manera de atención, se debe contar con una calidad de imagen, sonido y velocidad de datos de los periféricos, tal que no cambie el diagnóstico por error de apreciación. Es así, que se consideró de manera conjunta con diversas especialidades médicas dando como resultado las siguientes señales y velocidades mínimas.

SEÑAL	VELOCIDAD MÍNIMA
Video conferencia y cinta de video	256-512 Kbps
Audio estetoscopio	112 Kbps
Datos	19.2-128 Kbps
Digitalizador de Rayos X	128 Kbps
Proyector de cuerpos opacos	96-256 Kbps
EKG	19.2 Kbps

Es muy importante contar con las señales anteriores ya que en conjunto pueden dar un panorama muy claro al médico especialista sobre si el paciente teleconsultado debe ser transferido o reciba un tratamiento en forma local.

Existen en el mercado otras alternativas para la exploración, a distancia, de los pacientes tales como: el oftalmoscópio, otoscópio y dermatoscópio. Los cuales incrementan la capacidad de diagnóstico o una segunda opinión a distancia evitando errores que por falta de información puedan afectar el pronóstico del paciente.

La opción de video conferencia debe contemplar la posibilidad de enviar junto con ella otras señales como: digitalizador de imágenes de rayos X, electrocardiógrafo y otras. Por lo que se debe considerar la posibilidad de variar entre 256 Kbps (cuando es de señales múltiples) y 512 Kbps cuando es una video conferencia para Tele-Educación y atención médica.

Por lo anterior queda claro que la velocidad de cada canal es 512 Kbps mínima

V.- Selección del medio de transmisión

Al haber estimado que la velocidad de transmisión es de 512 Kbps, quedan automáticamente eliminados los canales telefónicos, INTERNET y radio enlaces, quedando únicamente los canales RDI y portadoras vía satélite por lo que los análisis subsecuentes se realizaron bajo esta definición.

a)Confiabilidad

Por requerimientos de la calidad de la señal con que se trabaja en TELESALUD, el mínimo aceptable de confiablidad es de 99.8%, el cual es estimado de acuerdo al tipo de posibles fallas que se presenten durante la vida útil del sistema, en los enlaces satelitáles, las fallas mas probables se deben a interrupción del servicio debido a los eclipses, posibilidad de ruidos atmosféricos, que bajan la calidad de la relación señal a ruido y cortes de energía eléctrica en las estaciones. Al contar con respaldos en órbita, tanto en transpondedores como con otro satélite de la misma familia, la confiabilidad del sistema queda asegurada siempre y cuando la selección del equipo de tierra sea estimado correctamente.

Los enlaces RDI que resultan inmunes a ruidos ambientales, presentan una probabilidad muy grande de corte total de la transmisión. Estos cortes, como se ha visto en el territorio mexicano, son debidos a fenómenos naturales como huracanes, temblores, inundaciones etc.Por lo que al seleccionar la opción RDI se debe considerar esta posibilidad.

b)Capacidad Instalada

En otros países, la instalación de las líneas de RDI es muy amplia y permite la instalación de canales E_0, y E_1 directamente a los edificios. No así en México, donde en un 90% de los lugares preseleccionados para Tesalud, no contaban con Fibra Óptica y el 10% restante contaba con la posibilidad de conexión directamente en el edificio, lo cual implicaba ,si asi se requería, instalar un tendido de fibra desde el nodo mas cercano hasta el hospital, con un valor adicional para el Instituto.

En los enlaces satelitales utilizando el sistema de satélites Solidaridad, se podía tener acceso a portadoras de 512 Kbps en cualquiera de los sitios seleccionados.

c)Cantidad de enlaces requeridos

En los enlaces por RDI, se requiere un par de canales por cada enlace, sin posibilidades de rehuso de canal a menos que se incorpore la tecnología "Frame Relay" no habilitada hasta el momento de la selección del medio de transmisión.

En los enlaces satelitáles, se consideró que el tiempo de uso de cada hospital regional no era de 24 hrs. por lo que un par de portadoras podrían ser utilizadas asignando horarios de atención , con lo que para la primera etapa del proyecto, 8 estaciones terrenas implicaban que se adquirieran menos de 8 portadoras.

Existe en el mercado la posibilidad de compartir canales en tiempo y en frecuencia TDMA y FDMA, aunque para las condiciones del usuario de TELESALUD, no se requiere estar conectado con todas al mismo tiempo debido a que los médicos especialistas requieren concentrarse en un paciente por vez. Por lo que la tecnología aplicable podría ser un SCPC normal. Debido a la ubicación de las unidades remotas en zonas de grandes velocidades de viento y muy alta incidencia de lluvia, se optó por la banda C.

d)Costo

En el análisis de los medios de transmisión se consideran los de instalación, renta mensual y largas distancias.Al delimitar la cantidad de enlaces para los ocho hospitales, se observo que un canal de 512 Kbps, en el caso de RDI, era aportado por 8 E_0, cuyo costo es mayor que un E_1, lo cual llevo a considerar la opción de rentar 8 E_1. Sin embargo, cabe mencionar que se agrega a esto el costo de instalación, de llamada de larga distancia y renta mensual con lo que la capacidad de pago de la Institución era sobrepasada considerablemente.

En los enlaces satelitales existe la posibilidad de compartir portadoras por horarios, esto se concreta a 4 portadoras de 512 Kbps, con los costos de instalación de las estaciones terrenas y sin costos de larga distancia que favorecen la inversión dada por el ISSSTE debido a que se considero por el Gobierno de México el apoyarlo como un programa prioritario y dió una tarifa preferencial que apoya directamente el crecimiento de la red.

Tabla de Costos*

CANAL DE 512 KBPS	SATELITE	RDI
COSTO DE INSTALACIÓN	1.8millones	600.000
COSTO DE RENTA MENSUAL	4.000	40.000
LARGAS DISTANCIAS	NA	3 p/min

*pesos mexicanos.

VI.- APLICACION REAL

Numero de sitios inicial: 8
Confiablidad: 99.8%
Tipo de señales: Vídeo digital , Audio, Datos
velocidad máxima multicanalizada de 512 Kbps
Medio de transmisión: Satélite banda C
Técnica de asignación de frecuencia: SCPC con rehuso por horario
Número de portadoras: 4 de 512 Kbps
2 Estaciones centrales: 3.8 m, 20 watts, redundantes
6 Estaciones remotas: 2.4 m, 5 watts, no redundantes

VI.- RESULTADOS

- La respuesta después de 435 video conferencias, tanto de pacientes como de médicos ha resultado positiva en un 94%, la calidad de la señal ha sido suficiente para el diagnóstico a distancia.

- En el entrenamiento a médicos y operadores del sistema ha resultado rápido de comprender, lo cual muestra que la autonomía de los hospitales no se ve disminuída al adquirir una nueva tecnología.

- Se han impartido 22 video-conferencias para TeleEducación, conseciones clínicas y radilógicas a enfermeras y paramédicos aprovechando que las estaciones terrenas pueden actuar únicamente como receptoras y solamente tener bidireccionalidad con una de las unidades remotas.

- Las especialidades interconsultadas demuestran que el equipo con sus periféricos es suficiente, para realizar un diagnóstico o segunda opinión según lo requieran las unidades remotas.

- Durante fenómenos naturales que se han presentado en esta primera etapa, las transmisiones se han suspendido parcialmente dentro de lo estimado sin llegar a rebasar un día.

TABLA DE RESULTADOS REALES (MES DE SEPTIEMBRE 97)

ESTADO	PACIENTES	CONSULTAS	TRASLADOS
CHIAPAS	52	71	32
VERACRUZ	23	23	15
LA PAZ	18	15	9
HERMOSILLO	18	18	10
TAMPICO	14	16	8
VILLAHERMOSA	4	6	2
TOTAL	**129**	**149**	**64**

Aproximadamente se ha contribuído al ahorro de la Institución en 500 mil pesos mexicanos.

VII.- CONCLUSIONES

Se puede observar la importancia de realizar el análisis de la red desde la referencia del usuario y seleccionar todos los detalles ubicándose mas en la viabilidad que en la tecnología.

El tipo de señales utilizadas fueron las mínimas: videoconferencia. Electro-cardiógrafo,, electroestetoscópio. digitalizador de rayos x , proyector de objetos opacos y videograbadora (agregándose esta última con fines de Tele-Educación). Esta red puede crecer de acuerdo a la aplicación y necesidades específicas de especialidades médicas mas solicitadas.

El medio de transmisión seleccionado ha mostrado ventajas de costo y respaldo convenientes, aunque para una tercera etapa sería conveniente involucrar enlaces RDI en los lugares donde se tenga acceso, ya que este proporcionaría la capacidad de internacionalizar las experiencias y no quedar como una red local.

Al utilizar rehuso de portadoras por asignación horaria , se evitó un gasto innecesario.

Lo más importante de la aplicación presentada, es que es un proyecto autosustentable al evitar traslados que pueden ser tratados localmente con opinión de los médicos especialistas y que se lleve el control a distancia del seguimiento de algún tratamiento, dando al derechohabiente un beneficio adicional, evitando el gasto socio-económico que implica un traslado.

Figura 0-2

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Satellite Navigation

EGNOS

The European Regional Augmentation to GPS and GLONASS

Programme Overview

European Space Agency
GNSS-1 Project Office

EGNOS

PRESENTATION OUTLINE

- European Satellite Navigation Programme (ESNP)
- EGNOS Operational Objectives
- EGNOS System description
- Standardisation
- EGNOS Implementation Programme
- Summary

EGNOS

European Geostationary Navigation Overlay Service

- European Satellite Based Augmentation (SBAS) to GPS and GLONASS
- Improve Integrity and Accuracy (with the required Availability and COS) of Satellite Navigation over ECAC
- Multimodal Mission (Aero, Maritime, Land users) driven by Aeronautical requirements

EGNOS Augmentation Service

- Satellite-based Navigation Overlay:
  - **RANGING**: GPS-like pseudoranges
  - **INTEGRITY**: broadcast of GPS and GLONASS Integrity messages (in addition to RAIM with FDE)
  - **WIDE AREA DIFFERENTIAL**: broadcast of differential corrections valid over full Service Area

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EGNOS

EGNOS INDUSTRIAL CONSORTIUM

THOMSON CSF
SEXTANT AVIONIQUE

GMV
INDRA ESPACIO
SENER
ALCATEL ESPACIO

RACAL
VEGA
MATRA MARCONI SPACE UK
LOGICA / SCIENCE SYSTEMS
SIEMENS UK

DASA
MAN
VEGA GMBH

SIEMENS AUSTRIA

CIR
ELCA

ALENIA AEROSPAZIO
VITROCISET
NUOVA TELESPAZIO

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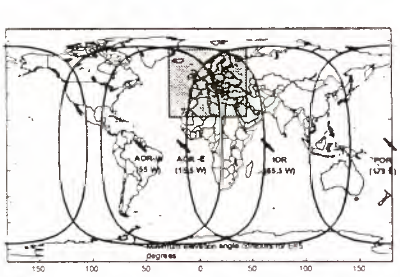
EGNOS

INMARSAT-III Geostationary Broadcast Areas



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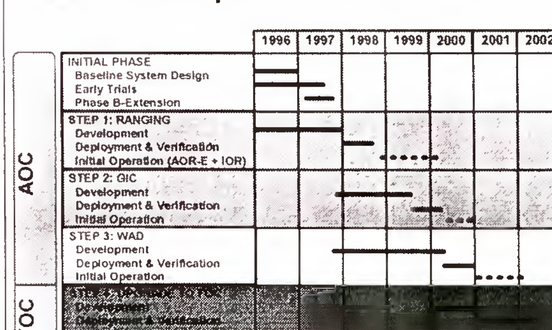
EGNOS Operational Milestones



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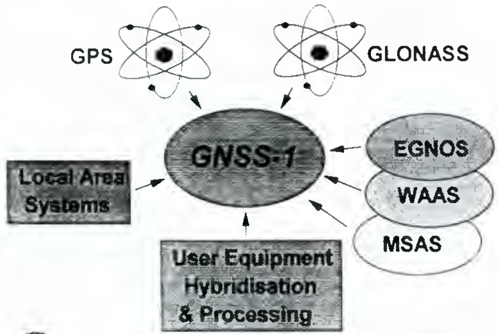
What is GNSS-1



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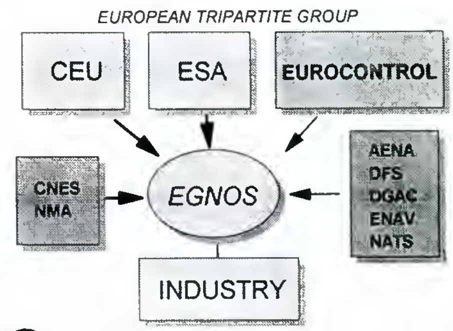
European joint venture



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What is GNSS-2

- GNSS under full civilian, international control
- capable to meet future navigation & timing requirements
- multimodal
- integrated navigation, broadcast and two-way communications
- Global standard
- cost effective

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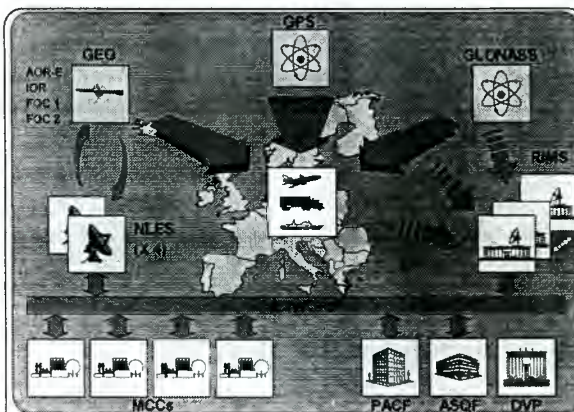

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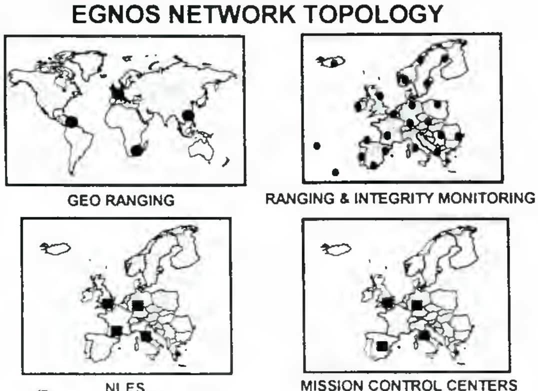
EGNOS NETWORK TOPOLOGY



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EGNOS system architecture

- Ground segment:
  - Ranging & Integrity Monitoring Stations (RIMS)
  - Mission Processing & Control Centers (MCC)
  - Navigation Land Earth Stations (NLES)
  - EGNOS Wide Area Network (EWAN)
- Space segment :
  - Geo satellites with navigation payloads
- User segment : air, maritime, land user equipment

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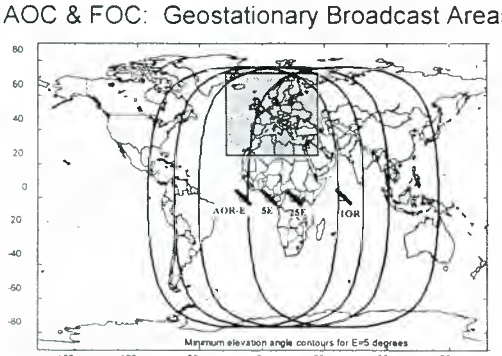
AOC & FOC: Geostationary Broadcast Areas



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European Satellite Navigation Programme (ESNP)

- defined by European Tripartite Group
  - Commission of the European Union
  - European Space Agency
  - Eurocontrol
- GNSS-1: EGNOS , LAAS, User Equip.
- GNSS-2
- Inter-Regional Cooperation

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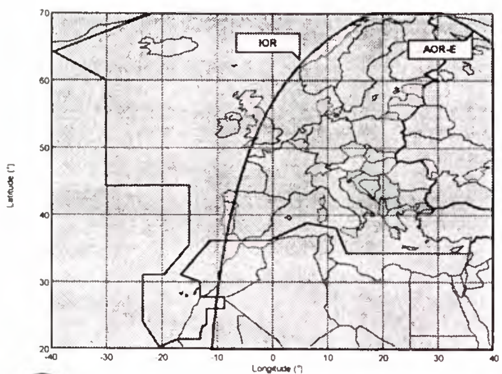

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EGNOS: Performance Objectives

- Ranging will enhance the availability of GPS RAIM FDE for En-Route down to NPA, over full GBA
- GIC will improve the availability of NON-INTEGRITY detection for all phases of flight down to precision approach, over ECAC
- WAD will enhance ACCURACY (10m VNSE GPS, 6m VNSE GPS + GLONASS),for precision approach applications over ECAC

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EGNOS

GLOBAL INTEROPERABILITY

- WAAS / EGNOS / MSAS
- Ensure **Seamless Service** provision
- **Optimise** use of Ground (monitors) and Space (Geo relay) **resources**
- **Standardisation**
  - Signal in Space
  - User Equipment
  - Network interfaces

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EGNOS

Operational Milestones

- AOC
  - Ranging .... year 1998
  - GIC .... year 2000
  - WAD .... year 2001
- FOC
  - pending programme approval
  - could be completed by year 2002

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EGNOS

Summary

- **GPS & GLONASS alone do not meet Civil Navigation requirements and suffer lack of civilian control**
- **An European Satellite Navigation Programme has been defined by the ETG, wich includes contributions to GNSS-1 and GNSS-2**
- **An overview of current European activities in the frame of the EGNOS Programme has been presented**
- **EGNOS is being developed to meet all technical requirements of aviation users as sole means of navigation, for En-Route down to Category I landing, by the year 2002.**

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EGNOS

G.P.S. and GLONASS : cornerstones of the Space-Based Positioning and Timing Infrastructure - 1st generation

- At the end of 1993, the U.S. Global Positioning System (G.P.S.) ha s been the first System to provide :
  - global, permanent and precise positioning and timing signals
  - free access to these signals to peaceful users
- In 1995, Russia offered a similar capability to worldwide potential users at equivalent conditions
- In March 1996, the United States of America announced their determination to maintain and modernize G.P.S. in order to durably satisfyneeds of american and foreign civilian users :
  => The G.P.S. Standard Positioning Service is offered to be an essential part of the emerging Global Information Infrastructure
- In spite of economical and budgetary difficulties, Russia is involved through ICAO, IMO, ITU Working Groups to allow the integration of GLONASS in this Global Positioning and Timing Infrastructure

G.N.S.S. : The European Approach

Europe has been involved in the Satellite Navigation Area for a long time :

• As soon as in the 80', the French Space Agency :
  • coordinated with the french Civil Aviation Authority
  • studied, tested and promoted the European Complement to G.P.S. whose concept is EGNOS, WAAS and MSAS sketch
  • engaged the EURIDIS program as a first step to the European EGNOS program

In 1994, the European Commission engaged the GNSS Effort :
• the EGNOS Program was engaged by ESA to reach a pre-operational Cat I capability by 2002 :
  • Thomson CSF is Prime Contractor, and leads a "very" european consortium
  • France is the first contributor (35 to 45 %)
• the E.S.A.conducted numerous preparatory works to a G.N.S.S. 2 too.

=> From the begining, France has been strongly determined to get Europe fully involved in the building of the Global Positioning and Timing Infrastructure.

<u>Europe Chose a two-step approach :</u>

<u>GNSS 1</u> :
Initial implementation of GNSS, based on GPS and GLONASS and additional civil augmentationsto provide for independent system monitoring and increased performance

=> to get early benefits from Sat Nav for low-risk applications
=> to evaluate the tru potential of Sat Nav integration in various critical infrastructure such as transport, telecommunications,...

G.N.S.S. 2 : A french point of view

Second Step, G.N.S.S. 2 : but why ?

Today :

• European Civilian Users have access to the GPS Standard Positioning Service
• European military users (and US' Allies) have access to the Encrypted Precise Positioning Service
• European Industry is engaged in development and sale of User Equipement and Related Services
• Quite Confident in US ability to maintain and modernize GPS to respond to Civil and Military Needs when complemented by regional and local extensions.

But Sat Navigation raises serious concerns :
  • global
    => enabling technology, diversity of applications
  • technical
    => today uncertainties remain concerning availability and resistance to interference
  • security
    => widespread access to precise positioning for possible misuse (terrorism, criminal activities)
  • political
    => control of a critical infrastructure

Growing perception in Europe of the importance of :

- certification problems for high-risk applications
- liability aspects when safety of life or high value goods are involved
- security aspects related to possible misuse
- sovereignty aspects
- being heard when evolution of services is concerned

=> Lack of Control of the system is the central point !

Conclusion : right to the future

To look in 1997 for ill-balanced and short-sighted solutions allowing to make compatible :

- the use of systems designed under military requirements during the cold war to be totally controlled and operated from one single point

and

- the legitimate right of every state to get the adequate level of control over such a critical infrastructure

i s to have a very pessimistic view of what technology allows today !!

Europe does have the technology and industrial capability to promote a 2nd generation infrastructure :
- responding to its users ' needs and to different security, strategical concerns
- allowing to non-European countries or regions to leverage at limited cost the benefits from Sat Nav while keeping significant control of services made available in their own airspace.

We can be confident in the will of European States to play an active role at international level to make it become true at the begining of next century.

POSSIBLE EXTENSION OF THE EGNOS SYSTEM TO LATINAMERICA / POSIBLE EXTENSIÓN DEL SISTEMA EGNOS A LATINOAMÉRICA

M.L. de Mateo, A.L. Arias
Aeropuertos Españoles y Navegación Aérea (Aena)
División de Gestión Internacional de Navegación Aérea
C/. Juan Ignacio Luca de Tena, 14, 28027 Madrid (España)
Tel.: (34-1) 321 34 34, Fax.: (34-1) 321 31 19
e-mail: mdemateo@ugdna.aena.es

Carlos F. Garriga, Javier Ventura-Traveset
Agencia Espacial Europea (ESA)
Oficina de Proyecto GNSS-1
18, Av. Edouard Belin – 31401 Toulouse Cedex 4 (France)
Tel.: (33-5) 61 28 28 09 Fax.: (33-5) 61 28 28 66

Giorgio Solari
European GNSS Sécrétariat
Rue de la Loi, 223, B 4
B-1040 Brussels, (Belgium)
Tel.: (32-2) 230 90 39 Fax.: (32-2) 230 90 81

ABSTRACT

The development of satellite navigation for civil use poses many challenges involving technical, financial, legal and political issues. However, the extent of the challenge is reflected also in the potential benefits of the system. For civil aviation, the advantages brought by satellite navigation have already been identified by ICAO that recognised in 1991 that the primary stand-alone navigation system in the 21st century will be provided by a Global Navigation Satellite System (GNSS).

The first generation Global Navigation Satellite System, GNSS-1, as defined by the experts of the ICAO/GNSS Panel, includes the basic GPS and GLONASS constellations and any system augmentation needed to achieve the level of performance suitable for civil aviation applications.

The EGNOS (European Geostationary Navigation Overlay Service) programme is being developed by the European Tripartite Group (ETG) composed by the Commission of the European Union (CEU), EUROCONTROL and ESA with the objective to provide a Regional Augmentation Service for GPS and GLONASS signals over the ECAC (European Civil Aviation Conference) service area, constituting the European contribution to GNSS-1 or European SBAS (Satellite Based Augmentation System).

The EGNOS system is being designed to serve the needs of all modes of transport (including maritime, land mobile and civil aviation) in the European Region. It will be capable of satisfying all civil aviation requirements for the different phases of flight (en-route, terminal area, non precision landing and precision landing up to CAT-I), as presently developed by the ICAO GNSS Panel. The system will be compatible and interoperable with other augmentation systems, like Local Area Augmentation Systems (LAAS) and adjacent SBASs (the American Wide Area Augmentation System (WAAS) and the Japanese Multi-Satellite Augmentation System (MSAS)).

Aena, together with other European air navigation service providers, is actively participating in the EGNOS Programme, financing the development and operation of some of the EGNOS ground segment facilities. With this participation, Aena, together with the ETG, is promoting the early implementation of the CNS/ATM concept endorsed by ICAO in 1991, and is ensuring the provision of a better service to aeronautical users from Europe and other parts of the world.

The EGNOS system has a potential of extension into the LatinAmerican region by means of deploying dedicated facilities over this region and reusing some of the European core elements. This extension would provide for optimum use of the air space in this part of the world, allowing a rationalisation of the radio navigation systems in service at present. It would also provide benefits to all Europe-Latin America air traffic and would open opportunities of cooperation between Europe and Latin America in this field.

This paper describes on a technical basis different system architectural options for the extended system and summarises the associated performances. The

implementation of a Demonstration Programme is also proposed, as a vehicle to demonstrate under real operational conditions the technical capabilities of the extended system.

ABSTRACTO

El Programa EGNOS (European Geostationary Navigation Overlay Service) que ha sido impulsado y cuenta con el fuerte respaldo del Grupo Tripartito (ETG) que está compuesto por la Comisión de la Unión Europea (CEU), EUROCONTROL y la ESA (Agencia Espacial Europea), tiene como objetivo el de proporcionar un Servicio de Aumentación Regional para las señales GPS y GLONASS en el área de servicio de la CEAC (Conferencia Europea de Aviación Civil).

El sistema EGNOS tiene potencial para extenderse a la región de América Latina mediante el despliegue en esa región de estaciones terrestres específicas y la reutilización de algunos elementos centrales del sistema europeo.

Este documento describe a nivel técnico diferentes opciones de arquitecturas para el sistema extendido y resume los niveles de servicio asociados. Asimismo, y dentro de las actividades de la Organización de Aviación Civil Internacional (OACI) para la implantación de los sistemas CNS/ATM en Latinoamérica se propone un estudio de viabilidad para estudiar más en detalle la implantación del GNSS en Latinoamérica y una posible implantación de un sistema piloto como vehículo para demostrar la capacidad técnica del sistema extendido en condiciones operacionales reales.

1. INTRODUCCIÓN

Tras la aprobación por OACI en 1991 de los futuros sistemas para la navegación aérea (concepto CNS/ATM) y, en concreto, del concepto de Sistema de Navegación Global por Satélite (GNSS), y la necesidad creciente de hacer frente al incremento continuo de la demanda de tráfico aéreo y dar un eficaz servicio a los usuarios, se produce a nivel mundial la necesidad de evolucionar de los sistemas de navegación aérea actuales hacia los futuros, basados entre otros elementos tecnológicos, en satélites.

El Grupo Tripartito constituido por la Agencia Espacial Europea (ESA), la Unión Europea (UE) y EUROCONTROL ha puesto en marcha un Programa dedicado al desarrollo e implantación técnica de la componente europea al GNSS-1 (denominada EGNOS-European Geostationary Navigation Overlay Service). El Sistema EGNOS complementará a las actuales constelaciones GPS y GLONASS utilizando satélites geoestacionarios (segmento espacial) y una red de estaciones en tierra (segmento terrestre) desplegadas fundamentalmente en Europa. Con ello, podrán asegurarse en Europa unos niveles de calidad de servicio adecuados (Integridad, Precisión, Disponibilidad y Continuidad) para los usuarios del transporte aéreo, marítimo y terrestre.

Aena conjuntamente con otros proveedores de servicios de navegación aérea europeos, está participando activamente en el Programa EGNOS, contribuyendo en la financiación del desarrollo y operación de algunas de las estaciones pertenecientes al segmento terrestre. Con esta participación, Aena, conjuntamente con el Grupo ETG, está promoviendo la implantación del Concepto CNS / ATM aprobado por la OACI en 1991, asegurando la provisión de un mejor servicio aeronáutico para los usuarios tanto de Europa como de otras regiones del mundo.

Este documento refleja la capacidad de extensión del Sistema EGNOS a Latinoamérica mediante el despliegue en esa región de estaciones terrestres específicas y la reutilización de algunos elementos centrales del sistema europeo. Asimismo, dentro de las actividades del Grupo Regional de Planificación y Ejecución de Navegación Aérea para el Caribe y Sudamérica (GREPECAS) de la OACI y en el marco de su programa de cooperación técnica para la implantación de sistemas CNS/ATM, se propone la posibilidad de llevar a cabo un estudio de viabilidad para estudiar en detalle la implantación de los sistemas GNSS en Latinoamérica, así como la posible implantación de un sistema piloto que sirva como vehículo para demostrar la capacidad técnica del sistema extendido en condiciones operacionales reales.

2. EMPLEO DE LA NAVEGACIÓN POR SATÉLITE EN LATINOAMÉRICA.

La OACI creó en 1983 el Comité FANS con el objetivo de estudiar un nuevo concepto del Sistema de Navegación Aérea (SNA) del futuro, teniendo en cuenta las limitaciones del sistema actual, las múltiples iniciativas estatales y multiestatales (USA y Europa) y, la necesidad de armonización requerida por las aeronaves que, en general, vuelan a través de distintos espacios aéreos. Todo ello con el objetivo principal de hacer frente a la creciente demanda del tráfico aéreo prevista para los años venideros. Las conclusiones de este Comité fueron presentadas y aprobadas en el año 1991, en la 10ª Conferencia de Navegación Aérea de la OACI. La aportación teórica más importante fue la definición del concepto CNS/ATM (Comunicaciones, Navegación y Vigilancia - Gestión del Tráfico Aéreo) como instrumento global del SNA, que habrá de implantarse en un plazo de 20 años.

Los principales beneficios esperados de la implantación del elemento de navegación (GNSS) son, entre otros, los siguientes:

- Servicios de navegación de cobertura global (mundial) de gran integridad y precisión utilizables como medio primario (-> único) para todas las fases de vuelo.
- Posibilidad de navegar en todos los espacios aéreos del mundo utilizando un equipo único de navegación en el avión.
- Ahorros de costes al reducir o no implantar ayudas para la navegación basada en tierra.
- Mayor capacidad del sistema a nivel mundial (mejor utilización de espacio aéreo y aeropuertos).
- Mejor precisión de la navegación en tres y cuatro dimensiones.
- Posibilidad de uso conjunto con otros sistemas (ej. navegación inercial), en apoyo de la RNP.

La OACI creó en 1990 el Grupo Regional de Planificación y Ejecución de Navegación Aérea para el Caribe y Sudamérica (GREPECAS) con el objetivo de identificar deficiencias específicas que existan en materia de navegación aérea y búsqueda de medidas destinadas a su solución. En 1997 el GREPECAS en su séptima reunión (Lima, Octubre 1997) ratificó el plan regional de implantación de los sistemas CNS/ATM y en especial de los nuevos sistemas de navegación por satélite en las regiones CAR (Caribe) y SAM (Sudamérica) recomendando su uso por los Estados que deberán iniciar actividades de coordinación regional para su implantación.

El sistema de navegación aérea por satélite resulta especialmente interesante para las características físicas y tecnológicas de Latinoamérica dado que la región consta de amplias zonas selváticas y montañosas y esta constituida por una escasa red de radioayudas de carácter puntual y de difícil acceso. Por otra parte, el sistema de navegación actual presenta limitaciones importantes dado que la señal es tan sólo de alcance óptico con escasa precisión y nivel de fiabilidad. Existe el impedimento de aprovechar eficazmente los perfiles de vuelo en los límites de las Regiones de Información dado los diferentes criterios de separación aplicados por los Estados. Todas estas limitaciones del sistema actual dificultan la implantación de rutas directas y/o paralelas condicionando en gran medida la capacidad del espacio aéreo.

En la siguiente sección, se describe una posible implantación de los nuevos sistemas de navegación por satélite en Latinoamérica mediante la extensión a esa región del sistema europeo (EGNOS) resaltándose todos los beneficios asociados.

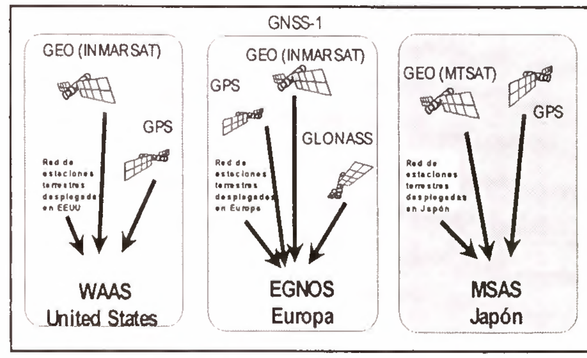


Figura 1. Componentes Regionales Actuales del GNSS-1

3. EXTENSIÓN DEL SISTEMA EGNOS A LATINOAMÉRICA

El Programa EGNOS es la iniciativa y componente europea al GNSS-1, también llamado SBAS Europa (Satellite Based Augmentation System), para aumentar (complementar) los actuales sistemas de navegación por satélite (GPS/GLONASS).

El sistema EGNOS está siendo desarrollado para afrontar la demanda de necesidades del sector aéreo, aproximaciones de no-precisión y aproximaciones de precisión catalogadas como CAT-1, y las de otros modos de transporte (marítimo y terrestre). El sistema será compatible e interoperable con otros sistemas de aumentación como los Local Area Augmentation System (LAAS) y los sistemas adyacentes SBAS (el sistema americano Wide Area Augmentation System (WAAS) y el sistema japonés Multi-Satellite Augmentation System (MSAS), ver **fig. 1**).

El sistema EGNOS consta de:

- Un segmento terrestre, que se compone de una serie de estaciones de monitorización (RIMS) desplegadas fundamentalmente en Europa y conectadas con estaciones de control (MCC) que realizan las funciones de procesado (calculo de correcciones), control y supervisión del sistema. La información procesada por las MCCs es transmitida a las estaciones de acceso a los satélites (NLES) para su difusión a través de los satélites geoestacionarios.
- Un segmento espacial, que se compone de transpondedores en cada uno de los satélites geoestacionarios INMARSAT III (IOR y AOR-E), discutiéndose en estos momentos el posible uso de los satélites ARTEMIS e Hispasat.

proporcionar un servicio de esas características. La figura 4, muestra la red de estaciones RIMS que se está considerando a nivel europeo y el área de servicio asociada. Como se puede ver en la figura 5, añadiendo 6/7 estaciones RIMS en Latinoamérica (con las localizaciones mostradas en dicha figura), se podría extender el área de servicio europea hasta prácticamente cubrir toda Latinoamérica. Es importante señalar que las simulaciones realizadas son preliminares por lo que sería necesario llevar a cabo análisis más detallados (tal y como se propone en el siguiente apartado) para corroborar los resultados obtenidos.

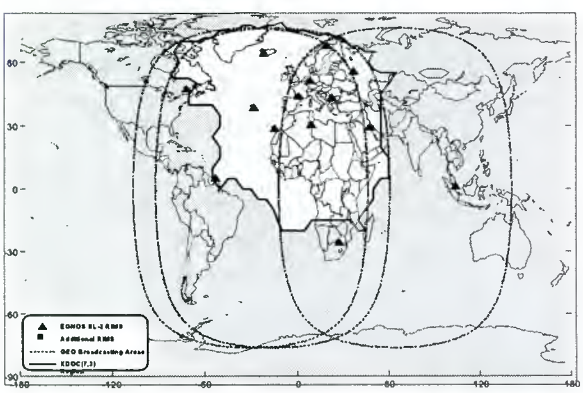


Figura 4. Red europea de estaciones RIMS para un servicio de NPA (nivel 2).

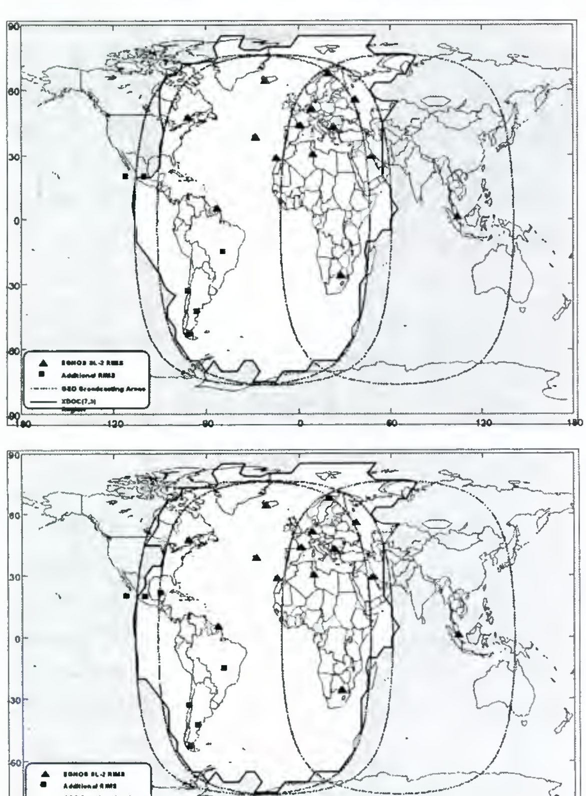


Figura 5. Red latinoamericana de estaciones RIMS para un servicio de NPA (nivel 2).

De producirse la extensión de EGNOS a Latinoamérica, el futuro sistema de navegación aérea quedaría armonizado y optimizado incrementado la capacidad del espacio aéreo sin detrimento de los niveles de seguridad y haciendo frente a la futura demanda del transporte aéreo. Dicha extensión proporcionaría un uso óptimo del espacio aéreo en esta parte del mundo, permitiendo la racionalización del sistema actual de radioayudas terrestres para la navegación. Además de esto, proporcionaría beneficios operacionales para el flujo de tráfico aéreo Euro- Latino Americano, y abriría oportunidades de cooperación entre Europa y América Latina en el campo de la navegación por satélite.

4. PROPUESTA DE ESTUDIO DE VIABILIDAD E IMPLANTACIÓN DE UN SISTEMA PILOTO.

Dentro del contexto de trabajo del GREPECAS y del futuro proyecto regional de cooperación técnica de la OACI para la implantación de los sistemas CNS/ATM en las regiones CAR (Caribe) y SAM (Sudamérica), Europa (a través del Grupo Tripartito) ha identificado dos posibles áreas de cooperación consistentes en un posible estudio de viabilidad para estudiar más en detalle la implantación de los sistemas GNSS en Latinoamérica, y la posible implantación de un sistema piloto.

Una vez que dentro de las actividades del GREPECAS, se hubieran identificado los requisitos operacionales latinoamericanos (analizándose la situación actual, planes de ampliaciones futuras, estructura del espacio aéreo, usuarios y flotas y tendencias futuras), el Grupo Tripartito podría dar apoyo en los análisis de las diferentes arquitecturas estudiándose en detalle sus ventajas e inconvenientes

Dichas actividades de apoyo incluirían propuestas de planes de implantación con un calendario de instalación de los equipos e infraestructura, el estudio de posibles escenarios financieros y actividades de divulgación y entrenamiento.

Por otra parte, la implantación de un sistema piloto serviría como vehículo para demostrar la capacidad técnica del sistema extendido en condiciones operacionales reales. Sería transportable y permitiría analizar las prestaciones del sistema y comprobar si estas se ajustan a la definición del mismo. Dicho sistema se compondría de:

- TBD RIMS portátiles con terminales VSAT.
- Conexión de las RIMS portátiles con MCC europea (Test Bed) mediante enlaces VSAT.
- Avión de ensayos en vuelo
- Recogida y análisis de datos

5. CONCLUSIONES

Este documento refleja la capacidad de extensión del Sistema EGNOS (o componente europea del GNSS-1) a Latinoamérica, con diferentes opciones de arquitecturas e importantes beneficios asociados, mediante el despliegue en esa región de estaciones terrestres específicas y la reutilización de algunos elementos centrales del sistema europeo. Asimismo, dentro de las actividades GREPECAS de la OACI y en el marco de su programa de cooperación técnica para la implantación de sistemas GNSS, se propone la posibilidad de llevar a cabo un estudio de viabilidad para estudiar en detalle la implantación de los sistemas GNSS en Latinoamérica, y la posibilidad de implantar un sistema piloto que sirva como vehículo para demostrar la capacidad técnica del sistema extendido en condiciones operacionales reales.

EUROPEAN CONCEPT FOR AN INDEPENDENT REGIONAL NAVIGATION SATELLITE SYSTEM. A Possible Optimisation for Euro-Latin America Zones

L.F. Alvarez-Gascón, J. Cosmen, J.R. Martín

GMV, S.A.
Isaac Newton 11, P.T.M. Tres Cantos, E-28760 Madrid, Spain
phone: + 34 - 1 - 8072100, fax: + 34 - 1 - 8072199, e-mail: lalvarez@gmv.es

ABSTRACT

The present global navigation satellite systems, GPS and GLONASS, while offering to civil users a invaluable service that has led to the development of a huge market for user equipment and services, have intrinsic limitations that raise the need for a civil GNSS. This future system should provide for a service satisfying the needs of a multimodal community of users, and satisfy all relevant institutional, social and political concerns. The European institutions have undertaken an active policy in support to the European contribution to GNSS. This paper presents a candidate system architecture for the European Navigation Satellite System (ENSS), based upon GEO and IGSO satellites. The proposed design allows the implementation of the future global satellite navigation service by means of international, regional and low-cost systems. As it is shown, some variations in constellation design allow to adapt service coverage area. The study case is devoted to the combined European and LatinAmerica regions.

Satellite navigation: a market reality

The fact that GPS has become the first truly global utility is a well known common place today. An ever expanding potential applications list, amazing market growths, business opportunities not conceived just a few years ago, all of them founded in an ever expanding community of users, have brought satellite navigation to the forefront of space sector offer to the society. At the same time, multiple challenges were posed by this wave of change too. Like in many other fields of technology, reality menaces to surpass the ability of institutions to effectively manage the change.

Today a classical reference, data from the US GPS industry council depicted in 1995 an exciting horizon for the GPS equipment market. Amongst these data, we will remark the increasing relevance of transport applications, particularly land transportation, and cellular communications. For these market segments, we will furthermore point out the potentially huge consumer base, their sensitivity to price and the joint consumption of navigation with other complementary services like mobile communications.

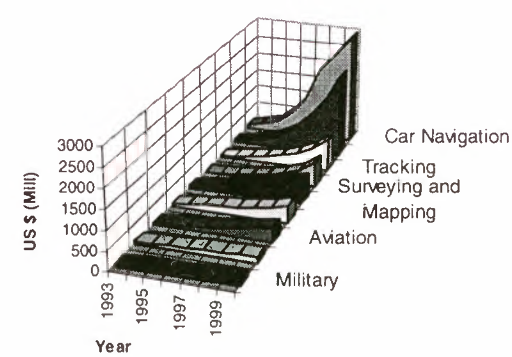


Figure 1.- GPS market projections

Almost two years after announcing its somehow uncertain full operational capability, GLONASS offers further service opportunities, particularly well appreciated within Europe and brought closer to the customers by a growing offer of receiver equipment.

Accompanying this market development, the services offered by either of the two systems, and even the combination of both, are subject to the deep scrutiny of their abilities to fulfil all user segments needs. Very often, this analyses concludes that there is a need for the so-called augmentations, i.e. complementary satellite or ground-based navigation services that provide for increased performances.

Looking to the future, whether GPS and/or GLONASS, adequately evolved and potentially complemented by the required augmentations, are the final answer for the foreseeable horizon of satellite navigation, or

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

alternatively new options are needed, raises strong controversy.

This paper supports the idea that the present scenario strongly recommends to undertake the endeavour of improved, diverse international navigation systems. The rationale will start by highlighting the limitations of the present services from a variety of points of view, of which the technical performance is just one component, and not necessarily the most important one. Latter on, the strategy for an institutionally-led promotion of new services to fill the identified gap will be delineated. We will conclude with a summary description of a system which is coherent with the selected strategy.

The aimed GNSS

We should start by being conscious that shaping the ideal GNSS must account for the variety of social interests associated to all involved citizens groups:

- service users, demanding the right performances at the best price
- tax payers, willing to see their contributions being allocated to fair and efficiently managed administration initiatives
- employees or shareholders of the industry and services, requesting employment and business opportunities
- members of a sovereign state, pursuing the respect and exercise of their rights, including security, within the international community

Once aware of the ample dimension of the problem, we can leave momentarily apart the fair interests of the stakeholders, and concentrate upon the service users, who are served in a first instance by the right combination of technical performances, driven by elements like:

- Good signal properties (free from intended or non-intended interference, data rates, able to discriminate propagation effects, measurements quality, fast acquisition)
- Good satellite geometries, in the applicable scenarios (e.g. even in urban canyons)
- Accurate navigational data
- High system and service availability, continuity, integrity
- Suitable receiving equipment

However, the above performance dimensions should not lead us to forget other essential components of the service, particularly when safety or key economical interests are concerned, like certification, liability, long term stability, standardisation, sovereignty and security

International civil control and frame agreements have been raised frequently as the necessary answer to these concerns. Even opponents to this approach, presumably supporting national interests, would like to see the multiple states co-operating in certification and law enforcement to protect its service.

From the economic analysis of the considered GNSS mission further critical issues come to stage, like funding, cost allocation and, eventually, cost recovery mechanisms.

Just to reflect the complexity inherent to navigation services provision, which of course come together with opportunities for additional service and business, we should recall the almost sure joint consumption with other services, provided potentially by multi-mission constellation

The above reflections illustrate us of the multidimensional nature of the aimed GNSS service, which should therefore address all above technical, social, institutional and economic issues.

GPS and GLONASS, a reality to improve

Despite any proposed improvement to the GPS service, a tribute of admiration has to be paid to the talent that brought this concept to reality. Moreover we should recognise that, as a result of political decisions and technical achievement, GPS authorities are driving their service on the road of increasingly satisfied customer demands, and the mid-term horizon seemingly deserves, with no direct fee to the user:

- A SA free service
- Access to dual frequency, at least to a second carrier
- Improved navigation data
- Progress in local jamming techniques as selective denial approach to serve security concerns

Still, some technical elements of this future service, like built-in integrity, number of satellites and even constellation design may not be optimal. The service augmentations will remain as a necessary complement for many users. But for other key issues, the way ahead remains unclear:

- Concerns about the certification of a protected system which can not be fully accessible are not less than challenging

- The primary GPS mission remains subject to national military control
- Liability aspects have not been addressed
- Funding and long term stability just based on declarations in national forum, like March 96 US Presidential Decision Directive (PDD)

In addition to GPS, the present also brings us GLONASS which, in combination to the US system, contributes very much to make the GNSS concept closer to reality:

- technically, by means of improved performance
- somehow institutionally, providing for a diversified service source
- further economic perspectives for user equipment industries

Anyhow, some decisive concerns on GLONASS remain:

- Multiple technical issues, like availability or continuity
- It is also a national military system
- Funding stability is uncertain

The real chances for the occasionally suggested Europeanisation of GLONASS as a way to work out the solution to these difficulties, are more than doubtful as such, although interesting perspectives for co-operation with Russia exist and must be further explored.

In short: multiple issues remain to be solved yet before GPS (and potentially GLONASS) becomes the backbone of GNSS, despite US confidence in building a de-facto, market driven standard.

To describe the potential future scenarios for satellite navigation services, it is convenient to consider three dimensions at this stage:

- Nature of service provider for signal in space: national, international clusters, global international
- Number of service sources: single, multiple
- Geographical coverage: regional, global, mixed

The option promoted by US policies (single, global, national service) would be hardly acceptable to European Union (EU) states and potentially to many others. For instance, the guidelines within March 96 US Presidential Decision Directive, like that backing the "no direct user fee" principle, should be developed in the context of international agreements. Moreover, the preceding RAND report, even if just playing an advisory role, depicts a clear US will for world wide dominance not only for security concerns, but also explicitly for economical objectives. In this perspective, even a status quo built upon GPS and GLONASS (multiple, global, national services scenario) seem to be more preferable for Europe.

Under this competitive scenario set up by US, it would be naive to assume one single global international service, in which EU eventually would share development and funding responsibilities, as the backbone for present European strategy. Like any other group of nations willing to play a role in GNSS services and industries, Europe is forced to build the fundamentals of its position, as a minimum, upon key capabilities which could allow to develop and finally converge towards a well balanced scenario. Regional satellite navigation systems with growth potential are a suitable solution to sustain a long term strategy, because:

- They involve a lower investment than a global system, both in ground and space
- They can support a market pull from the local users, which have access to multiple (i.e. enhanced) navigation services
- Institutional issues are eased by the limited geographical scope of the service
- They have the potential to co-ordinate efforts from diverse geographical areas

Dealing with the implementation of this strategy, we would like to develop in the next paragraphs some reflections on some key issues:

- The role of institutions
- The economics of the intended space mission
- Evolution or revolution

<u>Fundamentals of active public policies. The EU case</u>

After pertinent deliberations, EU has already adopted high level political decisions in support to active policies to make the European contribution to GNSS a reality, namely ENSS. We could still wonder why, in sight of the US promised scenario of a free access to the world community of civil users, should other countries administrations, EU in this case, promote new services.
It is quite straightforward to propose such answers:

- Better quality of life to citizens by means of improved service levels including safety and civil control. In this context, let us just recall that a service whose stability is not conditioned to external affairs is already an improved service.
- A new system offers job opportunities to the space industry, which were not available for the systems developed abroad in the frame of

military programs and, eventually, would be closed again in future systems enhancements

- ❑ Additional services create additional opportunities for the local industry, already from the supply side but also from the demand, as they would be pulled by a local market enjoying better service (really or perceivably: a foreign service is a matter of concern for certain users)
- ❑ All institutional responsibilities, including security, can be better exercised via a system in which at least partial control is exercise. Funding is the rightest way to ease such control.

Naturally, these initial motivations must face the ever challenging issues of budgetary limits. For this, and to ensure proper involvement of industry and service providers, public and private partnership should be searched as implementation strategy. An essential area of investigation is the business case for this type of systems.

ENSS: where is the business case?

GPS free availability to the users initially mines a business approach from private or public investors to any additional GNSS. The rationale for the US approach to the funding of its service must be found both in the externalities of such investment (e.g. deterrence for rival military systems, support to consolidated local manufacturing industry) and in the actual doubtful feasibility of imposing charges to the users following an (unknown) accepted and practical cost allocation scheme. For GLONASS, in addition to all that, we should recall that GPS was already there, and free of charge. Noticeably, none of these factors will necessarily last indefinitely for both services. Moreover, we should realise that a funding policy change should not need to affect the approach of no direct fee to the users, but future pressures to foreign governments to sustain such a widely spread public service might be enough.

To say the least, chances for a GNSS service competing with GPS (and GLONASS) on a commercial basis, i.e. recovering total or partially the costs directly from the users, remain uncertain at the moment. This uncertain possibility should be backed eventually by advantageous performances convincing the user to pay for this extras, of which present DGPS augmentations can be an example. Moreover, the possibility of conceiving the intended service as complementary to existing GNSSs, instead of a radical competitive alternative always remains there. One way or another, unless such a definitive service improvement is demonstrated to the user, always in relation to his actual needs, any direct fee approach risks placing the novel service immediately out of the market, particularly for those majority of users who are highly price sensitive. Deep yet broad market analysis, addressing the key issue that the user rarely wants merely a navigation service as such, can bring some light to this business perspective.

Until the multiple question marks about the navigation service business case are cleared up eventually, the public institutions of those countries willing to be players in the future scene will have to undertake necessarily the initiative to promote their contribution to the GNSS services development. Naturally, this should be accompanied by an actively support to the early involvement of private initiatives. The rationale behind current US and Russia position and policies can inspire this early determination, particularly in EU, from the institutions.

More than just a new navigation system

System studies for candidate new GNSS raise natural enthusiasm from the space industry and, being a basic infrastructure, the interest from public institutions and administrations. A lack of a parallel concerns for the development of user segment and, in particular, receivers is essentially condemning to failure the whole mission, for which any active policy must contemplate this fact. Fortunately, most of the industry and associated services business resides in the user segment, as a remainder and strong justification for such policies. As a rule of thumb, total costs for a GNSS system development, in the order of 2 billion $, has been equalled by the yearly receivers market already within the 90s. This figure illustrates, by the way, that should all the users be charged for using the service, just a moderate increase of his total costs would be generated.

A recurrent issue in European reflections on the strategic position of its industry when compared to US GPS manufacturers is that the evident US hegemony is directly a result of the national undertaking of its own navigation system. Facts are seemingly supporting this assert:

- ❑ GPS receivers industry heavily dominated by US manufacturers
- ❑ GPS equipment sales dominant at US market, seconded by Japan, at a great distance from European market

Is this US hegemony a result of the development of GPS system? Almost undoubtedly yes, but a similar mechanism is not to be given for guaranteed for any future development. The situation of GLONASS and Russian industry, although evidently can not be analysed under the perspectives of market economies, brings us a dramatic counterexample.

Probably a complete answer has to contemplate also two fundamental additional drivers for this differential success up to date of US with respect to EU and Japan:

- the complementary investments made in US in user segment, in an exemplary exercise of public and private sharing of roles,
- the development of the home market (initially military, then a civil community confident in a national system).

It is therefore of utmost importance to recall that the logic can not be immediately reversed: development of a new navigation system, open as the civil GPS service is, does not guarantee success for the local user equipment industry. Complementary measures and factors would be required. Initial purchases by institutions, following US example, and the dynamic EU components and applications industry can boost the receivers industry development even under the threat of their US competitors. However, the development of such industry has to be initiated already under the unfavourable present conditions. Active public policies should favour these undertakings.

GNSS-1 and GNSS-2: two alternative ways?

Almost immediately pursuant to the definition of the GNSS concept, the notions of first and second generation GNSS came to the stage, more noticeably within Europe than in other forum. Arguably, this reflects some a priori attitude towards the future of navigation systems. While consolidated players adopt a follow-on strategy, in which GPS, subject to the required evolution, would become the GNSS, some of the new entrants favoured a more radical approach and would want to see a GNSS-2 essentially different from present GPS and GLONASS. This latter choice has a recognisable rationale: the present systems will provide navigation services during the second decade of 21st century based upon concepts developed in the 60s and technologies of the 90s. There should be quite clearly room for more novel approaches offering improved service.

Should the feasibility of any "revolutionary" approach be demonstrated, it would be in support to the competitiveness of the proposed system, always demanding recognisable differential advantages to offer to the user with respect to the consolidated options.

On the other hand, changes in the service must face the fact that a wide customer base already exists, not to mention the regulatory and standardisation issues which can be of paramount relevance for some communities of users like aviation. The issue of backwards compatibility deserves therefore serious consideration. However, it has to be carefully weighted not to create artificial boundaries to the development of the future navigation systems. When the market base is considered, it is clear that most of the customers are not necessarily loyal to a certain service option. The service renewal cycle can be very well driven by the period of renewal of consumer electronics, like in car navigators or mobile phones, typically in the order of five years, or even shorter if it is a subject of software upgrade.

From the above considerations, two main streams of opinion have consolidated in Europe:

- that favouring an evolutionary transition from the present systems, initially via augmentations to GPS and GLONASS, like EGNOS and eventual breakpoints in the future, once a more solid position is built
- a second one fuelling a radical option for a straight way towards the so called GNSS-2, supposedly to reduce to the maximum possible extent the field taken by GPS.

We will just state that such a dilemma GNSS-1 versus GNSS-2 is not real from a strategic perspective today. Moreover, we will affirm that the proposed ENSS does not necessarily align with the "GNSS-2" option. In effect, even if the roadmap of future European contribution to GNSS drive us to completely new concepts, namely GNSS-2, this road must be build step by step. The present GPS and GLONASS augmentations, GNSS-1 if preferred, and particularly EGNOS, are more than advisable stages toward such an ambitious goal, which hardly could take less than ten years to achieve assuming full operational capability.

ENSS: a necessary and feasible option

Past paragraphs have tried to argue that:

- the future of GNSS must be plural and open to the international community from the service provision optics, either implemented at a global scale or stepwise from regional agreements
- the market could support coexisting (competing or complementing) systems bringing additional added value to the users, despite present no-fee approaches spoil seriously any business case
- navigation service is multidimensional, of which technical performances and cost are only the most apparent attributes, but depending on the user communities must be accompanied by additional complements like liability, certification or law enforcement capabilities

- ❑ multiple technical approaches exist, the selection of which must follow the selected strategy to develop.

Europe has undertaken its responsibility in contributing to the future GNSS, without initial prejudices and targeting to a fair and fruitful international co-operation. High level political support from governing institutions of the European Union has been achieved for active public policies promoting this contribution.

In the search of potential implementation options for the European contribution to GNSS, several mission analysis studies have been carried out by European industry and institutions, noticeably those promoted by the European Commission and the European Space Agency. Today, we are aware that the selected system option is not only to provide the best technical and economical performance, but also be coherent with and support the development of the EU international strategy. In short, we propose this concept to be:

- ❑ technically competitive, providing the desired performance levels to the target market niches, including safety
- ❑ supportive of service commercialisation, including potential for composite services
- ❑ economically affordable
- ❑ supportive of international co-operation, built stepwise upon initial regional groups of interest
- ❑ with the potential to grow

Amongst the considered systems architectures, and particularly in what platform and constellation are concerned, one option has emerged as particularly well suited: that built upon a constellation of IGSOs and GEOs satellites providing service initially upon Europe.

ENSS: General Objectives

The ENSS system has been thought to provide to the European community a navigation service capable to satisfy to a wide variety of users and necessities. The spectrum of applications comes from users concerned with safety of life applications, like civil aviation, railway or maritime regulators, to the many "non safe applications" demanding a better performance than the one provided by the current systems.

Expanding the high level concepts stated in previous section, the ENSS system is build up around the following major design objectives:

- ❑ For the referred user concerned with the safety of life, ENSS will offer an entirely European, completely independent under civil control, satellite navigation system.
- ❑ For the rest of applications, ENSS will offer an enhanced performance, therefore stimulating European markets and technologies.
- ❑ ENSS shall be a regional system. The aimed coverage area shall be the ECAC (European Civil Aviation Conference) zone or a significant part of it. However, it is also required that the ENSS could gradually evolve towards a world-wide coverage system.
- ❑ ENSS shall be possible with a reduced amount of resources (mainly number of satellites) with respect to world-wide systems thus providing a cost efficient solution for the coverage area.

ENSS Signal and Ground Segment: a first glance

Definition of ENSS signal is currently being deeply investigated by ESA. In the existing baseline, satellites will broadcast signals in three L-band frequencies, allocated at 1589.742, 1561.098 and 1215.324 MHz. BPSK modulation has been selected with CDMA access scheme. The use of these three frequencies allows the implementation of new techniques for optimising the user performance such as Three Carrier Ambiguity Resolution (TCAR).

The Ground Segment is composed of a Mission Control Centre and specific elements as required for providing the navigation service. Those second elements include Tracking Stations widely distributed in the coverage area and a Master Processing Centre (MPC) where navigation data is computed. Ground Based Integrity is proposed based on the use of Integrity Monitoring Stations whose data is also processed at the MPC. For the uplink of both, platform commands and navigation data, a set of Feeder-link Ground Stations (FGS) are also included. All ground elements are properly connected through a Terrestrial Network.

With the proposed signal and ground segment design, range measurements with an error (UERE) about 2 meters (1 σ) are achievable for an average satellite elevation of 30 degrees.

ENSS Constellation

According to the stated ENSS objectives, proposed constellation is based on satellites flying in Geostationary (GEO) and Inclined Geo-Synchronous Orbits (IGSO). These orbits allow the provision of the required regional service with minimum number of satellites.

The GEO orbital shape is well known due to its simplicity, and also due to the fact that it has been widely used for telecommunication. IGSO orbits are a generalisation of the GEO orbits, where a certain inclination angle with respect to the equator has been given to the orbital plane.

To design the nominal constellation an optimisation process has been followed. The proposed constellation includes only 6 nominal satellites, 3 IGSO + 3 GEO. In order to guarantee the required service availability, spares satellites have to be also included. The ground-tracks of the finally selected nominal constellation are shown in the next figure,

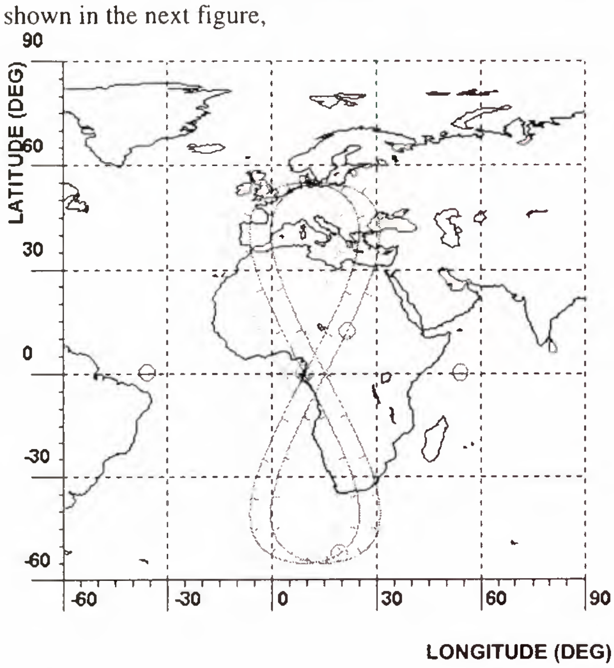


Figure 2: Ground-tracks of the ENSS constellation.

ENSS Performance

ENSS performance are derived from the proposed signal, ground segment and constellation design. ENSS is able to provide, in absolute mode, sole means navigation system for civil aviation users for 'en route' flight phases (up to RNP1) and non precision approach (NPA). In addition vertical navigation is also provided with a high accuracy but not reaching current CAT-I requirements as later presented.

Combination of the range measurements with the corrections provided by a local area station will result in a precision able to satisfy CAT-II. Some new techniques may allow to improve accuracy up to CAT-III requirements.

Service integrity is guaranteed with the use of specific ground infrastructure. According to the current knowledge of the proposed integrity mechanisms, it is envisaged that availability of service will be driven by the required vertical protection limit rather than by the vertical accuracy. However accuracy analyses as later presented are understood to well describe the overall system performance.

Simulation allows the estimation of expected ENSS performance. Following figure shows the worst (guaranteed) vertical navigation errors obtained at each location of the ECAC area when using absolute navigation. Horizontal performance are typically better than the vertical ones that together with the more demanding vertical requirements, makes its analysis not relevant for the constellation definition.

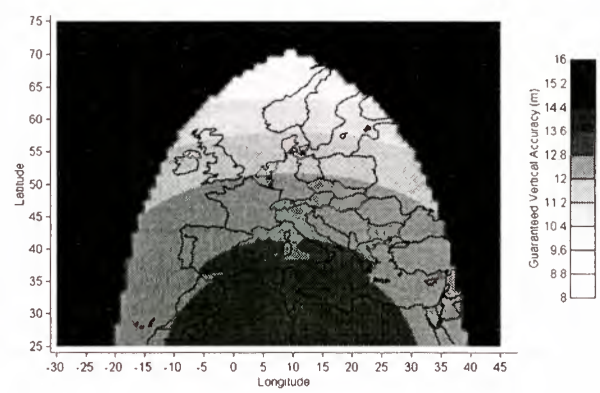


Figure 3: Guaranteed vertical Accuracy (95%).

The ENSS coverage area can be observed clearly in the above figure. This is the shadowed area limited by the GBA of the two extreme GEO satellites, which covers the central ECAC. In the black area, also belonging to the ECAC, a service is also provided, but with reduced availability.

The performance can be strongly improved locally by means of the addition of auxiliary equipment. If a LAD station is added, the presented accuracy could be reduced between 4 and 5 times taking advantage of the differential corrections given by this station. If the LAD corrections are combined with precise phase measurement, the accuracy in the positioning could be potentially reduced down to the decimetre level thanks to the use of the TCAR technique.

The combination of ENSS with other GNSS system will provide a synergy that allows high performance for non safety applications even under hostile environments such as urban canyons, thus improving considerably the performance achievable nowadays. In particular, combined use of ENSS and GPS satellites allows a good quality of service (95% horizontal accuracy below 40 metres in most of ECAC) when considering masking angles of up to 25 degrees.

Service Coverage Expansion

Although the ENSS was designed to provide a regional service over the ECAC, the symmetry of the GEO and IGSO orbits with respect to the equator (see ***Figure 2***), favours the expansion of the service to Africa by properly complementing the ground segment infrastructure with a relatively reduced cost.

The proposed ENSS system is regional, but also scaleable as it was required as design objective. The service area can be expanded adding other ENSS-like systems in other regions of the globe. With three systems like the one proposed, overall coverage would be achieved.

Moreover, a non negligible synergy effect between the different regional systems would appear, thus improving substantially the performance shown in the above figure. This synergy is caused by the fact that a ENSS user can track not only the six nominal satellites, but also some of those ones belonging to neighbouring ENSS-like systems. That synergy would also allow to provide the same performance with a more reduced constellation.

Simulations have anticipated that a global ENSS could provide a positioning accuracy in absolute mode approximately twice better than the provided by GPS-SPS nowadays. This is justified by an enhance signal structure based on the use of three carriers, higher chip-rates for the generation of the code measurements, and an optimised constellation design based on IGSO and GEO orbits.

Optimisation for ECAC-South-America Area: ESANSS

Simplest solution to provide a navigation service of the proposed performance over Latin-America would be the implementation of a "twin" ENSS system displaced 75degrees towards west. This solution allows for a performance like the one shown in ***Figure 3*** in the ECAC, Africa, North and South America, and an improved performance over the Atlantic ocean.

This solution is conceptually simple. The only drawback is the fact that duplication of the number of satellites is required, thus reaching a total of 12 (6 IGSO + 6 GEO). This number of satellites allows similar performance over Africa and North-America. In this context the following question arises: would it be possible to find a constellation providing the required service over South-America and ECA while reducing the number of satellites?

Here onwards, initial investigations towards an optimised constellation for the mentioned coverage area is outlined. The presented results have to be understood as a starting point for future analyses. A major effort is still required to reach similar level of confidence than the one achieved for ENSS.

As explained before, the IGSO orbits have a symmetric shape with respect to the equator, as the two lobes of the 'eight' are identical. The first optimisation we can imagine is based precisely on trying to break this symmetry, displacing the down lobe to the West until putting it over South-America. This is feasible by introducing appropriate eccentricity on IGSO satellites. It is important to highlight that this eccentricity has to be limited as it introduces some additional constraints on the system such as power differences over Earth surface, complexity of orbital control, higher Doppler, etc. These limitations are however possible to be technically solved whenever eccentricity is not very large. In our analyses we have constrained the analysis to eccentricity values of 0.1.

If we repeat this operation with the three IGSO satellite of the ENSS constellation, it could be possible to cover the ECAC with the Northern lobe of the ground-track, and South-America with the Southern lobes. In order to provide similar levels of service as the ones described for ENSS, additional GEO satellites have to be introduced.

The next figures shows the ground tracks and the performance of the optimised constellation where two additional GEO satellites over America are introduced and giving a small eccentricity to the 3 IGSO orbits of the nominal ENSS constellation. This implies a total of 8 nominal satellites. The resulting constellation is called ESANSS (European & South-America Navigation Satellite System).

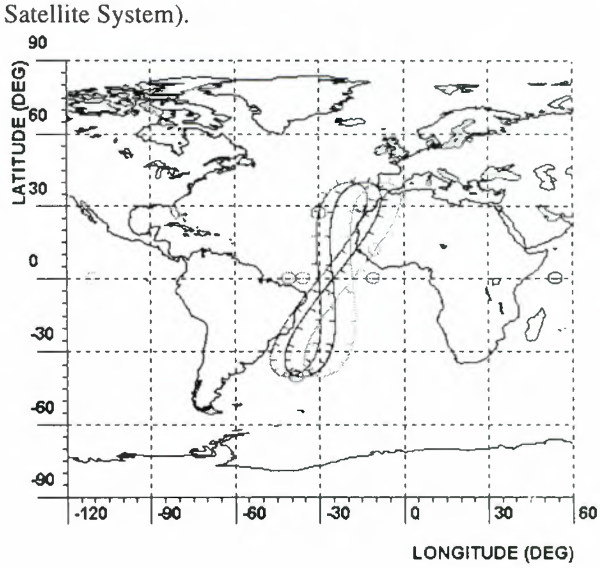


Figure 4: Ground Track of ESANSS

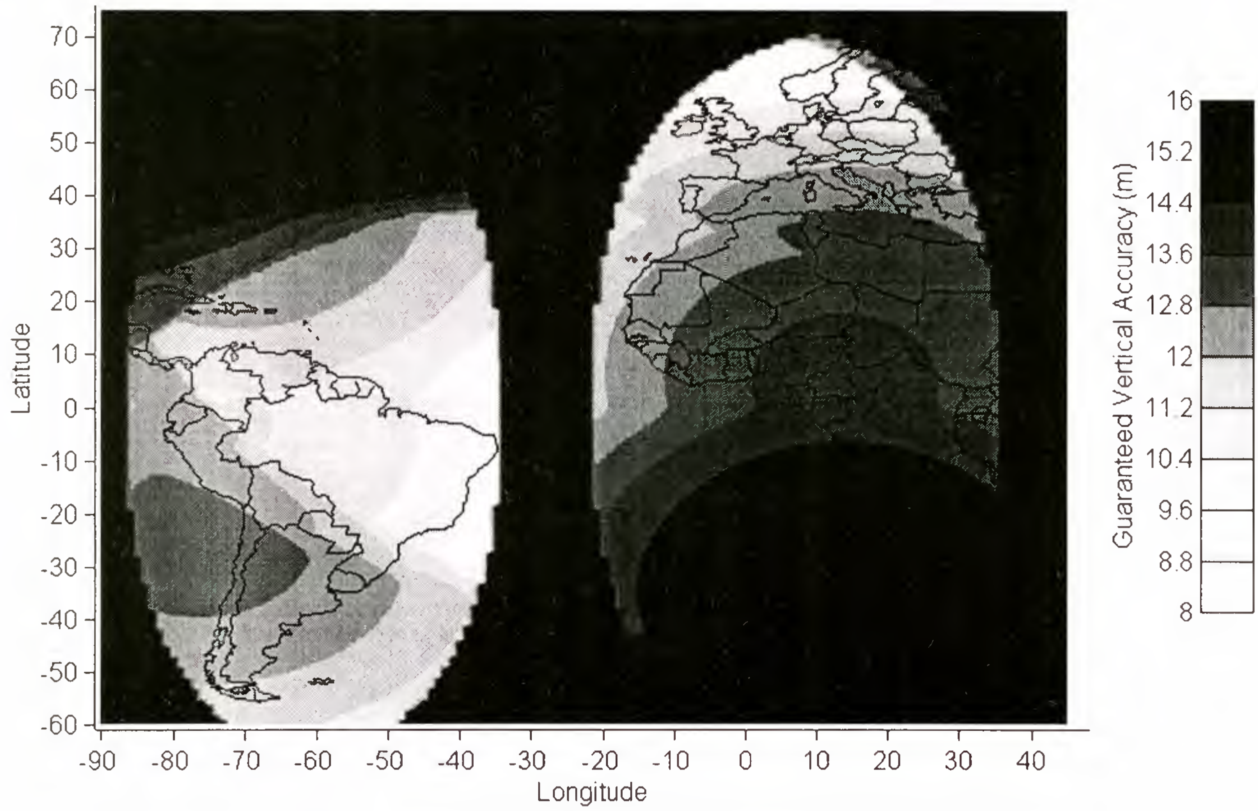


Figure 5: Guaranteed Vertical Performance of ESANSS

Conclusions

This paper has argued that the limitations of the services provided by present GNSSs have to be overcome by means of improved systems, to be ideally implemented in the frame of international co-operation. Europe has already launched initiatives for the development of its contribution to the future of satellite navigation. The presented ENSS concept supports the strategy based upon co-operation, improved performances and low-cost, based upon a regional system with growth potential. The basic architecture can be optimised for a service coverage area comprising LatinAmerica and Europe at a reduced cost.

ENSS, as the proposed European navigation system, has been briefly presented in terms of objectives, major design issues and performance.

A constellation covering ECAC and South America has been outlined constituting a technical starting point for potential future collaboration between these two regions in the area of satellite navigation.

Acknowledgement

Authors want to acknowledge the technical support provided by Mr. Pablos (ESTEC) which has made possible the present paper.

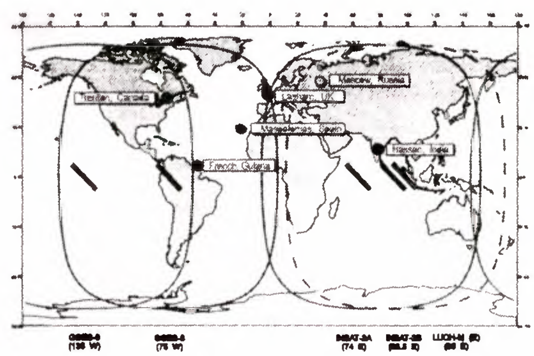
FUTURE ENHANCEMENT LEO COSPAS-SARSAT SYSTEM

P. Lafuma & B. Mathieu

CNES, Paris, France

- Many evolutions year after year
- SARSAT 2 (enhanced performances) aboard next NOAA launch (1998)
- Densification of the constellation, dedicated micro-satellites
- next generation SARSAT 3 already being studied

GEOSAR COVERAGE GEOLUT



FUTURE ENHANCEMENT NEW CONSTELLATIONS

"BIG LEO", "LITTLE LEO" and "HIGHWAY"

- HOPE
  - world wide coverage
  - real time
  - return path
- DOUBT
  - suddenness of accidents (no communication before, and after ?)
  - absolute priority allocated ?
  - false alarm problem
  - institutional "integration"

LEO LIMITATION

One of the most important element fo any successful SAR operation is the timely receipt of the initial alert.

LEO : limited access to the satellite
- average waiting time ~ 1 hour
  (between beacon activation and reception of the distress by the LUT)

SOLUTIONS :
- more satellites
- geosationnary system (GEOSAR)

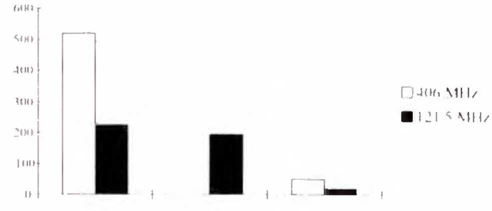
GEO LIMITATION

TECHNICAL POINT OF VIEW - GEOSAR useful but :
- absence of independant positioning capability
- high latitud coverage limitation
- low link budget

THE GEOSAR CAN'T BE AN ALTERNATIVE TO LEOSAR

INSTITUTIONAL POINT OF VIEW
- agreement limited to LEOSAR
- preliminary test achieved
- demonstration and evaluation plan under way
- intitutional GEOSAR integration in progress

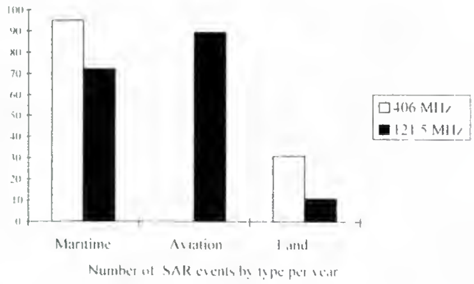
NUMBER OF PERSONS RESCUED



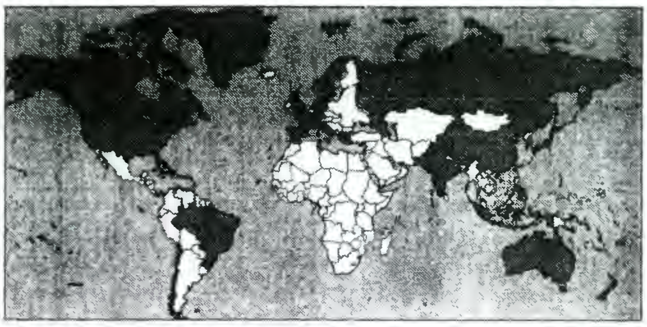
Number of Persons Rescued per year by type of SAR event

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

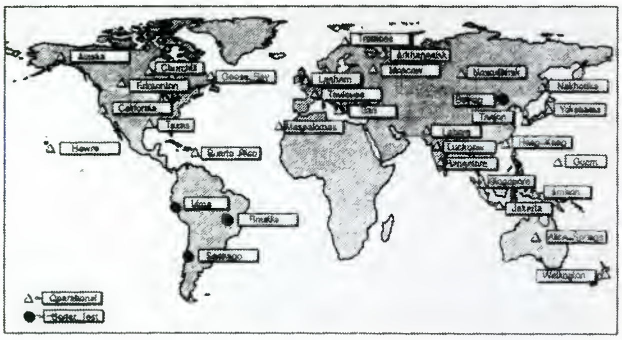
NUMBER OF SAR EVENTS



STATUS OF PARTICIPATION



COSPAS-SARSAT LUT LOCATION



INTERNATIONAL PROGRAMME AGREEMENT (2/4)

- FINANCIAL MATTERS
  - no exchange of funds
  - common costs shall be shared equally by the Parties
  - reception and transmission of distress alert free of charge
- STRUCTURE
  - the Council
  - the Secretary
- NON-PARTIES STATES
  - ground segment providers
  - user states

INTERNATIONAL PROGRAMME AGREEMENT (4/4)

- EURO-LATIN AMERICAN PARTICIPATION
  - GROUND SEGMENT PROVIDERS
    - Brasil (hosted the last Cospas-Sarșat Joint Comitee)
    - Chile
    - Italy
    - Peru
    - Spain
    - UK
  - USER STATES
    - Denmark
    - Germany
    - Greece
    - Netherlands
    - Sweeden
    - Switzerland

CNES CONTRIBUTION TO COSPAS-SARSAT AND FUTUR ASPECTS

- COSPAS-SARSAT today
- CONTRIBUTION OF GEO SATELLITES
- FUTURE ENHANCEMENT OF THE SYSTEM

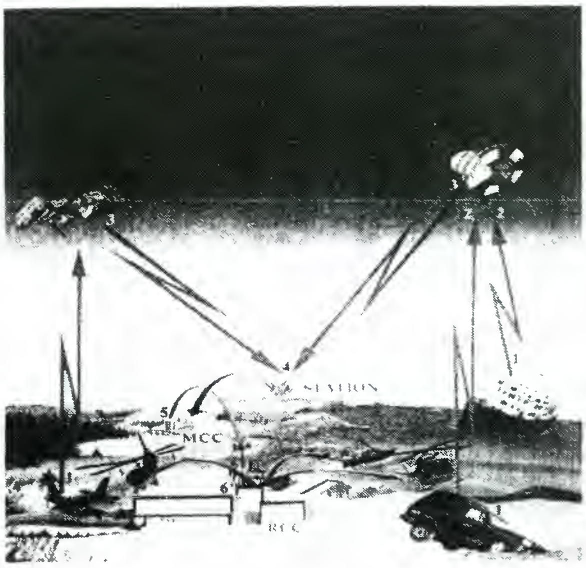
INTERNATIONAL PROGRAMME AGREEMENT SIGNED (1/4)

- 4 parties : Canada, France, Russia (USSR), USA
- Purpose :
  - long term operation of the system
  - non-discriminatory basis
  - support the objectives of IMO and ICAO
  - coordinate the management
- Responsabilities :
  - maintain the space segment of the system
  - contribution of at least one of the basic unit
  - deliver relevant C/S alert and location
  - coordination among themselves and exchange of information

INTERNATIONAL PROGRAMME AGREEMENT (3/4)

- FRANCE PARTICIPATION
  - one of the four founder countries
  - the French *Ministère des affaires étrangères* designated CNES to represent France in the executive-level proceeding
  - CNES Provides two 406 MHz receiver-processors carried onboard NOAA satellites
  - the FMCC (French Mission Control Center) distributes Cospas-Sarsat alerts over a large service area (maritime and terrestrial areas including about 20 european and African countries

SYSTEM CONCEPT



TOWARDS AN EARLY IDENTIFICATION OF OVER-CONSTRAINED CONDITIONS IN GROUND-SPACE SYSTEMS DESIGN. AN APPLICATION TO EGNOS GNSS-1

Alberto Domingo, Miguel Angel Rico, Santiago Hernández-Ariño

Aerospace Division, SENER Ingeniería y Sistemas, S.A.
Severo Ochoa, 4. 28760 Tres Cantos (SPAIN)
phone: +34.1.807.73.59, fax.: +34.1.807.72.05
e-mail : adomingo@dial.eunet.es - santiago.hernandezarino@mad.sener.es

ABSTRACT

Project management activities very often concentrate on qualitative aspects of management, rather than on quantitative analysis. This is particularly true for large, multinational and multidisciplinary space projects, where quantitative analysis is usually limited to cost and schedule at Project Management level, and to system performance requirements at System Engineering level. This lack of objective, quantitative analysis can have a very negative impact on the overall project success, creating a false equilibrium state where favored tasks use more resources than strictly necessary, imposing overconstrained condition on other tasks. This paper introduces a new notation for the formalization of the project constraints, and a novel approach to perform resources and constraints allocation, based on the minimization of a overall target equation derived from the actual project constraints. The approach is, finally, used to describe some potentially conflictive situations in a strategic European space project: the EGNOS (European Global Navigation Overlay Service) system.

1. INTRODUCTION

Large space projects very often involve many different companies, which must agree on quite specific details which are substantially mandatory for accomplishing the overall goals of the project. To add up to the complexity of the situation, there are many other constraints and influences, apart from technical requirements and budgetary restrictions, which can limit the success of the project, or greatly increase the required resources. As this kind of projects become more complex, system engineering skills call for a deeper involvement with multidisciplinary, quite specific tasks. Mainly due to reasons of short maturation time, lack of team co-ordination or the partial involvement of the system engineering team into one or more specific tasks (for which a deeper knowledge is required), design decisions might favor some relaxation into individual tasks, which derive in turn in over-constrained conditions for other tasks. Unfortunately, this is specially common during the first phases of the project, where the effects of the required rearrangements to compensate for the non-heterogeneous design conditions force reconditioning measures which dramatically impact over system cost, system performances, system complexity or, most of the times, a combination of the three of them.

Project management is a classic discipline where a set of common rules are developed (or adapted from other projects) for ensuring that the main objectives of the project can be achieved with the available resources. Unfortunately, most of project management activities are oriented to resource management, instead of to a quantitative analysis of the available resources and allocation among the different tasks.

System engineering comes in the aid of project management for this kind of analysis. This discipline is more concerned in the technical objectives of the project, and the coordination, apportionment and allocation of resources and constraints among tasks and project team members.

It is widely recognized that both project management and system engineering are, conceptually, more of an art than a science, where formalized tools are available for the problem resolution, but only once the general scheme has been designed. That is, in both disciplines there exist tools that help the controller follow up on resources and achievements, but do not help too much on the basic apportionment and allocation, nor on the detection of non-equilibrium states, which could lead to over-constrained activities, which could (in turn) endanger the overall success of the project. While there exist some basic approaches to the formal definition and apportionment of project constraints (such as the US DoD standards of acceptability for cost/schedule control systems, C/SCSC, dated back in the 70's), they have not addressed the complete problem nor, because of that, became standardized.

This paper addresses a novel approach to identification and analysis of unbalanced constraining, applied to generalized engineering scenarios (regardless of their sizes), proposing a simple test mean to early identify main over-constrained conditions. This methodology is, then, reflected on the current status of the EGNOS

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GNSS-1 project, which faces now the end of B phase and beginning of C/D phase, with multiple potential over-constrained conditions.

2. PROBLEM FORMULATION

The large variety of tasks involved in the planning, design and construction of a ground-space project can be considered to form a sort of lattice, where the equilibrium among nodes (the different tasks) impose a trade-off between the requirements and objectives to accomplish in each individual task, and the external conditions due to time constraints, budget allocation, or project management guidelines.

Figure 1 shows a three-dimensional representation of the activities considered for a generic project. Each node in the lattice represents an activity, whose spatial position is determined by the task level, subsystem or discipline, and task description. This representation is valid for all project phases, from conceptual definition to operations and maintenance (however, nodes will appear and disappear between phases, to represent activities specific for each of them).

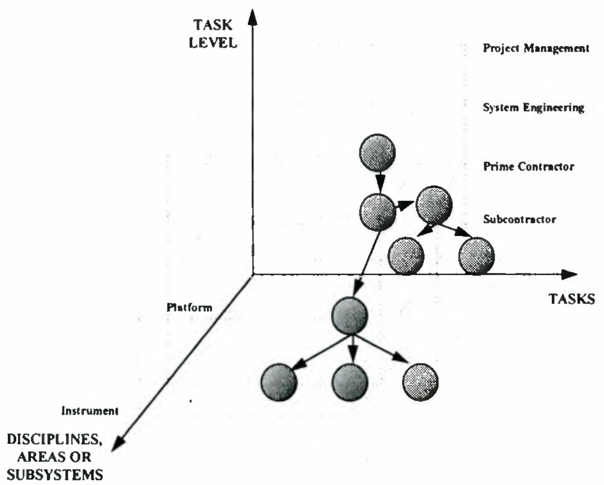

Figure 1. Representation of a Project Phase, decomposed into individual tasks.

It is convenient, as we will see later on this paper, to define the project nodes in a way that a tight hierarchical structure is achieved, with a single root node, and branches departing for each discipline and subsystem. This is consistent with general management principles, which seek the same architectural models, but based on the need to precisely define the supervisory data and control flows.

Conceptually, the accomplishment of the individual objectives of lower-level nodes (tasks) propagates to the higher levels of the tree (each layer adding additional accomplishments) to form the global solution of the project. From a quantitative point of view, there exist the requirement to define both the propagation paths (which will define, along with the nodes, the project architectural structure) and the parameters and expected flows associated with each of the identified paths.

For our purposes, the dependencies among project nodes shall be referred as *constraints*. A constraint is, therefore, a restriction (numerical or not) that a node must satisfy before the activity associated with the node can be considered to be completed. A given constraint, x, affecting the whole project, shall be represented as:

$$C^x \quad [1]$$

Such a constraint shall generally be derived from an external restriction, whose origin could be a requirement or an influence (organizational, structural, cultural, budgetary, and alike). The constraint may affect one or more than one nodes of the project. When the constraint is incorporated to the proposed structure, it is expressed in terms of the directly affected node, N_{ijk}. Equation [1] becomes:

$$C^x_{ijk} \quad [2]$$

If an external constraint affects more than one node, it is convenient to group all the influences and incorporate the constraint to the hierarchically precedent node to all affected ones, allowing, the, the constraint to propagate accordingly (this is consistent with the idea of a tight hierarchical structure).

An externally incorporated constraint will usually have some impact over different lower level nodes. This is referred as *constraint propagation*. The propagation of the constraint C^x from node N_{ijk} to node $N_{i'j'k'}$ shall be expressed as:

$$C^x_{ijk;i'j'k'} \quad [3]$$

being referred as an *inter-layer propagation* if $i \neq j$, and an *intra-layer propagation* otherwise.

If a constraint is completely propagated through a node, such node is called a *transparent node*. Otherwise, a *node constraint quote* is associated to that node N_{ijk}, for that specific constraint, x, whose value is computed from the following expression:

$$NQ^x_{ijk} = \sum_{i'j'k' \neq ijk} C^x_{i'j'k';ijk} - \sum_{ijk \neq i''j''k''} C^x_{ijk;i''j''k''} \quad [4]$$

Note that a node is transparent for the constraint x only if $NQ^x_{ijk}=0$.

Other important properties of a project node (a task) are the target (expected) constraint quote and the relative effect associated to the represented task. Both quantities are specified and apportioned at project management and system engineering levels, usually after discussion with the corresponding task performer (to avoid large deviations from the node quote). The *target constraint quote* of a node *ijk* associated to constraint x, referred as TQ^{x}_{ijk}, represents the apportionment of the considered restriction to the node, taking into account the real-life conditions associated with the partner or sub-contractor in charge of that activity. The comparison of this value with the one resultant from the system analysis (NQ^{x}_{ijk}) shall reflect the validity of the management solution. On the other side, the *effect* of the node, E^{x}_{ijk}, is a numerical value which expresses how important is the task associated with the node *ijk*, with respect to constraint x, when compared with the other nodes affected by the same constraint. Therefore:

$$\sum_{\forall ijk} E^{x}_{ijk} = 1 \qquad |5|$$

[Wer] provides some figures, based on experience, on how to apportion the effects for failure rates and costs. Many other examples exist in the literature for other types of constraints, and for specific project types.

According to the above, a node can be completely characterized by the associated node constraint quotes, target constraint quotes and relative node effect for each of the m constraints identified and formulated for the specific project. Those parameters can be expressed in terms of the following $(m, 3)$ dimensional matrix:

$$N_{ijk} = \begin{pmatrix} NQ^{1}_{ijk} & TQ^{1}_{ijk} & E^{1}_{ijk} \\ \cdot & \cdot & \cdot \\ \cdot & \cdot & \cdot \\ NQ^{m}_{ijk} & TQ^{m}_{ijk} & E^{m}_{ijk} \end{pmatrix} \qquad |6|$$

Another interesting property of a project modeled this way is the inter-constraint dependencies and compatibility. Two constraints, a and b, affecting the same node N_{ijk} are said to be locally independent if:

$$\frac{\partial C^{a}_{ijk}}{\partial C^{b}_{ijk}} = 0 \qquad |7|$$

In a broader sense, both constraints shall be independent if the above equation is satisfied for all project nodes:

$$\frac{\partial C^{a}}{\partial C^{b}} = 0 \qquad |8|$$

The compatibility between two different constraints is defined as the capability of satisfying simultaneously the both of them. When applied to a given node N_{ijk}, this can be expressed as:

$$C^{a}_{ijk} \wedge C^{b}_{ijk} = \begin{cases} 0 & \textit{incompatible} \\ 1 & \textit{compatible} \\ 0 \le C^{a}_{ijk} \wedge C^{b}_{ijk} \le 1 & \textit{partially dependant} \end{cases} \qquad |9|$$

According to the above definitions, a project node is said to be overconstrained if there exists any two local constraints which are mutually exclusive (incompatible), or for which the target constraint quote cannot be achieved, that is, if:

$$\exists x \ / \ TQ^{x}_{ijk} - NQ^{x}_{ijk} \ge 0 \qquad |10|$$

A local overconstrained condition can be locally solved if there exists a partially dependent constraint (y) affecting the node, with inter-constraint dependency function ω:

$$\frac{\partial C^{x}_{ijk}}{\partial C^{y}_{ijk}} = \omega \qquad (\omega \neq 0) \qquad |11|$$

so that the following inequities are simultaneously satisfied (note that the contribution of constraint y can be provided by any combination of locally significant constraints):

$$\begin{aligned} TQ^{x}_{ijk} - \left\{ NQ^{x}_{ijk} + \Delta C^{x}_{ijk} \right\} &\le 0 \\ TQ^{y}_{ijk} - \left\{ NQ^{y}_{ijk} + \omega \cdot \Delta C^{x}_{ijk} \right\} &\le 0 \end{aligned} \qquad |12|$$

It must be noted, however, that this solution is only valid around the working point (near the solution), for which the dependency functions are valid.

3. SYSTEM ANALYSIS AND DYNAMICS

Using the definitions introduced earlier in this paper, a project can be modeled in terms of tasks (nodes) and restrictions and influences (constraints). The following steps should be carried out by project management and system engineering teams:

1. Modelization of the problem to solve. Identification of nodes (tasks), usually from work package decomposition.
2. Identification of applicable external constraints, and quantification when possible.

3. Allocation of individual nodal contributions to constraints propagation, quotes and effects. Quantification, when possible, and relative effect ordering, otherwise. Spin-offs (additional interest of an specific task due to its strategic value, reusability from previous works, and alike) associated with each task should be incorporated to the target quote of the node (if the spin-off is only applicable to a given working team or company) or to the effect (if it is applicable for all potential bidders). A good introduction to spin-offs is included in [Gee].
4. Normalization of constraint propagation values and quotes, referred to every model layer, so that:

$$\sum_{\substack{\forall j,k \\ i\neq i'}} C^{x}_{ijk;i'j'k'} + \sum_{\substack{\forall i,j,k \\ i<i'}} NQ^{x}_{ijk'} = 1 \qquad [13]$$

5. Identification and quantification (when applicable) of inter-constraint dependencies.
6. Definition of a system dynamics energy equation to minimize (or maximize), through a MAP (*Maximum A Posteriori*) estimator solving procedure. Energy equation can be expressed in terms of overconstrain risk, overconstrain value, quote sharing or any other sensible magnitude. For illustration purposes, a basic network energy function to minimize, called NEF, could be used. This function could be based on the amount of nodal overconstraining at any given time t, as follows:

$$NEF(t) = \sum_{l} \omega_l \sum_{ijk} \frac{Pos\left(\mathrm{TQ}^{x}_{ijk} - \mathrm{NQ}^{x}_{ijk}(t)\right)}{\mathrm{TQ}^{x}_{ijk}} \cdot E_{ijk} \qquad [14]$$

$$, with \ \ \mathrm{Pos(x)} = \begin{cases} x & \text{if } x > 0 \\ 0 & \text{if } x \leq 0 \end{cases}$$

Being ω_l the weight factor associated with constraint C^{l}.

Node quotes can be updated at each algorithm iteration, taking into account the relative overconstraining of the node, compared with the overconstraining of the other nodes for that constraint, weighted again by the relative effect of the node, as follows:

$$NQ^{l}_{ijk}(t+1) = \frac{Pos\left(\frac{\mathrm{TQ}^{l}_{ijk} - \mathrm{NQ}^{l}_{ijk}(t)}{\mathrm{TQ}^{l}_{ijk}}\right) + \Delta\,\mathrm{NQ}^{l}_{ijk}}{\sum_{ijk} Pos\left(\frac{\mathrm{TQ}^{l}_{ijk} - \mathrm{NQ}^{l}_{ijk}(t)}{\mathrm{TQ}^{l}_{ijk}}\right) + \Delta\,\mathrm{NQ}^{l}_{ijk}} \qquad [15]$$

, *with*,

$$\Delta\mathrm{NQ}^{x}_{ijk} = \begin{cases} \delta \cdot E_{ijk} & \text{if } \frac{\mathrm{TQ}^{x}_{ijk} - \mathrm{NQ}^{x}_{ijk}(t)}{\mathrm{TQ}^{x}_{ijk}} = \max\left(\frac{\mathrm{TQ}^{x}_{ijk} - \mathrm{NQ}^{x}_{ijk}(t)}{\mathrm{TQ}^{x}_{ijk}}\right) \\ -\delta \cdot E_{ijk} & \text{otherwise} \end{cases}$$

7. Resolution of the defined energy equation by any analytical, suitable technique, such as linear programming, ICM (Iterative Conditional Modes), simulated annealing, MRF's (Markov Random Fields) or relaxation (specially well suited to accommodate constrained optimization). Some of these methods are described in [Ada] and [Num]. The solution converges when:

$$\lim_{t\to\infty} \left\| NQ(t+1) - NQ(t) \right\|^2 = 0 \qquad [16]$$

if the problem is not overconstrained, and to a value different from zero, otherwise. Although we have not been yet able to mathematically prove that equation [16] converges as t goes to infinity, we have observed that it exhibits the desired convergence behavior.
8. If the dynamics converge to a positive, non-zero value, iterate the following until the method converges to zero, or no further improving modifications can be performed:
   8.1. Identify overconstrained nodes
   8.2. Reduce target quotes when possible, and use inter-constraint dependencies to mitigate the overconstraining condition, as expressed in equation [10], otherwise:
   8.3. Solve the energy equation with the new constraint allocation.

   If the project remains overconstrained, relax (when possible) appropriate external constraints.

4. IDENTIFICATION OF OVER-CONSTRAINED CONDITIONS

The identification and description of the over-constrained conditions in a project plays a major role in the anticipation and selection of appropriate measures to overcome such situations. Because constraints can be derived both from quantitative and non-quantitative restrictions, it is difficult to precisely classify all potential over-constraint situations. Table 1 shows a primary classification of those conditions, based on the origin of the constraint and the elasticity of the over-constrained condition (capability of solving the over-constraint without modifying global constraint values).

ORIGIN	ELASTICITY	
	RIGID	ELASTIC
Lack of quote		
- Individual	Re-define constraints	Adjust individual node
- Propagated [1]	Adjust locally	Adjust local nodes
Incompatible Constraints		
- Mutually exclusive	Re-define constraints	Not applicable
- Cross-constrained	De-compose problem and re-adjust conditions	

[1] Propagation can be **lateral** or **vertical**. Lateral propagation should be converted into vertical ones, through a bottom-up plus top-down reassignment. Regarding the extent of the effect, they can be classified in global, local and nodal overconstraints.

Table 1. Constraints classification.

Figure 2 shows a basic example of a project decomposed into individual tasks. For simplicity reasons, a two-dimensional representation has been selected, with only three actual tasks below system engineering task. The identified constraints for this projects are the engineering budget (C^b), the components procurement budget (C^c) and the required power (C^p). The later constraint is assumed to propagate from a lower level task, while the other two constraints are originated at project management and system engineering levels.

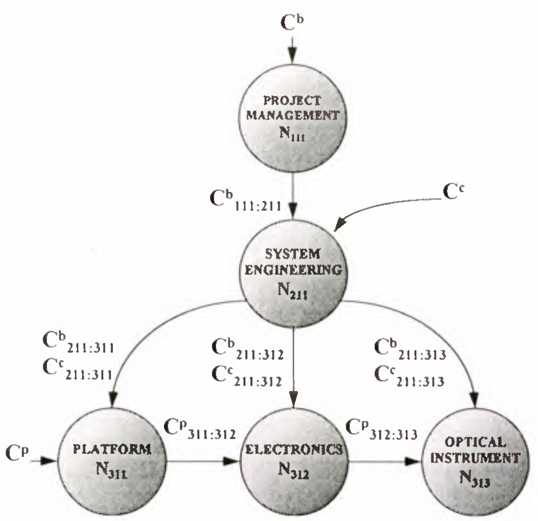

Figure 2. A simple project decomposed as described in the text.

The first project management apportionment activity should be capturing the individual requirements for each defined constraint and task. They should be agreed with System Engineering, so to ensure they are actually cost-based (or objective-based, in the case of power requirements). For this example, a budget of 100 accounting units for engineering, 60 for parts procurements and power budget of 20 Watts have been assumed. A preliminary identification of the nodes requirements (all normalized to the unit, except the engineering budget, normalized to 1.13 to account for PM - 5% - and SE - 8% - apportionment) could be the following:

$$N_{111} = \begin{pmatrix} NQ^b_{111} & TQ^b_{111} & E^b_{111} \\ NQ^f_{111} & TQ^f_{111} & E^f_{111} \\ NQ^p_{111} & TQ^p_{111} & E^p_{111} \end{pmatrix} = \begin{pmatrix} 0.05 & 0.05 & 0.05 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}$$

$$N_{211} = \begin{pmatrix} 0.08 & 0.08 & 0.08 \\ 0 & 0 & 0 \\ 0 & 0 & 0 \end{pmatrix}; \quad N_{311} = \begin{pmatrix} - & 0.4 & 0.2 \\ - & 0.3 & 0.4 \\ - & 0.5 & 0.5 \end{pmatrix} \qquad [17]$$

$$N_{312} = \begin{pmatrix} - & 0.3 & 0.42 \\ - & 0.2 & 0.2 \\ - & 0.4 & 0.15 \end{pmatrix}; \quad N_{313} = \begin{pmatrix} - & 0.4 & 0.25 \\ - & 0.4 & 0.4 \\ - & 0.3 & 0.35 \end{pmatrix}$$

E^{l} values are assigned by project management and system engineering, based on best available know-how. As we can see, first iteration requirements (target quotes) for each constraint may exceed or be below tentative available resources (in 1.2 times engineering budget, 0.9 times parts procurement and 1.2 times power budget). Identified inter-constraint dependencies were found between both costs (engineering and procurement), reflecting the influence of fixed costs (apart from general costs) not applicable to procurement. The considered dependencies are:

$$\frac{\partial\, C^c_{31i}}{\partial\, C^b_{31i}} = \begin{pmatrix} 0.9 \\ 1.12 \\ 1.06 \end{pmatrix} \qquad [18]$$

Next algorithm step consists in computing the values of NQ^b, NQ^c and NQ^p so that the [14] is minimized. For this simple case, a minimization based on linear programming has been used (however, because of the straightforward definition of the constraints, obtained results are pretty similar to those obtained by simple weighted distribution). Following the steps described in section 3, the following procedures were applied:

1. Nodal over-quotes (nodes with NQ>TQ) were distributed proportionally among under-quoted nodes for NQ^p_{311}, NQ^b_{312}, NQ^c_{312} and NQ^c_{313}.

2. Inter-node, inter-constraint dependencies were applied to solve engineering costs under-constrained conditions by reducing procurement costs over-quotes, using expression [12].
3. Intra-node, inter-constraint dependencies were applied to solve engineering costs under-constrained conditions by reducing procurement costs over-quotes, using also expression [12].

The following node matrix result when iteratively applying the above procedure (values normalized):

$$N_{311}=\begin{pmatrix}0.4 & 0.4 & 0.2\\ 0.3 & 0.3 & 0.4\\ 0.5 & 0.5 & 0.5\end{pmatrix}$$

$$N_{312}=\begin{pmatrix}0.3 & 0.3 & 0.42\\ 0.205 & 0.2 & 0.2\\ 0.2 & 0.4 & 0.15\end{pmatrix};\quad N_{313}=\begin{pmatrix}0.4 & 0.4 & 0.25\\ 0.4 & 0.4 & 0.4\\ 0.3 & 0.3 & 0.35\end{pmatrix} \tag{19}$$

The only remaining constraint is, then, the power budget for the project electronics. According to Table 1, this is an individual lack of quote constraint, which must be solved through constraint re-definition because of the lack of elasticity (there are no inter-constraints dependencies defined). System engineering should, then, increase the total value of power budget, or force a revision of the task design criteria. Following the previous reasoning, Table 3 shows the constraint apportionment among the different tasks (nodes), once de-normalized. The applied method not only shifts resources from procurement to engineering to maintain the total 160 accounting units available, but also keeps to a minimum the global overconstraining for constraints where dependencies are defined, pretty much as a simulated annealing procedure would for a system with a cooling rate slow enough.

	C^{b}_{ijk}	C^{c}_{ijk}	C^{p}_{ijk}
N_{111}	5	- -	- -
N_{211}	8	- -	- -
N_{311}	34.8	18	10
N_{312}	26.1	12.3	4*
N_{313}	34.8	24	6
TOTAL	**108.7**	**54.3**	**20**

Table 3. Budget apportionment after optimization. The asterisk denotes an over-constrained situation.

5. APPLICATION TO EGNOS GNSS-1

The European Global Navigation Overlay Service (EGNOS) aim is to provide an augmentation to GPS and GLONASS constellations, in order to substitute today's existing radionavigation aids. Figure 3 shows the basic scheme of operation of EGNOS. The GPS and GLONASS signals are collected at a number of receiving ground stations (RIMS), and the corresponding navigation solutions compared with the actual surveyed localization for all these stations. The measures, along with the errors, are sent to the Master Control Center (MCC), where a model is applied to estimate the error for the whole service coverage area. The computed corrections model is, then, sent to a GEO satellite through a NLES station, and broadcasted to all EGNOS receivers in the coverage area.

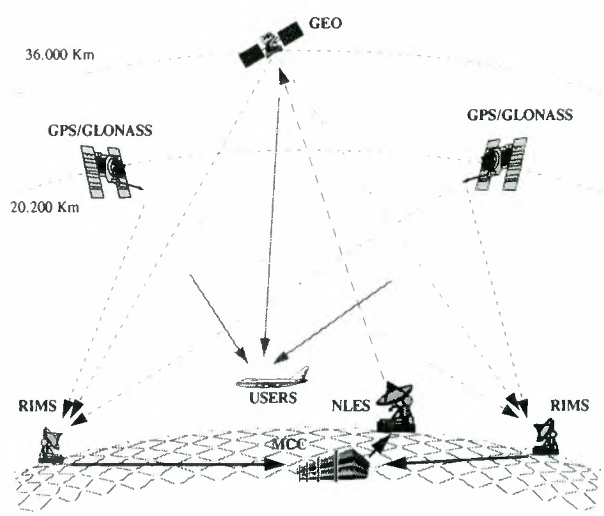

Figure 3. Simplified schema of the EGNOS system.

EGNOS project is, now, finishing phase B2 (high level design), and facing the preparation of C/D (implementation) phase, under the responsibility of the European Space Agency (ESA). Preliminary total cost, as estimated by ESA, should be around 140 MAU (95/96 EC), distributed in some 15 first level work-packages, spanning till end of year 2000. The very huge magnitude of this project, along with the complexity derived from the interface with other systems (GPS and GLONASS, INMARSAT, etc.), as well as because of the high complexity and technical challenges of the still in development phase correction algorithms, makes this project a very difficult to manage one, as well as a serious candidate to be used as an example of project management activities and consequences of adopted decisions.

For the on-going EGNOS phase activities, the following undesirable conditions have been identified (which can certainly be also applied to almost any other similar project):

Lateral constraints: When ICD's (Interface Control Documents) are not completely defined (most of the times due to the undefinition at system level), specific interface requirements are filled in by individual tasks, and propagated thereafter as lateral constraints.

In practice, if the constraint is not defined at, and propagated from system level, two undesirable side effects appear: problem becomes deformalized (constraint flow is not consistent) and, worse, individual pre-conditioning of constraints at specific tasks impose unnecessary constraints over same-level nodes (that is, node *ijk* is benefited against nodes *ij'k'*).

Apart from pure lateral constraints, also cross-constraints tends to difficult the overall management of the project, as the same constraint can affect a given task more than once. While this is correct from an analytical point of view, it usually derives in contradictory or hard to adopt simultaneous effects. A good approach is to restrict cross-constraints to those specific cases where a vertical apportionment is undesirable. This motivation is stressed by the fact that, unless full visibility of constraining is available for all nodes, there may appear some inconsistencies at integration level.

Unformalized external constraints: Everything that should be accounted for at system level should be formalized as a constraint. Other effects, while considered at project management or system engineering, should not be visible for individual tasks. These effects are known as influences. Influences can derive from political, structural, social or strategic conditions, among others, but should not directly constraint individual nodes. When an influence becomes too important to be ignored at individual task, it should be modeled as a new constraint at system level, and propagated thereafter.

As an example, in EGNOS the future software architecture is being considered during phase B. This task, useful but without the scope of the formalized constraints, causes unnecessary influences and arbitrary decisions to be taken, that furthermore overconstraint the design for specific, affected, activities.

Hard to define effects: For many tasks, relative effects of individual constraints are not well defined (or, at least, not known). It is difficult also to define top level constraints for influences detected at lower levels. This avoids the identification of the most favorable equilibrium state (*Maximum A Posteriori* of the energy function), while introducing inefficiencies in the system dynamics. It also allows the leakage of other phases tasks into present phase activities, because no correlation can be performed between target quotes and objective effects for each node. As a general rule, relative effects should be well known in advance, and made public for consultation and discussion at early project stages.

Lack of identification of inter-constraint dependencies: Some constraints are being dynamically modified, in order to limit the total project cost, development time, improve system performances, etc. While the individual constraint can be adapted, the implications over other constraints which are partially dependent are not always fully addressed. As an example, the use of commercial off the shelf hardware for critical tasks not only decreases cost and development time against total failure rates (the first, most evident effect). It also impacts over the overall system availability and continuity performances, among others, in such a way that (unless dependencies are fully formalized) makes it difficult to analyze and quantify the derived effects. Also, detected inter-dependency influences should be formalized into the appropriate configuration control.

Underpropagation: EGNOS project shows multiple vertical dependencies between companies and tasks. Individual companies set target quotes much higher than sensible applicable references, so that lower level nodes face overpropagation of constraints and are subject to severe overconstraining. Unless an iterative procedure to anneal the individual node constraint apportionment is used, unbalanced allocations shall occur, mainly for lower level tasks. The above is applicable both to agregable and distributable constraints. The former ones (for example, failure rate) result in unnecessarily increased costs, while the later ones (such as budget or time) risk the feasibility of the task.

Overpropagation. This effect appears when individual nodes create additional constraints which must be, later on, bottom-up formalized and propagated thereafter. The most typical cause for this undesirable effect is the willing of some partners to increase their participation by artificially creating extra project requirements. The actual effect is a cost increase and extra overheads, adding more complexity to the initial design.

Lack of visibility: Most of the times, project managers decide not to disclose the information related with node quotes and relative effects among the different partners and subcontractors. This is usually a wrong attitude, which only favors competitiveness against sounding technical and economical principles. In EGNOS, lower level contractors have spent a lot of resources trying to gain some visibility of the overall requirements, so to understand the specific tasks requirement apportionment.

Spin-off abuse: Some activities are clearly more attractive than others, due to strategic, technical, scientific or political reasons. Unless this effect (known as spin-off) is incorporated into the node quotes or the relative tasks effects, overfragmentation of tasks occur, because of the motivation of companies to retain high spin-off activities, while sub-contracting the others. This approach is undesirable, both because the inefficiencies associated to this over-fragmentation of work-packages, and because of the over-constraining that it usually imposes on lower-level tasks.

Non-heterogeneous lattice potential: If the project potential is computed from the difference between target and node quotes (normalized with respect to the relative node effects), it can be observed that certain nodes are much more over-constrained that others, specially lower level nodes, where overpropagation, cross and lateral constraining becomes more evident.

6. CONCLUSIONS

Large space projects are very difficult to manage, both because the large number of working teams and the amount of different disciplines involved. Lack of a formalized approach to constraint management tends to unnecessarily increase required cost and effort, while putting extra loads on some tasks. A formal identification of constraints and posterior analysis of their propagation can help to detect and overcome overconstrained conditions at early project stages, where measures can be taken so to minimize the impact over the whole project. Also, formalized procedures for constraint apportionment and allocation can help solving the identified overconstraining conditions. These procedures include, among other, the redefinition of lateral constraints and cross-constraints (in terms of pure-formalized vertical constraints), the total apportionment of identified constraints, the formalization of external influences as objective constraints or the analysis of completeness, consistency and compactness of the identified constraints, node quotes and relative efforts. The above approach requires the consolidation and usage of a suitable constraint management tool that assists on the actual implementation of the described procedures. The specification and implementation of such a tool is the purpose of future developments.

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ABOUT THE AUTHORS

Dr. Alberto Domingo is an aerospace engineer at SENER Ingeniería y Sistemas, and Assistant Professor at Alcalá University (Madrid), where he lectures on telematics and project organization. He received his MSc. and Ph.D. in Telecommunications Engineering from UPM, Madrid, in 1991 and 1996, respectively. He also graduated in business administration, strategic business and communications architectures. He is the author of two books and more than one hundred technical papers on these subjects.

Miguel Angel Rico works as software engineer at SENER Ingeniería y Sistemas. He received his MSc. in Physics (electronics) from UCM, Madrid, in 1989. He has been developing and integrating safety critical software applications for combat aircraft and satellite embedded systems since 1990.

Santiago Hernández-Ariño manages space projects at the Aerospace Division of SENER. He holds a MSc. in Aeronautical Engineering from the ETSIA (UPM). Initially, his career was devoted to aerospace stability and control. Currently is running, among others, SENER contract in EGNOS. He is responsible within SENER of ARIANE launcher affairs. He has published several papers and a course on quaternions.

Small Satellites, Technology & Launchers

TAILORED SMALL SATELLITES

B. Claudinon, H. Buchwalter and G. Berger

Matra Marconi Space

31, avenue des Cosmonautes

31402 Toulouse Cedex, France

Phone : 33 5 62 19 69 91 Fax : 33 5 62 19 51 10

Abstract

The Matra Marconi Space LEOSTAR small satellite series has been designed for a wide range of applications in Low Earth Orbit. Mission dedicated configurations are built in a quick and efficient way thanks to the modular LEOSTAR platform architecture organised around a generic core avionics. Applications range from Earth observation missions, whether optical or radar, launched with small dedicated launchers, to communications satellite constellations optimised for multiple launches.

Two standard platform products are available to fly low cost missions in the 250-1300 kg satellite mass range : LEOSTAR 500 optimised for 500 kg-class payloads and LEOSTAR 200 compatible with small launchers of the Pegasus XL class.

The conference paper will present the LEOSTAR platforms and their flexible development approach, show typical configurations for Earth Observation, Science and Communications applications, and provide examples of specific adaptations such as the satellites designed for the CCI/ECCO constellation services over tropical countries.

1. INTRODUCTION

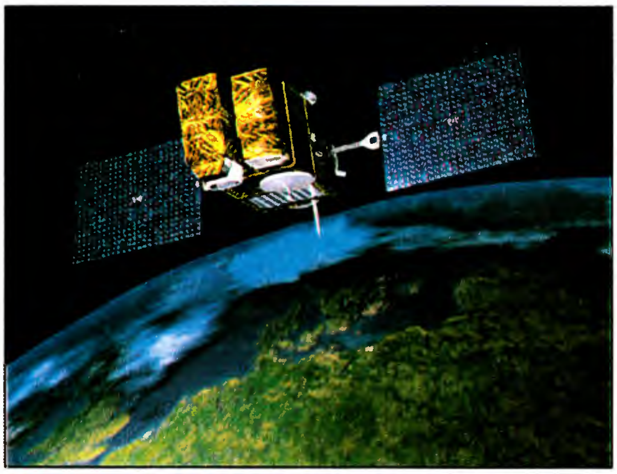
In answer to the growing demand in the small satellite class, Matra Marconi Space has initiated the development of the LEOSTAR small platforms which complement its successful buses : the LEO multi-mission platform used by SPOT and its derivatives, and the EUROSTAR series for GEO communication satellites.

LEOSTAR-based satellites are able to support demanding Earth Observation missions, including a combination of optical instruments or a Synthetic Aperture Radar, thanks to their relatively large payload capability in the small satellite class.

Customized versions making full use of the generic elements developed in the LEOSTAR framework are optimized for specific applications that include communication constellations such as the ECCO constellation for which Matra Marconi Space has been selected by CCI as space segment contractor.

LEOSTAR is being developed by Matra Marconi Space in its Toulouse, France, facility. The Critical Design Review has been passed successfully in April 1997.

2. LEOSTAR SMALL SATELLITE SERIES



Small satellite systems for a wide range of missions

Matra Marconi Space offers a complete small satellite capability including the LEOSTAR platforms, compact optical and radar instruments, communication payloads, and associated ground segments. Based on the strong Company heritage in optical and radar Earth observation satellites (SPOT, HELIOS, ERS, ENVISAT), and in communications satellites (the EUROSTAR series), the innovative small satellite development approach makes high performance products available to a large number of users.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

Thanks to the modular LEOSTAR architecture organised around a generic core avionics, mission dedicated configurations are built in a quick and efficient way. These configurations tailored to payload needs are optimised for either small dedicated launch vehicles (Earth observation, constellation maintenance) or multiple launch in large launchers (such as the deployment of constellations in clusters).

LEOSTAR platforms have been designed for all Low Earth Orbits (LEO). They can fly in any attitude, whether Earth pointing, or inertial pointing as required by some scientific applications. Very accurate pointing and high level of agility are achieved for demanding Earth observation missions and the power level can be tailored to suit with radar or communication missions.

Two standard platform versions are available : LEOSTAR 500 for launchers such as Cosmos, Rockot, LMLV, Taurus and PSLV ; and LEOSTAR 200 for Pegasus XL, Start, Shavit and VLS. These generic multi-mission platforms feature easy accommodation of any type of payload. They are ideal for low cost missions through the use of a standard platform product.

3. OPTICAL OBSERVATION APPLICATIONS

The miniaturisation of instruments coupled with the use of advanced bus technology make it possible to implement high performance Earth observations systems based on small satellites. LEOSTAR satellites may be equipped with very high resolutin optical instruments for cartography and surveillance, or payload assemblies focused on agriculture, environment or science missions.

Optical satellite based on LEOSTAR

4. RADAR OBSERVATION APPLICATION

Radar satellite based on LEOSTAR

The LEOSTAR mass and power capabilities are ideally suited to radar missions. A compact Synthetic Aperture Radar (SAR) instrument is being developed by Matra Marconi Space in its Portsmouth facility.

5. TELECOMMUNICATIONS APPLICATIONS

Communications satellites constellations

The solar arrays are sized according to the high power needs. The satellite shape optimises the space under the launcher fairing for the accommodation of several spacecraft. The pointing and stability performance of LEOSTAR is well adapted for the optical inter-satellite links requested for large bandwidth multi-media transmission.

Mobile telephony satellite

Applications which are beyond the capabilities of standard small satellites can be addressed. For the CCI/ECCO constellation, the Matra Marconi Space platform uses shielding and radiation-hardened components to survive the severe radiation environment at 2000 km altitude.

6. STANDARD PLATFORMS : LEOSTAR 200 AND LEOSTAR 500

Multi-mission potential

The LEOSTAR 200 and LEOSTAR 500 standard multi-mission platforms in the LEOSTAR Small Satellite Series have been defined to offer high performance at affordable price :

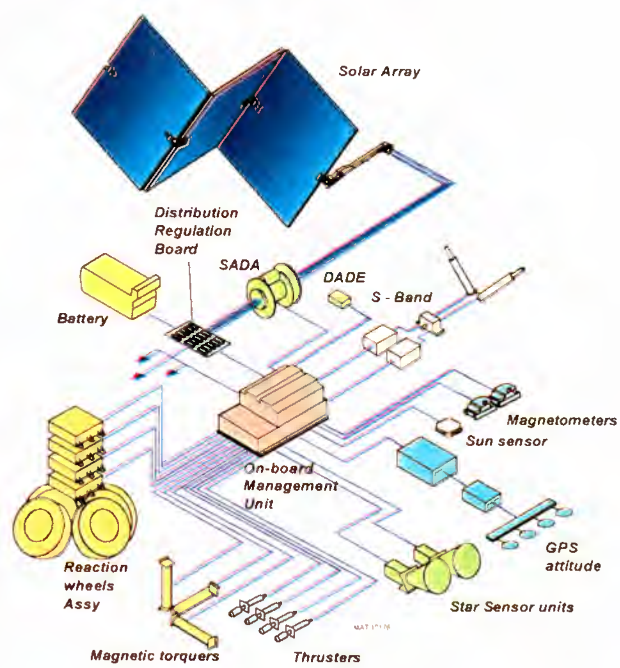
- high accuracy pointing and manoeuvring capability
- large autonomy and availability
- extended range of services to the payload.

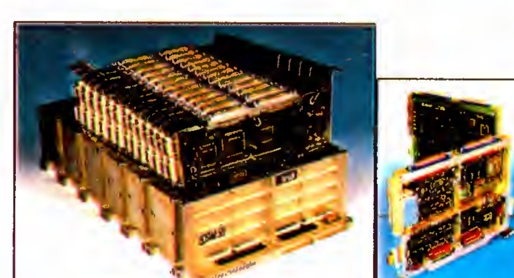
Both standard platforms feature easy accommodation of any type of payload in their respective class. Thanks to the modular design, a number of options can be selected to best suit to the mission needs in terms of orbit, mass, power, propulsion and data transmission capabilities.

Platform overview

The LEOSTAR standard platform layout is generic. Structural aluminium honeycomb panels provide support to the equipment. The attachment to the launcher is ensured by an adaptable frame bolted to the lower face of the platform. The upper face carries the payload. For certain missions, attitude sensors can be accommodated directly on the payload. The platform thermal concept has been qualified for the full range of Low Earth Orbits and attitudes, with thermal decoupling between the platform and the payload. The propulsion assembly used for orbit control is formed by an independent module grouping the thrusters, the tubes and the hydrazine tank, and directly mated to the lower floor. The solar array is modular, with one or two wings of up to three panels each with Si or GaAs cells. The power conditioning and distribution relies on a robust and straightforward concept, using solid state power controllers.

The internal layout is driven by volume efficiency, thermal requirements and EMC compatibility, and provides for easy accessibility during integration and tests. The avionics is organised around the On-Board Management Unit (OBMU) developed by Matra Marconi Space and featuring advanced technologies, ASICs and surface mounted components. This unit contains most of the platform electronics which dramatically simplifies electrical interfaces. The OBMU cradle has free slots to house additional payload-specific electronics boards.





Mission dependent equipment configurations are selected from a set of qualified options. To best cope with the variety of mission needs, a flexible attitude control architecture has been defined, which uses GPS attitude, star sensors and gyroscopes (sensors depending on the mission), reaction wheels and magnetic torquers. A full redundancy scheme is applied, and the platform is capable to operate in configurations mixing nominal and redundant units. The flight software implemented in the micro-processor based electronics has been developed in high level language, and structured in layers so that maintenance and adaptation to new missions is easy. For robustness, the operations are kept simple, with a reduced number of satellite modes.

Easy payload accommodation

The LEOSTAR standard platforms offers a generic basis for a variety of satellites, to which it provides services such as stable payload support, thermal control, power supply, attitude and orbit control, data management and communications to and from the ground control centre.

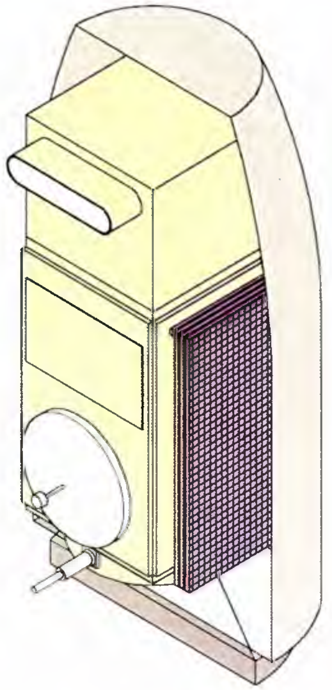
Payload accommodation is remarkably easy. A square flat, unencumbered payload plate allows for a variety of different mountings as well as a standard electrical connection. Data management, storage and communication services provided by the platform itself are sufficient for many payloads.

Payloads whose needs exceed available platform provisions may use their own data handling and downlink systems housed in a dedicated payload equipment bay, allowable within the mass and volume capabilities of the platform.

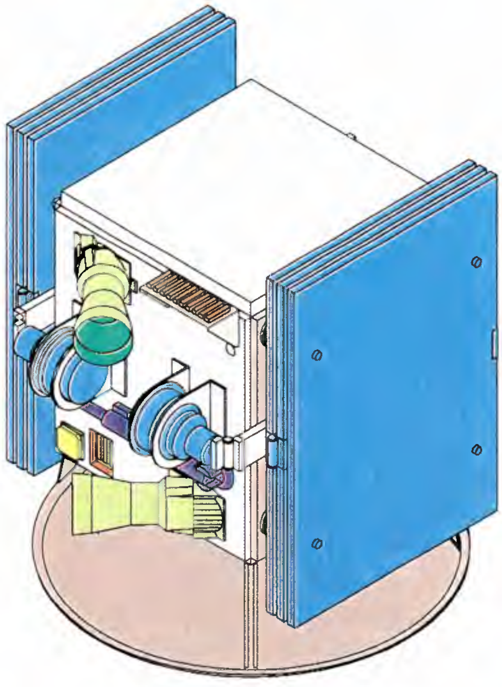
Multi-launcher compatibility

For maximum mission flexibility, satellites based on the standard LEOSTAR platforms are directly compatible with a large variety of launchers with 1.2 meter diameter (LEOSTAR 200) or 2 meter diameter fairing or higher (LEOSTAR 500). In particular, the platform design has been driven by the worst case within this set of launchers for each of the sizing parameters, e.g. dynamic performance, mechanical environment, launch duration or orbit injection inaccuracy.

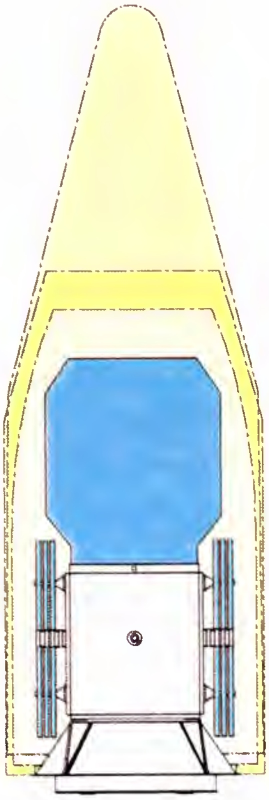
The platform body remains in a 0.9 m (LEOSTAR 200) or 1.4 m (LEOSTAR 500) diameter circle, while the adapter ring bolted to the bottom plate depends on the launcher.



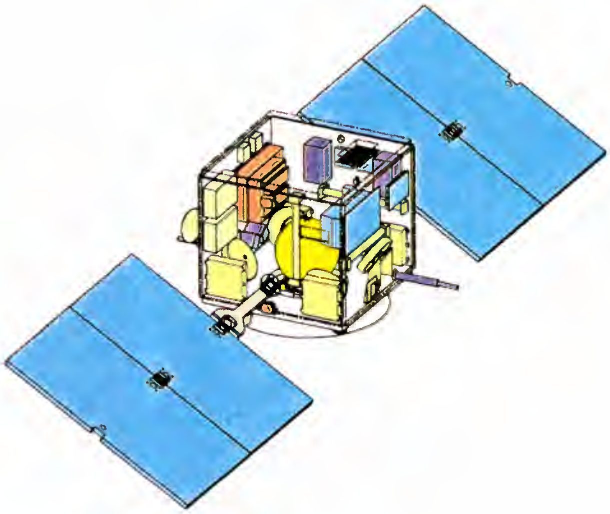
LEOSTAR 200 under Pegasus fairing



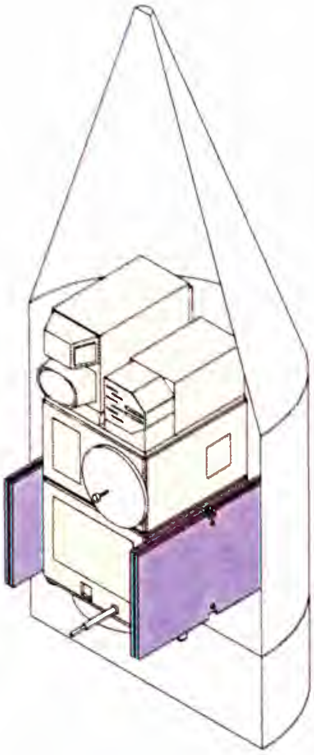
LEOSTAR 200 in stowed configuration



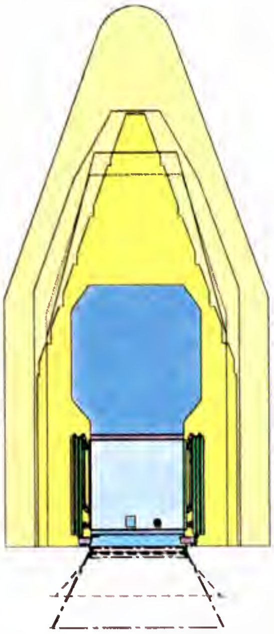
Payload envelope for LEOSTAR 200 satellites under various fairings



LEOSTAR 500 exploded view



Typical LEOSTAR 500 configuration (optical observation mission)



Payload envelope available with LEOSTAR 500

COMMON FEATURES OF STANDARD PLATFORMS

Orbits
450-1500 km altitudes, any inclination
Propulsion capability : up to 200 m/s

3-axis stabilisation
Nadir or inertial pointing
Pointing accuracy : 0.02-0.07° (3 σ)
Stability : 10^{-3}°/s

Design lifetime
> 5 years

Reliability
0.9 over 3 years

Payload data management

Payload data bus MIL-STD-1553 or OBDH, or individual serial links RS 422

Software provisions and PCB slots available for payload control

Data storage 2 Gbit with optional growth

Standard downlink 650 Kbps, S-band

Optional downlink > 50 Mbps, X-band

LEOSTAR 500 SPECIFIC FEATURES

Satellite mass range
500-1300 kg

Power
Modular solar panels, 400-1200 W

Platform main body size
0.95 x 0.95 x 0.95 m

Platform power consumption
140 W-170W

Platform dry mass
250-300 kg

Payload mass capability
200-1000 kg

Power available to payload
typ. 450 W (up to 1000 W) @ 22-35 V

LEOSTAR 200 SPECIFIC FEATURES

Satellite mass range
250-600 kg

Power
Modular solar panels, 250-750 W

Platform main body size
0.65 x 0.65 x 0.75 m

Platform power consumption
130 W-160W

Platform dry mass
150-200 kg

Payload mass capability
100-400 kg

Power available to payload
typ. 250 W (up to 600 W) @ 22-35 V

FAULT-TOLERANT CONTROL RESOURCES FOR A NON PROPELLED STABILIZED MICROSATELITE

Esaú Vicente-Vivas and Martín López

Instituto de Ingeniería, UNAM, DF. México
phone: (525) 622-8128, fax: (525) 622-8091
e-mail: evv@automatizacion.iingen.unam.mx

ABSTRACT

This paper describes the hardware and control technics developed to provide dependable automated operation for the Satex experimental microsatellite. Emphasis is given on specially designed fault tolerant (FT) hardware and software which enhance system overall. Hardware design and components were chosen to accomplish a reliable instrumentation and to keep attractive the implantation costs. Those approaches conform the strategy to pursue a relative low cost and reliable instrumentation platform for microsatellites. Implanted schemes also pursues a high degree of tolerance to some of the main possible system malfunctions which can be expected during the microsatellite life. Some explanations related with stabilization schemes to accomplish the desired pointing for a remote sensing camera and an optical communication experiment are also presented.

1. INTRODUCTION

The possibility to develop a reliable instrumentation platform for microsatellites was aimed since the beginning of the work to develop an experimental satellite. As the project was planned to be carried out by several research institutions from all over the country, the University of Mexico proposed and carried out the design, implantation and partial validation of a distributed fault tolerance instrumentation scheme to provide maximum performance and long life to a light weight space vehicle.

The proposed instrumentation is composed of electronic conditioning modules, 44 sensors, multiplexing modules, a reliable fault-tolerant computer, isolation and switching electronics, a redundant local area network (to provide communication between several dedicated processors inside the vehicle), small number of priority redundancies (to obtain reliable behavior with size and weight kept at a minimum), and special weightless FT software exploited at the maximum possible.

The original research idea was surpassed by new integrated ideas to increase the system reliability as well as by schedule extensions experimented by the project.

Above instrumentation was planned to develop several functions, between them: operations for the start of life, several types of telemetry acquisition, communication between fault-tolerant computer (FTC) and payload processors, activation and deactivation of equipment, module diagnosis, fault treatment, fault isolation and so on. For Satex the FTC is also in charge of performing the house keeping and satellite stabilization required by payloads. It is important to outline that fault tolerant distributed software written for Satex processors enable satellite operation and communications with earth even in the presence of some catastrophic failures. By instance the lost of one or several processing nodes from the satellite, which we call degraded mode in the sense that according with the type of failure more or less functions will be maintained in the satellite. However in order to keep a better degraded mode where major operations in the satellite can be sustained, it is required the FTC to survive. Hence the priority in the project to design and to develop a processing node with fault-tolerance attributes.

2. FAULT TOLERANT DISTRIBUTED ARCHITECTURE (FTDA)

The instrumentation for Satex is shown in Figure 1. The fault tolerant attributes are based on the use of two main networks, an FTC, redundancies and fault tolerant software distributed on every processing element in the full system. With those elements a low cost fault tolerant instrumentation was obtained which not only solves Satex automation needs, but also will be used in future microsatellites with small changes. This aspect was a goal during the planning efforts of this mission in order to apply the instrumentation platform in future space projects, either national or by cooperation with other countries.

The first network serves for communication between earth station (ES) and satellite. For this network special protocols were designed. Characterized by its small length and versatility where few operands are programmed according with the task to be

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

commanded. Commercial protocols were avoided to eliminate data volume, time and software overheads.

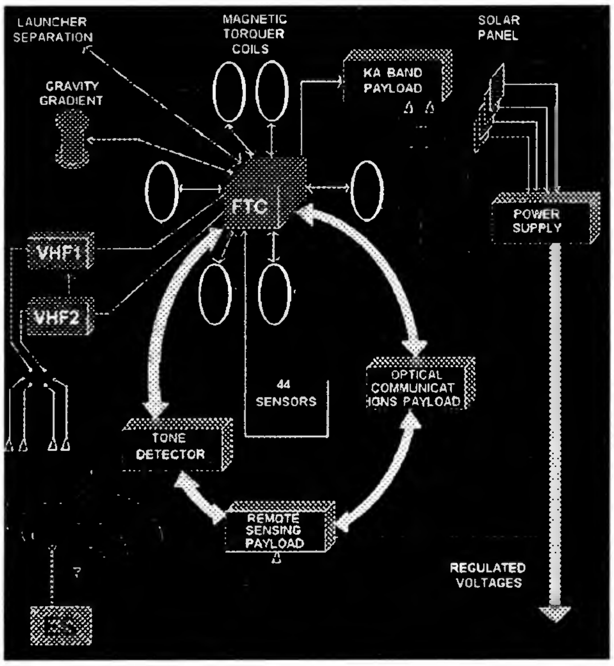


Figure 1. Satex instrumentation.

According with the time the commands are executed, two types of them were classified. On-line commands are those executed after they are decoded by the FTC. Commonly they are executed when the vehicle overflights the ES. Mission commands are a group of commands which are read and decoded by FTC but are kept in memory and executed once the satellite is out of reach from the ES.

3. UPLINK COMMUNICATION COMMANDS

Among some of the typical parameters which are programmed either in on-line or in mission commands are the followings:

- Specification to define command or new program sent to FTC or to any satellite payload.
- Destination processor on-board the satellite.
- Programmed options to accomplish the indicated command. This information can be related to the type of requested telemetry, image resolution, packet retransmition, etc.
- Information data regarding the specific command or in case of sending new programs information about the number of packets to be sent as well as the number of the current sent packet. The elaborated software allows sending new programs during several satellite overflights keeping the packet ordering and allowing the retransmition of damaged packets.
- Attachment of data integrity information for telemetry packets to make possible the retransmition of one or few of them.

Fault tolerant attributes were integrated in the software, among them we can mention:

- The possibility to send new programs will be helpful to override possible malfunctions or bugs presented in the flight software, either from the FTC or from payload processors. Also this attribute will transform the satellite in to an ideal lab to essay and to experiment new software in space.
- Telemetry and on-line commands can be used by earth personnel at the ES to figure out faults never detected by the satellite instrumentation. When such a found is confirmed commands can be sent to the vehicle to switch off the damaged equipment. This procedure further enables the isolation of sane modules thus preventing major malfunctions.
- Reception software in the satellite detects failures in the communication equipment (CE) in cases like this ensures a shift to the redundant channel.
- A redundant link between ES and satellite was incorporated using tones and installing a tone decoder in the satellite. With this link a degraded communication can be established even when the two CE or when FTC or both are failed.

4. DOWNLINK COMMUNICATION COMMANDS

Downlink information retrieved by the satellite depends on previous up-link commands sent from ES to the vehicle. Normally will consists of telemetry related to the 44 satellite sensors and status data about the equipment from FTDA (processors, communication equipment, memory, networks, gravity gradient boom, etc.). However up-link commands can also specify special telemetry and image retrieval from the remote sensing payload. Special telemetry refers to magnetometers data or data from any other programmed sensor. Sampling frequency can also be specified by command. In the case of image download, the amount of received information will depend on the programmed resolution for image acquisition.

The downlink protocol for telemetry contains few packets of identical length. Each containing telemetry and status for ten different telemetry samples taken during every satellite orbit from a total of sixteen orbits.

5. ON-BOARD REDUNDANT LOCAL AREA NETWORK

The second network is a redundant LAN (RLAN) implanted to communicate all the processors installed on-board the satellite. RLAN is used for several goals. When RLAN network is absent of failures the main RLAN is used by FTC to retransmit commands to or to receive commands from payloads. Those commands may contain specific tasks for payloads, payload data retrieval, and diagnosis information from any node. Through this network all processors continuously check operations from other processors, and when few failures are detected and confirmed a reconfiguration action is taken. In case of FTC failure a switching command is sent in order to reconfigure it, it is, the main processor and its resources are substituted by a redundant processor with redundant resources. In case of payload failures, a software flag is set and sent to ES within telemetry. With this information ES personnel can, by instance, decide to plan communications with the satellite via the tone decoder, or to plan new testing for failed processors.

The use and programming of the RLAN is fully transparent for the application software. Communication over RLAN is based also on specially designed protocols, must of them smaller than those used in the Satellite-ES network. The reason is because tasks are more simple and easy to be handled. However, for transferring programs to payloads the same Satellite-ES protocol is utilized.

When specific number of communication faults in RLAN are detected by the software, it automatically switches to the redundant channel. From there on communication accesses are made through the redundant channel. In case of failures in this channel, a new switching to the main channel is commanded. In this sense, RLAN is characterized by circular conmutations, which are also useful for software validation.

6. FTC ARCHITECTURE

As deduced from above sections, the DFTA enables satellite communication and operation even in the presence of faults in important modules from the satellite. In this sense several degraded modes are accepted. However, to obtain the major quality of operation in the satellite it is desired to count with the correct operation of FTC, because some sort of centralization is found in this node for best satellite operation.

As this instrumentation was proposed at the beginning of the project. It was clear that this computing node has to contain important fault tolerant attributes. Then a high reliability FTC architecture was designed, manufactured and presently is found in the validation stage.

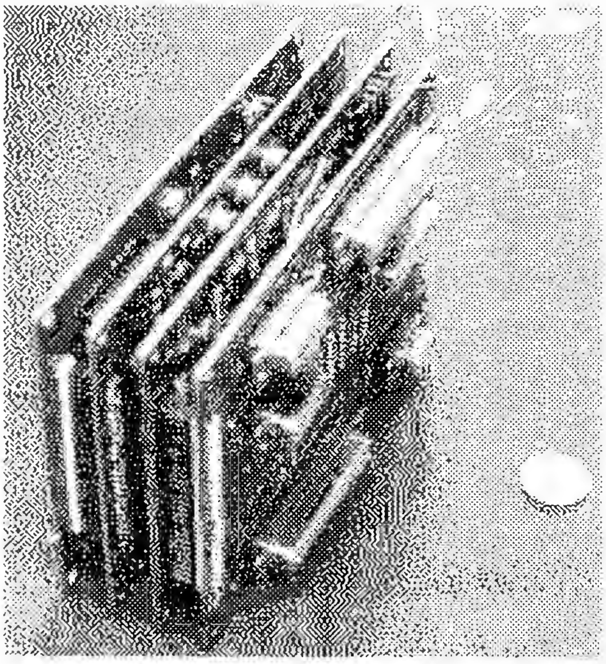


Figure 2. Fault Tolerant Computer.

FTC contains 2 processors, a principal processor (PP) and a redundant processor (RP). Each of them is based on a 16 bit 80C166 RISC microcontroller, 2 Mbit RAM, 0.5 Mbit EPROM, 10 bit A/D C, timers, serial ports, interrupt processor and 26 I/O lines, see Figure 2.

Fault-tolerance scheme is utilized when a permanent processor failure is detected in the system. In this case as above explained RP is commanded to take control of satellite operations (stabilization, telemetry acquisition and communication with ground).

Multiprocessing scheme is exploited when both PP and RP are failure free, in this case multiprocessing is allowed to execute stabilization algorithms with both processors. Communication between processors is performed according with RLAN protocols.

FTC also includes following modules:

- Switching electronics to connect the full instrumentation either to PP or RP.
- Conditioning modules for few sensors. A complementary conditioning module exists which is external to FTC.

- Multiplexing module to connect every satellite sensor to either PP or RP.
- Connectors for sensors, actuators, network lines and supplying voltages.

Because power consumption is a main constraint for space applications, FTC also includes switching electronics to control the electrical energization of few of its electronic submodules and some of its conditioning electronics for vehicle sensors. With these facilities FTC can operate in various power consumption modes according with particular commands. Turning submodules on and off is performed automatically when commands are decoded and executed by FTC. In this way power management is performed automatically, or on the other hand can be planned by ES personnel according with mission needs.

Other main characteristics of FTC are the followings:

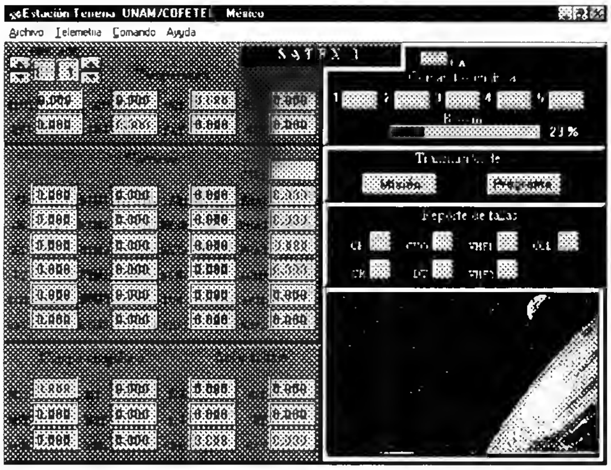
- MIL-STD 883 components. Only two FTC components are industrial type extended temperature grade, for them was incorporated special latch up protection electronics which works fully transparent to the software application.
- Principal and redundant 16 bit 80C166 RISC microcontroller, 2 Mbit RAM, 0.5 Mbit EPROM.
- Watchdog protection and networking capabilities to detect FTC faults.
- 10 bit resolution A/D converter with maximum 630 Khz conversion frequency.
- Three network ports, two of them with programmable baud rate from 75 to 625 Kbauds.
- Electronic protected network ports and additional protection for another three network ports.
- Acceptance of an external turning on electronic pulse for two different VHF transmitter equipment. The signal can be sent by any networked processor.
- Solid state relays to control electronic loads from up to 6 amps.
- Acceptance of external electronic pulses to command the switching from PP to RP and viceversa.
- solid state control electronics to switch all electrical signals from PP to RP (or viceversa) when faults are detected in the current processor.
- Solid state multiplexing module to accept up to 44 analog signals from sensors.
- Module for analog treatment of electrical signals from sensors. In particular following sensors are treated: 8 temperature sensors, 24 current sensors, 2 triaxial magnetometers, 2 biaxial fine sun sensors and 2 voltage sensor. However, FTC can be adapted to accept unipolar analog signals from up to 11 sensors with amplifications from 1 to 500 and bipolar analog signals from up to 32 sensors with amplifications from 1 to 6600.
- Operating voltages: +5, -5, +12 y -12.
- 16x12x9 cm aluminum box.
- Development system for personal computers and programmable in C language.

7. FAULT TOLERANT DISTRIBUTED SOFTWARE

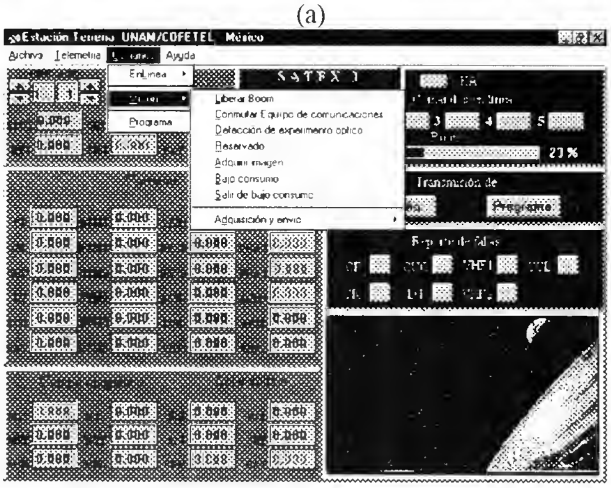
Software for FTC and payloads was developed in standard C language. It contains the algorithms to tolerate, isolate and reconfigure the distributed instrumentation in order to overcome some major failures, among them we can find:

- Detection of local failures in processing nodes with software procedures which interact with installed memory, CPU internal registers, serial ports, I/O lines, timers, etc.
- Generation of periodical calls between processing elements to perform diagnose procedures and to exchange results. In few cases, when a failure is detected and confirmed, payload processors are allowed to switch from PP to RP and viceversa. In other cases PP or RP are allowed to automatically connect or disconnect payload processors either when failures are confirmed or when current consumption readings overpass established limits.
- Data integrity checking for packet transmission between networked nodes. When errors are detected retransmission requests of particular damaged packets can be commanded from every receptor node.
- Back up timing procedures to skip infinite loops when communication between processing elements can not be set. In such a condition communications trials are executed using redundant channels for next accesses.
- Elaboration of failure reports and its integration in telemetry data to provide mission control personnel with information of satellite instrumentation.
- Execution of control commands to reconfigure the satellite instrumentation.

The complement for above mentioned algorithms is the ES software. Programming was done with Borland C++ under Windows. Software includes following facilities: telemetry visualization for 44 satellite sensors, visual indicators for alarmed sensors, exhibition of a failure report from satellite equipment, access to on-line commands, mission programming, program transmission, transmission of stabilization patterns and visual indication for captured images, see figure 3.



(a)



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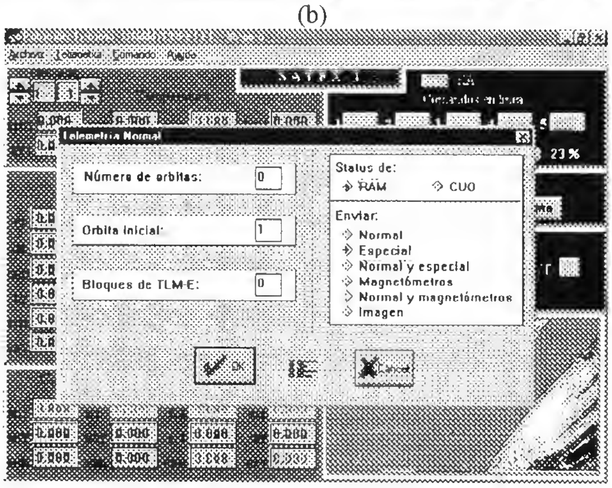

(c)

Figure 3. a) ES software presentation, b) Mission programming, and c) Telemetry programming.

8. SATELLITE STABILIZATION

Satex experimental microsatellite utilizes both passive and active stabilization techniques to obtain the required three axis pointing of on board payloads. Among them, an optical communications experiment and a CCD camera demand stabilization accuracy better than three degrees in the principal axis for successful payload performance.

A gravity gradient boom (GGB) and a set of six circular shape magnetic torquer coils are combined in order to achieve pointing demands. The magnetic torquers are placed on the XY, XZ and YZ planes and will produce a total torquer larger than the total torque from the environment.

Two stabilization stages were programmed in FTC. The first is started after the satellite liberation from launcher aiming the reduction of disturbances as well as the matching of the satellite vertical axis with the satellite orbital plane. When this dynamic behavior is reached and when GGB is found in opposition with Earth, GGB is commanded to be deployed. After this action payloads are found pointing to the planet with some disturbances around the satellite vertical axis.

The new dynamic behavior will allow a more suitable microsatellite pointing to perform payload focusing within allowed errors. At this point, the second control stage can be started to allow the microsatellite to be pointed according to mission requirements. This control stage makes use of the torquer coils to generate small momentums which when applied in a period of time produce pointing changes in the vehicle.

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A NEW EUROPEAN SMALL PLATFORM: PROTEUS, AND PROSPECTED OPTICAL APPLICATION MISSIONS

Jean-Bernard DUBOIS (1) - François PAOLI (2)

(1) CNES / Centre Spatial de Toulouse - (2) AEROSPATIALE / Centre Operationnel Satellites

RESUME - Les avancées technologiques des dernières années et les nouvelles méthodes industrielles rendent possible l'étude de missions optiques évoluées sur la base de petits satellites, comme la plate-forme multi-mission PROTEUS. Plusieurs missions utilisant des instruments optiques, placés sur cette plate-forme, ont été étudiées soit par AEROSPATIALE / ESPACE & DEFENSE, soit par le CNES (Centre National d'Etudes Spatiales).
Cet article présente :
a) l'approche retenue pour la plate-forme PROTEUS, développée en partenariat par AEROSPATIALE et le CNES pour améliorer l'accessibilité à l'espace dans la gamme des petits satellites (500 kg),
b) la description de la plate-forme générique et de ses principales performances (pointage, masse embarquable, puissance disponible, stockage de données, etc...), et les interfaces avec la charge utile (mécanique, thermique, électrique, contrôle/commande),
c) des exemples de missions optiques pour l'astronomie, l'exploration interplanétaire et l'observation de la terre.

ABSTRACT - *Progress in technology in recent years and new industrial approaches now make it possible to design valuable optical missions using a small-class satellite, like the PROTEUS multi mission platform. Some future space optical missions using existing or planned instruments, combined with the PROTEUS platform, have been assessed by AEROSPATIALE / ESPACE & DEFENSE and/or the CNES (French National Space Agency).*
This paper presents:
a) the approach for the smallsat platform PROTEUS, developed in partnership by AEROSPATIALE & CNES in order to increase space accessibility, with a new class of small satellites (500 kg),
b) the generic platform description and main performances (pointing, allocated mass, power, data storage, etc..), and payload interfaces (mechanical, thermal, electrical, command & control),
c) examples of optical missions for the astronomy, for the interplanetary exploration, and for the Earth observation.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

1. INTRODUCTION

This article presents a new European small platform: PROTEUS, currently developed by the CNES and AEROSPATIALE, and some prospected applications using optical instrumentation. CNES initiated the PROTEUS design study in order to define a new Low Earth Orbit Satellite class (500 kg) with the aim of improving space **accessibility**. Three major targets were then assigned to the PROTEUS platform. A **very wide field of missions** (orbits, attitude, instruments and launch vehicle compatibility) will be implemented on the PROTEUS platform at a **very attractive cost,** and within a delivery time of **24 months**.

Technically, the platform architecture is generic: adaptations to each mission consist in relatively minor changes in a few electrical interfaces and software modules. Generic mechanical and thermal validation is achieved through mock up manufacturing, testing and mathematical model correlations. Platform electrical and software validation is achieved through the implementation of a ESSVB (Electrical and Software System Validation Bench) on which each mission application software and electrical adaptation can be validated.
In addition, PROTEUS is developed as a product line, with all the engineering tools necessary to allow a quick adaptation to any new mission compatible with the generic user's domain of application.
Concerning organizational aspects of the program, we have devised methods of improvement by merging different program phases and reducing different Work Breakdown Structure layers.

- Engineering, Ground Validation & Testing, In orbit Satellite Operations
- Customer, Prime, Equipment manufacturers (no subsystem layer).

Regarding Quality, applicable requirements are tuned according to industrial experience in specific space applications and as a function of the technical risks involved.

AEROSPATIALE's industrial approach for the PROTEUS program has already been described in paper [Bert 96], while prospected scientific applications have been presented in paper [Dubo 96].

This one deals more specifically with optical payloads aboard PROTEUS.

2. PROTEUS PLATFORM DESCRIPTION

2.1. General platform description

The platform configuration complies with a wide range of small candidate launchers. Its shape is cubic (nearly 1m side) without central structure, and all the equipment units are accommodated on the four lateral panels and on the lower plate. The interface with the launcher is realized through a specific adapter bolted at the bottom of the structure. The mechanical interface with the payload is provided through the four upper corners of the platform. Figure 1 gives an overview of the general design of the platform.

The platform thermal control is sized to withstand the highest thermal environment loads extracted from the PROTEUS missions domain. The concepts uses passive SSM radiators and an active regulation, heaters being monitored by the central computer.

Electrical power is generated by a symmetrical two wings solar array covered with classical Silicon cells, providing about 800 W when facing the sun. It is distributed through a single non regulated primary electrical bus (21/35 volts) using a recurrent Spot4 NiCd battery.

The on board control & command chain relies on a fully centralized architecture shown on the figure 2. The main function devoted to this chain are the following :
- satellite modes management : automatic modes transitions and routines,
- failure detection and recovery : monitoring and switching to the SHM if needed,
- on-board observability : housekeeping telemetry permanently registered,
- satellite commandability : managing of the telecommands sent by the ground either to hardware or software.

The DHU (Data Handling Unit) performs most of the main tasks through the central 3-1750 processor running the satellite software. It supports also the management of the communication links with all the satellite units either via point to point lines or via a MIL-STD-1553 bus. It generates a clock reference, manages data storage and insures telemetry frame decoding. Finally, it distributes power towards platform and payload equipment.

There are five distinct AOCS modes : Star Acquisition (STAM), Normal Operations Mode (NOM), Orbit Correction Mode with 2 or 4 thrusters (OCM2, OCM4), and Safe Hold Mode (SHM). In NOM, a zero-momentum three-axis control with four reaction wheels and a gyro-stellar attitude determination provide a typical pointing performance better than 0.1 degree (3 sigma). In SHM where satellite is sun pointing, coarse sensors and magnetometers provide attitude measurement and magneto torquers generate torques. In addition, 2 among the 4 reactions wheels are used to provide gyroscopic stiffness.

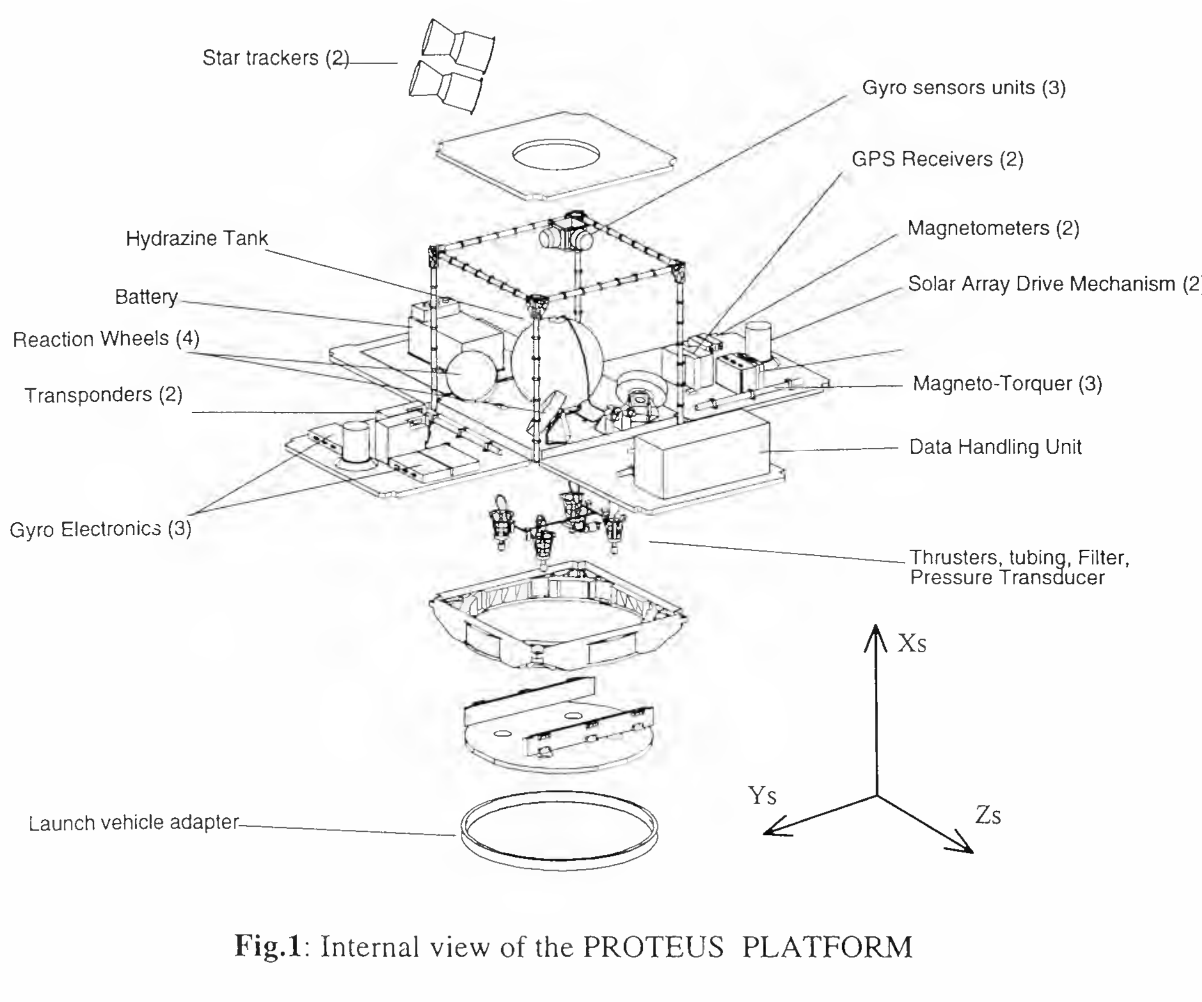

Fig.1: Internal view of the PROTEUS PLATFORM

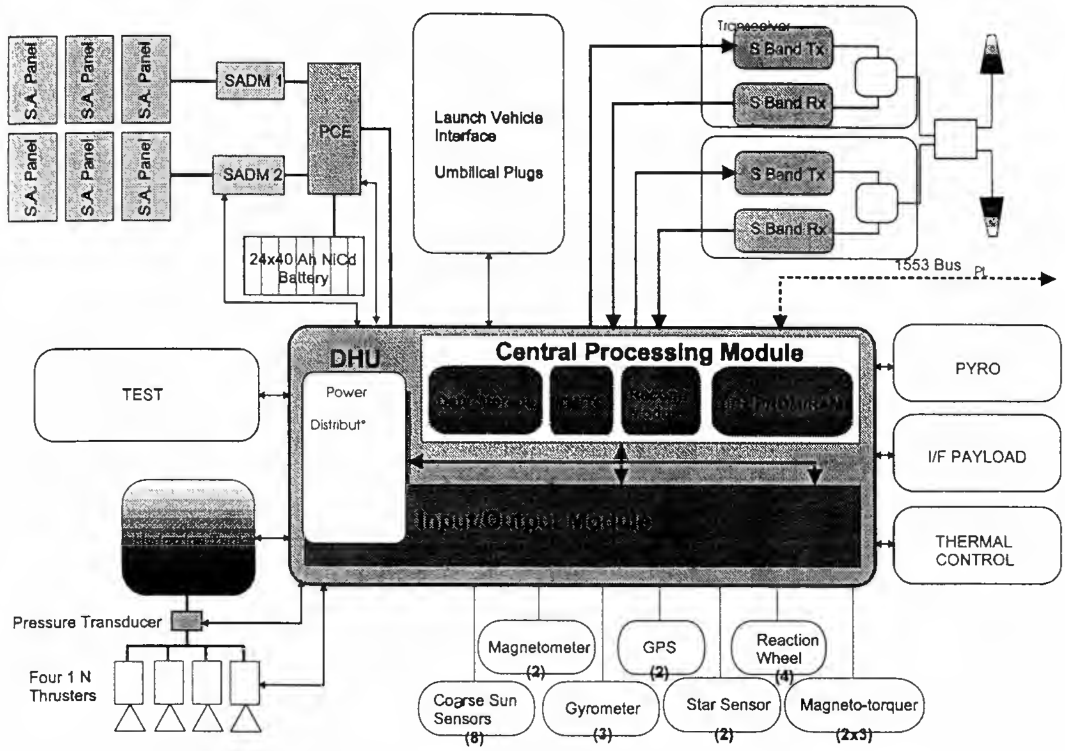

Fig.2 : PROTEUS Platform block diagram

2.2. PROTEUS Platform Main Performances.

- The following table summarizes the PROTEUS platform's main characteristics:

30 kg Hydrazine Capacity
Up to 5 Years Lifetime
Platform Dry Mass : 245 kg
Platform Average Power Consumption : 170 W
Platform Size (W/O solar Array) :
954 x 954 x 1004 mm3
QPSK 650 kbps S Band Down Link

The multi-mission performances of PROTEUS are expressed hereafter:

- The platform provides a wide range of payload pointing capabilities, the accuracy of which is mission dependent :
  - Earth and Anti-Earth pointing,
  - Inertial pointing,

Pointing Accuracy			
	Roll	Pitch	Yaw
Earth	0.035°	0.04°	0.035°
Inertial	0.02°	0.027°	0.02°

- The PROTEUS Platform is designed to be compatible with various orbits, with altitudes ranging from 500 to 1500 km, for *any* orbital plane inclination.

- The platform is designed to be compatible with several existing or currently developed launchers such as :TAURUS, Delta 2, LMLV 1&2, COSMOS, ROCKOT, PSLV, SOYOUZ and ARIANE 5. The stowed platform is then compatible with Small Launch Vehicle fairing diameters of 2 m.

2.3. Payload accommodation and interfaces

2.3.1. Typical payload accommodation for different types of pointing

The PROTEUS platform can accommodate a large variety of optical payloads. Considering the line of sight of each instrument, there are some preferred configurations.

- Earth pointing : in the case of an Earth pointing instrument, the satellite should generally be oriented with the yaw axis Zs toward the Earth. Two major sub-cases are encountered :
  - free pointing around Zs : if the mission imposes no constraint around yaw, the yaw rotation will be optimized with respect to thermal and power criteria. Thus, the satellite will follow a yaw steering movement to point solar array toward the sun. This payload accommodation is convenient for every orbit in the mission envelope.
  - three-axis pointing : if the yaw axis is imposed by the mission, the satellite will fly with its Xs axis near to the orbital speed. This is compatible with sun-synchronous orbits and low inclination orbits.
- Inertial pointing : in the case of an inertial or nearly inertial pointed mission, the instrument will have its field of view boresight toward +Xs satellite axis. In case of a free pointing around boresight, the attitude of the satellite around Xs axis can be chosen taking into account thermal constraints.

These typical payload accommodations must be adapted on a case by case analysis, considering all mission constraints.

2.3.2. Payload interface data

- Payload Mass: The payload mass is typically in the 100-300 kg range. The payload maximum mass is set at 300 kg taking into account the whole Proteus domain, including the envelope environment of above-listed launchers, and must be discussed on a case by case basis. In particular, AEROSPATIALE-led studies have shown that in case of a SOYUZ launch, payload masses up to 500 kg would be compatible with the PROTEUS platform current mechanical design.

- Power available to payload: The typical power available to the payload is up to 250 W on the Proteus flight domain. On specific orbits, like the dawn-dusk Sun-synchronous orbits, the available power is increased. For pulsed payloads, the available power is raised to about 800 W for 20 minutes. Dedicated payload lines are available for pyro (8 nominal + 8 redundant) and thermal needs (7 lines).

- Payload interface plate: The standard payload mechanical interface consist in 4 mechanical links at the 4 upper corners of the platform (860 mm distance between corner fittings).

- Payload data management: A MIL-STD-1553 bus line is available for standard payload commmand-control and data retrieval. Numerous acquisition (48 analog and 12 serial lines, 8 logical status, 24 relay status, 48 temperature acquisitions) and command (48 relay commands, 8 serial commands, 16 open collector-types) lines are provided for the payload. Data Handling Unit software, memory and computing power resources are allocated for the payload. A standard 2 Gbits End of Life payload data storage capacity is provided. The downlink rate is 650 kbit/s using the S-band telecommunication system. For mission requiring more data storage and downlink rate, typically Earth observation ones, a specific Mass Memory Unit and a high rate X-band system (up to 100 Mbits/s) will be implemented in the payload module.

2.4. PROTEUS project status

In July 96, the CNES decided to initiate the first satellite development with the Jason project. An AEROSPATIALE project team was immediately organized in Toulouse, in the framework of the CNES/AEROSPATIALE partnership. The Preliminary Design Review has been held successfully in April 1997. Phase C & D activities are on-going in order to launch Jason, the first Proteus satellite in the end of 1999.

3. EXAMPLES OF OPTICAL MISSIONS FOR THE ASTRONOMY

3.1. COROT

3.1.1. Mission and Orbit

COROT (COnvection and ROTation) [Cata 96] will be the second scientific mission on PROTEUS after Jason, and is a very high accuracy stellar photometry experiment. Its first objective is to study the interior of stars, by means of astro-seismology. COROT will measure luminance variations over a very long period of time (150 days for each mean star without any Earth occultation). This will enable stellar oscillations to be measured with a frequency resolution better than 0.1μHz.

As a second objective, COROT will be able to detect the presence of exoplanets if they transit in front of any star in the observed field of view.

The mission involves two observation programs : an exploratory program only with seismology measurements, and a central program comprising both types of measurements.

The exploratory program will take the place of the EVRIS mission on MARS 96. It will yield a 20-day observation of a great number of stars (30 to 40), allowing a fine seismological characterization through the Hertzsprung & Russel diagram. At least one giant planet (Jupiter or Saturn) will also be observed.

The central seismology program will be focused on hydrodynamic processes inside some well known stars. The resolution required for the detection of a photometric signal is 2.5 micromagnitudes for a star magnitude up to 5.

The search of exoplanets could lead to the discovery of about a hundred telluric planets slightly bigger and warmer than the Earth. To achieve such a result, the instrument will be able to measure a 10^{-4} loss of signal.

COROT's orbit will be polar, inertial, with an altitude around 900 km. The satellite attitude will also be inertial, the line of sight being assigned to keep the same direction for each 6-month observation period. The whole mission (at least 5 observation periods) will thus last 2.5 years.

3.1.2. Payload

The payload includes :
- a telescope,
- a CCD block, 1.5°x1.5° f.o.v.,
- a 2-axis pointing drive,
- electronic modules.

Several possibilities are under study for the telescope, the basic ones being:
- a TMA (three-mirror anastigmat) with a virtual entrance pupil,
- a telescope with a mix of mirrors and lenses and a real entrance pupil.

A block of 4 CCD will be used, two of them being used for asteroseismology (for 1 to 10 stars with a magnitude between 5 and 9), and the other two for the detection of exoplanets (for every stars with a 10 to 15 magnitude in the field of view).
One of the main challenges of this payload is the Earth light attenuation : a goal of 5.10^{-14} is allocated, in order to achieve a detection of 3.10^{-4} variation on the signal. Thus, a baffle (1,80 to 2,5 meter long, depending on the telescope design) will be necessary.

3.1.3. COROT Satellite description

On the PROTEUS platform, the COROT instrument is vertically assembled, its line of sight being the X-axis. On orbit, this configuration will allow very long periods (up to 6 months) without occultation by the Earth, as also the largest external surface for detector passive cooling.
Accommodation of the payload onto the PROTEUS platform uses generic interfaces, without any modification.
To improve pointing accuracy, the stellar sensor must be located on the telescope structure, and turned toward the same direction as the instrument. A specific fine pointing mode is being studied, using the instrument as a sensor, and both PROTEUS wheels and the instrument internal pointing drive as actuators.
The total mass of the satellite is 335 kg, with a 250 W mean power consumption.

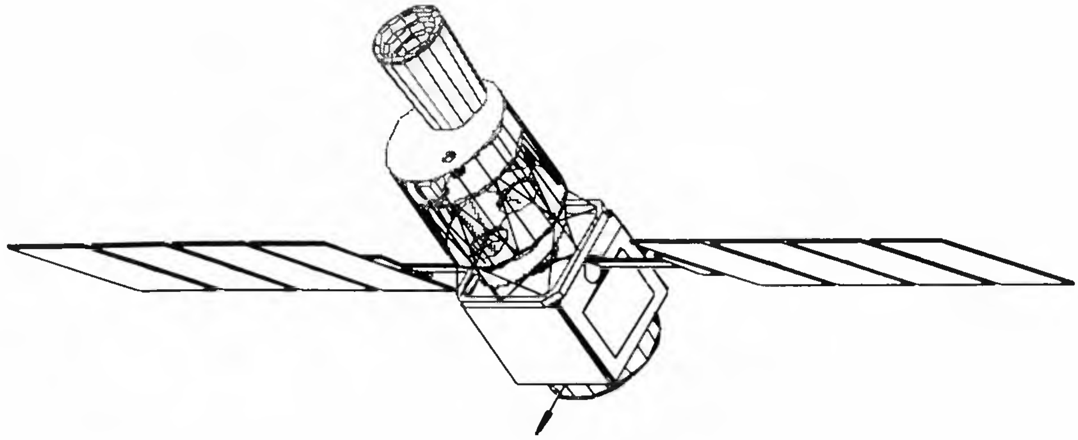

Fig.3 : COROT satellite configuration

3.2. UVEX (Aerospatiale proposal)

3.2.1. UVEX (Ultra Violet Explorer) Mission Description

The objectives of the proposed mission are to perform UV astronomy using two instruments accommodated on a PROTEUS platform. The cost of the mission would be minimized using a PROTEUS platform and already existing instrument concepts:
- the TAUVEX ([Bros 92],[Blas 93]) instrument developed by the University of Tel-Aviv (Israel)
- the UBRIS [Mill 96]: instrument proposed by the Laboratoire d'Astronomie Spatiale (France).

The science objectives are to perform a partial sky survey using TAUVEX and UBRIS.

TAUVEX : The purpose is to perform a partial sky survey in three UV spectral bands (centered at 155, 200, 250 nm, bandwidth 30 nm each) and specific observations in two other spectral bands. TAUVEX will cover in one exposure a field of view of 54 arcmin, with an angular resolution of 10 arc seconds, each field being observed once. The limiting monochromatic magnitude is 18.5 with a signal to noise (S/N) of 5 in the "intermediate band filters". Taking into account the 0,63 square degrees FOV of the instrument, and assuming an observing policy of one field per orbit, a partial sky survey, focused on the Galactic polar caps to a galactic latitude of 60°, leads to a mission duration requirement of 3,7 years. The science yield at the completion of the survey mission will be a catalogue of about 80,000 QSOs, 60,000 galaxies, and 1000,000 stars for which TAUVEX will measure the UV properties.

UBRIS: The purpose is a spectroscopic survey of diffuse sources in the spectral range 90-185 nm, with a 0,15 nm resolution. This diffuse background spectroscopy survey will trace the physical condition in the galactic interstellar medium and probe the origin of the extragalactic ultraviolet background with a sensitivity far exceeding any other existing or planned mission. This survey is essential for probing the global dynamics of the transitional ISM and for measuring the extra galactic background.

Proposed mission profile: This is based on the observation of one polar cap (the northern cap) during half a year (Summer, Spring), the other cap (the southern cap) for the other six months (Winter, Autumn), in order to avoid Earth occultation.

Pointing: The mission requires inertial pointing during each observation, with the following accuracies, for TAUVEX: 5 arc min. (maximum limit cycle: 2 to 3' arc); for UBRIS: 0,3 arc min. (+/- 20 arc sec.). The current platform performances (about 1 to 1,5 arc min) are sufficient for the TAUVEX mission, but are slightly below those required by UBRIS. The pointing accuracy could be increased by using the TAUVEX data (difference between the detected centroid of the tracking star and its expected location) as input to the PROTEUS attitude control system.

Orbit: A 650 km altitude, near equatorial orbit is proposed, taking into account the mission objectives, the launcher performances (Shavit 2 launched from Kourou taken as baseline), and the ground segment aspects.

3.2.2. Payload Description

TAUVEX :The instrument consists in 3 co-aligned telescopes of 20 cm diameter, imaging the same area with photon counting detectors.

The overall payload comprises:
- an optical module: 3 telescopes with their baffling system, a wheel filter on each telescope to separate the spectral bands, and associated electronic circuits for detector operations,
- an electronic module: common elements for data acquisition and storage (2 hard disks of 84 Mbytes in a pressurized container), power supply and thermal stabilization.

UBRIS :The instrument consists of two telescopes, working respectively in 90-120 nm (FUV) and 125-185 nm (VUV) bands.
The telescopes employ:
- a 13-15 cm diameter, 38 cm aperture off-axis primary,
- a spherical, holographically ruled grating in a Rowland mount.

3.2.3. UVEX Satellite configuration

The satellite mechanical and thermal architecture takes into account:
- the PROTEUS platform design,
- the instruments' mechanical interfaces,
- the instruments' mounting constraints (UBRIS must be preferably installed along the launcher longitudinal axis to withstand the launch environment),
- the thermal constraints (implementation of instruments electronics and associated radiators on satellite "cold faces")
- the compatibility with 1.6 m diameter launcher fairings (Shavit 2 class).

The resulting satellite configuration is illustrated below:
- Deployed configuration, showing the platform and the payload module with the instruments' cover deployed (the covers could possibly be dispensed with). The propulsion system, four nozzles located inside the spacecraft cylindrical sleeve at the opposite of the payload, is well away from the payload optics. Two semi-hemispherical coverage antennae on each side of the platform allow telecommunications links to be established independently of the S/C attitude relative to Earth.
- Stowed configuration (solar panels and telecommunications antennas folded, instrument covers closed). This "compact" satellite configuration, designed to be compatible with a 1.6 m diameter fairing has two non-standard platform features: vertical solar panel storage and deployable antennae. On the rear side of the platform, the stellar sensor used for attitude control, and the propulsion system valves can be seen.

The total mass of the satellite is 382 kg, with a 354 W mean power consumption.

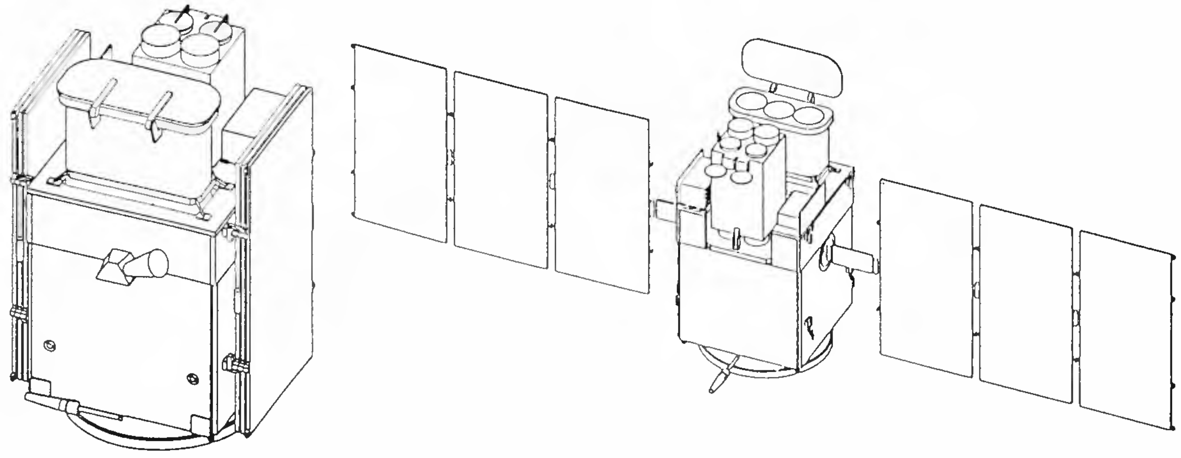

Fig.4 : UVEX Satellite configuration

4. EXAMPLE OF INTERPLANETARY OPTICAL MISSION: Mars 2001

4.1. Mars 2001 Mission Description

In the context of the Mars 2001 mission, analyses have been made of the potential of the PROTEUS platform for a mission to Mars [Darg 97].

This was performed in order to provide the scientific community with a reconfigurable vehicle for interplanetary missions, a quick access to space for science (<3 years), a modular concept, and a low cost satellite with the use of a generic platform derived from the Proteus CNES/ AEROSPATIALE program.

The mission case was a Mars 96 recovery mission, using 5 spare instruments of the Mars 96 spacecraft, with a launch target in Mars 2001.

The main other features of this tentative recovery mission were the following ones:

- launcher class compatible with a 1000 kg spacecraft
- direct injection in cruise orbit to Mars,
- a 198 days cruise to Mars,
- insertion into an elliptical Mars Sun-synchronous orbit by the S/C propulsion system,
- 2 years of exploitation in Mars orbit.

The activities around Mars are shared into 2 phases:

- obsevation phase: the S/C points to the planet for observation by the instruments (1 hour per orbit)
- communication phase: the S/C is oriented such as it can transmit data to the Earth, and the solar arrays are Sun pointed (4 hours per orbit).

4.2. Mars 2001 Payload Description

The following optical instruments have been selected for the payload:

- HRSC: High Resolution Spectroscopic Camera,
- WAOSS: Wide Angle Optoelectronic Stereo Scanner,
- OMEGA: Visible and Infra-red Mapping Spectrometer,
- PFS: Planetary Fourier Spectrometer,
- SPICAM-E: Multichannel Spectrometer.

Instrument	Unit	Unobstructed F.O.V. (deg)	Scientific F.O.V. (arcmin)	F.O.V. w.r.t. Nadir (deg)	Pointing type	Pointing stability (arcmin/s)
HRSC	Camera head	> 38° x 12°	> 38° x 12°	Nadir	Nadir	0,067 arcmin (short term)
OMEGA	OM-Camera	8,8	4	0 to 30	Nadir or 3 axis	< 1
SPICAM	SPICAM-E	10 x 10	1x1 3x4	Horizon to Nadir	3 axis	NA if star in FOV
PFS	MO	2 (SW) 4 (LW)	TBD	all	TBD	< 10
WAOSS	Camera	TBD	TBD	Nadir	Nadir	TBD

The total payload mass is 120 kg, the maximum payload power is 150 W.

4.3. Mars 2001 Satellite configuration

The spacecraft is constituted by the stacking of three modules:
- the bi-propellant **propulsion module** ensures the transfer to Mars up to the Sun synchronous orbit injection around the planet,
- the « **Proteus** » **module** drawn from the existing PROTEUS platform, ensures the servicing functions during the cruise and when the satellite is operational around Mars,
- the **payload module** supports the scientific instruments and is crowned by the high gain antenna.

The main difference with other Proteus mission configuration is the adding of the propulsion module comprising a 400 N engine for Mars insertion, 16 x 10 N thrusters for attitude control, 4 propellant tanks (630 kg total capacity), and 1 pressurant tank.

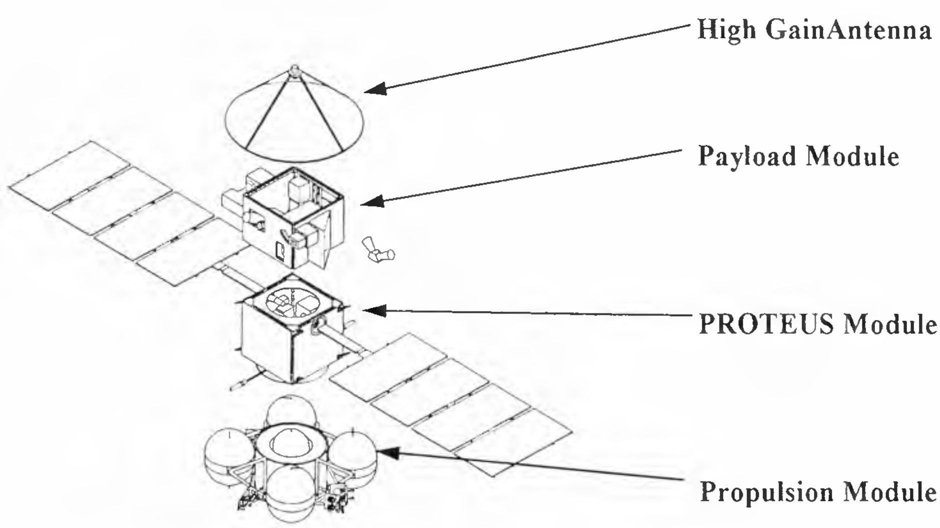

Fig.5 : Mars 2001 Satellite configuration

PROTEUS / MARS 2001	
Platform Mass	238 kg
Payload module Mass	57 kg
Payload Mass	116 kg
Propulsion module Mass	124 kg
& Bipropellant Mass	476 kg
Resulting Launch Mass	1011 kg
Δv Capacity	1920 m/s
Typical Launcher	SOYOUZ-MOLNYA
Apsis altitudes at Mars:	300-10000 km
Electrical Power profile	275 < P < 375 W
TM Capacity (worst-case / 2.7 a.u.)	16.9 Kbit/s
Data Storage Capacity (mass memory)	2 Gbit E.O.L.

Mars 2001 mission data

5. EXAMPLES OF OPTICAL MISSION FOR THE EARTH OBSERVATION

5.1. 3S (CNES proposal)

5.1.1. Mission & System

The CNES is currently evaluating the possibility to achieve a follow-on to its SPOT family after SPOT5 (to be launched in 2002), with a significant reduction of costs. One of the studied options for the new system is based on a PROTEUS platform, and is called 3S (for Suite du Système SPOT).

The 3S system is described in another paper of the ICSO'97 [Lac97]. It is composed of 3 high resolution (2,5 to 3 m) satellites, allowing a large coverage and a stereoscopic ability.

In the CNES assessment study, each satellite has a two degree of freedom pointing capacity : +/-45° along the roll axis, and +/-30° along the pitch axis. The first one allows a lateral access and is achieved through a pointing turret, which is set between the payload module and the telescope. The second one allows a single satellite stereoscopic capacity along the satellite track, and is achieved through a rotating mirror. As for the SPOT satellites, a third degree of freedom is added along the yaw axis, by the mean of an oscillating rotation of the platform, with a 5° amplitude.

5.1.2. Payload

The 3S payload is composed by an instrument, a data handling and compression unit, a mass memory unit, a high rate telemetry subsystem.

Parts of the instrument are : a TMA telescope, 3 video electronics boxes, the pointing mechanism and its electronic module. The estimated mass of the instrument without mechanism is around 100 kg.

Studies are currently led to adapt an off-the-shelf mechanism for the turret, with a raw specification of a 15 microrad position knowledge. Its speed shall be high enough to ensure a 60° amplitude within a 10 second time, including stabilization.

5.1.3. Satellite

On the PROTEUS platform, the 3S payload units are mounted on a 2-level structure. On the lower plate are stacked : the X-band telemetry subsystem, the mass memory unit and its controller, the stellar sensors of PROTEUS, and the turret mechanism supporting the telescope. The upper plate is hollowed in the middle to allow moving the telescope around the satellite vertical axis. This plate supports the video units and the control electronics of the mechanisms.

Apart from the video data storage and telemetry, which are performed at the payload level, all the PROTEUS facilities are used on the 3S satellite. Depending on thermal requirements for the telescope structure, an additional unit could be added to perform a very fine control of the heat gradients.

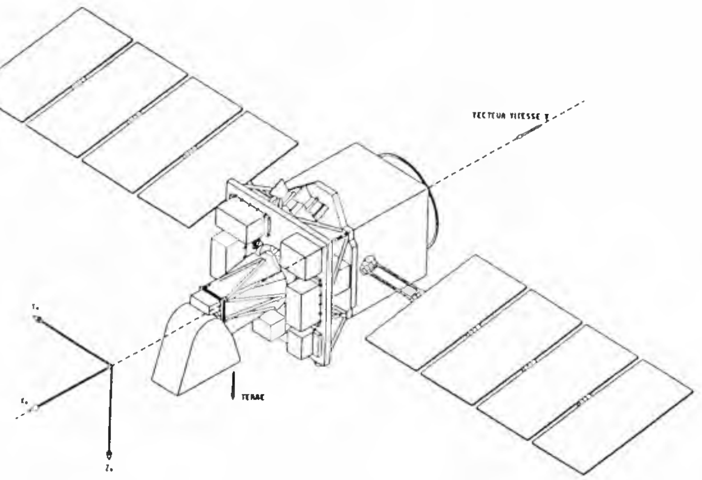

Fig.6 : The 3S Satellite

5.2. TOPS (Aerospatiale proposal)

5.2.1. Mission description

The Thematic OPtical Satellite (TOPS) is designed for cartography and remote sensing missions. Depending on the country latitude, TOPS can be launched into either near equatorial (typical 15 to 20 degrees inclination values) or Sun-synchronous orbits, with an altitude of about 800 km. It will perform direct visibilty imaging. TOPS offers, within a total field of view from 60 to 120 km, panchromatic (black & white images) observations with a 5 m spatial resolution, and multispectral (images in color) observations with 10 m spatial resolution. The access to a specific scene is made by performing a « roll flip » up to 40 degrees from Nadir, with the satellite.

The mission can be adapted to the customer's needs and improved versions could offer:
- better spatial resolution about 3m,
- increase over 200 km of the total field of view,
- quick repointing capabilities,
- imaging capabilities with on-board storage.

The TOPS system components include the launch services, the satellite(s), the satellite control center, the image processing center. AEROSPATIALE offer will be adapted to customer's wish, and could cover the procurement of the full system, or parts of this system ; e.g. the satellite plus the satellite control center, or e.g. the satellite only.

The TOPS system is designed to use off-the-shelf technology, components and equipments.

5.2.2. Payload description

The payload module includes:
- the optical instrument and focal plane CCD detectors,
- the processing electronics,
- the X-band downlink image telemetry system,
- the associated structure, thermal control, harness.

The optical instrument reuses existing technologies and components derived from other space instruments.

5.2.3. Satellite configuration

The satellite is composed of a dedicated payload module on board the generic PROTEUS multi-mission platform.
It offers simple payload / platform interfaces:

- mechanical interfaces: four fixation points
- power supply: semi regulated (21/35 V) bus
- command & control: 1553 MIL Std bus.

The payload and platform integrations can be done in parallel.

The satellite characteristics are typically a mass of 400 kg and a power of 300 W.

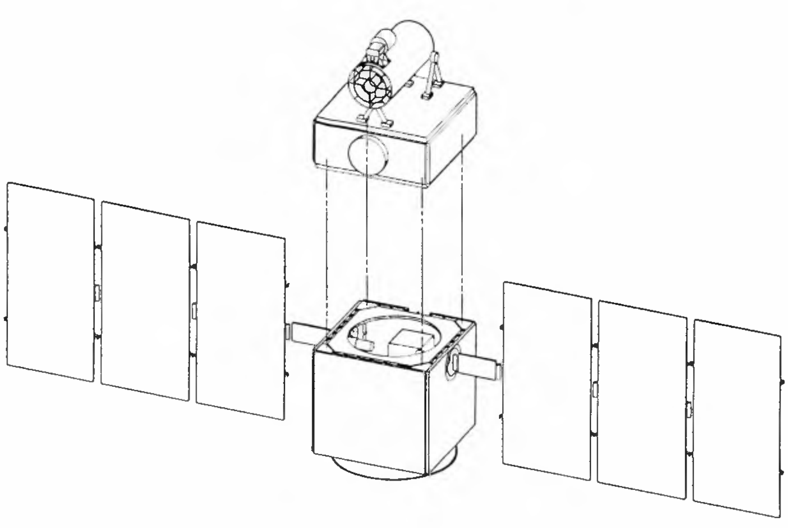

Fig.7 : The TOPS satellite

5.3. Land Explorer (Aerospatiale proposal)

5.3.1. Mission description

For the post 2000 time frame, the European Space Agency (ESA) is defining candidate missions for Earth Observation. In the class of the Earth Explorer missions, dedicated to research and demonstration missions, the Land-Surface Processes and Interaction Mission (LSPIM) involves a dedicated satellite carrying a single optical payload named PRISM (Processes Research by an Imaging Space Mission). PRISM is a multispectral imager providing high spatial resolution images (50 m over 50 km swath) in the whole optical spectral domain (from 450 nm to 2.3 µm with a resolution close to 10 nm, and two thermal bands from 8.2 to 9.2 µm. The mission provides multi-directional observations for measurements of Land Surface BRDF (Bi-Directional Reflectance Distribution Function) and an access to any site on Earth within 3 days. This means Line of Sight agility in across-track direction for the site accessibility, and along-track agility for the BRDF measurements. The proposed orbit is a 767 km altitude Sun synchronous circular one, with descending node at 11:00 a.m.

A detailed presentation of this mission and corresponding AEROSPATIALE activities at optical payload and satellite level is made on paper [Laba 97] also presented at ICSO'97.

5.3.2. Payload description

The payload comprises the hyperspectral imager PRISM and the associated on-board image chain.

The objective of the PRISM instrument is to produce sets of spectral images of selected Earth sites, simultaneously measured in different wavelength regions. Each spectral image is a 2-D array of samples made of an equal number of rows and columns. The images in all bands are spatially and spectrally co-registered for accurate exploitation of data. The instrument covers two main spectral regions. Region 1 covers the Visible-Near InfraRed (VNIR) and the Short-Wave InfraRed (SWIR) from 0.45 to 2.35 µm. In this region, the instrument works as an imaging spectrometer with a spectral resolution of about 10 nm. Region 2 covers the Thermal InfraRed (TIR), with two bands of spectral width close to 1 µm, from 8.2 to 9.2 µm. The instrument radiometric performance reach a high level of accuracy by involving on-board calibration capabilities. The overall architecture is based on the use of a single optical instrument to perform the complete requirements, in particular the use of a common telescope for region 1 and region 2, and the use of the same detector pitch in all spectral regions. The very large spectral range from VNIR to TIR leads to the use of an all-mirror telescope. The selected concept is a Three Mirror Anastigmat (TMA) with a real entrance pupil. The separation between region 1 and region 2 is performed at the telescope focal plane.

One important feature of PRISM is the very high data rate provided when full spatial and spectral observation is required. The payload data handling architecture includes the video electronics, a data processing unit, an instrument control unit, and a high capacity solid-state mass memory (60 Gbits) and a 100 Mbits/s X band telemetry system.

The PRISM push broom multispectral imager has a typical volume less than 1 m x 1 m x 0,5 m, mass (including electronics) about 300 kg, mean power about 300 W.

5.3.3. Satellite configurations

A candidate satellite configuration based on the use of a recurrent Proteus platform and an instrument equipped with an along track scan mirror is illustrated herebelow. Another candidate configuration consists in a satellite with high manoeuvrability capabilities. The two configurations are presented in [Laba 97].

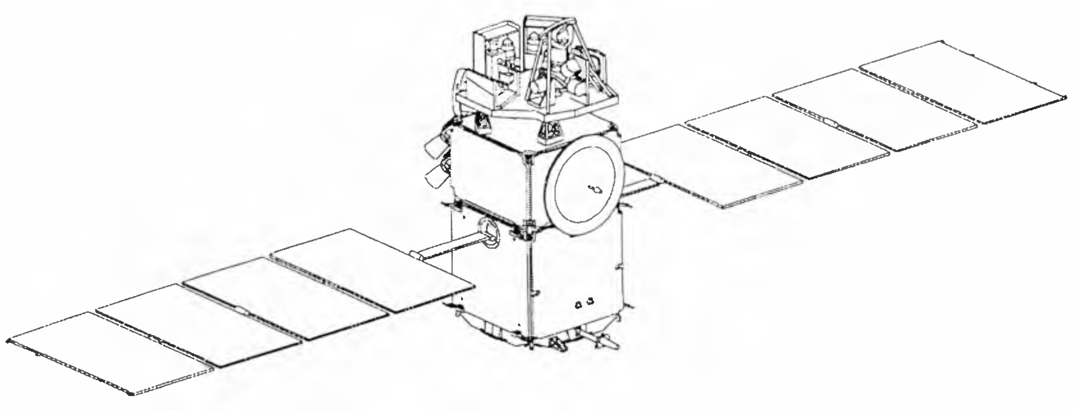

Fig.8 : Land Explorer concept based on Proteus

6. CONCLUSION

• Proteus is a new European multi-mission small platform. Its development is being carried out for the joint CNES / NASA Jason project, due for launch in the beginning of year 2000.

• The development plan allows for 1 mission per year starting from year 2000.

• Missions studied by CNES and AEROSPATIALE show the great potential of PROTEUS for various optical applications, together with an extended capability to domains other than that initially intended.

• PROTEUS is an attractive product for the space community, offering the following characteristics for future optical missions :

- multi-mission architecture,
- low cost and high capabilities,
- high accuracy payload pointing,
- easy payload accommodation,
- multi-launcher compatibility.

• An important aspect of the cost-reduction potential of this platform is the fact that future clients will be able to concentrate their financial and intellectual efforts on the *payload*, leading to optimal mission return for a given global cost.

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CARGA UTIL OPTICA Y SUBSISTEMAS DE COMUNICACIÓN PARA EL SATÉLITE EXPERIMENTAL SATEX I

Fco. Javier Mendieta, Enrique Pacheco y Roberto Conte

Depto. Electrónica y Telecomunicaciones, CICESE
Km. 107 Carr. Tijuana-Ensenada, Ensenada, B.C. México. 22860
Tels. +52 (61) 74-5050 al 53 Fax +52 (61) 75-0549
e-mail: jmendiet@cicese.mx / epacheco@cicese.mx / conte@birch.ee.vt.edu

RESUMEN

El Proyecto SATEX implica el diseño, construcción y operación de un satélite mexicano de órbita baja (LEO), está dividido en distintos subproyectos y el CICESE participa en tres de ellos, todos relacionados con los sistemas de comunicación entre el satélite y la estación terrena. Estos proyectos son la *Carga Util Optica* a bordo de satélite, los subsistemas de *Telemetría, Comando y Control* y la *Estación Terrena*. En este trabajo se presentan las características generales de dichos subsistemas, y los resultados obtenidos por el CICESE a la fecha.

INTRODUCCION

Existen varias formas de conocer el nivel de desarrollo de un país, como lo es a través de los indicadores económicos, sociales, financieros, educativos o de infraestructura. Uno de los más recientes es el grado de avance tecnológico de un país en cuanto a desarrollo de tecnología propia. En el área de la ingeniería electrónica, es tan importante el área de electrónica de consumo como la de control y, crecientemente, la unión de la computación con las telecomunicaciones (telemática)y el desarrollo de nuevos productos, materiales y metodologías. Resulta muy importante, entonces, conocer y dominar la tecnología espacial para lograr productos de mayor calidad, obtener metodologías y procedimientos que permitan mejorar el desarrollo de tecnología propia, así como para tener más y mejores profesionistas en nuestro país al pasar esta experiencia de maestros a alumnos en niveles técnico, profesional y de posgrado.

Con esta finalidad en mente, un grupo de académicos propusieron al Gobierno Mexicano su apoyo en la creación de un programa de desarrollo de tecnología espacial, cuyo primer fruto es el Proyecto SATEX, que implica el desarrollo de una serie de satélites experimentales por personal académico de instituciones mexicanas de prestigio. El Proyecto SATEX I gira en torno al diseño, construcción y operación de un satélite mexicano por instituciones académicas nacionales con fuerte presencia en labores de docencia y desarrollo e investigación científica y tecnológica. Este proyecto cuenta con el apoyo financiero del Gobierno Nacional a través de la Secretaría de Comunicaciones y Transportes y a estado coordinado por el Instituto Mexicano de Comunicaciones ahora parte de la Comisión Federal de Telecomunicaciones (COFETEL).

Dado que el Proyecto SATEX I está dividido en distintos proyectos tiene un carácter inter-institucional y multi-disciplinario. Las características principales de la misión son la de desarrollar una misión científica enfocada al desarrollo de las telecomunicaciones, y poder producir una plataforma multi-misión de bajo costo, simple y adaptable.

CONSIDERACIONES ORBITALES

Es importante aclarar que el satélite, al ser de órbita baja, tiene un constante movimiento con respecto a la Tierra, razón por la cual aparece en el horizonte, pasa sobre la estación terrena y vuelve a desaparecer. De acuerdo a la altura de la órbita propuesta para el SATEX (780 Km), su período orbital es de 100 minutos por cada vuelta a la Tierra. Sin embargo, dado que la Tierra gira sobre su eje polar, el satélite nunca pasa dos veces seguidas sobre el mismo punto, por lo que sólo cada determinado número de vueltas vuelve a aparecer sobre la estación terrena inicial. Esto permite un tiempo de visibilidad del satélite de entre 4 y 10 minutos, dependiendo de su

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

trayectoria sobre la estación terrena. Esto implica que solamente se tiene ese tiempo para contactar el satélite, subir y bajar información y esperar de nuevo a que vuelva a pasar. Además, la distancia al satélite varía entre un máximo (1,362 Km al horizonte) y un mínimo (780 Km arriba de la estación terrena), como se ve en la figura 1. Esto implica una longitud de arco (distancia recorrida) de 2,370 Km a una velocidad instantánea (tangencial) de casi 27,000 Km/h (7.5 Km/s), lo cual genera a su vez un corrimiento en frecuencia por efecto Doppler.

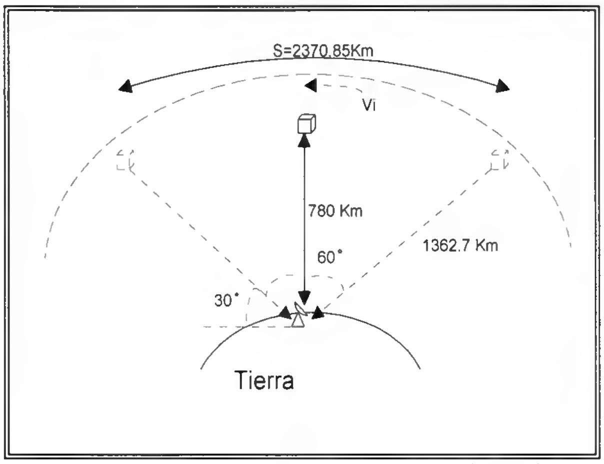

Figura 1. Geometria y Distancias al Satélite

CARGA UTIL OPTICA DEL SATEX I

El creciente incremento del volumen de la información en las comunicaciones por satélite requiere mayores velocidades de transmisión y por ende mayor capacidad en el mismo, si a esto le agregamos la saturación espectral en RF, nos encontramos en la necesidad de explorar formas alternas de comunicación.

Los recientes avances en comunicaciones ópticas permiten tener una alternativa viable para aplicaciones en donde se emplean microondas. Los sistemas ópticos pueden operar a altas velocidades, y requieren para una ganancia determinada, menores diámetros de antenas que los sistemas de RF debido al intervalo de frecuencias en las que trabaja. La potencia eléctrica requerida, el peso y el volumen del sistema total se reducen considerablemente. Los sistemas de comunicaciones ópticas son ideales para comunicaciones en el espacio libre y algunas otras aplicaciones espaciales. Algunos organismos como la NASA, el JPL y la ESA han o están trabajando en diferentes sistemas de comunicaciones ópticas.

El proyecto SATEX intenta demostrar las ventajas de un enlace óptico para aplicaciones espaciales. El objetivo general es el diseño y la construcción de un sistema transmisor-receptor para comunicaciones ópticas (en el cercano infrarrojo) con dirección satélite-tierra. Se tienen limitantes en cuanto a volumen, peso y consumo de potencia impuestos por las características de la misión, por lo que todos estos parámetros se tienden a optimizar durante el diseño del sistema. Además se busca obtener la mínima transferencia de acoplamiento para el movimiento de la antena óptica del satélite, alta sensitividad y un intervalo dinámico considerable para el detector en tierra. El diagrama general del enlace óptico se muestra en la figura 2.

La carga útil óptica (C.U.O.) consta de un transmisor a bordo del satélite (parte superior de la figura 2) y una estación receptora en tierra (parte inferior). El proceso de comunicación se da en base a una secuencia de tres pasos, adquisición, apuntamiento y seguimiento.

- *Adquisición.*- El sistema tiene que adquirir la señal del láser faro(beacon) en su campo de visión.
- *Apuntamiento.*- El sistema en el satélite alinea su sistema de espejos con la línea de vista del receptor en tierra. Este tiene que centrar el haz del láser en la superficie de detección.

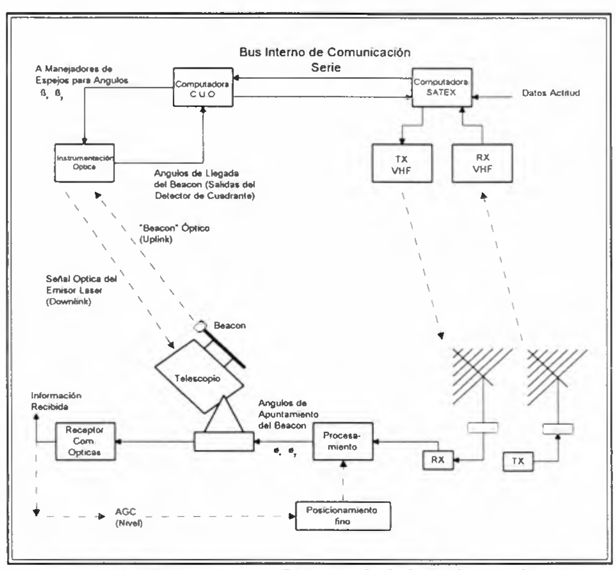

Figura 2. Diagrama General del Enlace Optico para el SATEX.

- *Seguimiento.*- En esta etapa se comienza a enviar la información, manteniendo el sistema alineado. La antena transmisora es ajustada en orden de mantener el haz centrado en el detector. La antena transmisora está manejada por un microcontrolador dedicado que convierte los datos del sistema de localización, el de orientación y del detector en señales manejables. Este microcontrolador interactuará con la computadora principal a bordo del satélite.

SUBSISTEMAS DE TELEMETRIA, COMANDO Y CONTROL

El objetivo de este subproyecto es el diseño y construcción de equipo para un sistema de comunicaciones digitales en las bandas de los 148 MHz (VHF, enlace ascendente) y 400 MHz (UHF, enlace descendente) para el SATEX, consistente en:

- Equipo transmisor-receptor redundante para el satélite.
- Equipo transmisor-receptor redundante en la estación terrena maestra.

Por un lado los subsistemas de control y comando permitirán al personal en tierra enviar señales de control para la operación remota del satélite, la computadora de a bordo y sus cargas útiles. El enlace de comando funcionará a una velocidad de canal de 9600 bps y una velocidad de información de 4800 bps asíncrona proveniente del puerto serie de la PC en tierra, en una frecuencia central de 148 MHz (VHF) con modulación en frecuencia (FM). Tanto el segmento terrestre como el espacial tendrán una redundancia de 2:1, como se ve en la figura 3. Este canal de comunicación trabaja en modo normal cuando el satélite no presente problemas de control para su supervivencia.

Por su parte el subsistema de control es un sistema de respaldo para las computadoras de vuelo, donde en caso de una falla se pueda recuperar el control del satélite mediante el cambio del equipo de comunicación o de la computadora redundante. Este subsistema de control funciona de manera complementaria al subsistema de comando; esto es, sólo opera cuando el de comando no funciona. Su principio de operación es mediante el uso de tonos de audio codificados (DTMF) que, mediante una secuencia prefijada, pueden avisar a un microcontrolador 87C51 que efectúe determinadas acciones de corrección o conmutación de subsistemas, incluyendo a las computadoras de a bordo.

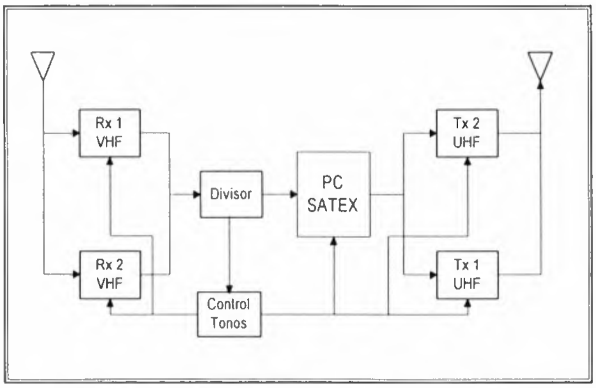

Figura 3. Diagrama General del Segmento Espacial

Por otro lado el subsistema de telemetría permitirá conocer el estado operativo del satélite mediante la recepción de sus señales de telemetría. Este enlace llevará información sobre los parámetros operativos del satélite, así como lecturas y mediciones efectuadas en los sistemas de carga útil a bordo. De ser necesario, se enviaran comandos correctivos o complementarios al satélite mediante el enlace ascendente de comando y control. El subsistema de telemetría utiliza señales digitales asíncronas provenientes del puerto serie de la computadora a bordo a una velocidad de canal de 9600 bps y una velocidad de información de 4800 bps en una frecuencia central de 400 MHz (UHF) con modulación en frecuencia (FM).

ESTACION TERRENA

El objetivo de este subproyecto es el diseño, pruebas, instrumentación y operación de una estación terrena que permita rastrear y localizar al satélite mexicano permitiendo con ello que se establezca un enlace de comunicaciones seguro y confiable. La estación terrena permite además adquirir y desplegar la información proveniente de los radios de telemetría, comando y control; todo ello mediante una interfaz en ambiente gráfico que facilita la interacción con el operador de la estación.

La estación terrena se compone principalmente de los siguientes elementos:

- *Antenas.*- Se utilizarán dos antenas tipo yagi, una para transmisión y otra para recepción. Estas antenas están diseñadas para trabajar en la banda de frecuencias de 138-144 MHz y 395-405 MHz respectivamente. Las antenas se moverán siguiendo la trayectoria del SATEX gracias al subsistema de rastreo, con ello el apuntamiento permitirá mantener la ganancia de las antenas constante.

- *Subsistema de Rastreo.-* Este subsistema permite tener un seguimiento en tiempo real del satélite cuando pase por el ángulo visible de la estación terrena. Para este subsistema de control se ha seleccionado un rotor que permite que las antenas se muevan tanto en azimuth como en elevación.
- *Subsistema de RF.-* Este subsistema incluye la conectividad de las antenas con el equipo de radio del sistema de telemetría, comando y control. Además se ha integrado un radio transreceptor de los usados por los radioamateurs para comunicaciones satelitales con el fin de adquirir información de otros satélites de características similares al SATEX. Además con ello se han definido las características de una estación receptora de bajo costo que permitirá en un futuro la instalación de más estaciones en todo el país.
- *Subsistema de Banda Base.-* Este subsistema permite la interfaz de los elementos que integran a la estación terrena. Lo componen elementos digitales, interfaces mecánicas y acondicionamiento de señales. Es importante destacar que existe equipo de medición dedicado para el monitoreo de parámetros importantes del sistema en general, tales como medidores de potencia, frecuencia, así como variables ambientales, etc.
- *Programación para Registro de Eventos, Control y Visualización.-* El desarrollo de esta parte del proyecto permite tener una interfaz de usuario en base a elementos gráficos que efectúan el registro de los eventos generados en el satélite, la ejecución de acciones de control y la visualización en general de todos los parámetros del satélite. Esta programación se está desarrollando en una plataforma de ambiente gráfico proporcionada por el paquete C++, el cual permite la programación orientada a objetos. La interfaz que se está generando tiene el objetivo de ser gráficamente informativa, amigable y de fácil manejo.

En la figura 4 se aprecia un diagrama general de la estación terrena, donde se puede apreciar la interconexión de los elementos del sistema.

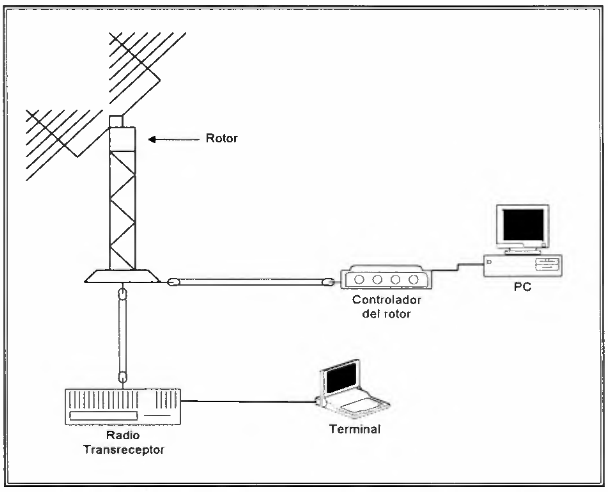

Figura 4. Diagrama General de la Estación Terrena.

CONCLUSIONES

Los tres proyectos aquí descritos y en desarrollo en el CICESE han representado un reto para todos los participantes, pero también han presentado la oportunidad de aprender sobre nuevas tecnologías de grado espacial. Gracias a la iniciativa y el apoyo inicial del Instituto Mexicano de Comunicaciones y continuado ahora por la COFETEL, se han dado pasos importantes para incluir a México en la vanguardia del desarrollo tecnológico espacial. En el contexto científico se ha profundizado en el conocimiento del entorno del ambiente espacial, los estándares a los cuales se someten los sistemas que viajan al espacio, los componentes a utilizar y, sobre todo, a realizar diseños robustos, confiables y con controles de calidad muy altos.

El grado de avance de los proyectos en el CICESE es importante, ya que se encuentra en las etapas terminales de pruebas de sistemas y prototipos de vuelo. El grupo inter-institucional y multi-disciplinario que se ha formado mantiene una comunicación estrecha y ello ha propiciado un entorno de cooperación, difusión e intercambio de ideas y experiencias. Esto es importante para el desarrollo de la actividad científica, educativa y tecnológica en México en general. Los resultados más importantes son la experiencia y el conocimiento adquirido y transmitido, ya que el desarrollo del SATEX I permitirá enfrentar el reto de un segundo satélite mexicano con aún mejores perspectivas, y con ello dar inicio a toda una infraestructura técnica, humana y de conocimientos que, basados en la experiencia de la tecnología espacial, generen el desarrollo de tecnología nacional propia.

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THE GaAs SOLAR ARRAY FOR SPACE APPLICATIONS: A MATURE TECHNOLOGY OF THE ITALIAN INDUSTRIES

A. Caon, G. D'Accolti, A. Trivulzio

FIAR S.p.A., a Finmeccanica company
Via Montefeltro, 8 - 20156 MILANO, Italy
phone: ++39 2 35790310, fax: ++39 2 33400981, e-mail: fiarskco@iol.it

ABSTRACT

With the support of ASI (Agenzia Spaziale Italiana) and in harmonisation with ESA (European Space Agency), the Italian GaAs photovoltaic technology for space applications has been developed by FIAR S.p.A., a Finmeccanica company, and CISE S.p.A., a research company belonging to ENEL, the Italian public electric company.
A wide ground testing activity and the realisation of solar panels for technological missions let to qualify the technology and to propose competitive generators in the commercial arena.
In fact, after R&D and flight technological demonstrations, from GaAs cells to complete and deployable solar arrays, FIAR confirms its capability to design and manufacture GaAs solar arrays winning commercial programmes world-wide: the Danish Oersted, the Spanish Minisat-1, the Argentinean SAC-A, the Mexican UNAMSAT, the US SpaceQuest constellation and the German Safir-2. Moreover, Italian technology is under consideration for the large solar array of the ESA's Rosetta spacecraft and for its lander with GaAs LILT (Low Intensity Low Temperature) solar cells from CISE, CICs (Covered Interconnected Cells) qualification for both Si and GaAs LILT cells and electrical network lay-down from FIAR.
Finally, FIAR is now in charge for the design and manufacture of the complete deployable solar array of the new Argentinean scientific satellite named SAC-C; this project involves CISE for GaAs solar cells manufacturing and Rome based Oerlikon-Contraves S.p.A. for the design and manufacturing of the mechanical parts of the solar array.

Main performances of the above realisations are presented together with the on-going technological and manufacturing improvements in progress in order to offer more powerful and cost competitive GaAs solar arrays for commercial satellites.

1. INTRODUCTION

Since 1984, Italian industries led by FIAR are cooperating in the technological line related to advanced photovoltaic generators for space application based on GaAs cells. The activity has been possible thanks to ASI support in a coherent development and technology demonstration programme in harmonisation with ESA activities [Ref 1-7]. In particular, ASI have been directly supporting the following tasks:

- development of space based bare solar cells of GaAs on GaAs substrates (GaAs/GaAs) type growth with LPE (Liquid Phase Epitaxial) technology;
- development of cells dressing and solar array electrical network lay-down with soldering and welding technologies;
- demonstration of technology's advantages flying complete GaAs solar array on ARSENE and SAC-B satellites, respectively as part of ASI cooperation with French's CNES and Argentinean's CONAE.

Through participation to ESA programmes ASI have supported also the following complementary initiatives:

- development of GaAs cells based on MOCVD (Metal Organic Chemical Vapour Deposition) growth process;
- technological demonstrations in the frame of ESA's TDP (Technology Demonstration Programme);
- preliminary development of multi-junction cells.

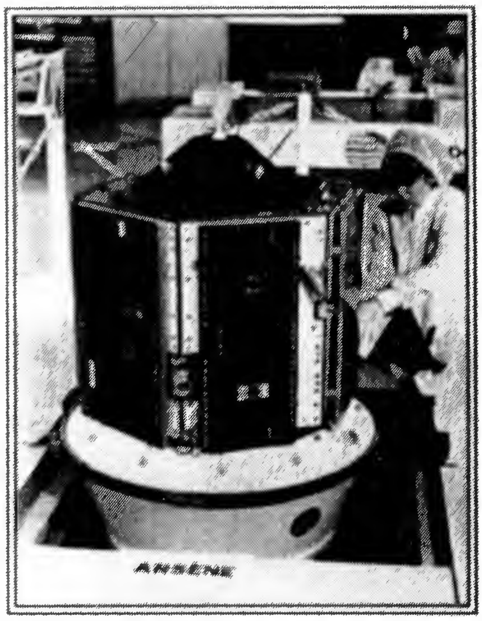


Figure 1.1
ARSENE Satellite
First Satellite Fully Powered by European GaAs Solar Array

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

The above activities have been resulted in a series of records for the European GaAs solar array technology:

- 1990: first flight of a panel based on 2x2 cm^2 GaAs/GaAs European technology (UoSat-E);
- 1991: first flight of 2x4 cm^2 GaAs/GaAs solar cells (TUBSAT);
- 1992: first flight of GaAs/Ge and GaAs/GaAs concentrator cells (ASGA experiment on EURECA);
- 1993: first satellite fully powered by European GaAs solar array (Arsene);
- 1994 first flight of 4x4 cm^2 GaAs European cells (STRV-1A);
- 1996: first flight of GaAs/Ge cells (UNAMSAT).

Evolution of Italian GaAs arrays performances is provided in Figure 2.

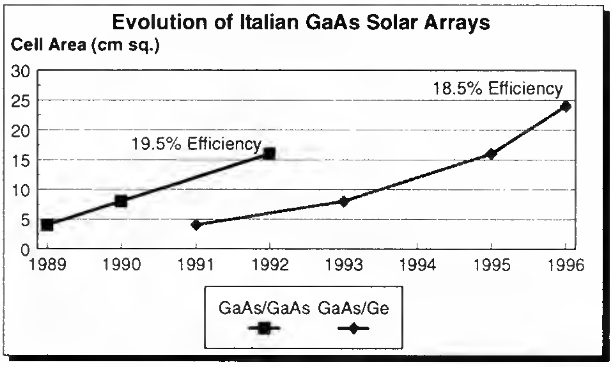


Figure 1.2
Evolution of Italian GaAs Solar Array Technology

The SAC-B GaAs solar array, developed in the frame of a ASI-CONAE-NASA cooperation, is characterised by four equal deployable panels. The panels, of CFRP/Al honeycomb type, are shaped to meet required EOL power within the dual-launch PEGASUS XL firing envelope constraints.
The mechanical aspects and realisation have been in charge to Oerlikon-Contraves

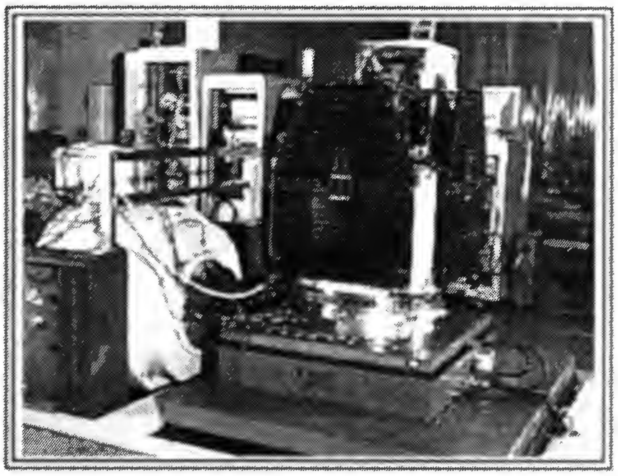


Figure 1.3
SAC-B Satellite During Testing Activities at INPE facilities

After the development, qualification and flight demonstration phase, FIAR and CISE can offer very high efficiency solar arrays to the international market with a qualification status able to cover every type of mission, in terms of electrical and mechanical performances and reliability. The production capability improvements already in progress will allow to satisfy expected increasing request of GaAs solar array for space applications.

2. OVERVIEW OF COMMERCIAL REALISATIONS

2.1 Oersted Solar Array

Oersted is a Danish scientific mini-satellite whose mission is to conduct a research programme in the field of the solar-terrestrial physic comprising magnetosphere, ionosphere and atmospheric physic in combination with research in the magnetic field of the Earth. The satellite is gravity gradient stabilised with the boom pointing away from the centre of the earth. The satellite will be launched in 1998 as copassenger of a Delta II launcher.
The solar array is composed of five solar panels mounted on the lateral and top faces of the satellite body. The mechanical structure of the panels consists of epoxy kevlar face skins on Aluminium honeycomb

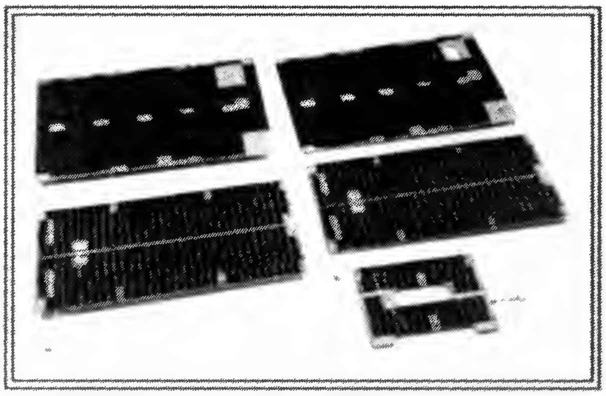


Figure 2.1.1
OERSTED Solar Array Panels

substrate. The solar array embodies 1102 2x4 cm^2 GaAs cells characterised by an average efficiency higher than 18%.
The electrical network is protected by blocking diodes at string level. Top panel strings are also protected by shunt diodes, due to shadow problems.
To prevent interference with the satellite instruments, the electrical layout and wiring have been designed to minimise the panel magnetic dipole momentum. In particular, circuit backwiring and twisted wires solutions have been followed.

2.2 MINISAT-1 Solar Array

Minisat-1 is a Spanish mini-satellite managed by INTA and successfully launched by a PEGASUS XL beginning 1997.

The satellite carry three experiments: to study the behaviour of water in absence of gravity, the measurements of gamma-rays and the UV radiation. It is a two-axis stabilised satellite using a solar array composed of four identical, rectangular, rigid and deployable solar panels placed in four of the six faces of the spacecraft's body.
The mechanical structure of the panels consists of Al/Al honeycomb with a fibreglass insulation layer on the front side dedicated to the cell lay-down. The panel mechanical structure has been realised by CASA (E) as part of the overall satellite structure.
The array has been designed for an EOL power of 180W, even if two strings are lost. The average measured efficiency at panel level was in excess of 17.5%.

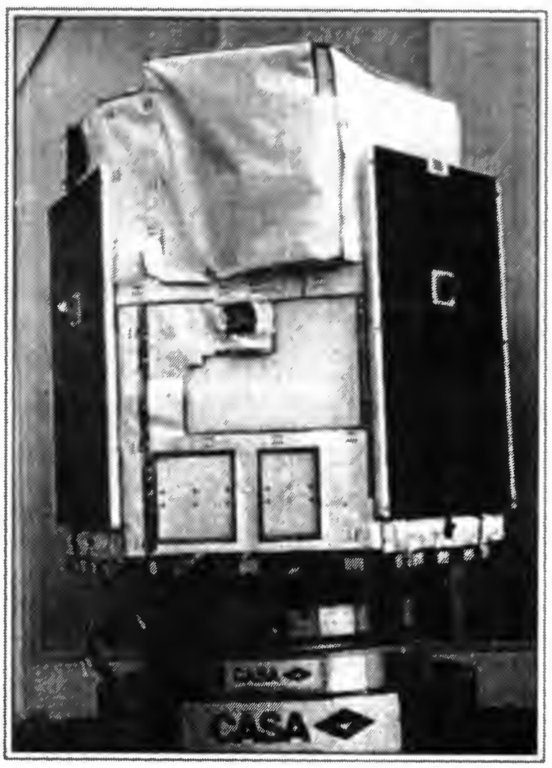


Figure 2.2.1 - Minisat-1 Solar Array

2.3 SAC-A Solar Array

SAC-A is an Argentinean scientific micro-satellite managed by CONAE and INVAP.
The GaAs solar array consists of eight fixed panels mounted to the body of the spacecraft. The eight panels of 250 x 350 mm^2 size are composed of milled Aluminium panels with front skin insulated by a kapton foil.
To achieve the required power coupled with a very tight programme schedule (two months from design starting to delivery) the panels have been assembled with GaAs cells of different size as follows:

- four panels with 4x4 cm^2 cells
- one panel with 3x4 cm^2 cells
- three panels with 2x4 cm^2 cells

for a total installed power of 100 W capable to provide an average maximum power of 29 W at 24 V at satellite level.

2.4 UNAMSAT Solar Array

The UNAMSAT satellite was designed for scientific research as well as radio-amateur use. Built by Universidad Nacional Autonoma de Mexico, is a 10.7 kg micro-satellite, basically a cube of 24 cm side.
The satellite has been launched on September 5, 1996 and all data received confirm the correct operation of the solar array.

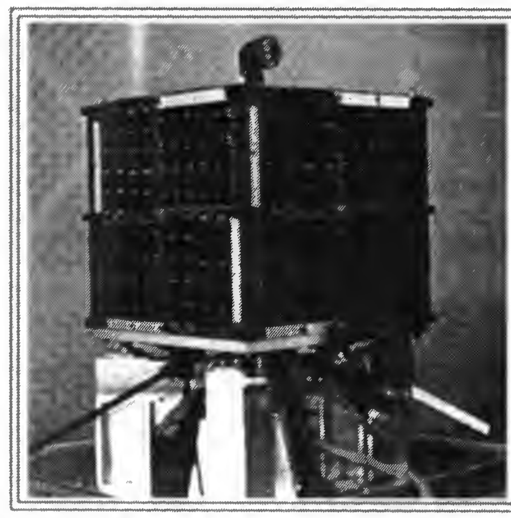


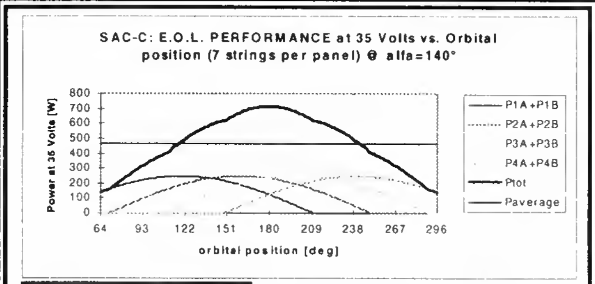
Figure 2.4 - UNAMSAT Satellite

The solar array consists of five body mounted panels. Each panel contains four clips of fibreglass on which the solar cells and relevant electrical part have been integrated.
Cells size of 2x4 cm^2 have been selected. Two panels have been realised with GaAs/GaAs cells while the remaining three with GaAs/Ge cell with an average efficiency of 19.3% at panel level.

2.5 SPACEQUEST Solar Array

US based SpaceQuest company is planning to deploy a constellation of micro-satellites in the 1998-2000 period. Each solar array consists of six body mounted GaAs panels realised with 24 cells of 2x4 cm^2 for a total power in excess of 5 W per panel. A total of 438 panels are required for a total of >2190 W installed.
The programme is planned in four phases for complete constellation to be deployed by end 2000. FIAR have been awarded a contract for Phase 1 activity with options for the remaining phases.
Phase 1 contract, covering the delivery of 26 panels, is near to be completed and Phase 2 option, for further 26 solar panels, is expected to be awarded by January 1998.
Measured efficency at panel level is 19.8%.

The solar array is an octagonal configuration realised with two deployable wings. When folded the wings surround the spacecraft's main body. Each wing is composed of four CFRP/Al honeycomb fixed panels joined by a "H" shaped Titanium profile connecting the edges of the panels.
To achieve a minimum EOL average power of 453 W @ 35 V after four year mission and one string failure, a total installed power in excess of 1200 W will be provided by 2800 GaAs/Ge CISE cells of 4.1x4.24 cm^2. The predicted EOL performances are provided in Figure 3.2.2.



E.O.L.values	P(35V) [W]
max	712.7
min	138.4
average	466.7

EOL average P (35V) = 458.4 W with 1 string of reliability

Figure 3.2.2
SAC-C Solar Array EOL Expected Performances

Four coarse sun sensors will be incorporated in each wing. The solar array will be fully protected against shadowing effects.
The solar array panels, the deployment and the restraint/release mechanisms will be designed and realised by Oerlinkon-Contraves making maximum reuse of components developed in the frame of SAC-B programme.

4. MARKET PROSPECTS

With exception of NASA and US DoD applications, the market for GaAs solar arrays has been limited up to now to a niche market represented by micro- and mini-satellites for scientific or store-and-forward messaging applications. With the implementation of Big-LEO constellations for mobile communications (e.g. Iridium and ICO) and the introduction of new more powerful GEO telecommunications satellites, from 1994 the market demand has risen sharply creating an over demand respect to industrial capacities.
In Europe, the ESA, the CNES and the commercial satellite Primes are recognising the needs of GaAs technology for their programmes and investments are considered to establish a remarkable European autonomy in the field.
With the ASI efforts and companies' capital equipment and infrastructure investments Italian industries have now reached a basic position in order to become a major player in the market.
Realisation of GaAs electrical network is not just a simple straightforward process from the Si based technology, as exemplified by the several problems encountered by world-wide respected solar array integrators [Ref. 8-9]. In fact, GaAs based cells integration requires dedicated processes, handling methods and procedures: all this know-how is available at Italian industries being their manufacturing capabilities tailored to the GaAs technology. Moreover, being this technology applicable also to Si based solar arrays, the Italian industries can provide also Si type or mixed Si and GaAs type solar arrays.

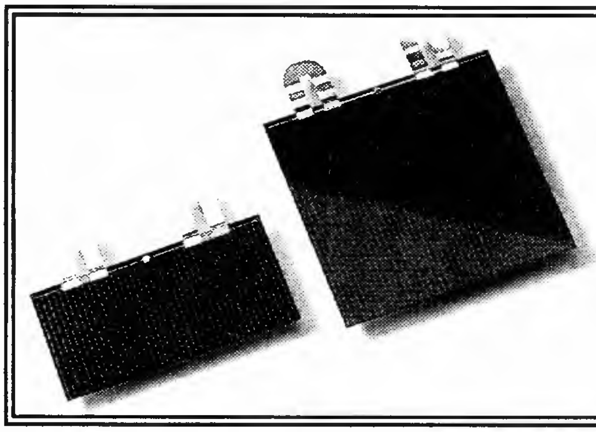


Figure 4.1
2x4 cm2 and 4x4 cm2 CICs from FIAR

To meet the market prospective the Italian industries are presently concentrating their efforts in the following areas:

- near term production capability increase;
- improvements of process yields to reduce costs;
- development and industrialisation of multi-junction GaAs based cells and relevant electrical integration.

Presently, CISE have GaAs cells production capability of about 8 kW/year and is upgrading its line to boost cell line capacity throughput to 20 kW/year by 1998.
FIAR have a manufacturing facility for CICs and electrical lay-down built around a module approach and capable of 10 kW/year electrical lay-down. To meet expected market growth, new investments have been approved. A new integrating area layout is under implementation and equipment, similar to those already specifically designed and manufactured for GaAs technology, will be added in order to increase production capacity to 20 kW/year per shift and to expand present panels dimension handling capability from 1.5 m^2 panel area to about 6 m^2 panel area equired by large solar arrays.
Moreover, addtional R&D efforts are needed in this hi-tech are planned in order to provide more performant solar arrays at lower cost. These efforts are in the following area:

2.6 SAFIR-2 Solar Array

SAFIR (Satellite For Information Relay) is a two-way data communication and tracking service proposed by German firm OHB System of Bremen.

SAFIR-2 micro-satellite is an enhanced version of its precursor SAFIR-1 and is under construction at OHB in cooperation with OHB's Italian Subsidiary, Carlo Gavazzi Space S.p.A., which is in charge also for the solar array management.

The solar array is composed of four body mounted panels. Each panel is realised with GaAs cells for a total satellite power in excess of 35 W. Measured typical efficiency at panel level is 19.4%.

The launch is foreseen in 1998.

3. NEW PROGRAMMES

3.1 ROSETTA Solar Array

Rosetta is a ESA's cornerstone of the Horizon 2000 scientific programme. It is a cometary mission which will be launched in year 2003 by Ariane 5. After a long cruise phase, the satellite will randez-vous with comet Wirtanen and orbit it, while taking scientific measurements. A Surface Science Package (SSP), also called Rosetta Lander, will be landed on the comet surface to take in-situ measurements. During the cruise phase, the satellite will be given gravity assist manoeuvres. The satellite will also take measurements in fly-by of two asteroids.

The mission imposes the following critical requirements to the solar arrays of both the spacecraft and the lander:

- operation at very low temperatures (-130 °C);
- Sun light intensity very low (<0.03 Suns);
- high total radiation dose absorbed during the mission (equivalent 7×10^{-14} MeV for Si and 2×10^{-14} MeV for GaAs).

The solar array baseline is a two wing approach with a total area of about 60 m^2, representing the largest solar array developed for a ESA' spacecraft.

Two candidates LILT (Low Temperature, Low Intensity) solar cells are under consideration:

- Si HI-ETA®/NR LILT cells developed by ASE (D)
- GaAs/GaAs LILT cells developed by CISE (I)

Provided that both cells will be qualified and that mission constraints will be confirmed, the best architecture from technical and cost point of view is a mixed approach i.e with both GaAs and Si cells.

FIAR is presently under qualification of CICs with both type of cells To withstand the large thermal stress, FIAR has chosen the parallel gap interconnection technology, already qualified years ago the frame of a ASI technological contract.

Competition for the electrical network realisation will take place as soon as cell qualifications will be completed.

Should the GaAs LILT cells qualified, ASI will support the realisation of the electrical network of the Rosetta Lander, as part of its National contribution to the mission.

3.2 SAC-C Solar Array

SAC-C is a new Argentinean's project developed by CONAE in cooperation with NASA, ASI and Danish Space Board.

SAC-C is a 300 kg class satellite designed to fulfil the following mission:

- research programme in the field of the solar-terrestrial physic mapping the Earth's magneti field and studying its interaction with the solar wind;
- measure of refractivity of GPS signals occulted by Earth's atmosphere and ionosphere;
- environmental monitoring and studies related to desertification processes in semi-arid zones, identification and prediction of agricultural production in pampean region, flood areas surveillance and environmental studies of coastal and fluvial areas.

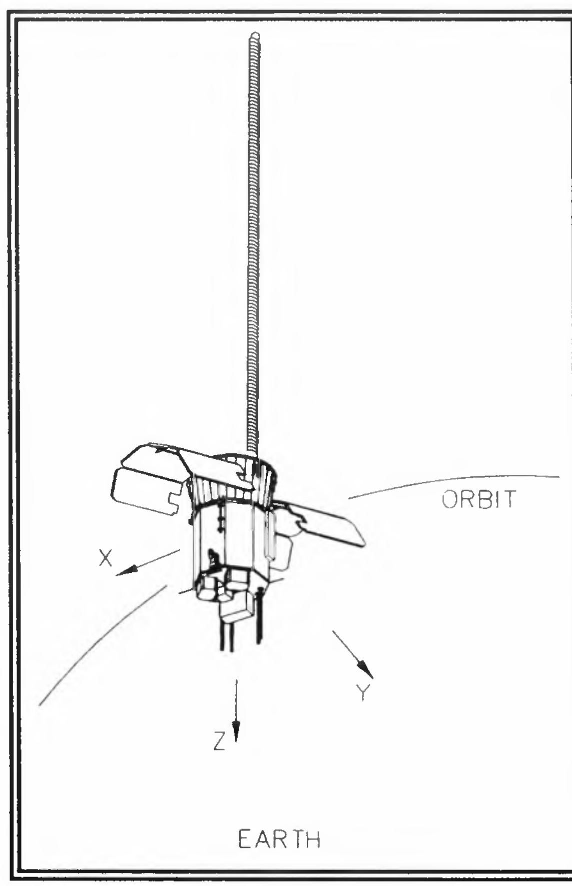


Figure 3.2.1
SAC-C In-Flight Configuration

ASI is supporting the mission as far as GaAs/Ge deployable solar array.

The satellite will be placed in a polar orbit and launched as a piggy-back of NASA's EO-1 satellite by a Delta II rocket planned by mid 1999.

- lightweight GaAs/Ge cells development;
- multi-junction cells development;
- capability to integrate large panels at reduced cost;
- additional automation of some processes to further reduce manufacturing costs;
- qualification and industrialisation of ultrasonic welding interconnection technology;
- solar arrays with concentrator cells.

5. CONCLUSIONS

Development status of Italian GaAs solar array technology has been presented together with overview of realised commercial programmes and activity running in the frame of Rosetta mission and SAC-C programme.
The market for commercial GaAs based photovoltaic generators is rising sharply and Italian industries have all technical know-how an pilot manufacturing capability to become major European players.
Investments running to increase manufacuring capability and development of new products are been highlighted.

6.ACKNOWLEDGEMENTS

The authors wish to thank ASI and ESA for the support in establishing an Italian GaAs solar array technology as well as our industrial partners CISE and Oerlikon-Contraves.

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ELECTRO-OPTIC INSTRUMENTS FOR SMALL SATELLITES

Mike A Cutter

Electro-optics Division Sira Ltd,
South Hill, Chislehurst, Kent, BR7 5EH, England
Phone: +44-181.467.2636, Fax +44-181.467.6515, e-mail: Mike_Cutter@Siraeo.co.uk

Abstract

This paper describes two forms of space based electro-optics systems which are being developed in the Electro-optics Division of Sira Ltd. The first is a new form of imaging spectrometer for remote sensing applications and the second is a state of the art star tracker designed specifically for the emerging mobile phone satellite constellations. Both these payloads are ideal candidates for small satellite missions.

1. INTRODUCTION

The Electro-optics Division of Sira Ltd has been involved in the study and design of space systems for twenty years and has manufactured a range of space hardware including x-ray detector for EXOSAT, data handling systems for the Gamma Ray Observatory (GRO), life science facilities for EURECA, star trackers for ROSAT, focal plane assemblies for the ENIVSAT GOMOS instrument and an IR surveillance system for STRV2.

Currently, the Division is developing a Compact High-Resolution Imaging Spectrometer (CHRIS), to be flown on the ESA small satellite PROBA mission, and miniature star trackers.

The imaging spectrometer system has been designed principally to provide remote sensing data for land applications but is intended to demonstrate that compact imaging spectrometers can provide low-cost but viable instruments when combined with agile small satellite platforms. The instrument will provide a spectral coverage from 400 to 1050 nm with a minimum spectral sampling interval ranging between 2 and 10 nm and a ground sampling interval of 25 m. The payload will be flown on the ESA PROBA small satellite platform. In this mission the satellite platform will provide along and across track pointing.

Miniature star trackers are being developed in the Division to address the new generation of satellite constellations for mobile phone communications these demand small, low power, moderately high-performance star trackers with 15 year life times but at prices considerably lower than commonly associate with scientific missions.

2. COMPACT HIGH-RESOLUTION IMAGING SPECTROMETER (CHRIS)

2.1 Objectives

The science objective for the CHRIS instrument is to provide data on Earth surface reflectance in the visible/near-infrared (VNIR) spectral band, at high spatial resolution. The instrument will use the PROBA platform pointing capabilities to provide Bidirectional Reflectance Distribution Function (BRDF) data (variation in reflectance with view angle) for selected scenes on Earth surface. The instrument will be used mainly to provide images of land areas, and will be of interest particularly in recording features of vegetation. One interest will be to validate techniques for future imaging spectrometer missions, particularly with respect to precision farming, regional yield forecasting and forestry inventory.

The technology objective of the instrument is to explore the capabilities of imaging spectrometers on agile small satellite platforms, such as PROBA, and to provide a demonstration unit for future small satellite missions.

2.2 Concept

The instrument is an imaging spectrometer of basically conventional form, with a "telescope" forming an image of Earth onto the entrance slit of a spectrometer, and an area-array detector at the spectrometer focal plane. The instrument will operate in a push-broom mode during Earth imaging. The detector will be a thinned, back-illuminated, frame-transfer CCD. CCD rows will be assigned to separate wavelengths, and CCD columns to separate resolved points in the Earth image.

The platform will be required to provide pointing in both across-track and along-track directions, for target acquisition and for BRDF measurements. The platform will also be required to provide slow pitch during imaging in order to increase the integration time of the

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

instrument. This increase in integration time is needed to achieve the target radiometric resolution, at the baseline spatial and spectral sampling interval.

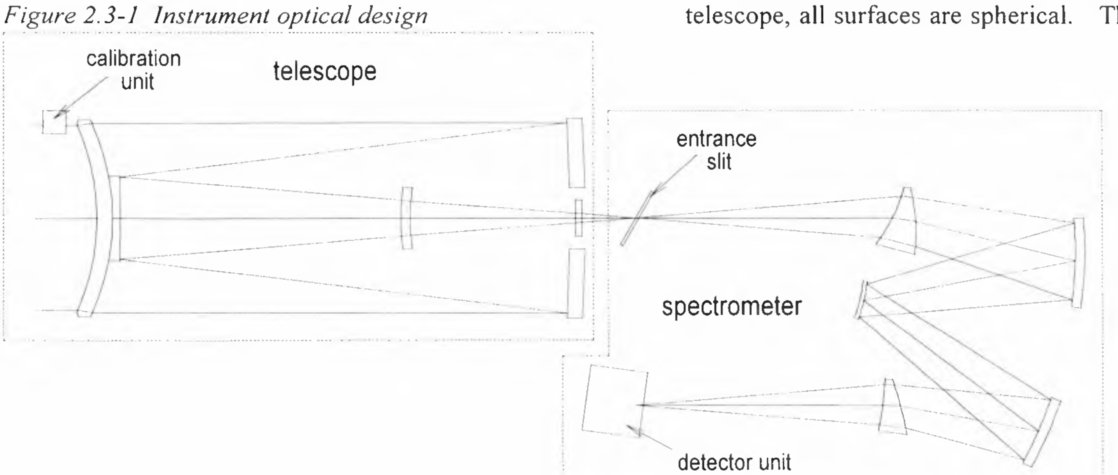
The spectral waveband covered by the instrument will be limited to the band 400-1050 nm, which can be achieved using a single CCD area-array detector. In a later development, it will probably be considered very desirable to add the short-wave IR range up to 1700 nm (for additional vegetation and moisture features) or to 2500 nm, (to include features of minerals). For this reason, the design form selected for the spectrometer is capable of extension to cover the whole spectral range from 400 to 2500 nm by addition of a SWIR detector array in a later development.

The instrument will be calibrated in flight, for radiometric response, by use of (a) a dark scene, and (b) sunlight deflected into the instrument field, through optics of stable transmission and geometrical spread. This will provide data in calibration mode that will be used for flat-fielding and for absolute and relative spectral response measurement. Wavelength calibration may be corrected using data generated in flight from the atmosphere oxygen absorption band at 762 nm.

2.3 CHRIS Design

The instrument optical design is shown in figure 2.3-1. The system comprises a catedioptric telescope and an imaging spectrometer. The system has no moving parts.

Figure 2.3-1 Instrument optical design



2.3.1 Telescope

A catedioptric design is preferred for the telescope, since it can provide the required spectral range without aspherics or off-axis elements. For an altitude of 800 km, the focal length of the system will be 720 mm, and the aperture diameter will be 120 mm (f/6).

All refracting elements in the present design, including the large refracting element at the front of the telescope, and the small element near the focal plane, are made of fused quartz. The secondary mirror, which is cemented to the first large refracting element, will also be fused quartz. The telescope primary mirror will be made in a common optical glass. This choice is made, in order to athermalise the telescope (i.e. to limit change of focus with temperature change). Athermalisation depends mainly on the materials of the primary mirror and the telescope structure: titanium structure, with a glass mirror, will allow athermalisation over a large temperature range.

The telescope is axially symmetrical and has only spherical surfaces, so that conventional construction methods can be applied.

2.3.2 Spectrometer

The spectrometer is a design recently patented by Sira. It uses 'prisms' with curved surfaces integrated into a modified Offner relay. Curved prisms have been suggested on many occasions previously, but have seldom been used in practice because of detailed problems in performance and/or construction. The design proposed by Sira has only spherical surfaces, and uses only one material - fused quartz - for the prisms.

The spectrometer mirrors will be made in a common optical glass. The baseline design, shown in figure 2.3-1, has three mirrors and two curved prisms. As for the telescope, all surfaces are spherical. The dispersion of the spectrometer varies from approximately 2 to 10 nm across the spectrum with the highest dispersion at 400 nm and the lowest in the near infrared at 1050 nm.

The spectrometer design will provide registration to better than 5% of the pixel in both spectral and spatial directions, with resolution limited essentially by the detector pixel size.

2.3.3 Detector

The CCD detector will be an EEV device. It will have the following features:

- CCD area array
- frame transfer
- thinned and back-illuminated, (providing good blue response)
- 770 nominal resolved elements per swath width
- 576 lines in exposed region (approx. 200 active for spectral resolution - others used for smear/stray-light correction)
- dump gate (providing fast parallel dumping).

The frame-transfer period will be approximately 0.6 ms (at 1MHz line-shift rate), which is fairly large compared with the total frame time of 11.3 ms.

2.3.4 Electronics

The instrument electronics will include:

- programmed line integration and dumping on chip for spectral band selection
- pixel integration on chip for spatial resolution control
- correlated double sampling (noise reduction circuit)
- dynamic gain switch (TBC) for optimum usage of 12 bit ADC resolution
- 12 bit ADC.

For the PROBA mission it is anticipated that an image buffer will be included.

2.4 Operational, Platform & Orbit Aspects

The platform will receive demands from ground control for:

- target location - requiring roll manoeuvres to point across-track,
- viewing directions for each target in one orbit - requiring pitch manoeuvres to point along-track,
- spectral bands and spectral sampling interval in each band,
- spatial sampling interval.

The platform will perform the required pitch and roll manoeuvres and transmit control signals to CHRIS to initiate and terminate imaging, with the required spectral and spatial characteristics.

The platform will receive digitised data from CHRIS, store the data in a mass memory unit, implement image processing and data compression using a DSP and transmit to ground on command.

The currently anticipated ground station will achieve an effective down link of 1 Mbit/s enabling 10 images (19 x 19 km) to be down loaded, assuming a moderate level of on-board data compression. Other ground stations may be provided.

The platform is currently anticipated to operate at an altitude of approximately 820 km in a near circular, polar and sun-synchronous orbit.

2.5 CHRIS Specification

The provisional specification for CHRIS is as follows:

spatial sampling interval	25 m (nadir), integration to 50 m, 75 m etc.
swath width	19 km at nadir
spectral range	400 to 1050 nm
spectral sampling	2 to 10 nm
spectral bands	19 band readout @ 25m
radiance range	albedo 1
radiometric resolution	0.5% @ 20% albedo
across-track pointing	range ±45°
along-track pointing	range ±50°

2.6 Programme Schedule

The CHRIS instrument is scheduled to be launched in the period 1999 to 2000. Options for the launch vehicle are currently being considered.

Over the next two years applications for this mission will be established by Sira and its collaborators and specific operational schedules derived.

3. MINIATURE STAR TRACKERS

3.1 Basic Concept

Modern solid-state star trackers are based on optical heads rather like video cameras, in which a detector such as a CCD image sensor is placed in the focal plane of a lens. The angle between the direction of incoming light from a given star and the optical axis of the star tracker is translated into an x, y position of the star image on the detector pixel matrix. The output of the camera is processed by a computer-based electronics system to determine the pointing direction.

3.2 Current Requirements

Star trackers have traditionally been used mainly in space science missions with very high pointing requirements. Of all the types of optical attitude sensors, they are capable of the highest accuracy. In the past the market has therefore been for a relatively small number of high-priced items. However, star trackers are also the only sensors which can provide the complete attitude solution alone (other instruments, such as Earth and Sun sensors, have to be used in combination). As a result, they are now being considered for a wider range of applications, including geostationary communications satellites, low-orbiting communications constellations and a variety of small satellite missions. The reasons for this surge of interest in star trackers are as follows:

- the ability to provide the attitude solution alone is spawning new techniques in attitude control which are being formulated to take advantage of the reduced cost of the sensor suite;
- the ability to provide the attitude solution alone is attractive to small satellite missions, where insufficient accommodation is available to mount a multiplicity of sensors;
- pointing accuracy requirements for commercial satellites are increasing so as to need star tracker accuracies (due, for example, to more accurate spot beams on communications satellites, inter-satellite cross-linking in constellations, and the proliferation of Earth imaging instruments on small satellites).

Although a small number of opportunities will continue to exist for high accuracy (typically 1 arc second) instruments on scientific missions, a large market is emerging for small, cheap star trackers with low to moderate accuracy (0.1 to 0.01°). These new star trackers will often be required to generate autonomously an attitude solution (i.e. have a "lost in space" capability) by the use of a star catalogue and pattern recognition algorithms embedded in the sensor itself rather than in a central attitude control system computer as in the past. This allows the evolution of new, simpler attitude control systems in which the star tracker forms perhaps the whole of the attitude determination system and other inertial sensors, such as gyros, can be omitted, although cheap rate sensors may be added when high slew rates are present and GPS receivers added when orbit positional information is needed.

3.3 Current Technology Status

The advances in technology which make possible the new generation of star trackers described above can be listed as follows:

- better detectors, e.g. CCDs with higher numbers of pixels and better cosmetic quality;
- more powerful processor chips, e.g. DSPs, RISC processors;
- higher levels of electonic integration in general, e.g. FPGAs, ASICs, high-density memory;
- miniaturisation of electronics assembly, e.g. surface mount, multichip modules (MCMs).

Sira is developing star trackers for this new market. A typical specification which is applicable to several different mission types is given in table 3.3-1.

Field of view	19° x 14°	
Sensitivity	5 m_v stars	
2-axis accuracy	50 arcsec/axis	5 arcsec/axis
Roll accuracy	0.1°	0.01°
Slew rate	0.03°/sec	0.3°/sec
Update rate	1 Hz	10 Hz
Power	6 W	
Mass	2 kg	
Reliability	0.995 for 15 years GEO	

Table 3.3-1 Typical range of miniature star tracker performance

The accuracy achievable by a given hardware design varies according to the amount of calibration which is performed, and can therefore be traded against price. At the lower end, the accuracy is commensurate with the pixel resolution of the detector and the distortion characteristics of the lens. The instrument can simply be assembled, functionally and environmentally tested, and flown. Extension of the performance to the higher accuracies quoted requires mapping of the field of view, calibration or careful selection of detector properties, and the use of centroiding algorithms to interpolate the star image position to higher resolution than the pixel resolution. In a sensor with the quoted field of view, an accuracy of 0.01° can be achieved in two axes (the x, y axes of the detector) merely by determining on which pixel the star image is falling. In the third axis, namely roll around the star tracker line of sight, the accuracy is typically a factor 10 lower. Centroiding will be needed, to achieve higher accuracy in the other two axes, in order to yield 0.01° accuracy in roll.

A star tracker being developed at Sira is shown in concept in figure 3.3-1. The instrument is based on a CCD with 770 x 576 pixels from EEV Ltd in the UK. A purpose-designed lens uses radiation resistant glass.

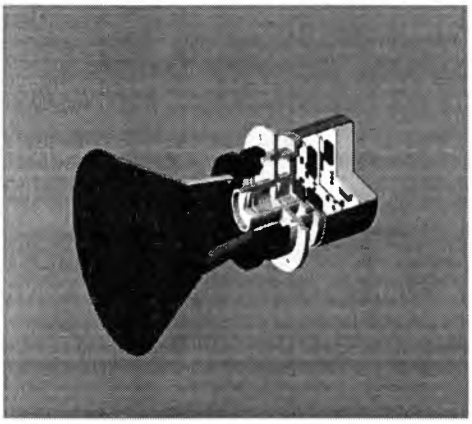


Figure 3.3-1 Miniature Star Tracker

The electronics including the processor, can, if desired, all be placed in the optical head, which has a volume of about 150 mm length by 130 mm diameter, excluding the stray light baffle. However, the electronics may be separated off for a variety of reasons, for example, if the processor power consumption cannot be dealt with in the thermal design of the head bearing in mind the mission specific spacecraft interface, or if it is desired to have a central processing box serving several heads or even other sensor types as well.

3.4 Design Limitations

In the face of increasing miniaturisation of the electronics, optical considerations will determine the size of the instrument. The lens must be sufficiently large in diameter to gather enough photons from the dimmest stars which need to be tracked, bearing in mind the noise of the detector and electronics and the need to achieve the signal-to-noise ratios demanded by the detectability and noise-limited accuracy requirements. The stray light baffle dimensions are even less under the star tracker designer's control. Star trackers with the described field of view require to track stars down to $5m_v$ or dimmer in order always to have enough trackable stars available for any pointing direction. With stars of this brightness level a two stage baffle against Sun and Earth is required. Given the Sun and Earth stay-out angles defined by the operational envelope of the satellite, the baffle size will be uniquely determined.

Another major limiting factor is radiation damage during the mission. The orbits of commercial geostationary missions are quite demanding on radiation tolerance and are now specified with 15 year lifetimes as typical. Even worse are the multi-satellite constellations now being proposed, which tend to be in orbits around 1400 km with very high doses of trapped protons. The softest part of the electronics is currently the detector itself. The increase of dark current with total dose is well understood and part of the dark current can be reduced by the use of a type of CCD called MPP (multi-phase pinned). However, CCDs are also susceptible to damage from protons which occurs in the bulk of the silicon and cannot be overcome. This leads to dark current hot-spots which can look like false dim stars. It also leads to reduction of charge transfer efficiency which causes the star images to become skewed as charge is lost from the leading pixel into following ones during the readout process. Currently, good design and shielding allows these problems to be tolerated for most missions, but CCDs probably cannot be used for 1400 km orbits because of the charge transfer efficiency problem. One possible way out is development of a new CCD type called a p-channel CCD, which should be harder against proton damage. Sira is currently involved in the development of such a device and will be testing devices in the spring of 1998.

3.5 Thermal Considerations

In view of the fact that all currently available silicon detectors are susceptible to proton damage producing image spikes, all star trackers require cooling to temperatures in the region of -20°C to reduce the spike size relative to the dimmest stars used for tracking. The range of temperatures which are found on a spacecraft panel simply cannot be allowed to be transmitted unattenuated to the star tracker. Traditionally, star trackers have used thermoelectric (Peltier) coolers to cool the detector, but these themselves add a few watts more power consumption to the instrument as a whole, which must be dumped eventually from a radiator. As star trackers get smaller for small satellite missions, the increased consumption and size of the Peltier cooler and its power supply become increasingly unattractive. Alternatively, the star tracker could be cooled purely passively, using the stray light baffle as a radiator. This gives a cheaper and less complex instrument more suited to small satellites. Thermal design tends to be mission specific, because the thermal excursions of the satellite, the range of orientations with respect to Sun and Earth and the available radiation and conduction environments all vary from mission to mission. This tends to defeat moves towards a completely off-the-shelf star tracker, which is what the customer would like to see from a cost and availability viewpoint.

3.6 Future Technology Developments

A new type of image sensor, called an Active Pixel Sensor (APS) is now being developed in a number of companies and institutes. This sensor uses standard CMOS processes and is cheaper to make than CCDs. Unlike CCDs it works off normal logic signal levels and does not need special drive circuits. Other functions, such as ADCs and even image processing electronics can be integrated on-chip, reducing the amount of circuit board real estate which is needed in the star tracker. This type of sensor is still affected by radiation damage in terms of dark current increase and proton spikes, but it does not have the charge transfer efficiency problem of CCDs and may therefore be more applicable to high radiation orbits. However, its general radiation tolerance has not yet been tested, and Sira will be performing radiation testing of an APS produced by IMEC of Belgium in the spring of 1998.

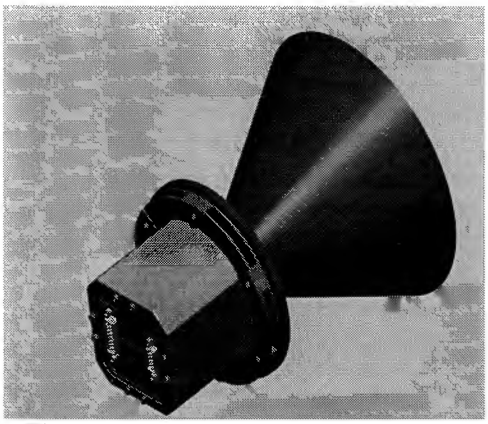


Figure 3.6-1 APS Miniature Star Tracker

Sira is now designing the next generation of star trackers. These will use APS sensors and highly integrated electronics including powerful processors on small MCM packages to produce very small instruments such as the one shown in figure 3.6-1. The size of the lens and baffle (in this case the baffle has been sized for a 45° sun angle) will remain the limitation to the miniaturisation which is possible, although techniques like the use of diffractive elements may reduce the complexity and therefore the mass of the lens.

4. SUMMARY

This paper has described two development activities which are currently being undertaken within Sira which are particularly suited to small satellite programmes. The first is a compact high-resolution imaging spectrometer which will be flown on an agile small satellite platform, and the second, a miniature star tracker principally designed for the new suite of global communication satellites.

Spanish MINISAT Program. Program Objectives and Operational Results.

Miguel A. García Primo
MINISAT Program Manager. INTA.
Departamento de Programas y Sistemas Espaciales.
Subdirección de Investigación y Programas.
Crta. de Ajalvir km. 4 - 28850 Torrejón de Ardoz. Madrid - SPAIN.
Tel. 34-1-5201951. Fax. 34-1-5202043. e-mail: garciapma@inta.es

Abstract. The Spanish MINISAT program has been structured in three main stages plus several associated developments, achieving a modular family of low cost platforms in the small satellite segment, designed to use mainly in low earth orbit (LEO) applications.

The first stage of the MINISAT program have concluded with the complete development and orbit qualification of the platform MINISAT 0 together with the operational experiences is being achieved to perform the scientific mission 01, launched on April 21st 1997. The second stage of the MINISAT program consist of the modular upgrading of the platform 0 up to reach the maximum performances or platform MINISAT 1 to do earth observation missions. The first mission with the platform 1 started the phase A of feasibility study in 1995.The third stage of the MINISAT program will consist of the development of the platform MINISAT 2 that will be an adaptation of the platform MINISAT 1 to be able to do communication missions even in the geostationary orbit.

This paper describes the mission 01 objectives, the satellite and ground segment architecture, as well as the launch operation and the operational phase of the system, taking into account the low cost philosophy applied in the program. MINISAT 01 small satellite was successfully launched in April 21st , 1997 by a Pegasus launch vehicle from Gran Canaria Island, Spain. After more than 5 months of nominal operation, this paper presents also the first operational results from the scientific point of view and mainly the most important houskeeping telemetry data, comparing the current performances with the requirements.

Introduction

The opportunity to entry in space activities at a relevant level for small and medium size countries has been a very difficult aim during the past decades.

In the ninetieths, the technological advances in materials in general, and in microelectronics in particular, together with the experience achieved during the previous decades, has permitted to perform a significant space mission with small satellites.

MINISAT program was born in this context that allows to small and medium countries to access to space missions at system level.

The main objective of the MINISAT program was to provide with the necessary capabilities for designing, developing, qualifying, manufacturing and operating space system to the Spanish aerospace sector, and doing this with the minimum budget, so MINISAT should be a cost driven program.

The satellite is comprised of a low cost multipurpose bus slightly adapted to this mission and a payload module with three different experiments plus a technological demonstrator. The ground segment is comprised of Mission Control System (MCS) and the Scientific Operation Center (SOC). The launch operation was supported by three major elements, the air launched vehicle Pegasus with the satellite inside that was dropped from an aircraft L-1011, the NASA Wallops Mobile Test Range and the Launch Operations Control Center (LOCC). The operational work is clearly split of the real time operations and the off-line operations, being perform in separate locations.

Mission 01 Segments

The first mission of the MINISAT program is composed by three main segments :

Flight Segment or Satellite MINISAT 01

The satellite MINISAT 01 has been split off in two different modules :

The Service Module (SVM) or bus is composed of all the subsystems and associated equipment's the instruments need to perform the mission and besides has inside the technological demonstrator.

The Payload Module (PLM) is composed of all the instruments and the associated electronics and some common equipment like harness, thermal control

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

devices and the structural plate is supporting the instruments.

Ground Segment

The Ground Segment is composed of three main modules :

The Remote Tracking Station (RTS) perform all the real time task with the satellite and is located at INTA Maspalomas Space Station, Canary Islands, Spain.

The Mission Control Center (MCC) perform all the off line task, mainly the mission planning and the engineering analysis of the telemetry.

The Scientific Operation Center (SOC) perform all the task associated with the experiments and is located at Villafranca del Castillo Station.

Launch Segment

The Launch Segment is composed of three main modules with a special configuration due to launch from Spain :

The launch vehicle, an air launching Pegasus from an aircraft Lockheed 1011, injected MINISAT 01 in the desired orbit, from Gran Canary Island.
The Launch Operation and Control Center (LOCC) remotely controlled all the launch operation and was located at the facilities of INTA in Torrejón de Ardoz, Madrid, Spain.

The Flight Safety and Tracking Center was in charge of tracking the launch vehicle and its safety during the launch. It was composed of the NASA Wallops Test Range mainly and some INTA facilities, all of them located at Maspalomas Station, in Gran Canary Island, Spain.

Mission 01

The first mission of the MINISAT program is composed of three scientific experiments and a flight technological demonstrator :

EURD

The Extreme Ultraviolet Spectrograph for the Study of Diffuse Radiation is conducting spectrographic observations of the diffuse extreme ultraviolet radiation in the 300-1050 Å bandpass, to study the nature of the interstellar medium, the upper atmospheric airglow specially the atomic oxygen and oxygen lines, and finally to search for the dark matter associated with our galaxy, in the form of massive(~[29 eV]/c2), long lived (> 1024 sec) neutrinos.
The spectrum generated will have 100 times more sensitivity and 10 times more resolution than any other previous experiment in this wavelength. Besides, in this mission EURD will have the opportunity to observe more than doubled time than any other previous extreme ultraviolet mission.

This experiment has been developed by an international scientific team with INTA (National Institute for Aerospace Research), Spain and University of California, Berkeley, USA.

CPLM

The Column of Liquid Bridge in Microgravity conditions is studying the behavior of axilsimetric liquid bridge in microgravity, with induced accelerations by means of satellite maneuvers.

This experiment has been developed by the Politechnical University of Madrid, Spain.

LEGRI

The Low Energy Gamma Ray Imager is studying the low energy (10-100 KeV) gamma radiation of the gamma sources in the universe, using a new generation of detectors of HgI_2 . This detectors have an specially good behavior in the low energy part of the gamma spectrum.

This experiment has been developed by an international scientific team with University of Valencia, INTA, and CIEMAT for the Spanish contribution, and Birminghan University, Southampton University, and Rutherford Appleton Laboratory for the British contribution.

ETRV

The Technological Demonstrator of a mechanical Speed Regulator has been deployed with a dummy getting all the parameters of the deployment as it was expected. This mechanism will be very useful in the deployment of big antennae, panels or booms.

This mechanism has been developed by the Space Division of CASA, Spain.

Instrument Mission Requirements

The instrument requirements with respect to the mission are the following :

EURD Requirements

This experiment requires to observe pointing in the antisun direction during the eclipses, a nominal orbit altitude between 400 and 600 Km, an orbit inclination between 20° and 40°, and more than 2000 hours of effective eclipse during the operational life.

CPLM Requirements

This experiments requires no specific orbit but the satellite must spin around Z axis, and the body rate must be commanded in the range of ± 0.375 rpm to induce inertial accelerations.

LEGRI Requirements

This experiment requires no specific orbit to observe pin pointing a celestial target during several time (days).

ETRV Requirements

This experiments only requires to be in orbit.

Additional Requirements

Requirements drivers by minimized the cost of the global program impose to use just one ground station and located in some of the INTA space stations. Maspalomas Station is compatible with all the requirements.

Finally safety requirements to launch from Spain imposed a retrograde orbit.

The selected orbit was a circular with an altitude of 587 Km and inclination of 29° retrograde. See figure 1.

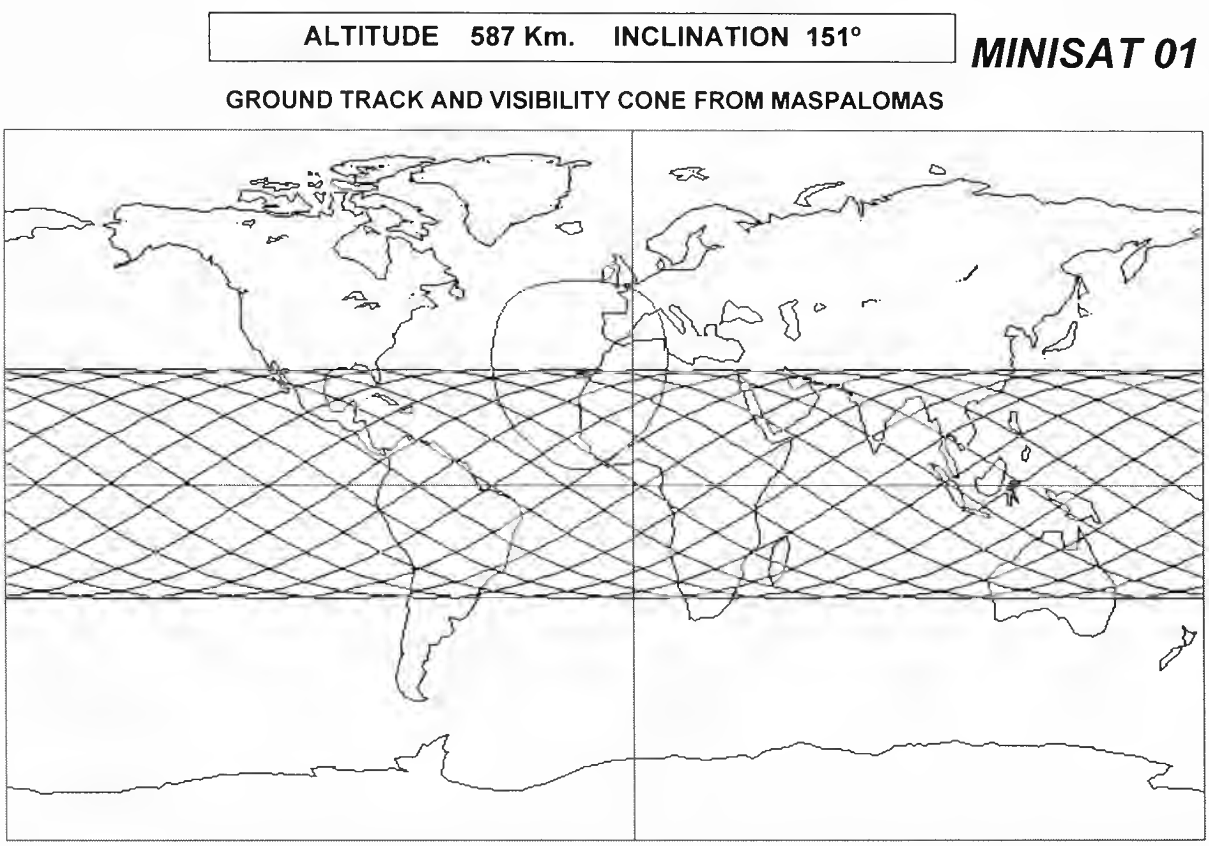


Figure 1

Configuration and Main Performances

MINISAT 01 configuration follows a modular concept with a physical separation between PLM located in the upper part and the SVM located at the lower part of the satellite when in normal vertical position (+ Z axis of the satellite, and it is the same that the longitudinal launcher axis). It has 4 solar panels arranged in a petal like fashion. The SVM configuration consist of two hexagonal platform (upper and lower), a central tube connecting both and with an adapting cone to interface with the launcher.

MINISAT 01 is a sun pointing, momentum bias stabilized satellite with capability to be converted into a three axis stabilized one by torque rods control. Z axis is antisun pointing and EURD is aligned also with this axis. However LEGRI and the liquid bridge are in the horizontal plane of the PLM and in particular are aligned with the X axis, in a such a way it is possible to induce micro accelerations in the bridge direction (axilsimetric) and can be pointed LEGRI rotating around Z axis without the 4 solar panels (perpendicular to Z axis) are loosing the sun. See in figure 2 the SVM in vertical position during the integration and test phase.

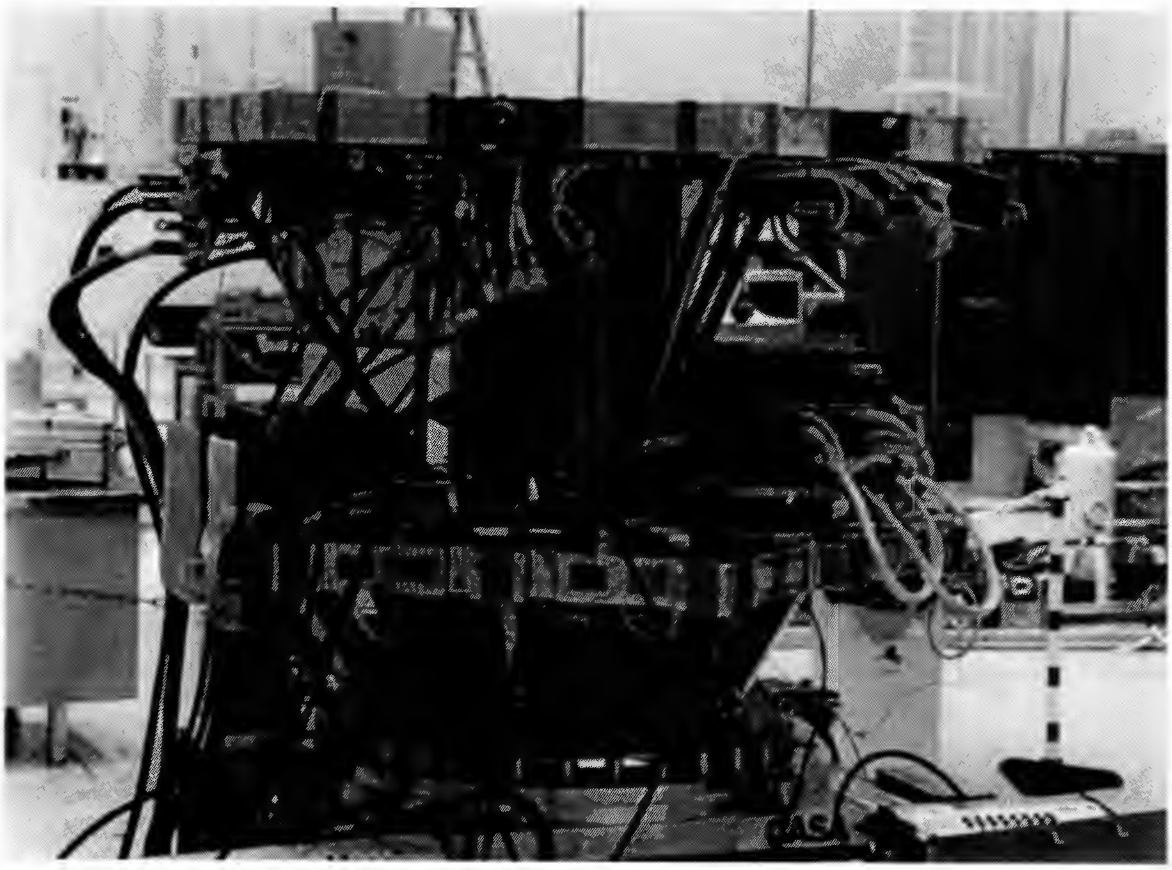


Figure 2

A summarized of the satellite main characteristic is showed below.

- MASS

BASIC MODULE :	105 Kg
SPECIFIC EQUIPMENT :	N/A
PAYLOAD :	90 Kg
TOTAL :	195 Kg

- POWER

NON REGULATED BUS :	28 V
POWER PER PANEL EOL :	50 W
NUMBER OF PANELS :	4
SVM CONSUMPTION :	65 W
PLM CONSUMPTION :	45 W

- DATA

STORAGE INCREMENTS :	32 MB
TOTAL STORAGE :	32 MB
DATA RATE TRANSMISSION :	1 Mbps
TELEMETRY BAND :	S
TRANSPONDER POWER OUT :	5 W

- ATTITUDE

STABILIZATION :	3 AXIS
POINTING ERROR :	3°

- MISSION

LIFE TIME :	2-3 years
SVM RELIABILITY:	0.8

However the bus can growth in a more or less modularity way until to get the maximum performances needed for an hypothetical mission that requires the capabilities showed below. In around this performances will be the highest limit of the platform concept developed.

- MASS

BASIC MODULE :	120 Kg
SPECIFIC EQUIPMENT :	180 Kg
PAYLOAD :	~300 Kg
TOTAL :	600 Kg

- POWER

NON REGULATED BUS :	28 V
POWER PER PANEL EOL :	50 W
NUMBER OF PANELS :	12
TOTAL POWER :	600 W

- MISSION

LIFE TIME :	4-5 years
SVM RELIABILITY:	0.8

- DATA

STORAGE INCREMENTS :	5.5 GB
TOTAL STORAGE :	60 GB
TELEMETRY BAND :	S
RATE TRANSMISSION :	1 Mbps
TRANSPONDER POWER OUT :	5 W
DATA TRANSMISSION BAND :	X
DATA RATE TRANSMISSION :	50 Mbps

- ATTITUDE

STABILIZATION :	3 AXIS
POINTING ERROR :	< 0.1°

- PROPULSION

N_2/N_2H_4 ΔV:	>100m/s

Launch Operation

From the beginning of the MINISAT program the main objective was to provide with the necessary capabilities in every space program phase to the Spanish aerospace sector, from the earliest conceptual designs until the launch operation and finally the operational phase. This is one of the reason to launch MINISAT 01 from Spain. Additionally the launcher selected (Pegasus) is an airlaunched vehicle from an aircraft Lockheed L-1011 and this allowed to carry the Pegasus to Spain, to integrate the MINISAT 01 into the Pegasus at INTA satellite integration facility and finally to launch from Spain. See figures 3 and 4.

Figure 3

Figure 4

The launch operation was in the following sequence :

One time it was finished all the integration test between MINISAT and Pegasus and Pegasus and L-1011, the L-1011 took off on April 18th, 1997 from Torrejón Air Base followed by a 2 hours and 30 minute flight Gando Air Base (Gran Canary Island, Spain), in order to reduce the captive flight in the real launch. This flight had to be do a couple of days earlier than planned due to the adverse meteorological condition forecast.

On April 21st, 1997 and within the launch window established (12 :00 UTC ± 8 minutes), the Pegasus was released from L-1011 at 11 :59 :06 UTC and in the planned point of launch.

All the launch operation was escorted by two Spanish Air Force F-18, with the range responsibility of NASA Mobil Wallops Test Range located at Maspalomas Space Station and with the control of the LOCC.

The orbit finally gotten was very near to the nominal as NORAD data, and very well within the requirements as can be seen below.

	Requirement	Mesurement
Apogee	>500 Km Nominal 587 Km	566 Km
Perigee	>500 Km Nominal 587 Km	585 Km
Inclination	151° ± 0.35°	150,97°

Operational Phase

The operation of MINISAT 01 is mainly conditioning by the satellite orbit (almost circular with an altitude of 576 Km and inclination of 29° retrograde) and by the geographical location of the Remote Tracking Station (Maspalomas, with a longitude of 15°37′45′′ W and a latitude of 27°45′49′′ N). Besides the Ground Segment Architecture (splitting of the real time operations and the off-line operations centers) and the operational strategy are also conditioning the operation.

Regarding the operational strategy following, only passes with elevation angles above 20° are tracked (there are 6 passes per day the 20% of the days, 5 passes per day the 75% of the days and 4 passes per day the 5% of the days). This is plenty enough to down link all the data stored on board the satellite and by the other hand means to reduce the period of time between the first pass and the last pass of the same sequence to 6 hours and 45 minutes in mean. Finally the above mentioned allows an important cost reduction because the real time operations can be performed with an unique shift of 9.5 hours per day with a changeable starting time to match with the satellite visibility periods from the station.

Basically the experiments operation is distributed throughout the orbit in the following way : EURD is ever observing in eclipse with the satellite pointing to the antisun direction. LEGRI is observing in sun with the satellite pinpointing to an specific γ source during long periods of accumulative time (~ 10^5 seconds). LEGRI will also observe in eclipse when EURD is not observing. Additionally both EURD and LEGRI are not observing when the satellite is in the South Atlantic Anomaly (SAA). CPLM is operating with an average of one time per week during five minutes approximately with the satellite spinning within a commanded rate range of ± 0.375 rpm, to induce micro accelerations in the liquid bridge and to measure the associated deformations.

As illustration of the in orbit satellite working it is showed some figures of stored telemetry on the satellite during one day, with the exception of small periods when a contact with the ground station is doing and in this case the telemetry is down linking in real time and is not stored on board. This telemetry was down linked the day 243 (September 1st , 1997) and corresponding with data from the days 242 and 243. The contacts are very good appreciated in the transponder temperature telemetry, where a discrete jump in the temperature can be see in the contacts (~ 11 :05, 13 :35 and 15 :05 of day 242 and ~ 11 :05 of day 243), due to not storage telemetry data during the heating phase of the transmissor within the communication with the ground station. See figures from 5 to 10.

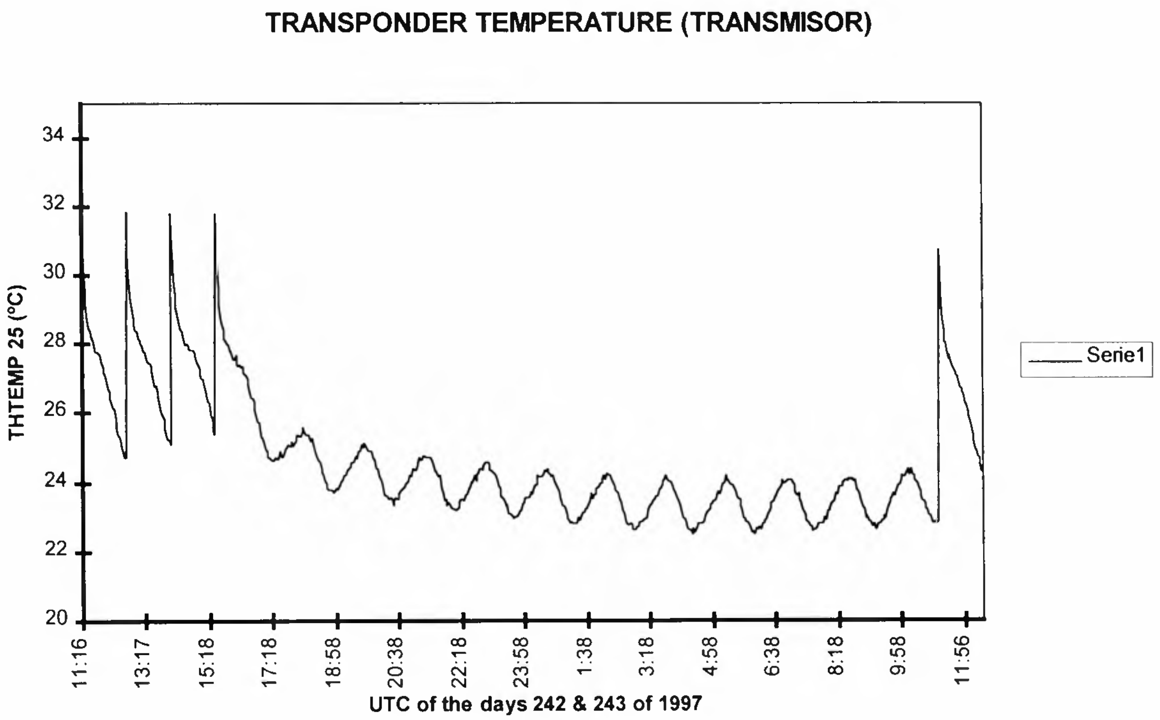


Figure 5

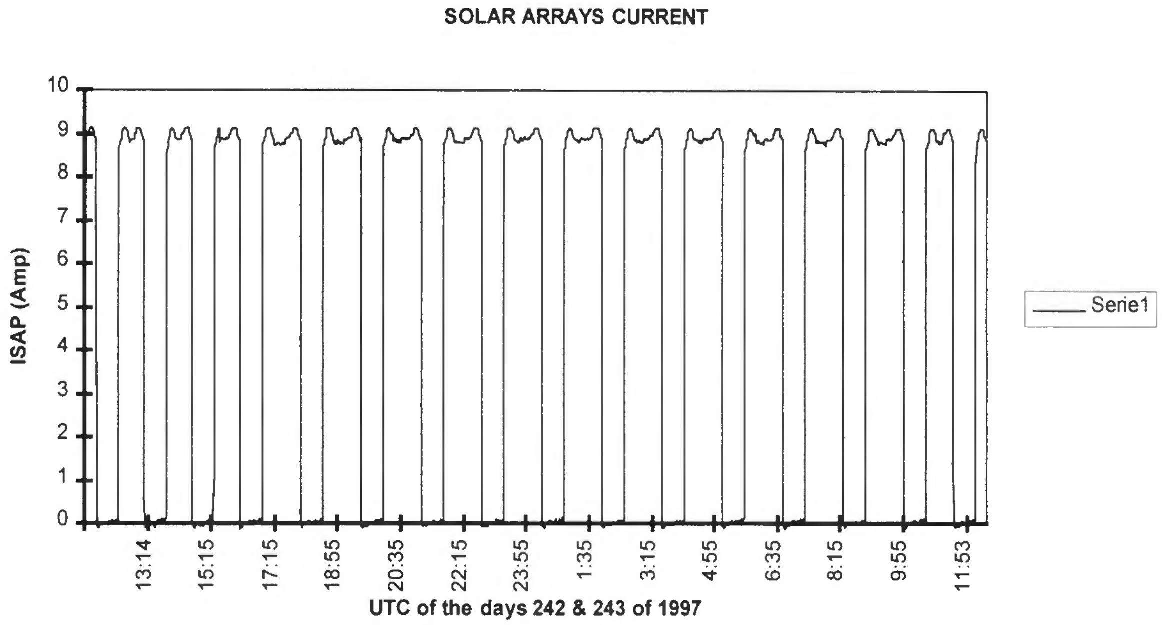


Figure 6

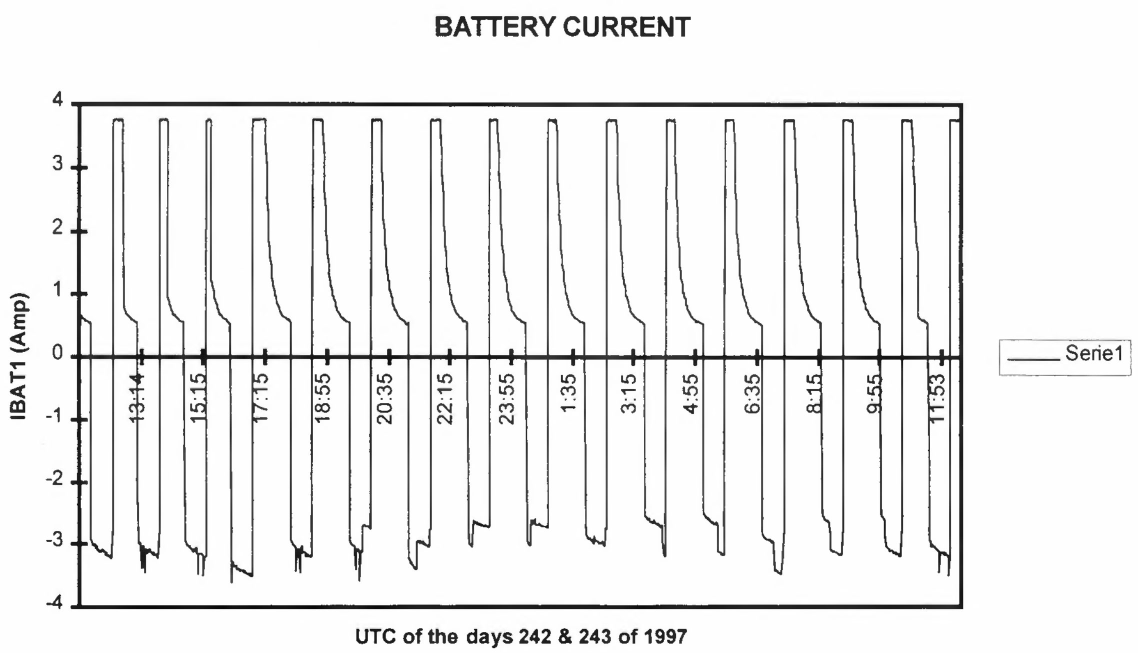


Figure 7

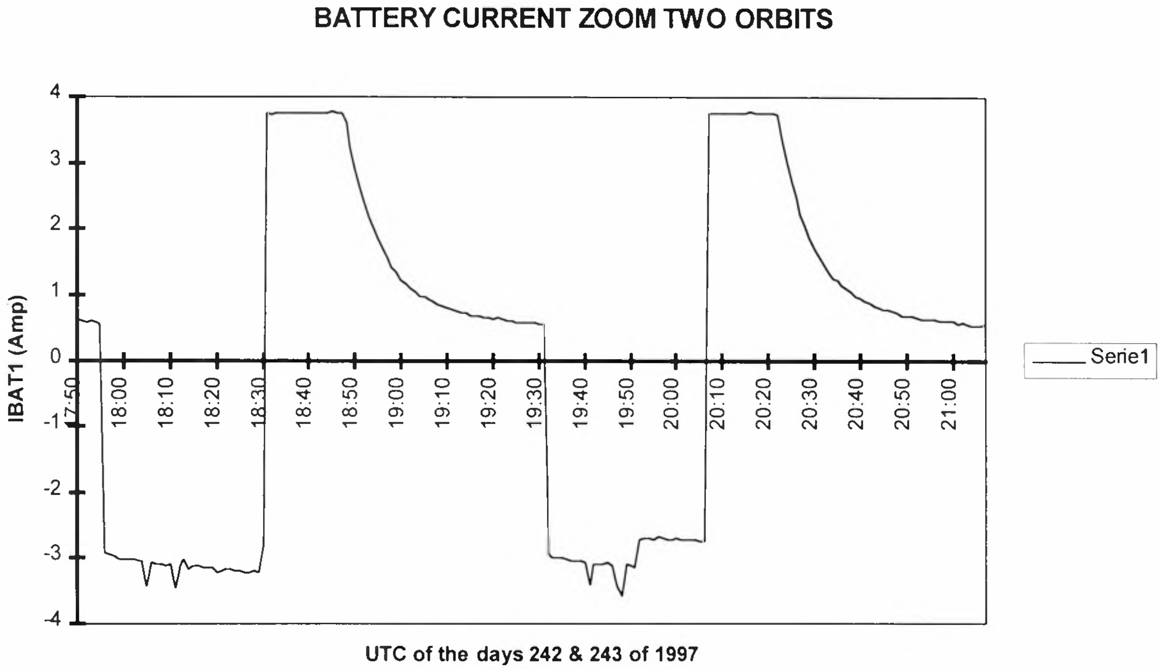


Figure 8

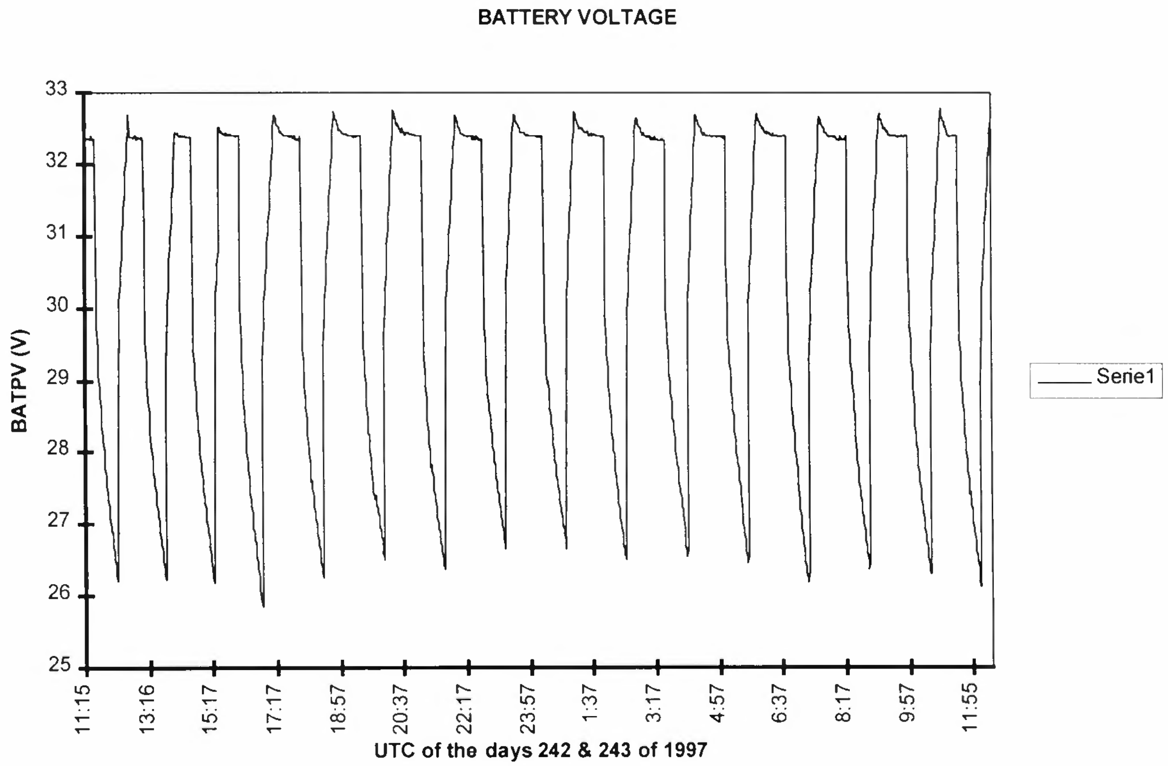


Figure 9

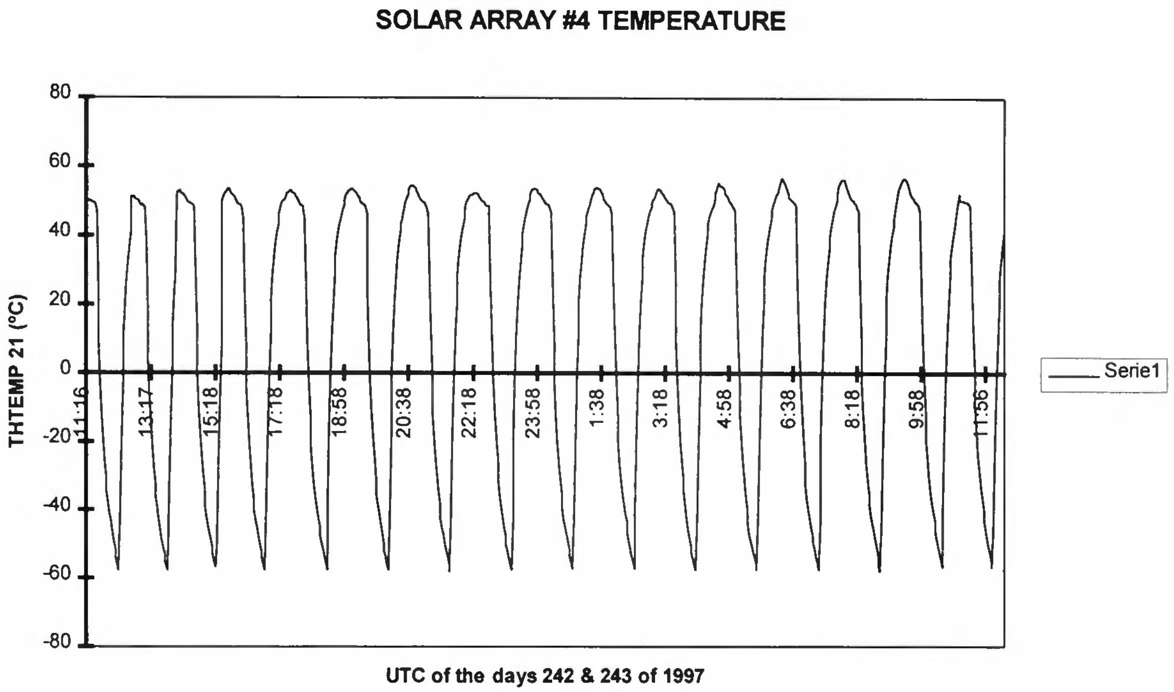


Figure 10

Finally it can be appreciated the satellite attitude control performances in the following figures of real time telemetry during the second contact of the day 243. The roll and pitch pointing error requirements are 3° and the yaw is 5° (3σ). It is observed a much better performances than specified. Additionally it can be appreciated a yaw maneuver in the middle of the contact to better point the satellite antenna to the ground station. See figures from 11 to 13.

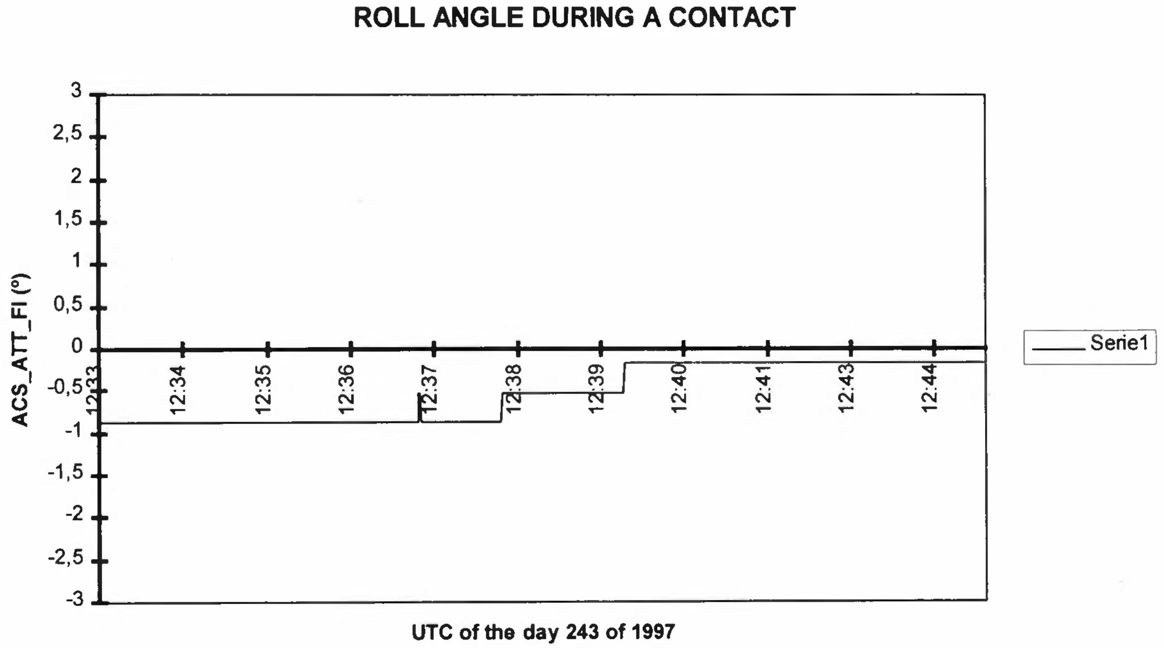


Figure 11

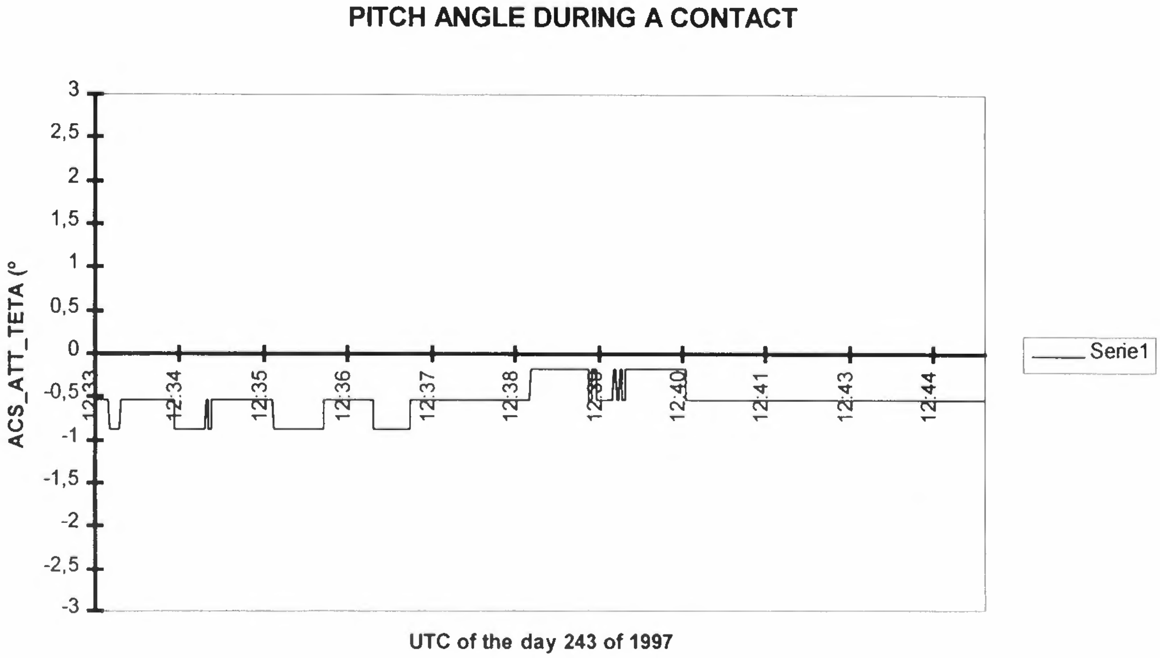


Figure 12

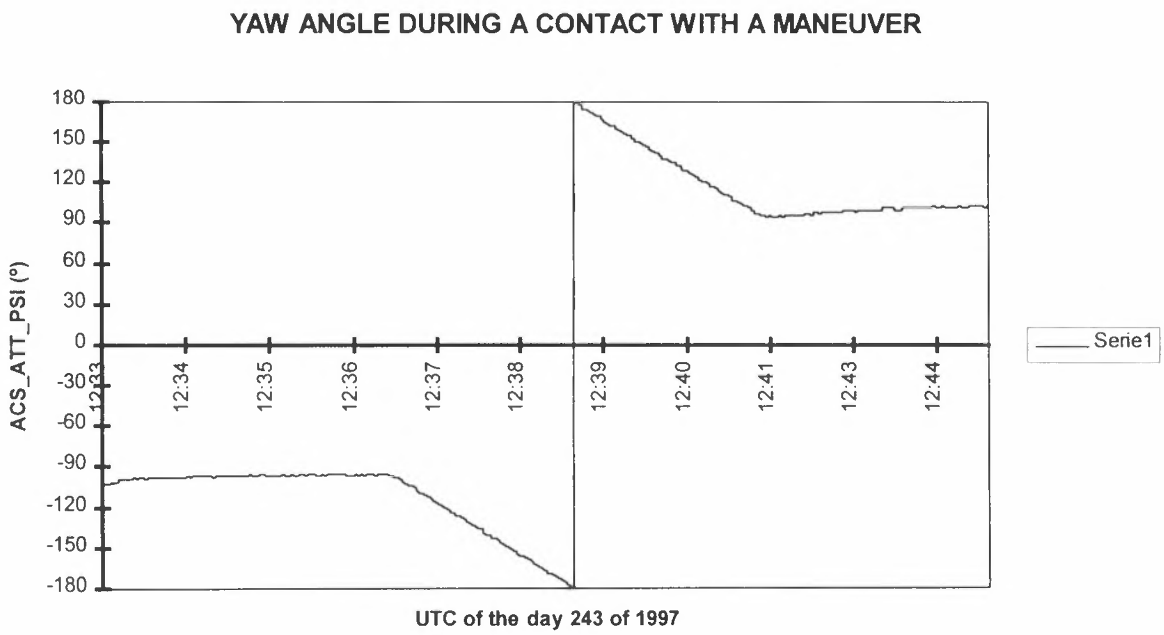


Figure 13

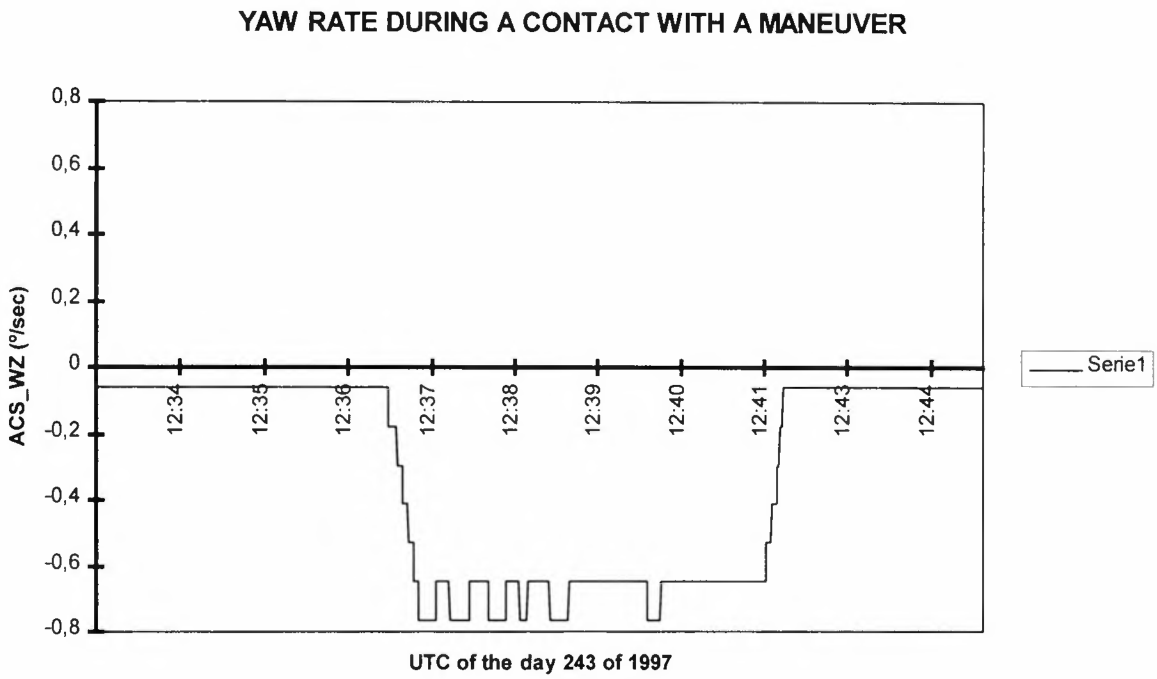


Figure 14

The technological demonstrator ETRV was activated the May 23rd , 1997, and the mechanism deployment was performed very successfully with a nominal value of all of the control parameters.

Acknowledgment

MINISAT is a program belonging to the Spain's National Space Plan, approved by the Inter-Ministerial Committee of Science and Technology (CICYT), supported by the Center for the Development of Industrial Technology (CDTI) and managed by the National Institute for Aerospace Research (INTA), Ministry of Defense.

The author wish to take this opportunity to thank the hard effort performed in this program by many engineers and scientists from INTA and by the rest of firms and institutions participating in the different phases : CASA as SVM prime contractor, SENER, INDRA Space, CRISA, TGI, INSA, Telefónica, Ball Aerospace, University of California Berkeley, Politechnical University of Madrid, University of Valencia, CIEMAT, Birmingham University, Southampton University, Rutherford Appleton Laboratory, Spanish Air Force, Spanish Navy, Iberia, AENA, Spanish Meteorological Institute, Orbital Sciences Corporation and NASA. Many others companies and institutions, whom have participated in the program as subcontractor of the above mentioned, can not be cited here but their work are very appreciated.

Without the enthusiastic and generous participation of all of them, this program will not have been culminated.

INTESPACE FROM TEST TO ENGINEERING

J.L. MARCÉ - J.C. PASQUET
INTESPACE
BP 4356 - 18 av. E. Belin - 31029 TOULOUSE cedex 4
Phone : + 33 (0)5 61 28 11 50 - Fax : + 33 (0)5 61 28 11 12

ABSTRACT

The decision to create the SOPEMEA Test Center and then INTESPACE, taken by the CNES (French Space Agency) 35 years ago, made it possible to set up and gradually build a Center capable of receiving and testing satellites weighing several hundred kilograms in the 70s up to satellites weighing as much as 4.5 tonnes at the present time.

In order to meet the ever-changing requirements of the space industry over the last 35 years, the Center has never ceased to increase its test capacities and modernize its installations, in particular with the creation of an integrated complex including:

- A high-power (300 kN) vibration installation.
- A large (1100 m^3) acoustic chamber.
- Two large (600 m^3) space simulators.
- A large, compact antenna range (30 m x 20 m x 16 m).
- An electromagnetic compatibility chamber (16 m x 10 m x 11 m).
- A technical data management system based on the DynaWorks® software package.

The technical solutions devised when designing the Center, in order to meet the new requirements, facilitate testing logistics and improve quality, will be presented.

Besides the constant technical efforts made over the last few years, INTESPACE has managed to meet the changing demands by adapting its technical and human resources to make it competitive on the international marketplace.

Furthermore INTESPACE has set up, based upon its experience as test center operator, a unique competence in the field of engineering and training for testing.

INTRODUCTION

The INTESPACE test center is located in TOULOUSE (FRANCE) and had been created for testing space experiments and spacecrafts launched by ARIANE or others USA and Russian Rockets.

In a position to act throughout products lifecycle - from design to removal from service, the company has been structured to encompass five complementary areas of activity :

- Testing
- Support for testing onsite of customer
- Studies and Training
- Engineering
- Data processing

At the moment, the test center capable to lead a complete test campaign on experiences from some kilogrammes up to satellites of 4,5 tons.

The development of center has been carried out following three fondamental criterions :

- To offer to our customers modern facilities, services of quality, a maximal security for the goods and persons and all of this with competitive prices, and with condimous effort in order to shorten testing duration.

- To offer a completly integrated center which enables to do the whole test under the same roof without the rupture of cleanliness class.

- To provide to every customer an independent center.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

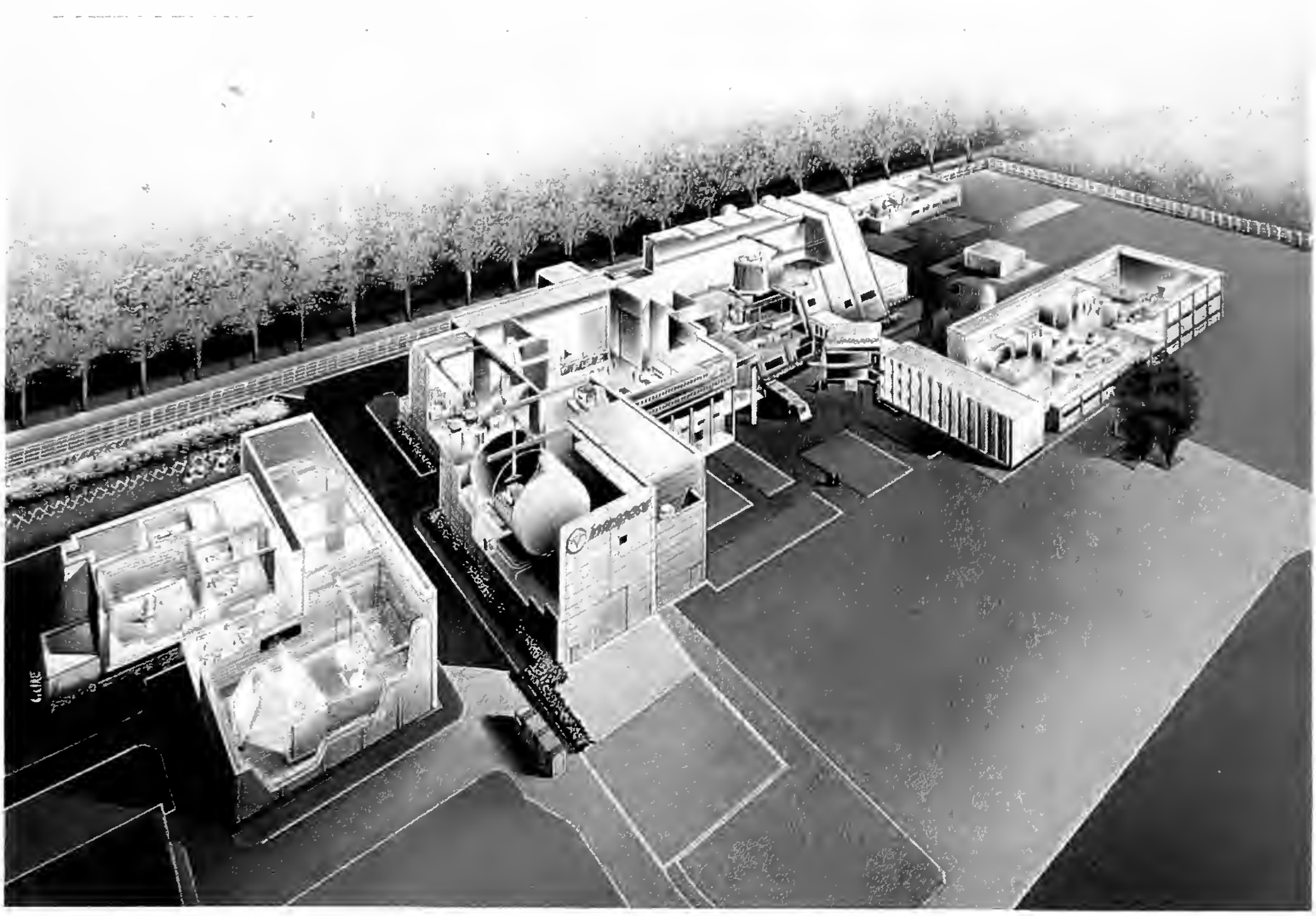


Figure 1: The INTESPACE environmental test centre

INTESPACE : INDEPENDENT CENTER

INTESPACE was created in 1983 in pursuance of SOPEMEA - Toulouse space activities in the form of a CNES-SOPEMEA joint-venture. In addition to CNES and SOPEMEA (35 % each), INTESPACE shareholders are major French space industrials: MATRA MARCONI SPACE (9%), AEROSPATIALE (9%), ALCATEL ESPACE (3%) - plus the Employees's Mutual Funds (9%).

INTESPACE is one of the 4 European coordinated test centres and formally approved by the European Space Agency, to conduct a number of services on behalf of the main international space industrials involved in European programmes. INTESPACE is RNE/COFRAC- and BNM/COFRAC- accredited at national level and has been designated as competent Body in EMC by the French Ministry of Industry.

INTESPACE operates also together with its partner CRI (Danemark) and IABG (Germany) under ESA contract, the ESTEC Test Facilities at Noordwijk.

INTESPACE offers a wide range of test facilities and technical support services, specifically designed to test spacecraft and launcher subsystems.

These test facilities include :

- a 1100m^3 reverberant acoustic chamber,
- a 300 kN multi-vibration system,
- a 6 m diameter solar thermal vacuum chamber (SIMLES),
- a 10 m diameter thermal vacuum chamber (SIMMER),
- a 1760 m^3 electromagnetic compatibility facility,
- mass properties facilities,
- a compact antenna range.

To which are added calibration and metrology test facilities a design office and a mechnical workshop.
All the above facilities, together with the preparation high bays, are located in a single building permitting thereby to reduce the time spent on moving a spacecraft from one facility to another and, consequently, the

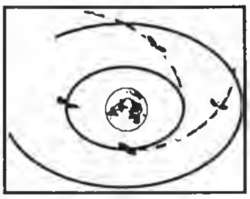
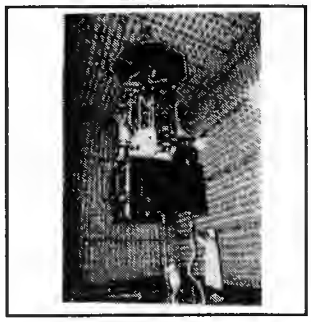
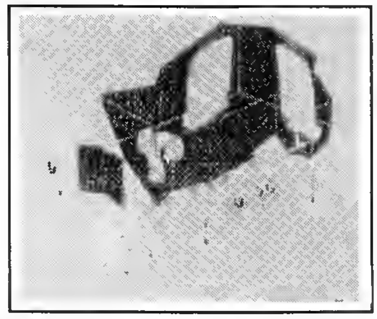
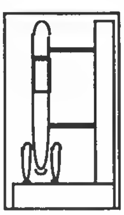
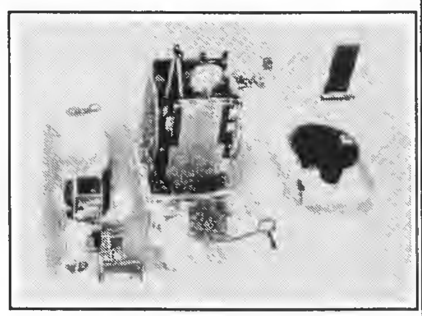
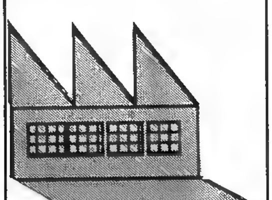
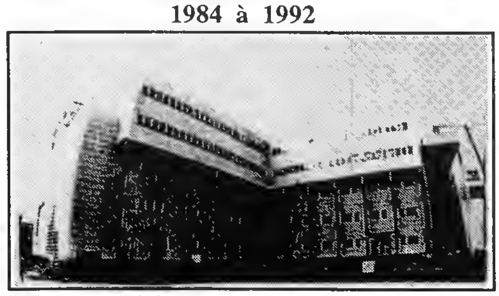
overall cost of the tests. Cleanliness conditions correspond to Federal Standard 209, 100 000 class and can be improved in some areas if so required.

The large anechoïc chamber for electromagnetic compatibility testing and compact antenna test range located next to the test building. Here, spacecraft can be submitted to EMC measurements and antenna measurements in the widest frequency range used for space communications.

The test facilities include integrated computerised control & command and data acquisition systems, both to ensure the protection of the test specimen and to provide information on, and analyses of, its behaviour during and after the tests.

A number of complementary technical support services include calibration equipment for both French and European standards, large-scale computers, consultancy services, plus a design office and a workshop. A team of over 150 highly-qualified staff is available on site.The INTESPACE Environmental Test Centre provides test services, technical expertise, test software development to governmental and European space agencies, and to international aerospace industries throughout the world.

An overview of the evolution of the center over the last 10 years is given herunder

SITUATION	ENVIRONMENTAL TESTS AND CHECKS	FACILITIES
 Orbital life	**Functional test** - EMC - Autocompatibility - Performances Antennas - RF budget	**1989**  Anechoïc chamber (extension) **1996**  **MISTRAL**
	Natural Environmental - Vacuum - Temperature - Radiation	**1986**  SIMLES Space simulation improvement **1992**  SIMMER Thermal vacuum chamber
 Launch	**Induced environmental conditions** - Vibrations - Pyro. - Acoustic noise - Acceleration	**1984**  Acoustic chamber **1987**  MVS Multi Vibrations System
	- Final integration - Test configuration - Mass properties measurements	**1984 à 1992**  Blaise Pascal Complexe 2 integration high bays

Space simulation testing at INTESPACE

INTESPACE's thermal facilities comprise two chambers in which the space environmental conditions --high vacuum, low temperatures, solar radiation-- can be simulated for the purposes of qualifying the thermal design of a spacecraft and performing the acceptance tests. These facilities can also be used for the mechanical tests in vacuum.

The SIMLES solar thermal vacuum facility consists of two chambers: a vertical main chamber (6 m dia. and 7 m high) and a horizontal auxiliary chamber (5.1 m dia. and 8.75 m long) placed side-by-side. The chamber's bottom loading system, at the base of the cylinder, facilitates the installation of spacecraft of up to 3000 kg on the gimbal system.

The attitude simulator has two main functions :

- first, to simulate the satellite's movements in relation to the Sun (two-axis motion : tilt motion + to -90° and spin motion; one rotation/24 hours to 10 rpm);
- second, to provide an electrical interface and TC measurements (600 TC) between the satellite and its ESGE for the measurements to be made on the satellite itself and for temperature measurements as well (using the 220 channel-rotating collector).

The solar simulator, based on a Cassegrain system, features 36 optical blocks equipped with xenon arc lamps, a field lense, and a folding mirror as prime power sources, all of which being outside the chamber at normal atmospheric pressure. The collimation mirror, in the auxiliary chamber, is under vacuum conditions. The collimated horizontal solar beam, up to 4 m in diameter, delivers 400W/m^2 to 1600 W/m^2 per user test requirements.

The chamber is equipped with stainless steel shrouds heated and cooled by circulating gaseous nitrogen for temperatures controlled in a range from 100 to 360 K. The pumping system produces high-vacuum conditions of 10^{-5} mbar.

This facility has its own preparation bay -- 580 m^2 and 22 m high-- used to integrate the specimen prior to its testing.

The SIMMER thermal vacuum chamber consists of a large horizontal chamber (10 m dia. and 13.6 m long) equipped with a horizontal loading system. An adaptable trolley is used to install the spacecraft in either a vertical or horizontal position inside the chamber's test volume (9 m in dia. and 8.8 m long; possible extension up to 15 m).

The chamber is equipped with stainless steel shrouds that are temperature-controlled, using either gaseous or liquid nitrogen in a range from 100 to 360 K. High-vacuum conditions of 10^{-5} mbar can be achieved with the pumping system.

SIMMER also has its own preparation high bay (560 m^2 and 13 m high) used for final integration prior to testing. A brand new device based upon simulation of heat sink by plates temperature regulated allowing thermal balance test has been qualified within Simmer and will be operationnal early 1998.

The SIMLES and SIMMER chambers are both connected to dedicated data handling systems, each with 500 channels for data acquisition and reduction to yield real-time test results.

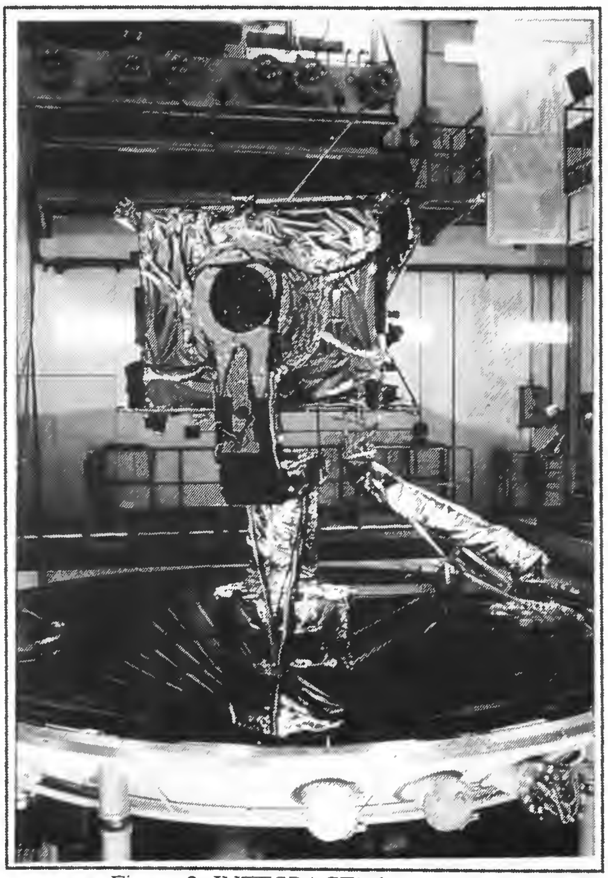


Figure 2: INTESPACE's large space simulation chamber (SIMLES)

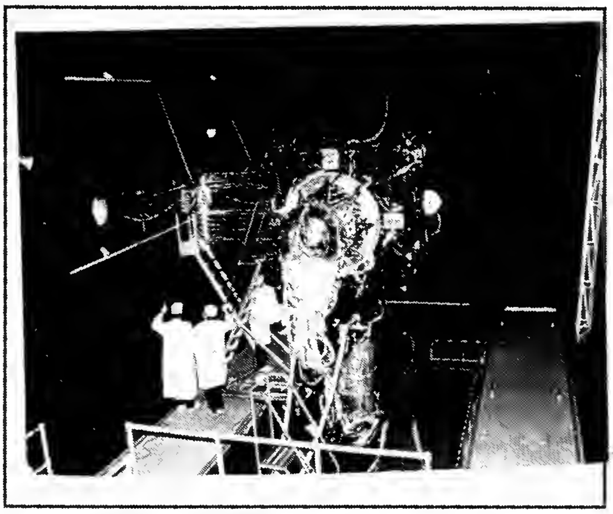


Figure 3: INTESPACE's large thermal vacuum chamber (SIMMER)

Dynamic testing at INTESPACE

INTESPACE's mechanical test facilities include a vibration test facility, an acoustic noise test facility, (reverberant acoustic chamber) and the mass properties machines to verify the integrity of the structural design of spacecraft and of their subsystems.

The controller ensures the safe operation of all subsystem and protects the specimen against excessive vibration levels via sensors placed over 15 points and at the shaker/specimen interface over eight points (as a maximum).

The acoustic noise facility simulates the noise generated by launch vehicles' engines and the vibration test facility reproduce the vibrations space vehicles are submitted to at launch. Qualification tests are performed on structural or protoflight models and acceptance tests on flight models.

The multi-vibration system consists of two shakers. Two 150 kN shakers are coupled to a hydrostatic head expander (2.1 m in dia.) for tests in the vertical axis, and to a large slip table (2.1 m x 2.1 m) for tests in the horizontal axis.

Vibration levels are programmed and the specimen monitored and safeguarded from a multi-channel controller, and its safety ensured.

A specific preparation high bay (200 m^2 and 13 m high) facilitates final integration prior to testing.

Finally, the vibration test facility satisfies the constraints due to the use of isopropyl alcohol in spacecraft pressurised tanks.
The reverberant acoustic chamber simulates the spectral noise levels encountered by the spacecraft and portions of the launch vehicle during launch. An overall noise level of 156 dB can be reached in the 1100 m^3 reverberant acoustic chamber.

Figure 4: INTESPACE's large reverberant acoustic chamber

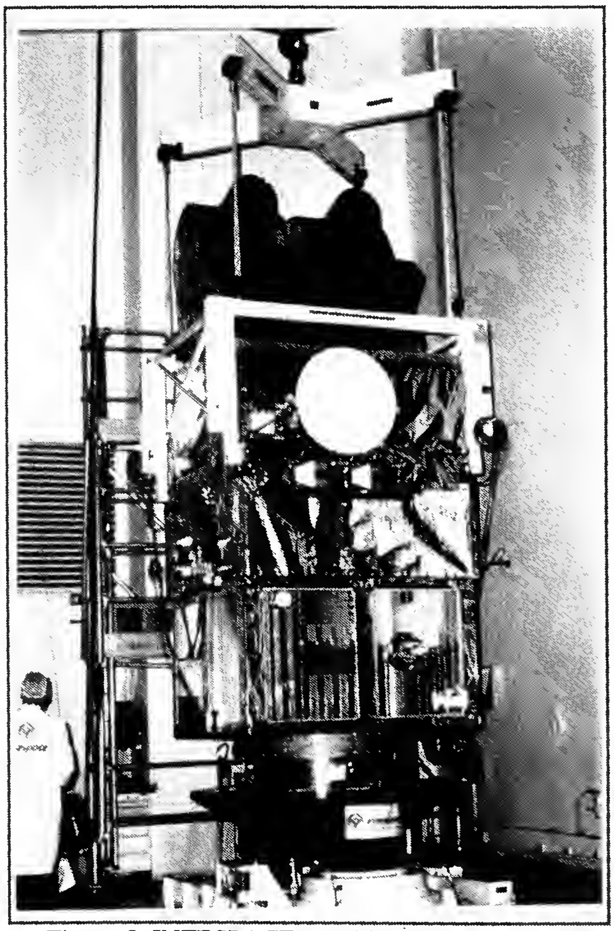


Figure 5: INTESPACE's multi-vibration system

Noise generation is ensured by pressurised gaseous nitrogen passing through three horns.

A flexible data acquisition subsystem provides for the acquisition and storage of the necessary vibroacoustic data from both the multi-vibration and the acoustic test facilities (accelerometers, strain gauges, microphones, etc).

This subsystem consists of a 256 channel-data acquisition system and a data processing system being equipped, in addition to standard sinusoidal, random and acoustic data handling functionalities, with the DynaWorks® software package. DynaWorks® provides rapid sequences of operations for quicker visualisation, statistical comparison and analysis, permitting thereby to significantly reduce preparation times and test durations.

INTESPACE's mass properties machines are used to determine the mechanical characteristics of spacecraft (balancing, cog, moments of inertia). Specimens can be placed in either a horizontal or vertical position by means of a specific L-shaped associated with a turn-over device.

These facilities were specifically designed for the purpose of reducing test sequence durations.

The particularities of dynamic testing are :

- No changement of shakers configuration during vibration test, due to this configurationthe acceptance test duration for Telecom spacegraft is 5 days.
- No sensors disconnection between vibration and acoustic tests.
- Utilisation of the same data acquisition for vibration and acoustic tests and consequently no changement of configuration.

Electromagnetic testing at INTESPACE

INTESPACE's electromagnetic test facility is available for electromagnetic and electrostatic tests on either fully-integrated spacecraft or individual subsystems for the purpose of ensuring that mission performances will meet spacecraft specifications.

Figure 6: INTESPACE's EMC chamber

The test range consists of a large Faraday chamber with a useful test area 14 m long, 8 m wide and 10 m high. The walls and floor of the chamber are lined up with anechoïc materials. This shielded chamber is large enough to test large spacecraft with an antenna fully deployed for electromagnetic compatibility and auto-compatibility. A second Faraday cage is used for accommodation of the checkout equipment and a 200 m^2 area adjacent to the anechoïc chamber is used for spacecraft test preparation activities and accommodation of the EGSE.
Development and qualification tests are conducted according to space test specifications. Conducted and radiated emission tests and susceptibility tests are performed in the 30 Hz to 40 GHz frequency range. Electrostatic discharge and high-field susceptibility measurements for large devices can also be performed.

INTESPACE's testing capabilities were improved to meet more stringent requirements, as defined in MIL-STD-461.

Electrical field levels are now 200V/m over 90% of the 10 kHz to 18 GHz frequency range. In the 18 to 40 GHz range, they are limited to 80 V/m. Test operations are fully automated via a real-time and closed-loop software.

High-field testing can be carried out on smaller subsystems in a third anechoïc test chamber.

INTESPACE's EMC anechoic chamber is designed to ensure that all system tests on integrated spacecraft --i.e. RF health tests, auto compatibility tests, "pimp tests"...-- are performed in the most effective way.

INTESPACE also provides EMC consultant services to the experimenters in the elaboration of the specifications and specific test procedures, and for test analysis.

Auxiliary test equipment --including antennas and antenna masts-- and microwave measuring equipment is made available to the customers. Finally, EMC test equipment is redundant on a stand-by mode to ensure test continuity and reduce test durations.

A new compact test range --MISTRAL-- has been put into service 1997.

Situated in the INTESPACE's Coulomb building, the MISTRAL compact antenna test range is a new test facility specifically designed for radiofrequency tests of spacecraft in their flight configuration.

The RF test range operates in the fully-controlled and isolated environment of the shielded anechoic chamber (30 x 20 x 15.5 m).

In a restricted space area, the Compact Test Range provides for the creation of a flat radiofrequency wave showing the same characteristics as those generated in a far-field range.

A series a RF sources covering the 1.47 to 40 GHz frequency band (provision is being made for 200 GHz) is placed in the focal plane of a hyperboloid subreflector which reflects RF radiations to a main paraboloid reflector. Its Cassegrain-type design provides for a test volume (8.8 x 5 x 6 m) within a short distance of the main reflector.

The spacecraft to be tested is placed on top of a 3-axis positioner.

The following measurements could be performed : antenna patterns measurements, end to end tests, transponder tests, Pimp, RF saturated flux density.

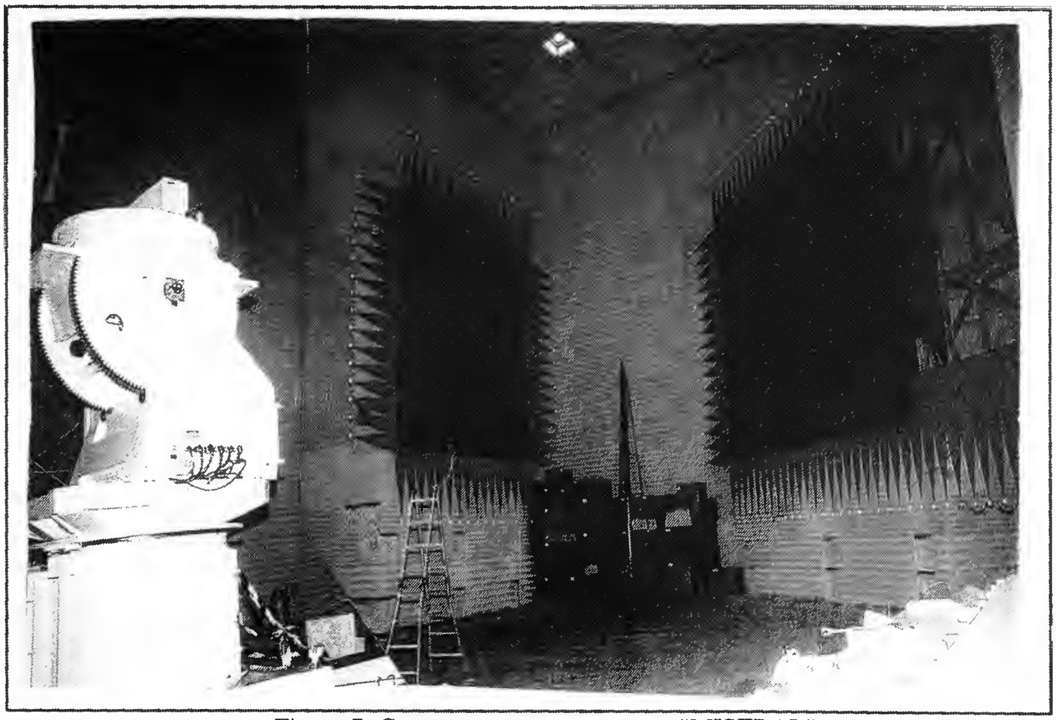


Figure 7: Compact antenna test range "MISTRAL"

INTESPACE : A UNIQUE TEST CENTRE IN EUROPE

The INTESPACE Space Test Centre features unique characteristics for satellite projects, which positions it as one of the leading test centres in Europe. The major distinctive characteristics of INTESPACE are as follows:

INTESPACE: a specialist in satellite testing

INTESPACE is a company specifically dedicated to the control of environmental conditions, with satellite and subsystem tests representing approximately two-third of the total activities of the company. The management of INTESPACE's personnel and technical facilities is entirely oriented towards space projects and turnkey test services and associated logistics support services.

INTESPACE carried out more than 100 test campaigns on satellites and large systems to the benefit of the international space community over the last fifteen years (1982-1997).

All the test facilities under one roof

- The major test facilities at INTESPACE are grouped under one roof, with all the test high bays beingcontrolled as per class 100 000 cleanliness conditions (Fed. Std 209).

  The integrated spacecraft to be tested can thus move smoothly and quickly from one facility to another without having to be reconfigured between the tests, thus reducing the risk of not fulfilling all cleanliness conditions. A centralised control system helps the experimenters in monitoring and verifying the cleanliness parameters, via terminals distributed in all the test areas.

- INTESPACE offers a full range of test facilities specifically adapted to the testing of spacecraft, including acoustic, vibration, thermal balance, thermal vacuum, electromagnetic compatibility, physical properties facilities.

  The last test facility to be added to the already-existing ones is a Compact Test Range for antenna measurements, of which the construction is under way. This Compact Test Range --MISTRAL operational since 1997 will supplement a number of test facilities for complete satellite qualification or acceptance programmes.

Optimised mechanical test facilities for a better productivity

- Vibration tests are performed on two dedicated vibration test facilities:

  - a shaker for tests in the longitudinal axis of the satellite (coupled to a vertical head expander 2.1 m in diameter);

  - a shaker for test in the lateral axis of the satellite (coupled to a horizontal slip table 2.1 x 2.1 m).

  This configuration is used to avoid loosing time when tilting the shaker in the case of a single shaker configuration.

- In addition, the interconnection panels of the accelerometers are mobile and maintained connected to the satellite throughout the vibration and acoustic tests. This specific characteristic offers two advantage : (1) ensuring that the test is being performed ina most riskfree manner in terms of error, connection, cable damage, and (2) contributing to reduce preparation durations and increase the overall quality of the tests.

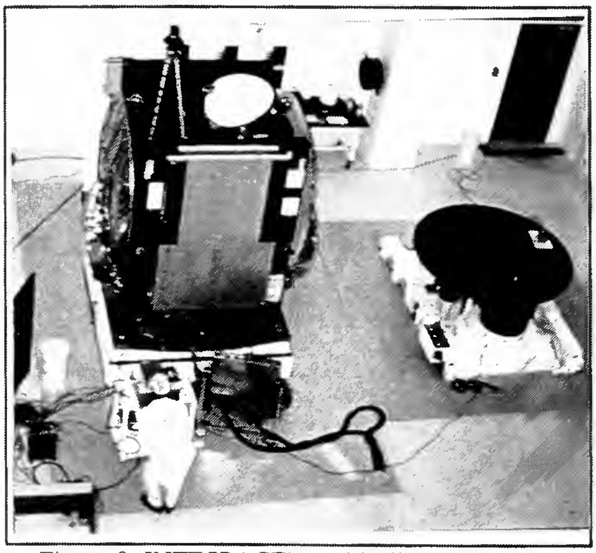


Figure 8: INTESPACE's multi-vibration system

Effectiveness increased through test predictions

The vibration tests are performed with increased effectiveness due to the use, by INTESPACE, of a test prediction tool allowing to determine the satellite/test facility interaction in advance, and thus, to adjust the test facility's control parameters.

Test predictions for tests on an electrodynamic shaker per given specifications can be obtained by coupling a model of the shaker --derived from analysis or modal survey-- with either a physical, matrix or modal-type model of the specimen and of its adapter. Control predictions can also be obtained from the simulation of the control loop and the use of previous test results or data. All of these predictions will yield analyses that will respond to any situation, i.e. from feasibility studies for such aspects as the shaker's performance capabilities, parasitic motions, and specimen behaviours to the determination of the shaker's optimum control prior to or between the test runs.

The shaker, adapter, and specimen models together with the control parameters, feasibility test results, adapter performance, specimen behaviours, and control performance capabilities can be obtained from given test specifications to prepare the test campaign and/or ajust the test parameters prior to or between the test runs.

This methodology is likely to be applied to the INTESPACE's multi-vibration test facilities, with an updated finite element model of the moving part of the shaker. This will be achieved in two steps for taking basic requirements first into account and then for providing a general tool.

Improving test productivity : the DynaWorks® response

INTESPACE develops solutions for today's applications to ensure the successful integration of the tests in the industrial development of the product.

The DynaWorks®, software is the result of INTESPACE's eminent experience in testing.

DynaWorks®, is the response to the necessity for improved productivity and when environmental factors are extensively involved in sectors of industry such as the aeroanautics, space, defence, automation and transport, energy, shipbuilding, etc. sectors. It is a valuable tool intended to design and structure analysis departments, environmental testing laboratories, in-site environment measuring instruments, environmental engineering specialists and management teams.

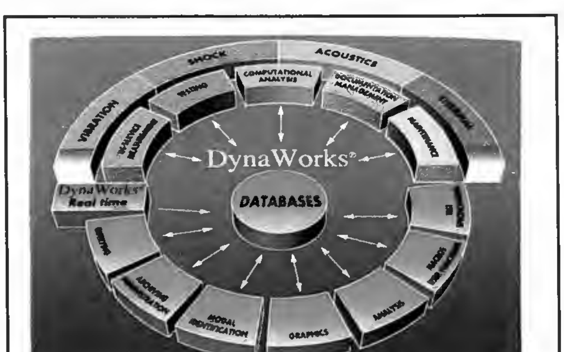


Figure 9: DynaWorks®, an open product tailored to your individual needs

DynaWorks®, is a powerful relational test data management and analysis system that allows product designers and test engineers to capture, analyse, and organise the test results generated throughout the product's life cycle. The test results obtained from heterogeneous systems during the vibration, shock, acoustic, thermal balance, ... tests can now be standardised and organised effectively with DynaWorks.

The powerful query functions of DynaWorks® provide for quick and comprehensive analysis of complex correlations such as the correlation of predicted results against experimentally obtained results, reducing thereby the development cycles of the products. With an excellent 2D and 3D graphics, a user-friendly X-WindowsTM interface, and context-sensitive on-line helps, the users will enjoy immediate increases in productivity.

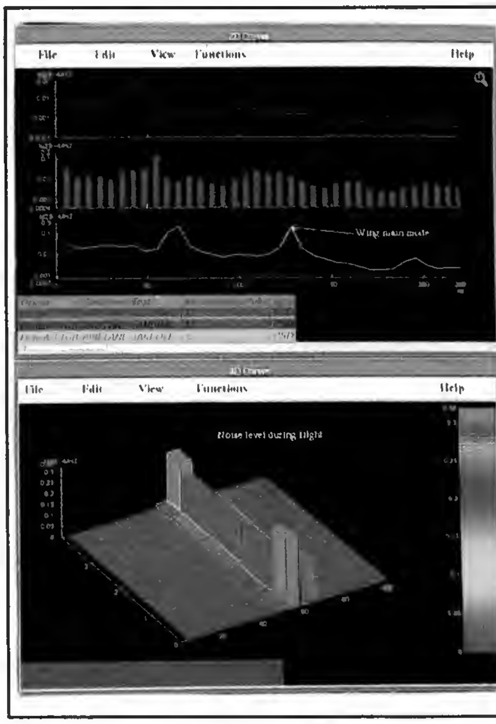


Figure 10: DynaWorks® high-level graphics capabilities

Combining physical measurement facilities for high-performance measurements

INTESPACE performs all the measurements related to the physical properties of a satellite (i.e. inertia, cog, balancing) on a combined test facility coupled with a tilt device to safely position the satellite on its three-axes.

This unique combined test facility configuration facilitates the handling of the satellite and significantly reduces the duration of the measurement campaign.

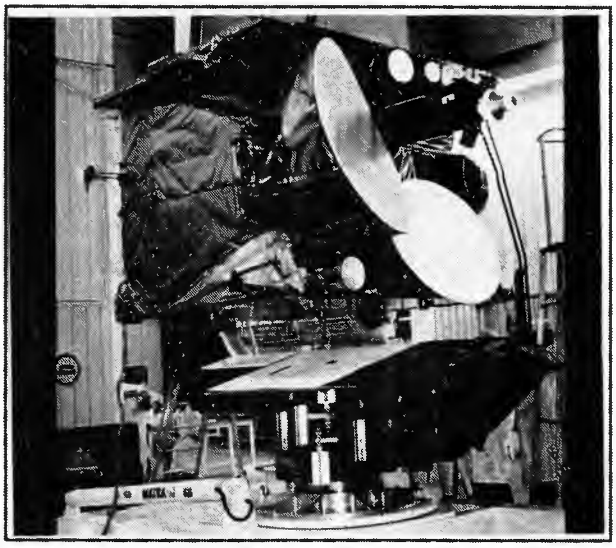


Figure 11: INTESPACE's physical measurement combined facility

Redundant and flexible thermal test facilities

INTESPACE has two large thermal-vacuum chambers, mutually compatible, dedicated to satellite acceptance tests :

•the SIMLES test chamber --a vertical chamber with a useful volume of $200m^3$,

•the SIMMER test chamber --a horizontal chamber with a useful volume of $560m^3$.

Both test facilities are perfectly compatible with one another in terms of mechanical and electrical interfaces with the satellite. Likewise, the measuring systems and test data processing systems are identical for both test chambers.

A high availability rate for the thermal test facilities is ensured to customers -even in the case of a failure during the test- through the provision of redundant facilities.

Improving predictions and analysis tests results

INTESPACE offers design, research and consulting services in environmental techniques for the design of sophisticated mechanical systems and prediction of their behaviour. These activities cover the following :

- In the acoustic and vibrations tests area :
  - solving vibration and noise problems,
  - environment diagnosis,
  - verifying and readjusting previsional models in view of testing,
  - development platform of an analysis for structural dynamics,
  - vibroacoustic transmission analysis,
  - system or equipment qualification,
  - creation of environment databases.

- In the advanced dynamic tests area :
  - accurate measurement of the transfer function,
  - experimental modal analysis (multipoint excitation or shaker-induced excitation),
  - microdynamic tests (equipment or transmission characterization),
  - transient vibrations.

Calibration

Sensors and measuring equipment in the following areas :
- Acceleration.
- Temperature.
- Mass.
- Electrical quantities for which INTESPACE has COFRAC* calibration accreditation.
- Particule counters.
- Flowmeters.
- Pressure sensors.
- Acoustics, an area in which INTESPACE has earned industrywide recognition.

* COFRAC : French certification organization.

- In the development area of new thermal testing methods:
  - infrared tests,
  - tests with temperature-regulated plates.

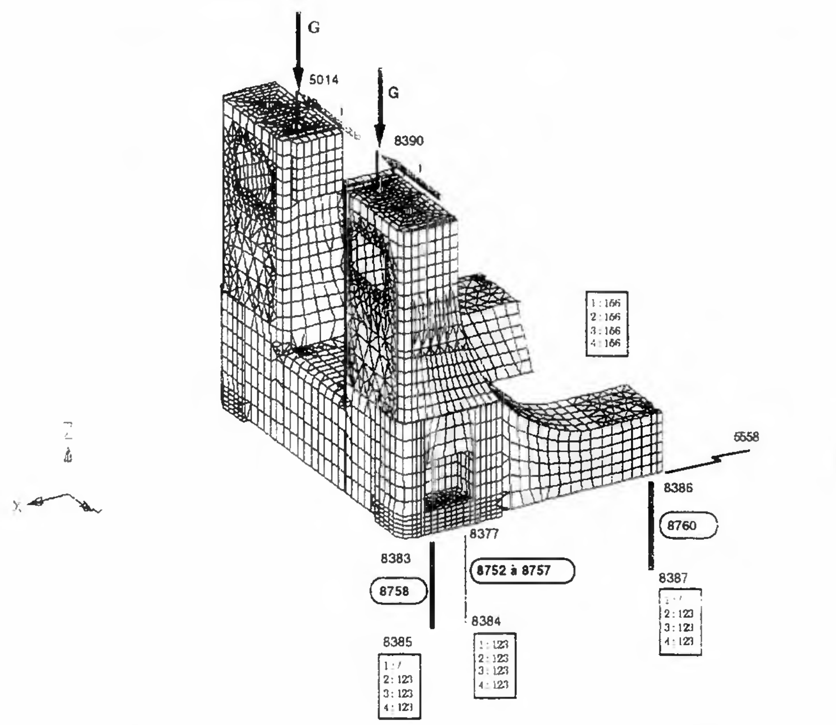


Figure 12: Finite element modelisation experimental modal survey

Improving the quality of the test

INTESPACE offers a high-quality service encomparsing calibration, verification and adjustment of out - of - tolerance measuring equipment.

Metrology
Simulating the space environment calls for highly sophisticated vacuum, cryogenic, optical and thermal technologies that must be closely monitored by skilled personnel applying a strict methodology. INTESPACE qualifies materials, paints, test facilities and other items for the space industry.

From test to Engineering

INTESPACE offers also complementary services to various customers from Space and general industry :

- studies and training
- engineering

Studies and training

Based upon a team of highly graduated structural engineers, INTESPACE performs adhoc studies and, especially in the field of model tuning. In particular, a continuous activity flow has also been established with car manufacturers like PSA , BMW and RENAULT ; INTESPACE has also participated to various research programs from the European Community :

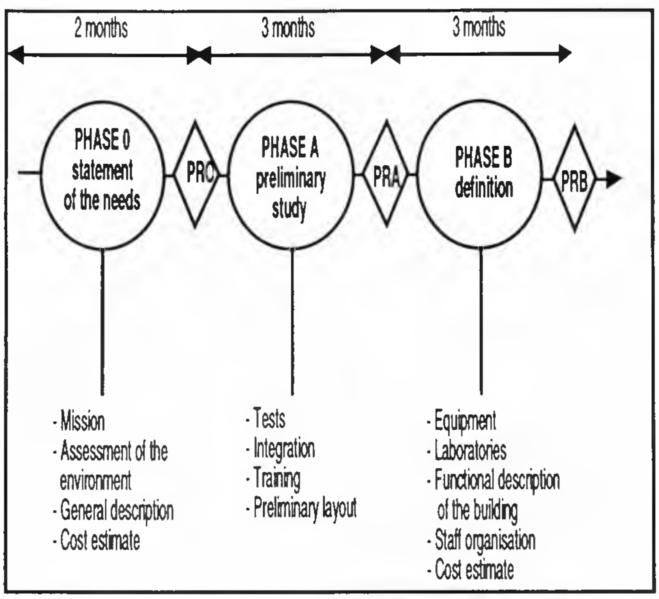
- 2 BRITE-EURAM programs are over and 2 ESPRIT programs are currently running.

INTESPACE is also offering training courses on various kinds :

- training customized to customer' specifications
- regular training courses on different topics (about 50 trainees are regularly taught each year)
- engineering

Engineering

INTESPACE is also offering engineering services and consultancy for building of test facilities or Space Testing centers. INTESPACE has developped a special method for AITC Development as outlined below :



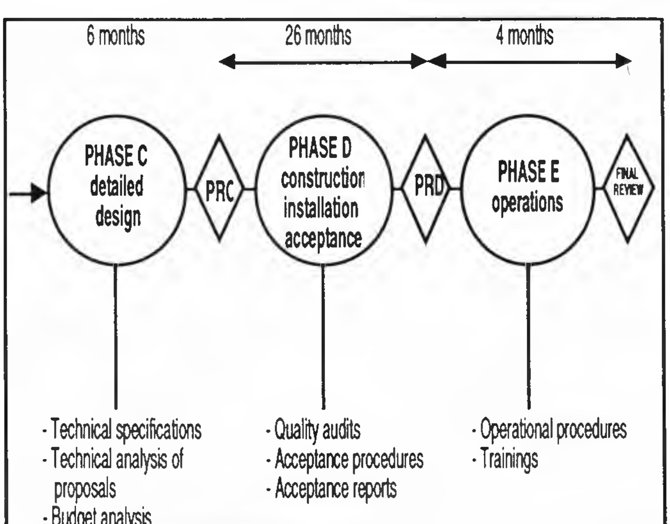


Figure 13 : AITC Development

Associated to the Engineering and Technical Assistance for Assembly-Integration & Test Centre development the following training are provided :

- Executive training courses intended to familiarized management staff with the test centre's activities
- Specialized training courses intended to specialized engineers (Hyper-frequency, Thermic, Mechanics) with a previous substantial experience
- In-house training. The training program is designed for the training of engineers and technicians involved in test performing.

  These sessions could be done for the first part in INTESPACE and for the second period in your test centre.

Currently INTESPACE is under contract with :

- INPE-LIT (Brasil) for the improvment of their integration and Testing Center of Sao José Dos Campos
- NSPO (Republic of China) for the development and commissioning of their Testing Center which will be ready for operation in 1998
- ALENIA SPAZIO - HYUNDAI for the training of the team and commissioning of various facilities for their GLOBALSTAR Assembly and Testing Center.

INTESPACE in this field customizes its services to the needs of its customer.

Conclusion

As a conclusion, INTESPACE is able to provide more than 30 years of experience as Test Center Operator not only to customer performing testing in the INTESPACE Toulouse Center but also to a various range of space and non space customers in the field of

- technical studies
- training
- engineering

throughout all the world

MAIN PARAMETERS OF THE INTESPACE FACILITIES
Thermal testing facilities

THE SIMLES SOLAR SIMULATOR	
Configuration (main chamber)	
Orientation	vertical
Test volume	6 m dia. x 7 m high
Access	bottom loader
Pumping system	
Working pressure	< 10^{-5} mbar
Roughing	mechanical : 12 000 m^3/h
Booster	turbomolecular : 6500 l/s
High vacuum (cryopumps)	20 K. 130 000 l/s
Thermal shrouds (main chamber)	
Temperature range	100 - 360 K
Temperature uniformity	± 10 K at 100 K
Emissivity	≥ 0.85
Absorptivity	≥ 0.95
Solar simulation	
Solar beam (horizontal)	up to 4 m dia.
Intensity	400 - 16000 W/m^2
Intensity uniformity	± 4 %
Collimation angle	± 1.9
Stability	< ± 1%
Spectrum	xenon
Gimbal system	
Two-axis	S/C mass : 2500 kg
Spin axis in vertical position	S/C mass : 3000 kg
Spin motion (variable)	1 rotation/24hr to 10 rpm
Attitude motion :	
• alternating	± 90°
• speed	7.5°/min

THERMAL DATA ACQUISITION AND PROCESSING SYSTEM

- Acquisition and storage of 396 Cu-Con thermocouple signals
- Acquisition and storage of 96 voltages and 96 currents
- Real-time analysis of test results using dedicated software packages
- Transfer of test results via a dedicated Transpac link (X.25 packet switching network)

THE SIMMER THERMAL VACUUM CHAMBER	
Configuration	
Orientation	horizontal
Overall dimensions	10 m dia. x 13.6 m long
Test volume	9 m dia. x 8.8 m long
Access	horizontal loader
SIMMER bay	560 m^2 x 13 m high
Pumping system	
Working pressure	< 10^{-5} mbar
Roughing	mechanical : 12 000 m^3/h
Booster	turbomolecular : 6500 L/s
High vacuum	130 000 L/s
Thermal shrouds	
Temperature range	standard 100 - 360 K option 80 K
Temperature uniformity	± 10 K
Emissivity	≥ 0.85
Absorptivity	≥ 0.95
Platform (load capacity)	
Vertical axis	4000 kg
Horizontal axis	2500 kg
Interface plane: horizontally adjustable during test	accuracy 0.5 mm/m range : ± 30 mm/m

Electrical testing facilities

THE ELECTROMAGNETIC COMPATIBILITY TEST FACILITY

Configuration	
Chamber	
. overall dimensions	16 x 10 x 11 m high
. test volume	14 x 8 x 10 m high
Door access	5 x 6 m high
Preparation bay	16 x 14.5 x 13 m high
Crane	100 kN
Cleanliness	class 100 000
EMC test capability	
RF performance of the shield anechoïc chamber	
• reflectivity	UHF > 30 dB
	L band > 40 dB
	C band > 50 dB
	K band > 50 dB
EMI isolation	
• electric fields	14 kHz - 200 MHz
	atten. > 12 dB
• plane waves	200 MHz - 1 GHz
	atten. > 100 dB
	1 - 10 GHz, atten. > 80 dB
• magnetic fields	14 kHz, atten. > 70 dB
	250 kHz, atten. > 100 dB
Measurement system	
• emission measurement	emission receivers
• spectrum analysis	30 MHz - 1 GHz
	range 100 Hz - 22 GHz
	extension to 40 GHz with mixers
Susceptibility system	
• generators	10 Hz - 10 GHz
• amplifiers (range)	10 Hz - 18 GHz
	power 10 - 2000 W
	18 - 40 GHz, 3 W power

THE COMPACT ANTENNA TEST RANGE

Shielded anechoic chamber	
Dimensions	30 x 20 x 15.5 m
Environmental parameters :	
• temperature	21°C ± 2°C
• humidity	50% + 10%
• cleanliness	100 000 class (Fed. Std 209)
Seismic ground isolation	
Faraday cage	
Reflectors	
Dimensions	7.5 x 6 m (66 tons)
Subreflector dimensions	5.6 x 5.3 m (44 tons)
Serration length	150 cm
Surface accuracy	25 µm RMS
Equivalent focal length	130 m
Quiet zone performance	
Dimensions :	
• height	5 m
• depth	6 m
• width : . focused :	5.5 m
. defocused :	up to 5.5 m left
	up to 3.3 m right
Frequency range	1.47 - 40 GHz (provision to 200 GHz)
Polarisation	linear, circular
Ripple amplitude	± 0.5 dB
Ripple phase	± 6°
Typical cross polarisation	< -40 dB
Cross polarisation accuracy at -30 dB	± .75 dB
Measurement accuracies :	
• Side lobes at -30dB	±.75 dB
• Gain	± .25 dB
Ground support equipment	
Positioner	5 axes
Load capacity	6 000 kg
Travelling overhead crane capacity	10 tons
Anechoic chamber access door	6 x 11 m
Experimenters room	128 m2
Automatic access controlled area	
Fire detection and fighting systems	

THE 1100 m^3 ACOUSTIC TEST FACILITY

Configuration (chamber)

Volume	1100 m^3
Dimensions	10.3 x 8.2 x 12 m high
Door access	6 x 11.5 m high
Crane load (max.)	100 kN
Cleanliness	class 100 000

Acoustic capability

Overall sound pressure level	156 dB
Chamber suspension resonant frequency	16 Hz
Lowest frequency cut-off	13 Hz
Excited frequency	22.4 Hz - 11.2 kHz
Max. contr. frequ. bandw. random :	125 - 1000 Hz
Modal density	5 modes/1/3 oct. at 31.5 Hz
	> 100 modes per 1/3 octave at 100 Hz
Mean reverberation time	10 s

Control capability

Control	8 microph. in chamber
Processing	multiplexing, real-time analyser

THE 300 kN MULTI-VIBRATION SYSTEM

Vibration capability

Force ratings	
• longitudinal axis	300 kN sine mode
• lateral axis	
- standard	150 kN sine, random
- push pull	300 kN sine
Frequency bandwidth	
• sinusoïdal low level	2 - 2000 Hz
• sinusoïdal high level	2 - 500 Hz
• random	10 - 2000 Hz
Maximum payload	3500 kg
Maximum velocity	1.6 m/s
Displacement	50.8 mm in random and shocks
	38 mm peak to peak in sine mode
Maximum acceleration (unloaded)	14 g
Vertical head expander	2.1 m
Horizontal slip table	2.1 x 2.1 m

Control capability

Digital console	
• control channels	8 max. sine
	16 max. random
• monitoring channels	15 for notching
	and/or S/C safety

MECHANICAL DATA ACQUISITION & PROCESSING SYSTEM

Vibro-acoustic data handling system

• Accelerometer channels	176
• Strain gauge channels	64
• Microphone channels	16
Acquisition capabilities	256

Reduction capabilities
- Sine : global and/or filtered amplitude transfer function, distortion
- Random : PSD (narrow band, 1/3 octave, octave), RMS value, transfer function, coherence function
- Acoustic
  - accelerometers and others as random process
  - microphones : ASPL (narrow band, 1/3 octave, octave), OASPL

Summary of INTESPACE Training courses
- 1997 -

VIBRATIONS

- V1 : Environmental testing in real vibrations
  Analysis and specifications

- V2 : Dynamic structural Analysis in an industrial context

- V3 : Signal processing for vibrations and acoustics
  Basic Technics

THERMAL

- T1 : Thermal environment for electric equipments
  Characterisation - Design - Test

ELECTRO MAGNETIC COMPATIBILITY

- E.M.C. : Basic EMC Training
  Guidelines for the design of electronical systems in industrial and spatial domains

INTESPACE References

- Test centres engineering
  . 30 years' experience running our own test centre
  . Team of specialist test engineers and operators
  . Close ties with nearby aerospace industry partners (CNES, ONERA, CEAT, MATRA MARCONI SPACE, ALCATEL, AEROSPATIALE, ETC.)
  . Major customers in Space: CNES, INPE, IAI, KARI, NSPO
  . Other sectors : DCN (Naval shipbuilding arm of French Defence Ministry), DAT, IFREMER

- Industrial environmental testing
  . Major customers :
  In France : AEROSPATIALE, ALCATEL, BERTIN, CEA, CEIS, CNES, DASSAULT, DGA, MATRA MARCONI SPACE, PEUGEOT, PHILIPS, RENAULT, ROCKWELL COLLINS, SEP, SEXTANT, SIEMENS, THOMSON, TURBOMECA.
  International : ALENIA, CASA, DASA, DOWTY, ESA, FOKKER, IAI, INPE, ISRO, MARTIN MARIETTA, SENER.

- Test facilities engineering
  . Consultancy
  MMS : Optical equipment test chamber
  CEPR : Calibration equipment
  CEA/CESTA : very high level acoustic test facilities
  ESA/ESTEC : HYDRA multi axis hydraulic test facility
  ESA/ESTEC : Large European Acoustic facility (LEAF)
  . Engineering
  INTESPACE : High level vibration facility
  INTESPACE - IAI/MBT : 1100m3 acoustic reverberation chamber
  ETW/ONERA : Mock-up strain measuring equipment
  LRBA : Combined environmental test facility
  MMS/INTESPACE : Thermal infrared test facility
  DGA : Multi-purpose test facility
  DCN/MDTC : Custom test facilities
  . Adapter and Mock-up design and construction
  Vibration test equipment for TELECOM 2 (MMS) and SPOT (SEP) fuel tanks
  Mechanical and thermal adapters for mounting satellite to test facility (L-adapter, vibration test equipment)
  PRONAOS mock-up (CNES)

- Studies and development - Consultancy Vibation and Acoustics
  . Resarch Projects
  CNES : Industrial model refinment and validation method
  ESA : Dynamic mass measurement
  ESA : Definition of force measurement system characteristics
  ESA : Devlopment and management of satellite testing database used to draft equipment qualification specifications
  BRITE-EURAM project n°P-2381-5 European Life Time Assessment System Development (1989-1991)
  BRITE-EURAM project n°P-7666(UPDYN) New integrated Updating Tools for Transportation Vehicle Vibration Quality Improvment (1994-1997)
  MESR : Model refinement and validation for LMARC Besançon and Framasoft
  EDF/DER : Refinement of robot models
  CTSN/MDTC : Vibration transmission by frequency smoothing
  CTSN/MDTC : Software optimizing vibration transmission through structures
  PSA : Prototype structural dynamics software
  RENAULT : Viscoelastic layer damping solutions

- DynaWorks®
  . Consultancy and Design
  ESA/ESTEC : Assessment of technologies and architectures for vibration measurement acquisition systems
  ESA/ESTEC : Satellite mechanical testing database
  ESA/ESTEC feasibility study for in-flight satellite thermal database
  SALOMON : study of measurement and analysis system for ski testing
  CISI/ DCN Ingénierie : Study of sonar signal tape library
  . Recent projects :
  INTESPACE : Prime contractor overseeing development of two measurement acquisition and data management systems for satellite thermal testing
  INTESPACE : 256 channels system for acquisition and processing of measurements during spacecraft vibration and noise testing
  CEA-CESTA : Measurement management and analysis system
  DCN-MDTC Toulon : Data acquisition system for underwater explosion testing
  CEAT : Data acquisition and processing system for crash testing
  CAP : Test data mangement and analysis system
  Electronic document management at INTESPACE Centre
  ESA, CEA-CESTA, EDF : Data acquisition management interfaces

PEQUEÑOS SATÉLITES PARA OBSERVACIÓN TERRESTRE: MISIÓN, CARGA UTIL Y AOCS

J.M. del Cura, J. Santamaría y S. Hernández Ariño
SENER Ingeniería y Sistemas, S.A.
División Aerospacial
Severo Ochoa 4, PTM, 28760 Tres Cantos, España
e-mail: jmanuel.del_cura@mad.sener.es; javier.santamaria@mad.sener.es; santiago.hernandezarino@mad.sener.es

EXTRACTO

Después del éxito de Minisat 01, se está planteando en España continuar el programa con un satélite de Observación de la Tierra y con una carga útil constituida por un instrumento con dos canales, trabajando cada uno de ellos en longitudes de onda visible e infrarroja, respectivamente. El satélite, con una masa en torno a 500kg, será previsiblemente inyectado en una órbita heliosíncrona a unos 500km de altitud mediante un lanzador Taurus. Con el objeto de reducir el tiempo de revisita del satélite es necesario que éste pueda maniobrar en balance para adquirir objetivos situados fuera de su traza sobre la superficie de la Tierra. Para poder tomar imágenes estereoscópicas es necesario, además, que el satélite tenga capacidad de maniobra en cabeceo. Por último, un movimiento en guiñada es necesario con el fin de eliminar el efecto de la rotación de la Tierra en la imagen.

La caracterización de las prestaciones y la calidad de un sistema de formación de imágenes, como el requerido para un satélite de este tipo, exige la manipulación simultánea de múltiples parámetros de naturaleza diferente y con interrelaciones complejas, siendo muy dificil predecir el comportamiento final del sensor. Por ello hemos desarrollado herramientas para el modelado de sensores de imagen facilitando la tarea de definición, configuración y evaluación. Se describe el modelo realizado así como los parámetros considerados y sus leyes de relación.

El satélite tiene un apuntamiento nominal a nadir con una estabilización y control en tres ejes con momento cinético nominal nulo. La alta precisión de apuntamiento requerida por la carga útil y su maniobrabilidad han conducido a la especificación de un subsistema AOCS sofisticado, compuesto principalmente de sensores estelares, plataformas inerciales, magnetómetros, sensores solares, ruedas de reacción y electromagnetos. Todos estos elementos se encuentran bajo el control de un procesador dedicado con conexiones con el resto de subsistemas del satélite, principalmente el subsistema OBDH. La determinación y el control de la órbita se realiza en el segmento terrestre. Las órdenes para la activación del subsistema de propulsión se envían al satélite. No existe control de actitud mediante propulsión, sólo control de órbita. El resto de funciones del AOCS se realizan a bordo. Uno de los puntos críticos desde el punto de vista del AOCS son las perturbaciones en la dinámica del satélite introducidas por la flexibilidad de los paneles solares. Este problema ha requerido de un detallado análisis con el objetivo de mantener bajo control su influencia y cumplir las prestaciones del subsistema.

El objetivo de fiabilidad del subsistema y la vida de la misión, establecida en 4 años, ha provocado que la configuración resultante sea altamente redundante para cumplir esos requisitos. Algunas de las unidades necesitan ser duplicadas y diferentes niveles de redundancia pueden encontrarse en el resto de equipos. Sólo los elementos muy fiables como los sensores de Sol o los electromagnetos no se han redundado.

La lógica de modos del AOCS ha sido ya definida e incluye modos de pre-adquisición, de adquisición inicial, operacionales y modos seguros. Han sido definidos dos modos seguros, uno de ellos basado en control digital del subsistema y otro básico de supervivencia basado en control analógico.

1. INTRODUCCIÓN

El interés en el segmento de los pequeños satélites ha ido creciendo de forma sostenida durante los últimos años en el mundo aerospacial. La posibilidad de tener un acceso al espacio que sea flexible y a un coste razonable está interesando a todo el mundo, independientemente de su involucración actual en programas espaciales en marcha. Por consiguiente, se espera en este sector un crecimiento aún mayor en la próxima década.

España no se ha quedado fuera de esta tendencia general y ha lanzado su propio programa llamado MINISAT.

La primera unidad del programa MINISAT fue el Minisat 01, un satélite de 185 kg con una carga útil científica que fue lanzado con éxito el 21 de Abril de 1997 y cuyo Sistema de Control de Actitud fue desarrollado por SENER Ingeniería y Sistemas, S.A.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

	Prestaciones Máximas
Masa Carga Útil	hasta 330 kg
Potencia para Carga Útil	hasta 300 W
Precisión de Apuntamiento (3 ejes)	mejor que 0,1°
Propulsión	hasta 100 m/s
Tamaño de Memoria	hasta 150 MB

Tabla 1: *Prestaciones máximas del módulo de servicio de MINISAT*

Este programa tiene continuación en un satélite de observación terrestre. El objetivo de este artículo es resumir los trabajos realizados hasta la fecha durante la fase B del desarrollo del satélite. El peso del satélite es de unos 500 kg con una carga útil de observación de la Tierra trabajando en el espectro visible y en el infrarrojo.

Las altas prestaciones de la misión y las restricciones exigidas en cuanto a fiabilidad del subsistema, sobre todo, han condicionado la arquitectura del AOCS. Los requisitos exigidos por la carga útil conducen a que se deban alcanzar las prestaciones máximas por parte del módulo de servicio de MINISAT. La solución adoptada después de la fase de diseño conduce a una configuración casi por completo redundante usando equipos comerciales ya calificados para aplicaciones espaciales incluyendo un procesador específico con las redundancias adecuadas para cumplir con las funciones del AOCS. Además del procesador, el AOCS está constituido por tres sensores solares analógicos, dos unidades inerciales de medida, tres sensores estelares con una única caja electrónica, dos magnetómetros de tres ejes, cuatro ruedas de reacción y tres electromagnetos. Existe un subsistema de propulsión para realizar el control de órbita pero es un subsistema completamente independiente bajo la responsabilidad del propio INTA. El interfaz con el AOCS se realiza mediante comandos de interfaz bien definidos.

Está previsto que el satélite sea lanzado mediante el lanzador americano Taurus no antes del año 2000.

Las secciones de las que consta este artículo pretenden describir brevemente elconcepto del satélite para centrarse en una descripción mas detallada del subsistema AOCS y del canal visible de la carga útil, responsabilidad también de SENER. Toda la información utilizada para escribir este artículo proviene de las Refs. 1-4.

2. DESCRIPCIÓN DEL SATÉLITE

El satélite en el que se ha estado trabajando es un minisatéllite de unos 500 kg. Sus dimensiones en la configuración de lanzamiento se encuentran entre 1 y 1.3 metros, mientras que la distancia entre los extremos de las puntas de los paneles solares desplegados es de casi 4.4 metros con un tamaño transversal de 2.2 metros para la configuración de paneles solares de referencia. El satélite se desarrolla a partir de una plataforma (Plataforma 1) basada en el Módulo de Servicio Básico (BSM) del programa MINISAT (Minisat 01 incorporaba la Plataforma 0). Las características y prestaciones que definen el BSM han sido especificadas por las prestaciones de la carga útil.

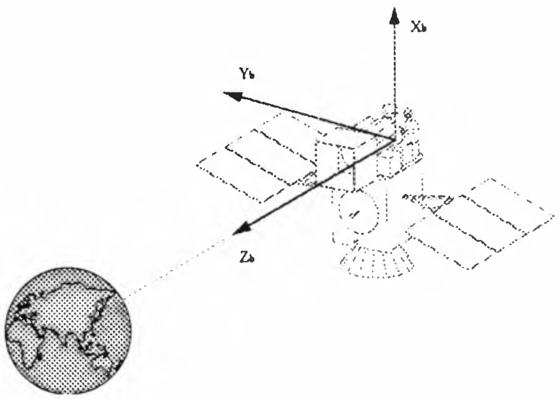


Figura 1: *Convenciones de ejes y ángulos*

La carga útil consiste de un instrumento óptico trabajando en los espectros visible e infrarrojo y que requiere tener un apuntamiento a Nadir. Este instrumento está siendo también diseñado por SENER Ingeniería y Sistemas, S.A y sus características se resumirán en la siguiente sección.

Las necesidades impuestas por la carga útil conducen una estabilización del satélite en tres ejes, nominalmente con apuntamiento a Nadir y con autoridad total para maniobrar en torno a cualquiera de sus tres ejes, aunque no con la misma capacidad para todos ellos. La Figura 1 muestra la configuración del satélite con los ejes del satélite definidos de la manera habitual. Las prestaciones exigidas por la misión conducen a la necesidad de definir una función de control orbital que es realizada por el subsistema de propulsión. La determinación de la órbita se realiza en el segmento terrestre utilizando la información procedente del receptor de GPS embarcado. Las órdenes para abrir las válvulas de las toberas se reciben desde la estación terrestre y se transmiten al AOCS que es el que tiene la interfaz definida con el subsistema de propulsión. Los requisitos del instrumento son bastante exigentes y, por ello, condicionan el diseño del AOCS, llevándolo muy cerca del límite establecido como prestaciones máximas del módulo de servicio del programa MINISAT mostradas en la Tabla 1.

La carga útil está situada en una plataforma hexagonal unida al BSM desarrollado para esta unidad. La potencia eléctrica necesaria la proporcionan dos paneles solares con capacidad de girar en torno al eje Y cuerpo. Se han considerado durante la fase B del estudio dos posibles configuraciones de paneles solares que han dado lugar a dos controles distintos pero basados en el mismo concepto.

El satélite será inyectado en una órbita heliosíncrona prácticamente circular de unos 500 km. de altitud y con una hora local para el nodo descendente (LTDN) próxima a mediodía. Consecuentemente, el satélite experimentará eclipses durante todas sus órbitas a lo largo de su vida.

La estación terrestre usada para el seguimiento del satélite será la Estación Espacial de Maspalomas (Islas Canarias), propiedad del INTA, con enlace continuo con las instalaciones principales del INTA en Madrid. El satélite ha sido dividido en el conjunto habitual de subsistemas, cada uno de ellos bajo la responsabilidad de una empresa española. SENER es la responsable del subsistema AOCS y del canal visible de la carga útil, que es un desarrollo completamente nuevo e íntegramente español.

3. CARGA UTIL. DISEÑO DE SISTEMAS DE FORMACIÓN DE IMÁGENES.

3.1 Introducción.

La caracterización de las prestaciones y la calidad de un sistema de formación de imágenes exige la manipulación simultánea de múltiples parámetros de naturaleza diferente y con interrelaciones complejas, siendo muy difícil predecir el comportamiento final del sensor. Por ello hemos desarrollado herramientas para el modelado de sensores de imagen facilitando la tarea de definición, configuración y evaluación, como paso previo al diseño de sensores para aplicaciones específicas.

Los modelos permiten manejar interactivamente parámetros de los siguientes tipos:

- Ópticos: Longitud focal, apertura, obturación, campo angular, transmitancia, corrección de aberraciones (aberración de onda de borde, RMS o desenfoque equivalente), MTF difraccional, degradación de MTF por vibraciones residuales, por movimiento del sensor, por movimiento de la escena, etc.

- Espectrales: Anchura y localización del espectro. Actualmente se considera espectro equienergético, pero la inclusión de la forma del espectro, implica sólo cambios menores.

- Detector: dimensiones, distancias intercentros y número de elementos detectores, sensibilidad espectral o detectividad cuántica, MTF del detector por área y por movimientos, degradación de MTF por anchura espectral, existencia y número de etapas TDI (Time delay and Integration), ruido de lectura y amplificación, eficiencia de barrido o de lectura, radiometría individualizada para cada posición angular de elemento en plano focal, frecuencia de Nyquist.

- Escena: reflectancia de la escena, objeto y fondo y cielo , tamaños de objeto, transmitancia atmosférica, degradación de MTF por la atmósfera, reflectancia máxima de la escena, temperaturas de escena y fondo para sistemas IR, leyes de trasnmitancia de contraste visual o térmico.

- Misión: posición angular del sensor, características de la órbita y del sol para el caso de satélites de observación, radiancia de referencia para cálculos radiométricos.

- Adquisición: bits por píxel de la digitalización, limitaciones de ancho de banda, volumen de datos, distancia de monitor de observación e integración visual (para sistemas IR)

- De calidad: Huellas lineales y angulares de elementos detectores sobre la escena, PSF eficaz, MTF resultantes, distancias o tamaños de detección, reconocimiento e identificación, valores de ruidos, señales y SNR, tiempos de integración, NEDL y NEDr (Noise equivalent differential luminance or reflectance), NETD y MRTD (Noise equivalent differential temperature y Minimun resolvable temperature difference) para sistemas IR.

Los modelos desarrollados son fácilmente combinables con algoritmos de tratamiento digital de imagen asociados a dichos modelos, lo que permite simular con precisión los efectos de la resolución, degradaciones por MTF y por ruido sobre imágenes test de escenarios reales.

Estos modelos, desarrollados para visible e infrarrojo en diferentes versiones según el tipo de operación, o según el detector (CCD, Infrarrojo de barrido, de matriz 2D, barredor de línea, *push-broom* etc.), además de su interés genérico como elemento de evaluación se ha utilizado para la definición del instrumento de alta resolución de la carga útil del minisatélite actualmente en desarrollo.

A continuación se describen con más detalle los procedimientos de cálculo de la función de transferencia de modulación (MTF: *Modulation Transfer Function*) y de la relación señal-ruido (SNR: *Signal to Noise Ratio*), como parámetros más relevantes.

3.2 Modelización de la M.T.F.

3.2.1 Cálculo de la M.T.F.

En este punto se incluye una descripción detallada del modelo utilizado para la estimación de la función de transferencia de la modulación (M.T.F., *Modulation Transfer Function*) de la cadena completa de adquisición de imágenes. De acuerdo al formalismo de la MTF, este modelo permite tratar de forma integrada el efecto sobre la calidad de imagen de cada uno de los elementos que constituyen la cadena de adquisición, suministrando una medida cuantitativa de calidad para cada configuración de adquisición estudiada.

En el presente análisis se han tenido en cuenta las siguientes contribuciones a la MTF final del sistema:

- MTF del sistema óptico
    - ◊ MTF difraccional
    - ◊ MTF desenfoque
    - ◊ MTF aberraciones
- MTF del detector
- MTF asociada al movimiento del sensor
- MTF atmosférica
- MTF debida a microvibraciones

Al corresponder a efectos que se combinan de forma incoherente, la MTF global se puede obtener de forma directa mediante la multiplicación punto a punto de las funciones de transferencia calculadas.

3.2.1.1 M.T.F. Óptica

La función de transferencia de la modulación (MTF) del sistema óptico viene dada por el efecto combinado de la difracción y las aberraciones del sistema. En los sistemas basados en la utilización de un detector, la MTF del sistema óptica-detector se ve incrementada por la potencial presencia de desenfoques, que en presente estudio se engloban dentro del presente epígrafe. La posibilidad de considerar los efectos del desenfoque de forma integrada dentro del sistema será utilizada dentro de la presente nota técnica en el análisis de los requisitos del mecanismo de refocalización.

En este modelo las aberraciones residuales del diseño se han modelado como desenfoque por simplicidad matemática , si bien en principio pueden incluirse con la estructura de aberraciones que resulte del diseño.

Se han considerado las siguientes contribuciones

- * MTF difraccional (pupila circular y/o anular)
- * MTF desenfoque
- * MTF aberraciones

** Pupila circular sin obturación*

La MTF difraccional para un sistema de óptico con pupila de entrada circular, libre de aberraciones y operando con luz monocrómatica de longitud de onda λ viene dada por:

$$MTF_{opt}(fx) = \frac{2}{\pi}\left[\arccos\left(\frac{f'\cdot fx}{fc}\right) - \left(\frac{f'\cdot fx}{fc}\right)\sqrt{1-\left(\frac{f'\cdot fx}{fc}\right)^2}\right]$$

Donde:

fx = Frecuencia espacial (l/mm)

f' = Distancia focal imagen (mm)

fc = Frecuencia corte (l/rad) = 10^3 D/λ

D = Diámetro pupila de entrada (mm)

λ = Longitud de onda (μm)

La MTF para el caso de luz policromática puede estimarse de forma directa substituyendo λ por la longitud de onda media o, de forma mas precisa, calculando el valor promedio de la MTF dentro de la banda espectral de trabajo. En este último caso, a la MTF correspondiente a cada longitud de onda debe asociarse un peso proporcional a la densidad espectral de radiancia en la radiación incidente.

** Pupila circular con obturación*

Para sistemas con obturación central (como es el caso frecuentemente en telescopios catadióptricos), la expresión analítica de la MTF se complica significativamente. Como alternativa a la utilización de estas expresiones, la MTF se ha calculado como la autocorrelación de la función pupila. Este enfoque, que tiene validez general, permite un tratamiento unificado de los efectos debidos a obturaciones y los producidos por la presencia de aberraciones en el sistema óptico, al incluirse todo ello en la función pupila.

La función pupila , *p(x,y),* es una función bidimensional que representa la distribución de campo complejo en la pupila de salida del sistema óptico. De forma habitual, se utiliza la siguiente descomposición del campo complejo en módulo y fase:

$$p(x,y) = p_0(x,y) \circ \exp\left(-i\frac{2\pi}{\lambda}\cdot W(x,y)\right)$$

Donde p_0 representa la amplitud (real) del campo el punto (x, y) de la pupila de salida. El factor exponencial representa la desviación de fase del frente de onda respecto al caso ideal (frente de onda esférico convergente). W(x, y) se denomina aberración de onda.

En el cálculo de la MTF difraccional, se toman en cuenten exclusivamente en cuenta los efectos derivados de la apertura finita del sistema. En estas condiciones, la aberración de onda es idénticamente nula y la función pupila toma un valor constante en la zona que permite el paso de la radiación, siendo nula en la zona exterior y en el área ocupada por la obturación.

La obturación actúa preferentemente sobre las frecuencias bajas y medias de la función de transferencia, manteniendo constante la frecuencia de corte del sistema.. La zona operativa esta delimitada por la frecuencia de Nyquist asociada al muestreo del detector . En nuestro caso, la mayor caída en frecuencias debido a la obturación se produce para esta zona.

La MTF correspondiente se estima generando una aproximación digital a la función pupila como una matriz de dimensiones *M x M* y calculando su función de autocorrelación. En el caso de pupila circular con obscuración circular centrada, la MTF resultante es función de los parámetros que definían la MTF para apertura circular (Diámetro exterior, longitud de onda de la radiación incidente y distancia focal), y, adicionalmente, de la relación entre los diámetros interior y exterior de la pupila

** M.T.F. debida a desenfoques*

De acuerdo a lo mencionado en el apartado anterior, la MTF asociada a una degradación genérica (difracción, desenfoques, aberraciones) se calcula de forma directa mediante autocorrelación de la función pupila asociada. Esta función puede derivarse directamente a partir de los valores de aberración de onda correspondientes a la degradación bajo estudio.

En el caso de un sistema desenfocado sin aberraciones, la diferencia de fase respecto al sistema perfecto viene dada por la diferencia de camino óptico entre dos frentes de onda esféricos tangentes en el eje óptico y con centros dados por los puntos imagen real y de referencia (desenfocado). En primera aproximación, se puede demostrar que la aberración de onda, W(x, y), para un sistema perfecto desenfocado viene dada por la expresión:

$$W(x,y) = \frac{1}{2}\cdot\delta\cdot\frac{\left(x^2+y^2\right)}{f'^2}$$

Donde (x, y) son coordenadas sobre la pupila de salida del sistema, δ es el desenfoque y f' es la distancia focal imagen del sistema óptico

** M.T.F. asociada a aberraciones*

La MTF asociada a las aberraciones del sistema óptico se calcula a partir del conocimiento de la función de aberración de onda correspondiente. En la literatura se pueden encontrar expresiones de esta función para aberraciones de tercer orden (esférica, coma, astigmatismo). En la práctica, las aberraciones presentadas por un sistema óptico son una combinación de varios tipos primarios, con posibles contribuciones significativas de aberraciones de orden superior. La MTF de estos sistemas se ha determinado a partir del cálculo de la OPD (Optical Path Difference) del sistema mediante trazado de rayos, opción incluida en diversos programas de diseño óptico.

En primera aproximación, se puede estimar la MTF debida a aberraciones en función del dato de aberración máxima del frente de onda. Para ello, se supone que la aberración producida por el sistema es del tipo de la inducida por desenfoque, y se ajusta el valor de la aberración de onda (de tipo cuadratico, como se presenta en el apartado 5.1.1.3) de forma que la aberración en el borde de la pupila coincida con el valor máximo proporcionado.

En caso de disponer como dato del valor RMS de la aberración de onda, la aberración máxima se puede estimar a partir de ésta mediante la aplicación de fórmulas obtenidas mediante un ajuste polinómico de las relaciones típicas entre valores RMS y valores máximos de aberración en sistemas ópticos reales. A continuación se incluyen fórmulas de conversión en las dos direcciones.

3.2.1.2 MTF del detector

A efectos del cálculo de la función de transferencia global del sistema, el efecto asociado al tamaño finito del detector se modeliza como la composición secuencial de las siguientes operaciones:

- Integración espacial de la irradiancia en el plano focal en áreas delimitadas por el tamaño del detector elemental.
- Muestreo de la señal integrada según un patrón dado por las posiciones centrales de los detectores elementales.

La función de transferencia asociada a la operación de integración viene dada por la transformada de Fourier del perfil 2D correspondiente a un detector elemental. Para detectores rectangulares, la función resultante, MTF_{DET}, es del tipo sinc:

$$MTF_{DET} = \frac{sen(\pi \cdot f_x \cdot a)}{\pi \cdot f_x \cdot a}$$

Donde:
fx = Frecuencia espacial (l/mm)
a = Tamaño del pixel (mm)

La operación de muestreo que se aplica sobre la señal integrada, tiene como efecto romper la invariancia espacial del sistema, por lo que, estrictamente, el formalismo basado en MTF no sería aplicable al caso de sistemas que utilicen un array de detectores. Adicionalmente, esta operación de muestreo es causa potencial de aparición de fenomenos de *aliasing* en la imagen, al permitir las funciones de transferencia del sistema el paso de frecuencias superiores a la frecuencia de Nyquist (≡ ½ frecuencia de muestreo) asociada al detector. En cualquier caso, los efectos derivados de la presencia de aliasing serán pequeños en la mayor parte de las aplicaciones operativas, por lo que se ha considerado la aproximación lineal para el análisis del sistema.

3.2.1.3 MTF debida al movimiento del sensor

La existencia de un movimiento relativo entre el sensor y el terreno lleva asociado una contribución a la función de transferencia global del sistema. Esta contribución se modeliza como la correspondiente a una integración temporal de la señal provista por el detector durante un intervalo igual al tiempo de integración del sistema. La integración en el dominio temporal se puede analizar de forma equivalente en el dominio espacial, considerando una PSF rectangular de dimensiones dadas por el espacio recorrido por el punto central de la huella del detector (en coordenadas X e Y) sobre el terreno durante el tiempo de integración del sistema. Esta función de transferencia resultará, en general, en degradaciones diferentes en la imagen en direcciones paralela y perpendicular a la línea detectora, en función de la órbita especifica del minisatélite.

Una vez que se dispongan de los valores de las proyecciones sobre el terreno del desplazamiento (bidimensional) del detector, las MTF correspondientes se pueden estimar por aplicación directa de la fórmula descrita al tratar el efecto de la integración espacial del detector.

3.2.1.4 MTF de la Atmósfera

La MTF asociada a los fenómenos de *scattering* atmosféricos se ha estimado mediante el siguiente perfil de tipo Gaussiano:

$$MTF_{ATM}(f_x) = \exp(-2 \cdot \pi^2 \cdot \sigma_\theta^2 \cdot f'^2 \cdot f_x^2)$$

Donde:
f_x = Frecuencia espacial (l/mm)
σ_θ = Desviación estándar PSF atmósfera (mrad)
f' = Distancia focal imagen (mm)

3.2.1.5 MTF debida a microvibraciones

La MTF debida a microvibraciones (*jitter*) de alta frecuencia (respecto a una frecuencia de referencia definida como el inverso del tiempo de integración) se puede modelizar adecuadamente mediante una función de tipo Gaussiano similar a la utilizada en la estimación de la MTF atmosférica. Al igual que en este último caso, la función de transferencia se calcula de forma directa a partir del conocimiento de la desviación estándar de la oscilación de la línea de mira del sensor debida a las microvibraciones

3.3 Cálculo de la SNR

La relación señal/ruido se define como el cociente entre el valor medio de la señal y el valor rms del ruido para unas condiciones operativas nominales. Estas magnitudes se estiman en los apartados siguientes.

3.3.1 Valor medio de la señal

El valor de la señal de salida de un elemento detector se ha estimado a partir del análisis de las transformaciones inducidas en la señal por los distintos elementos de la cadena de observación. Esto resulta en un procedimiento que incluye el cálculo sucesivo de los siguientes parámetros:

* Radiancia de suelo
* Atenuación atmosférica
* Irradiancia sobre el detector
* Energía recibida en el tiempo de integración
* Número de fotones equivalentes
* Carga (e^-) en el elemento detector

A continuación se describe brevemente el procedimiento de cálculo de cada uno de los parámetros enumerados:

Radiancia del suelo

La radiancia del suelo esta determinada por los siguientes factores:

- Rango espectral
- Irradiancia solar exoatmosférica
- Atenuación atmosférica (antes de reflexión)
- Reflectancia del suelo

La irradiancia solar sobre el terreno presenta un valor inferior a la correspondiente magnitud exoatmosférica debido a la atenuación producida en la atmósfera. Los efectos atmosféricos pueden tenerse en cuenta utilizando una reflectividad aparente del suelo obtenida como producto de la reflectividad real por la transmitancia atmosférica media.

Utilizando datos tabulados para los valores de irradiancia solar , transmitancia atmosférica y reflectividad del suelo, la radiancia del terreno se estima para difusión Lambertiana como $R= \rho * Irr / \pi$. A efectos de cálculo de la relación señal/ruido del sistema se ha tomado el valor requerido por la Ingeniería de Sistemas. La radiancia de saturación permite determinar el rango dinámico del sensor y se empleará para dimensionar el intervalo de digitalización de la señal analógica, de acuerdo con las ganancias del sistema electrónico de la detección.

**Atenuación atmosférica (después de reflexión)*

La atmósfera produce una atenuación de la radiación procedente del suelo debido a fenómenos complejos de absorción y difusión. Como resultado de estos efectos se obtiene una transmitancia equivalente que se encuentra tabulada para un conjunto de atmósferas estándar. Para una atmósfera fija, y para las condiciones de observación definidas (sensor exoatmosférico de observación de la Tierra), esta transmitancia se puede considerar como función exclusivamente del ángulo de observación respecto al cénit.

En los cálculos globales iniciales se utilizó la aproximación de considerar la transmitancia atmosférica dentro de la banda de trabajo como constante. Posteriormente se ha incluyó en el modelo el uso de la curva completa de transmitancia atmosférica espectral para el cálculo de la atenuación de la radiación en su doble trayecto a través de la atmósfera (antes y después de la reflexión sobre el terreno).

Los cálculos de SNR realizados con los valores obtenidos son análogos a los obtenidos considerando valores medios, aunque se observa una ligera disminución en los resultados debido a la pequeña disminución de la transmitancia en las zonas extremas del espectro.

**Irradiancia sobre el detector*

La irradiancia sobre el detector (Irr_D) viene dada por la siguiente expresión:

$$Irr_D = \frac{\pi}{4} \bullet R \bullet T_{opt} \bullet \left(\frac{D}{f}\right)^2$$

Donde R es la radiancia del suelo (considerando la atenuación atmosférica) y T_{opt} y D/f son, respectivamente, la transmitancia y el inverso del $F^{\#}$ del sistema óptico.

**Energía recibida por tiempo de integración*

La energía recibida (E) durante el tiempo de integración del detector viene dada por el producto de este tiempo por el área del detector ($P_x * P_y$) y por el valor de la irradiancia:

$$E = Irr_D \bullet P_X \bullet P_Y \bullet \tau$$

**Número de fotones equivalentes*

Se puede estimar el número de fotones (N_{fot}) correspondiente a la energía recibida durante el tiempo de integración sin más que dividir ésta por la energía de un fotón con longitud de onda (l_m) correspondiente al valor medio del rango espectral de operación:

$$N_{fot} = \frac{E}{\frac{h \bullet c}{\lambda_m}}$$

* *Carga (e^-) en el elemento detector*

El número medio de electrones (N_{e-}) generado en el elemento detector esta determinado por el producto para cada longitud de onda del número medio de fotones por la eficiencia cuántica del detector. En primera aproximación, este valor puede estimarse como el producto de N_{fot} por la eficiencia cuántica media dentro del rango espectral.

3.3.1 Valor rms del ruido

Se han considerado las siguientes fuentes de ruido:

* Ruido fotónico (s_f)
* Ruido de lectura del detector (s_l)

El ruido asociado a la digitalización se ha excluido explícitamente del presente estudio.

Dado que las tres fuentes de ruido pueden considerarse como independientes, la desviación estándar correspondiente al ruido total del sistema (s) vendrá dada por la expresión:

$$\sigma = \sqrt{\sigma_f^2 + \sigma_l^2}$$

A continuación se derivan valores RMS típicos correspondientes a las fuentes de ruido consideradas.

* *Ruido fotónico*

El ruido fotónico esta causado por el carácter probabilístico de la emisión atómica de luz. Esto introduce un factor aleatorio intrínseco en el número de fotones detectado por unidad de tiempo. El proceso de detección responde al modelo de procesos de Poisson, por lo que su desviación estándar viene dada por la raíz cuadrada del número medio de fotones detectado durante el intervalo de observación. La desviación estándar en electrones (s_f) se obtiene multiplicando este valor por la eficiencia cuántica del detector:

$$\sigma_f = Q_{ef} \bullet \sqrt{N_{fot}}$$

* *Ruido de lectura del detector*

Se tomará como ruido de lectura el siguiente valor típico para los detectores CCD existentes en el mercado:

$$s_l = 50\ e^-$$

Con los resultados obtenidos del valor medio de la señal y del valor rms del ruido se obtiene directamente la relación señal ruido que debe satisfacer los requisitos impuestos. En caso contrario deben modificarse los parámetros del diseño (esencialmente, apertura del sistema, obturación y anchura espectral), siempre minimizando la eventual degradación de la MTF y de la resolución.

4. SUBSISTEMA AOCS

4.1 Funciones y requisitos del AOCS

El subsistema AOCS es responsable de realizar la determinación y el control de la actitud del satélite y de la generación de los comandos del subsistema de propulsión. La función de determinación de órbita se realiza en el segmento terrestre utilizando la información suministrada por un receptor GPS embarcado. Los comandos de control orbital se generan también en tierra y se transmiten al AOCS a través del OBDH. Estos comandos se remiten al subsistema de propulsión. El AOCS, para cumplir con estas funciones, queda constituido por un conjunto de sensores y actuadores, así como las funciones lógicas que permiten el funcionamiento de estas unidades.

Según ha sido ya parcialmente introducido en las secciones previas, el AOCS tiene que:

- realizar la determinación y el control de actitud en tres ejes;
- mantener el eje Z cuerpo del satélite apuntando hacia el objetivo o en un apuntamiento a Nadir (ver Figuras 1 y 2);
- realizar las maniobras de balance (para reducir el tiempo de revisita) y de cabeceo que se requieren;
- compensar el efecto de la rotación de la Tierra en la toma de la imagen mediante una compensación en guiñada (*yaw steering*);
- generar la referencia para el Mecanismo de Apuntamiento de los Paneles Solares (SAPM) con el objetivo de mantener éstos apuntados hacia el Sol;
- asegurar una operación segura del satélite durante toda su vida.

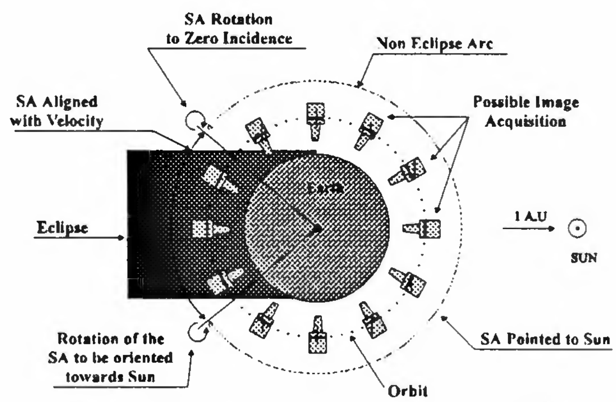


Figura 2: *Esquema de la operación del satélite*

En el caso de que aparezcan problemas a bordo o en el enlace de comunicaciones, el AOCS debe de ser capaz de mantener el satélite activo pasando a una actitud de apuntamiento al Sol en donde se asegure la recarga de las baterías. Con el objetivo de conseguir esto, se han definido dos modos seguros que se detallarán en la sección 4.3.

Finalmente, el AOCS tiene que determinar la actitud del satélite a bordo y en tierra debido a motivos operacionales y para referenciar la imagen tomada. Una determinación de actitud más precisa se realizará en el segmento terrestre mediante programas de cálculo independientes de los embarcados pero este aspecto no se detallará en el presente artículo.

La solución que se ha adoptado para el AOCS durante su diseño consiste en una configuración estabilizada en tres ejes con momento angular nulo. La próxima sección detallará la arquitectura del AOCS.

Además de las funciones expuestas hasta el momento, el AOCS debe de ser capaz de desempeñar una serie de funciones adicionales para el correcto funcionamiento del subsistema. Estas funciones adicionales son las siguientes:

- definición y gestión de los modos y estados del AOCS. La operación del AOCS se ha estructurado mediante varios modos definidos para los distintos modos de funcionamiento del satélite definidos;
- detección, aislamiento y recuperación de fallos (FDIR). Todos los problemas que den lugar a un funcionamiento degradado o incorrecto del AOCS deben de ser identificados y, si es posible, recuperados. Como mínimo, la supervivencia del satélite debe de estar garantizada mediante la transición a uno de los modos seguros;
- procesado de los telecomando. La operación del AOCS es completamente automática y solamente ciertos comandos enviados por el segmento terrestre se aceptan. A través de ellos, y junto con otras acciones, las referencias de actitud se cambian, por ejemplo;
- generación de los datos para la telemedida. Todos los datos relevantes del AOCS son formateados y preparados para su transmisión a través de la telemedida. El análisis en tierra de estos datos servirá para comprobar el apropiado funcionamiento del sistema y para realizar la determinación de actitud refinada;

4.2 Arquitectura del AOCS

Debido a las altas prestaciones requeridas por esta misión (precisión de apuntamiento, maniobrabilidad, fiabilidad, etc.), se requiere una configuración altamente redundante con equipos comerciales. Se considera necesario un procesador dedicado al AOCS que se desarrollará utilizando componentes calificados para espacio también comerciales.

El subsistema AOCS tiene interfaces con los siguientes subsistemas del satélite: OBDH, SAPM, GPS, Propulsión y Potencia (ver Figura 3).

El subsistema OBDH, con su propio microprocesador, es responsable de la gestión global del satélite,

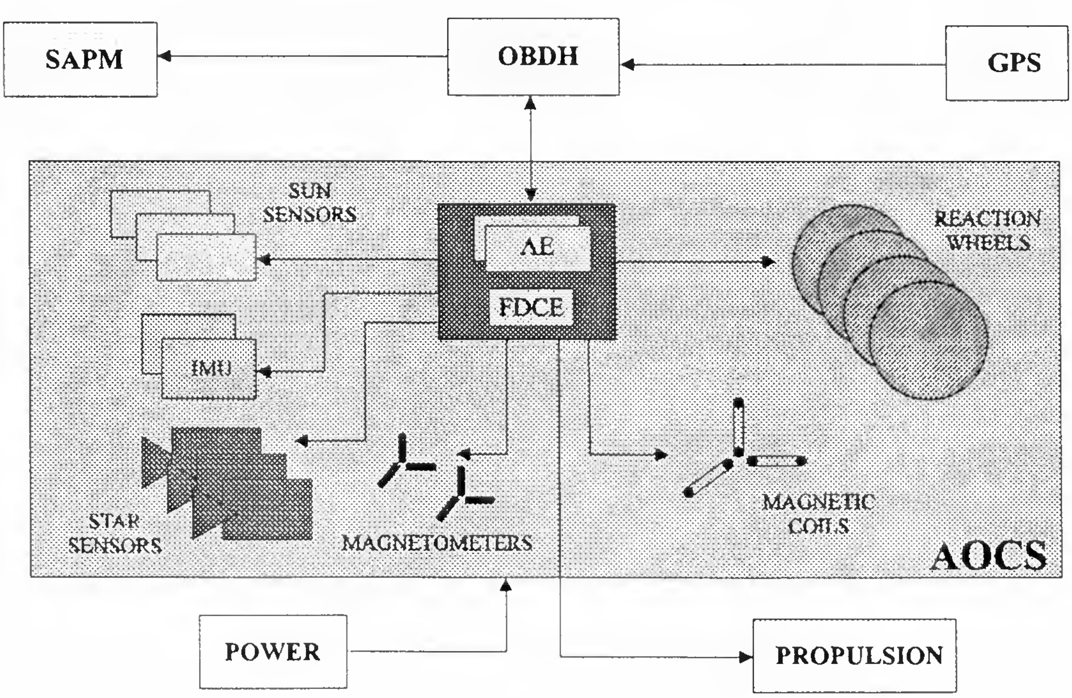


Figura 3: *Arquitectura del AOCS*

incluyendo la carga útil. Todos los datos de telemetría y telecomandos se envían a través del OBDH que tiene la interfaz del satélite con el segmento terrestre.

El AOCS genera la referencia para el SAPM, que es el subsistema encargado de hacer girar los paneles solares. Estos se encuentran apunados hacia el Sol durante el arco iluminado de la órbita, mientras que durante los eclipses, se orientan según el vector velocidad con el objetivo de minimizar el impacto de la resistencia aerodinámica en el satélite. Durante las tomas de imagen, los paneles solares se mantienen fijos para evitar que la flexibilidad de éstos perturben la dinámica del satélite. El satélite realizará un máximo de una imagen por órbita, por lo que el impacto de la pérdida de potencia no es crítico ya que el perfecto apuntamiento de los paneles solares hacia el Sol sólo se pierde durante unos minutos cada órbita, dando lugar a una pequeña desviación de los paneles solares.

A pesar de que no hay un enlace directo entre el subsistema GPS y el AOCS, este subsistema resulta ser relevante para el AOCS ya que la información de aquél es transmitida a tierra para determinar la órbita y producir los comandos de control orbital que se transmitirán al AOCS a través del OBDH.

El subsistema AOCS controla el de propulsión que es un subsistema independiente. El AOCS es responsable de comprobar la salud de este subsistema y transmitirlo a tierra a través del OBDH.

El subsistema de potencia está basado en dos paneles solares simétricamente dispuestos a lo largo del eje Y cuerpo(ligeramente deflectado para tener en cuenta el LTDN). Cada uno de ellos tiene tres placas con el objetivo de permitir una configuración de lanzador lo mas reducida posible. Dos posibilidades han sido consideradas durante la fase B: con todas las placas individuales a lo largo de esta dirección o perpendiculares a ella.

El AOCS está compuesto de los siguientes elementos:

1. sensores;
2. actuadores;
3. cajas electrónicas.

La arquitectura del AOCS se muestra en la Figura 3, donde se pueden ver las distintas interfaces con el resto de subsistemas del satélite.

4.2.1 <u>Sensores.</u>

El AOCS usa las medidas procedentes de los siguientes conjuntos de sensores:

• <u>Giróscopos:</u>

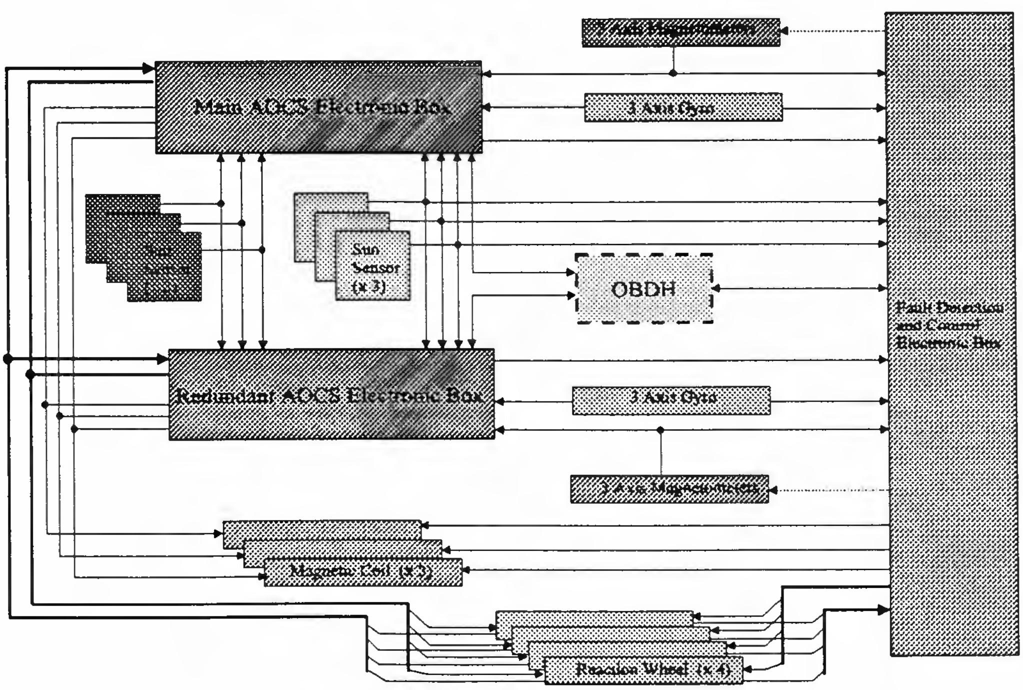


Figura 4: *Arquitectura eléctrica del AOCS*

Constituyen el núcleo del sistema de determinación y control de actitud embarcado. Existen actualmente dos opciones de distintos proveedores basados en distintas tecnologías: DTG y RLG. el momento no se ha decidido cuál será la opción escogida. Si se eligiera el giróscopo DTG, éstos proporcionarían una salida en dos ejes, siendo necesarias tres de estas unidades para cumplir el requisito de fiabilidad. Si, por el contrario, se seleccionara la opción RLG, se necesitarían dos de estas unidades que proporcionan medida en tres ejes. Estos sensores necesitarán ser calibrados mediante una referencia externa de actitud debido a su deriva inherente. Los sensores estelares se utilizarán con este objetivo.

- Sensores estelares:
  Se usan principalmente para localizar la imagen tomada con la precisión que se necesita. Adicionalmente, este sistema proporciona una medida de actitud redundante que puede ser utilizada para calibrar los giróscopos, para incrementar la precisión de apuntamiento durante las fases en las que el satélite no gire demasiado y para comprobar la salud de la medida de los giróscopos. Se necesitan tres sensores estelares a bordo en una configuración redundante de 2-de-3 para poder tener la precisión requerida en torno a los tres ejes para cualquier orientación posible del satélite durante una toma de imagen y previendo el fallo de una de las cabezas. Dos de ellas funcionan nominalmente y la tercera se encuentra apagada en redundancia fría dirigida según la bisectriz de las direcciones de los sensores estelares operativos nominalmente. Un total de cinco opciones para este sensor se consideran actualmente, todas ellas satisfaciendo los requisitos.

- Magnetómetros:
  Dos magnetómetros de tres ejes han sido seleccionados para este AOCS. La unidad de referencia es la misma que la utilizada en Minisat 01. La medida de esta unidad no se utiliza en la determinación de actitud debido a su baja precisión sino para operar los electromagnetos que se usan para desaturar las ruedas de reacción. La medida de los magnetómetros se utiliza únicamente durante los periodos de tiempo en los que los electromagnetos no están activados para que no se falsee su medida del campo magnético terrestre. Debido a su relativo bajo coste, ligereza y pequeño tamaño se ha duplicado con el objetivo de simplificar el manejo de las redundancias por parte de las cajas electrónicas aunque la redundancia de esta unidad no es estrictamente necesaria desde un punto de vista de fiabilidad. Los magnetómetros se utilizan también durante el modo de Adquisición de Tierra para la determinación de actitud como sensor primario.

- Sensores solares:
  Se ha considerado necesario el embarcar tres sensores solares similares a los utilizados en Minisat 01. Estos tres sensores se encuentran equiespaciados en el plano X-Z cuerpo con el objetivo de cubrir una banda completa de la esfera celeste. El objetivo de esta configuración es asegurar la adquisición del Sol mediante un comando que haga girar al satélite en torno a una dirección contenida en este plano. No se han considerado redundancias para estos sensores debido a su alta fiabilidad y a que la operación podría aún realizarse con uno sólo de ellos, si bien de una manera más compleja. Estos sensores se usan para adquirir los modos seguros, definidos por un apuntamiento al Sol y, por tanto, también para establecer una de las referencias de actitud durante estos modos. Durante el resto de modos, la información que proporcionan puede utilizarse para comandar directamente el SAPM y para funciones del FDIR.

4.2.2 Actuadores.

La función de control de órbita es realizada por el subsistema de Propulsión que ha sido segregado como una parte independiente del AOCS. Para control de actitud, se utilizan dos actuadores embarcados:

- Ruedas de Reacción:
  Debido a la maniobrabilidad que necesita la misión, el actuador que se ha seleccionado como adecuado es un conjunto de ruedas de reacción. Se consideran cuatro ruedas de reacción en una configuración redundante en caliente 3-de-4 similares a las utilizadas en Minisat 01, si bien algo mayores. Las ruedas se encuentran colocadas en una configuración piramidal orientada hacia el eje de balance, con lo que este eje pasa a ser un eje privilegiado desde el punto de vista de la actuación ya que los pares que se requieren en torno a este eje resultan ser los principales.

- Electromagnetos:
  Se cuenta con tres electromagnetos dirigidas a lo largo de cada uno de los tres ejes X, Y y Z cuerpo como fuente externa de pares para desaturar las ruedas de reacción. Este actuador se emplea utilizando la medida que proporcionan los magnetómetros y que es ignorada en los instantes de tiempo en los que los electromagnetos se encuentran activados.

4.2.3 Cajas electrónicas:

Las funciones lógicas embarcadas se ejecutan en un procesador dedicado que se encuentra duplicado para proporcionar una redundancia en frío. Ambas cajas electrónicas se encuentran bajo el control de la Electrónica de Detección de Fallos y Control (FDCE) que realiza además las funciones de control durante los modos en los que un control digital no es posible por algún motivo (principalmente, en el modo seguro de supervivencia). La arquitectura eléctrica se muestra en la Figura 4, donde todas las conexiones entre todos los elementos del AOCS pueden verse.

4.3. Modos del AOCS

El AOCS se ha organizado para que opere mediante cuatro posibles conjuntos de modos con el objetivo de alcanzar sus prestaciones:

- modos de pre-adquisición;
- modos de inicialización;
- modos operacionales;
- modos seguros.

Todos estos modos se muestran en la Figura 5, donde pueden verse las distintas transiciones entre unos modos y otros.

4.3.1 Modos de pre-adquisición.

Estos modos sólo serán utilizados durante el corto periodo de tiempo que sigue a la inyección del satélite en su órbita nominal. Estos modos son automáticamente activados por el FDCE. Una vez que la secuencia a lo largo de estos modos se ha completado, se comanda automáticamente una transición al modo autónomo HW (un modo seguro de supervivencia) para asegurar una operación segura del satélite en un periodo de tiempo reducido. Se han definido tres modos en este conjunto:

- Lanzamiento (L):
  Este modo establece la configuración de los equipos que vayan activados durante la fase de lanzamiento.

- Regulación de velocidades (RR):
  Este modo se usa para regular las velocidades angulares inicialmente existentes tras la separación del lanzador. Se activa automáticamente por el FDCE. Las velocidades angulares se estiman utilizando las medidas procedentes de los giróscopos y los pares de control se obtienen a partir de las ruedas de reacción.

- Despliegue de los paneles solares (SAD):
  Una vez que las velocidades angulares se han

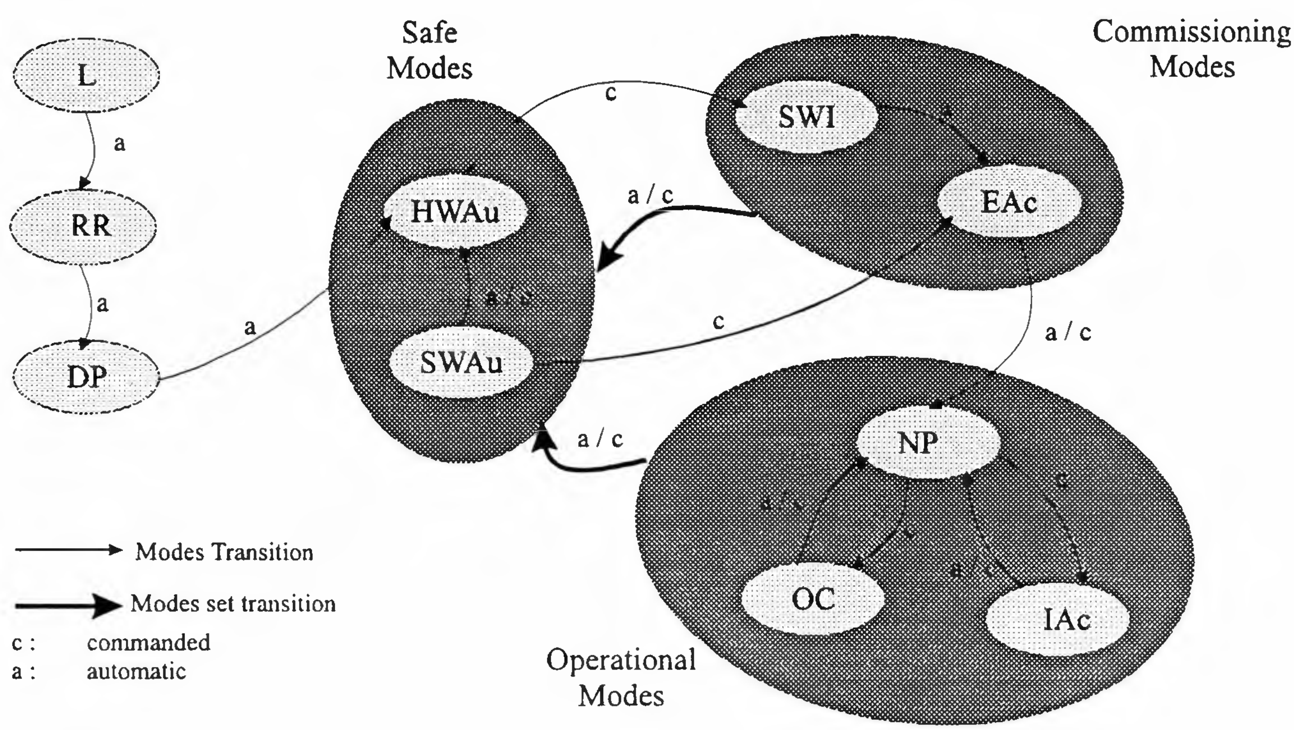


Figura 5: *Modos del AOCS*

controlado, los paneles solares se despliegan. El control se basa en el mismo concepto que en el modo anterior y es también automáticamente comandado por el FDCE.

El enlace entre estos modos se realiza mediante una transición unidireccional y no es posible volver hacia atrás. Después de que la secuencia de estos modos se ha completado, el satélite pasa a operar en un modo autónomo HW (modo seguro de supervivencia).

4.3.2 Modos de inicialización.

Estos modos realizan la transición desde los modos seguros a los operacionales. La transición tiene que ser telecomandada. Este conjunto lo constituyen dos modos:

- Inicialización del SW (SWI):
  A este modo sólo puede llegarse desde el modo HWAu mediante un comando. En este modo, se mantiene el apuntamiento al Sol que existía en el modo HWAu, los datos embarcados se refrescan desde la estación de tierra, así como las efemérides del Sol y del satélite y el modelo de campo magnético terrestre. Los algoritmos adicionalmente se inicializan. El control se realiza por el FDCE aunque el procesador del AOCS (ya sea el principal o el auxiliar) se activa y se realizan las comprobaciones pertinentes de su estado. Una vez que todas las acciones de este modo se han completado, el procesador se encontrará activado y se comandará una transición automática al modo de adquisición de tierra. El enlace entre ambos modos de este conjunto es unidireccional y no es posible una vuelta atrás sin pasar antes por el modo HWAu.

- Adquisición de tierra(EAc):
  En este modo, se determina la dirección del Nadir usando las medidas procedentes de los sensores solares y de los magnetómetros. Una vez que la dirección del Nadir se ha determinado, se obliga al satélite a apuntar su eje Z cuerpo hacia esta dirección. Puede accederse a este modo desde el modo SWI de forma automática o bien directamente desde el modo SWAu mediante una transición comandada. Este modo es la puerta de acceso a los modos operacionales, una vez que el satélite ha adquirido la dirección del Nadir (nominal de apuntamiento).

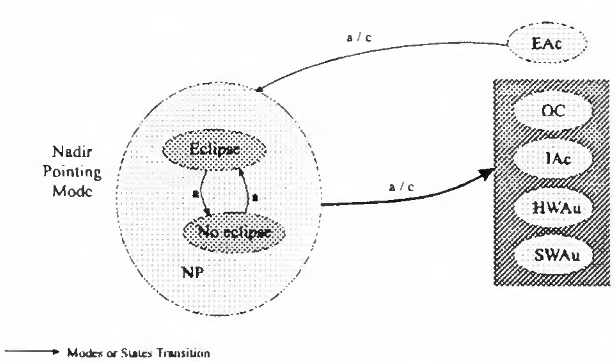


Figura 6: *Estados del modo de apuntamiento a Nadir*

4.3.3 Modos operacionales.

Estos son los modos mas relevantes para cumplir los objetivos de la misión. El satélite en estos modos se encontrará completamente operativo para poder activar la carga útil y tomar las imágenes pertinentes de la superficie terrestre. Este conjunto queda compuesto de tres modos, estando dos de ellos constituidos por varios estados adicionales, tal y como se expone a continuación:

- Apuntamiento a Nadir (NP):
  El satélite apunta a Nadir y la actitud se determina nominalmente a partir de la medida de los sensores estelares y de los giróscopos. El control se realiza mediante las ruedas de reacción que requerirán una desaturación periódica mediante la actuación de magnetómetros y electromagnetos. El acceso a este modo puede realizarse desde cualquier otro modo de este conjunto pero, desde modos externos, el acceso sólo es posible desde el modo EAc, mediante una transición automática o comandada. Este modo será el habitual en el que se encuentre el satélite en espera de que vaya a tomar alguna imagen. Se han definido dos estados dentro de este modo, dependiendo de cuál sea la iluminación solar (eclipse o no). La principal diferencia tiene que ver con la referencia que se le proporciona al SAPM, ya sea que apunte al Sol o que se alinee con la velocidad. Las transiciones entre estos estados y otros modos se muestran en la Figura 6.

- Adquisición de imagen (IAc):
  En este modo, se obtienen las imágenes de la superficie de la tierra por parte del instrumento embarcado. Las maniobras para adquirir el objetivo se incluyen dentro de este modo. Durante las maniobras, la determinación de actitud se realiza procesando la información procedente de los giróscopos, ya que las maniobras no son compatibles con el uso de los sensores estelares. Sin embargo, a pesar de esto, las medidas de los sensores estelares se envían a tierra para geolocalizar la imagen con la precisión adecuada. La lógica del modo se ha organizado usando cuatro estados: Calibración de los giróscopos, Rotación, Apuntamiento Fino a Nadir y Adquisición de Imagen, tal y como se puede ver en la Figura 7. La transición al modo IAc se comanda

desde el modo NP. Para garantizar las prestaciones de los giróscopos durante la adquisición de la imagen es necesario realizar una calibración de esta unidad. El paso siguiente será apuntar hacia el objetivo deseado en la superficie terrestre. De esta forma, se realiza una transición automática al estado de Rotación como paso previo a establecer el estado de adquisición de imagen. En el caso de que el tiempo que transcurra entre la calibración de los giróscopos y la adquisición de la imagen sea grande, se ha definido un estado de apuntamiento fino a Nadir como estado de espera para evitar problemas en el subsistema de Potencia. En este caso, el paso al estado Iac (comandado automáticamente) debe realizarse necesariamente a través del estado de Rotación.

- Control orbital (OC):

El control orbital necesita ser realizado de forma periódica a lo largo de la vida del satélite. De esta forma, el encendido del subsistema de Propulsión debe de ser compatible con una operación "normal" del satélite. El satélite mantendrá un apuntamiento inercial durante este modo usando los sensores estelares para determinar la actitud y las ruedas de reacción (y los electromagnetos si es necesario) para controlarla.

4.3.4 Modos seguros.

Se han definido dos modos seguros para garantizar un funcionamiento autónomo del satélite en el caso de que se presenten posibles contingencias: los modos autónomos SW y HW.

- Autónomo HW (HWAu):

En el caso de que se presente alguna contingencia que pueda afectar a la supervivencia del satélite, se realiza una transición comandada o automática a este modo. Desde cualquier orientación inicial, se realiza una giro en torno al eje X cuerpo para asegurar la adquisición del Sol mediante alguno de los tres

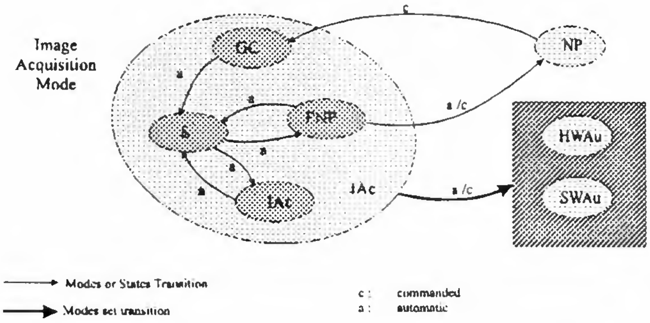


Figura 7: *Estados del modo de Adquisición de imagen*

sensores estelares. En el caso en el que el satélite se encuentre en el arco de órbita en eclipse, esta rotación continuará hasta que el satélite quede nuevamente iluminado por el Sol. Después de haberse detectado la dirección del Sol, el eje -Z cuerpo es orientado hacia esta dirección estableciéndose un giro controlado en torno a este eje. Las necesidades de potencia quedarían cubiertas con esta configuración. Este modo permitirá un funcionamiento autónomo del satélite hasta que el enlace de comunicaciones con el segmento terrestre quede establecido de nuevo. Para recuperar los modos nominales a partir de éste es necesario pasar al modo SWI. Este modo (HWAu) puede ser alcanzado desde cualquier otro modo, con excepción de los de pre-adquisición. Después del lanzamiento, la secuencia de modos de pre-adquisición es ejecutada y automáticamente se lleva al satélite al modo HWAu. El apuntamiento al Sol del eje -Z cuerpo queda asegurado mediante la medida de los sensores solares y el uso de un simple control analógico es suficiente para mantener esta referencia. La velocidad de rotación alrededor de la dirección del Sol es mantenida a partir de la medida proporcionada por los giróscopos. El control se realiza mediante ruedas y los electromagnetos para su desaturación.

- Autónomo SW (SWAu):

Este modo se define de una manera muy similar al anterior. La principal diferencia estriba en el uso del procesador para desarrollar las funciones del AOCS permitiendo tener mejores prestaciones y una recuperación más rápida que en el caso del modo HWAu. La recuperación desde este modo se realiza a partir de una transición directa comanda hacia el modo Eac evitando el paso por el modo SWI. Este modo puede alcanzarse desde cualquier otro en el que control esté basado en el uso del procesador. Una transición desde un modo con control analógico no es posible.

La asignación de sensores y actuadores para cada modo se detalla en la Tabla 2.

4.4. Simulador del AOCS

Se ha desarrollado un simulador completo de la dinámica orbital y rotacional del satélite con el objetivo de verificar las prestaciones del AOCS diseñado. Este simulador ha sido desarrollado utilizando la herramienta Matlab/Simulink, habiéndose reutilizado varios módulos del simulador de Minisat 01, principalmente los generales de la dinámica y de los modelos de sensores y actuadores que son comunes.

Las perturbaciones introducidas por la flexibilidad de los paneles solares tiene un efecto importante en el diseño de las leyes de control a la hora de conseguir las prestaciones que se buscan. Esta perturbación se incluye en el simulador mediante un modelo detallado del comportamiento estructural de los paneles solares. Este modelo ha sido proporcionado por CASA, que es la responsable del desarrollo de los paneles solares y del SAPM, e incluye los primeros once modos del panel. No todos estos modos resultaron ser relevantes para el control. Sólo los primeros, con una frecuencia natural por debajo de 1Hz tenían un impacto real en el diseño del controlador.

Las prestaciones del AOCS han sido comprobadas para la configuración básica mostrada en la Figura 1, aunque una alternativa fue considerada durante la realización de este estudio. Esta otra opción se basa en una configuración geométrica distinta de los paneles solares.

5. CONCLUSIONES

Se ha diseñado un Sistema de Control de Órbita y de Actitud para el satélite, la segunda unidad del programa español de minisatélites MINISAT. Este satélite operará en una órbita circular heliosíncrona de unos 500 km. de altitud y está dedicado a una misión de observación de la tierra mediante un instrumento con dos canales, uno visible y otro infrarrojo.

El satélite está estabilizado en tres ejes con un momento angular nominal nulo. El apuntamiento nominal es a Nadir y tiene una autoridad de control total en tres ejes. Los requisitos de apuntamiento son altos (los máximos obtenibles con el módulo de servicio del programa MINISAT) y se necesita control orbital.

Este alto nivel de prestaciones ha condicionado el diseño del AOCS en una gran medida. A pesar de que el coste es uno de los condicionantes del programa MINISAT en general, los requisitos conducen a que se tenga una configuración casi por completo redundada en la que se utilizan equipos comerciales calificados para espacio.

La arquitectura del AOCS incluye dos unidades de giróscopos con salida en tres ejes, tres sensores estelares con una electrónica común, dos magnetómetros de tres ejes, tres sensores solares, cuatro ruedas de reacción y tres electromagnetos. El subsistema de Propulsión se ha segregado del AOCS y es una parte independiente de éste. Existe un procesador dedicado para el AOCS que se encuentra duplicado en frío con una caja electrónica adicional de detección de fallos y de control.

Se ha definido una lógica de control del AOCS compacta y modular que facilita la operación de éste. Se han definido también dos modos seguros, uno de ellos basado en control digital y el otro en analógico.

El diseño del AOCS ha sido verificado usando herramientas de simulación desarrolladas en el entorno Matlab/Simulink. Las perturbaciones procedentes de los paneles solares flexibles tienen una gran incidencia en el diseño del sistema de control y ha sido necesario utilizar un modelo detallado de la estructura de estos paneles.

AGRADECIMIENTOS

Modo		RW	MGT	SS	MGM	ST	GYR	CPU
L		TBD	TBD	TBD	TBD	TBD	TBD	
RR		X	X		X		X	
SAD		X	X	X	X		X	
HWAu		X	X	X	X		X	
SWAu		X	X	X	X		X	X
SWI		X	X	X	X		X	X
EAc		X	X	X	X	X	X	X
NP	N E	X	X	X	X	X	X	X
	E	X	X	X	X	X	X	X
IAc	GC	X				X	X	X
	FNP	X				X	X	X
	S	X					X	X
	IAc	X				X	X	X
OC		X	X	X	X	X	X	X

Tabla 2: *Asignación de los elementos del AOCS para cada modo*

Los autores quisieran agradecer su contribución a todos los miembros del equipo de SENER que han participado en este diseño.

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THE FIATAVIO CONCEPT FOR SMALL MISSIONS IN EUROPE AND FOR A FAMILY OF SMALL LAUNCHERS

Antonio Fabrizi

FiatAvio
C.so Garibaldi 22, 00034 Colleferro (Roma), Italy
phone: +39 6 97292235; fax: +39 6 97292738

ABSTRACT

In the course of years 95 and 96, under contract with ESA, FiatAvio conducted a study, namely *Small Missions Opportunities Initiative*, for the definition of a package of services and hardware to serve European and global market. All the study was based on a market survey and competition analysis.

This paper summarizes the results of the study, providing details on market survey, competition analysis and on the definition of three main elements constituting the S.M.O.I. package:

- Bus service (satellite platforms)
- Ground services
- Launch services

together with cost and programmatic aspects.

The results of the study have emphasized the lack of a European solution for launch services, confirming the validity of the FiatAvio proposal for a family of small launchers, namely the VEGA program.

This paper describes also the VEGA project, from the concept definition to the current status of development: VEGA is a family of two launchers with payload capability of 300 kg and 1000 kg respectively. Both have two solid stages and two liquid (3rd stage and upper module): 2nd, 3rd and 4th stages are in common.

FiatAvio started the critical development activities in 1995 with its own funding and the support of some technology contracts with ASI and IMI, promoting in parallel the full development under ASI sponsorship.

This last is becoming reality in these days, thus providing high degree of confidence that at least the smaller VEGA will be ready for operations by the beginning of the year 2001, while the bigger version will be avalable shortly after.

MARKET ANALYSIS

Our definition of *Small Missions* is based on the principle of frequent flight opportunities at low cost (typical mission overall cost below 50 million US$) of satellites with masses between 100 and 1000 kg at altitudes between 400 and 900 km with inclinations from 0° to sun-synchronous, requiring a dedicated launch (no piggy-backs).

Because of the current launchers avalability (mainly based on Pegasus, Taurus, Rockot and the LMLV's for dedicated launches and Ariane for multiple launches) it resulted convenient to classify the market in classes:

A:	80-250 kg	dedicated launch
B:	>250 kg	dedicated launch
C:	>80 kg	multiple launch
D:	<80 kg (micro)	multiple launch

The initial market survey made in the frame of the ESA contract was based on a number of different sources:

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

Euroconsult studies
Arthur D. Little study
Literature
Direct inquiries
Dedicated workshop with the European scientific community

The initial survey results have been later constantly updated by FiatAvio for obvious internal purposes and for the Italian Space Agency.

The annexed chart shows the last issue of number of satellites distributed by launch mass range and year.

As should be clear from this chart, there are a very large number of satellite missions and programs under consideration. The large number being considered means that there will be a substantial market, may be not fully open, even if only a small fraction of these programs are actually realized. Forecasts for the actual small satellite market based on the large number of programs currently under consideration vary from less than one hundred to more than one thousand over the next 10 years. The high estimate basically assume the launch of most of the programs (excluding Teledesic) while the low estimates have a tendency to consider only programs which are currently funded. In fact numerous market studies predict that only between 1 and 3 of the proposed LEO constellations are likely to see deployment. We feel that the two extremes misrepresent the potential market which falls somewhere in between. Clearly not all the satellites listed will be launched; many will turn out to be only *paper satellites*. The market assessment discriminated among the technical, financial, political and regulatory needs and constraints of potential customers to establish an accurate profile of the capturable market.

The majority of the satellites are from the USA, primarily due to LEO communications satellite constellations. In particular, thhe large numbers of satellites listed in the period 1998 to 2000 are, primarily, the result of the proposed deployment of these LEO constellations. The total number of foreseen satellites appears to taper down early in the next decade. However, this is not an actual market drop but just an expression that plans are not firm that far in advance. Furthermore, several (possibly many, if history can be used as guide) of the realized missions will suffer delays and slip into the next decade. Generally, the projects which are actually realized over the next five years will, in large part, determine the scenario during the next decade. It is clear that the potential for small satellites sales opportunities is global and covers a wide mass range.

A screening of all these missions for our purposes lead to the following pointts:

- generally, commercial telecommunications constellations (Teledesic, Iridium, Globalstar, Ellipso, Starsys, ...) are not expected to be users of the SMOI operator as defined by ESA. However it is possible that small launch services could be requestedon a competitive basis from time to time.

- Programs sponsored by national agencies outside Europe, such as NASA, DOD, NASDA, ISAS, ISO, CSA and RKA will not be user of our services.

- National European programs are currently planned around national capabilities and assets, as much as possible. However, there does appear to be some interest in an SMO service and for sure in a European small launcher service.

At the end of the study, 34 European missions (Denmark, Finland, France, Germany, Italy, Norway, Spain and Sweden) were identified as SMO package possible users, and 16 additional projects from different countries (including also USA, Brazil, South Korea, Taiwan, Argentina and Canada) have been classified as capturable by a complete or partial SMO service for a total of 181 satellitesin the next ten years.

Annexed charts show the accessible market for the simple launch services by means of a European small vehicle (Vega) and also the orbit locations of the main identified launch services potential users.

THE SMOI PACKAGE

The three main elements of the SMO service are:

- *the launch service,*
- *the bus (platform) service, and*
- *the ground control station service*

to be provided by a SMO Operator, to be selected by ESA, that shall bear all mission resposibilities as required by the customer.

In a small mission the cost of the launch service can weight up to more than 50% of the entire mission cost. The lack of a European small launcher has therefore a direct impact on ESA interest to develop small missions.
As a consequence the approach for the launch service is to support the development of a European solution and buy on the world market the most competitive launchers until the European launcher will be available. The competitive positions of the various available launchers is depicted in the annexed charts.

The FiatAvio concept of European small launcher is described in a dedicated section of this paper.

For the bus service, the main objective of SMO is to provide low cost, routine accomodation of payloads to ensure reliable payload data generation and transmission during the mission. The bus service is intended to include the procurement of the satellite platform and required GSE, payload acceptance and integration onto the bus, the system AIT campaign, the launch campaign and satellite in orbit commmissioning.

In this case several solutions are available in Europe, like the CNES-Aerospatiale Proteus, the MMS Leostar, the Spanish Minisat, ...).
The implementation of small missions can therefore rely on good products that can be chosen subject to competition in function of thier adaptability to the specific mission and to the cost.

In the frame of the ESA study, in order to provide an independant technical and economic view, FiatAvio utilized the data of a standard bus partially developed in house with the support of the US company CTA.

The ground control station service of the mission mainly consists of:

- Satellite command, control and monitoring, both for the bus and the payload, usually known as telemetry, tracking and command (TT&C)
- Receipt and processing of payload data.

Different approaches are possible:

- Customer dedicated ground control stations (GCS): in this case the ground station is delivered to the Customer who operates the satellite after spacecraft and GCS commissioning;
- Multimission centralized GCS: this option is based on the use of only one SMO dedicated centralized GCS that is operated by the ESA designated SMO operator and supports all operative SMO missions, and
- Intermediate option: one centralized GCS with several customer dedicated GCS and/or terminals; the centralized station is operated by the SMO operator.

After the trade off, the last solution has been selected. However, whatever should be the solution eventually adopted in the implementation of the SMOI concept by ESA, all technologies are available in Europe and/or in the Countries of the potential customers considered.

Considering all the studied mission elements, the result was that, once the operations of SMOI are actvated, the launch can be accomplished in 18 months from contract signature with customer.
The cost estimated for the SMO package to serve a typical mission resulted:

Launch service	*15*	*million $*
Service operator	*3.3*	"
Flight control	*0.14*	"
Launch operations	*1.9*	"
GCS dedicated	*0.8*	"
Bus service	*13*	"
TOTAL	*34.14*	"

for the entire mission without the cost of the payload.

THE VEGA PROGRAM

The modular Vega Small Launch Vehicles Family has been defined by Fiat Avio for dedicated launches of lightsats, in harmony with performence and cost requirements developed in the SMOI study.

Actually, the Vega family is composed of two launchers: the Vega "Kzero" devoted to class A small satellites (100 to 300 kg) and the Vega "K" for the class B small satellites (600 to 1000 kg)

The program is now part of the new ASI 5 years Plan and therefore the full development of the two vehicles is being conducted by FiatAvio under ASI contracts (the first started on September the 20th of this year).

Waiting for these events, new ASI plan and contracts, the development was already started thanks to FiatAvio decision to initiate the program, limited to the Kzero version, with its own funding.

The concept of the Vega "Kzero" launch vehicle, currently under development, is based on a four stage design. Nominal payload delivery capability is about 300 Kg to a 700 Km high circular, polar orbit.

The first two stages utilize the same Zefiro solid rocket motor (SRM), that will be described in more detail, while the third and fourth stages are based on reliable, flight proven liquid bipropellant ukrainan engines. The third stage utilizes an enhanced version of the Ukrainan Cyclone third stage propulsive system called RD 861. The first three stages are equipped with thrust vector control (TVC) systems and the needed electric and pyrotechnic units. The fourth stage, which provide both the final "delta-velocity" necessary to reach the orbit and the final correction needed to reach the desired accuracy, is also based on a ukrainan engine, actually the RD 869. The launch vehicle avionic is located on the fourth stage and includes the Vega guidance, navigation and control system (GNC), the telemetry and safety systems. A payload fairing, with an outer 1.9 m diameter, is mounted around and above the fourth stage.

The Zefiro motor, currently under development, will be qualified with two different nozzles due to the benefit in payload capability obtained using a second stage motor having a higher expantion ratio (25 instead of 11).

The third stage propulsive system is a gimballed improved version of the Cyclone third stage. This engine, produced by Yuzhnoye, is fed with 6 tons of bipropellant (UDMH/NTO) and provides about 80000 N thrust.

The Vega fourth stage consists in a Liquide Propulsive Module (LPM) that is composed by the main engine, the Yuzhnoye RD 869 providing a thrust of 2000 N, and a set of small thrusters providing the attitude control of the fourth stage / satellite composite. These propulsive components of the LPM are both fed by UDMH/NTO bipropellant.

The Vega Kzero LV is provided with a Guidance, Navigation and Control System (GNC) composed of the following subsystems and units:

- an Inertial Navigation System (INS), constituted of an Inertial Measurement System and a Navigation Flight Computer (NFC), that performs the calculations necessary to define the LV ascent trajectory and sends the commands for the LV state sequential modifications and for the launch vehicle control system,
- three Thrust Vector Control systems (TVC) that control pitch and yaw during combustion of both Zefiro motors and RD 861 engine,
- a second stage Reaction Control System (RCS) whose functions are the LV roll control during the flight of the first two stages,
- Multi Functional Boxes (MFB), located one per each stage, that provide to the above

mentioned actuation systems with the commands and also execute all the sequential commands necessary to the LV configuration evolution (separations, ignitions, etc.),
- a MIL-STD-1773 optical bus that connects the INS with all the units distributed along the LV.

The Vega GNC main units (IMU, NFC) as well as those of the other electrical subsystems (telemetry, radar tracking system and flight termination system) are located on-board the last stage structure in order to fulfil range requirements and to increase LV overall accuracy.

The 1.9 m payload fairing of the Vega Kzero LV provide the satellites with an available volume over 3cubic meters.

.The overall height of this launcher is 21 m while the lift-off mass is about 42 tons.

The second and more performant launch vehicle of the family, the so-called Vega "K", is also composed of four stages. It is obtained from the Vega Kzero by replacing the Zefiro first stage with the P85 SRM (the 85 tons solid rocket motor derived from the Ariane 5 solid rocket booster) or, in principle, with an equivalent motor or group of motors having approximately 50-85 tons of propellant. The remaining subsystems, units and components are the same used for the Vega Kzero with the exception of some elements like first-second stage interstage and the larger payload fairings.

The Vega "K" provides the potential spacecrafts with payload fairing having 2.4 external diameter and 937 mm payload adapter interface. For this Vega version it is foreseen the possibility of multiple launches of lightsats by means of a structure that is under design.

The total length of this Vega version is 25 m with a total lift-off mass of about 80 tons.

The Zefiro SRM is a 16 tons solid propellant motor, 4 meter long, 1.9 meter in diameter, used as first and second stage of VEGA launch vehicle. The motor employes a light weight carbon epoxy case, EPDM based thermal insulation, HTPB propellant, and a flex-joint nozzle. The characteristics of the motor are essentially the following:

- Vacuum Total Impulse (MNs)41.5
- Vacuum Max. Thrust (KN) 850
- Combustion Time (s) 72
- Propellant Mass (Kg) 15600
- Max. Nozzle Deflection 6.5°
- Mass Fraction 0.915
- Propellant Grain Configuration FinoCyl

The particular thrust law shape, the dual thrust type, is required by the use of the Zefiro motor on the Vega launch vehicle like first and second stage.
The case pressure vessel is made by filament wound technology using an high strength pre-preg carbon fiber. This technology has been successfully used at Fiat Avio in missile applications. Both forward and aft skirt are made by carbon reinforced epoxy fiber by using pre-preg fiber and preimpregnated carbon tape. Polar fittings and interstage flanges are made by high strength aluminum forging.A stiff metallic segmented mandrel is used. Each segment is realized by sectors which are linked by bolts and centered by alignament pins. Segmented sectors are used for forward and aft domes.

The material used for the internal thermal insulation are EG8 and EG2 Fiat Avio rubbers. Both are EPDM based elastomers, with a different percent of filler material (aramid fibers for the latter and also silica for the first). EG8 is used on the forward dome and on the cylindrical propellant zone, while, EG2 was selected for the aft part of the motor (star zone and aft closure) where an high ablative resistance is required. Stress relief flap is provided in the forward zone of the motor.

An HTPB 1614 composite propellant, with a binder in Hydroxy-Terminated-Polybutadiene and 16% of aluminum is used. In order to respect the specification on the performances, a finocyl grain has been selected, positioning the star section in the aft zone of the motor near to the maximum polar opening. This permits to remove the casting decomposable mandrel. Star section consists of a conventional 9 tips star, with a 3D transition region coupled to the cylindrical region. Under worst case of load conditions and load combinations, structural margin of safety is greater than 120%.Casting core mandrel consists in a cylindrical part on which each fin is mounted. The linking system between each fin and cylindrical core is a mechanical type with a double-T element which garantees the necessary loads by means of spring system.

The design of a submerged, swivel nozzle is performed according to Fiat Avio specific know-how. The actuation of the nozzle in pitch and yaw angle is realized by a flexible joint with an aft pivot point architecture. This joint allows 6° of orientation. It is made by steel shims rubber bonded. An insulation system (boot-strap) protects the flexible joint by the hot gas.

The Vega Kzero third stage utilizes a modified verion of the RD 861 engine currently used for the Ukrainan Cyclone vehicle. Actually, this propusion system has been adapted to the Vega needs by means of both a gimballed attachment to the fixed motor frame and a different geometry of tanks, pressurization system and feeding lines.The modified RD 861 can provide with a 80'000 N thrust level using 6'000 kg of UDMH/NTO bipropellant through the feeding of a turbopump.The exhaust gases of this turbopump are used, through the utilization of small nozzles, to generate the lateral thrust levels necessary to perform the roll control during the third stage flight. On the other hand, the LV pitch and yaw control is obtained by means of the third stage TVC system that rotates the entire RD 861 motor. The main features of this propusive system are the following:

- Vacuum Specific Impulse (MNs) 325
- Vacuum Max. Thrust (KN) 80
- Combustion Time (s) 500
- UDMH/NTO Mass (Kg) 6000
- Max. number of ignitions 5

The Vega Kzero fourth stage is supplied with a bipropellant (UDMH/NTO) pressurized system that fulfils both the main propulsive function and the attitude control function.

Actually, its mission is composed of the following phases:

- first main engine ignition after third stage separation at transfer orbit perigee,
- second main engine ignition at transfer orbit apogee for circularization,
- final orbit altitude and inclination correction,
- attitude control of fourth stage during firing and before payload separation,
- empty stage de-orbiting.

The liquid propulsion module is largely based on existing eastern components, expecially ukrainan. It is composed of

- pressurization system (Helium),
- tanks for UDMH and NTO,
- main engine (RD 869) and
- set of lateral thrusters for control.

The main engine provides 2200 N thrust and uses 450 kg of propellant.
The Vega LV family is designed in order to meet the requirements of both the San Marco Equatorial Range (SMER) and Kourou launch range located in French Guyana. The first is chosen for the qualification flight and selected scientific missions, while the latter represents the baseline range for the Vega commercial flights.
The Vega launch and control equipments, on the other hand, are designed in order to be movable and largely indipendent from the test range, to make the system flexible as much as possible and to have an overall launch operations with a maximum duration of three weeks including stage final assembly (each stage is pre-assembled at Colleferro factory before shipping), payload processing, LV stack, LV final checks, countdown and orbit insertion of the satellite.

Presently, the first Qualification flight of the Vega "Kzero" version is scheduled by the beginning of 2001 while commercial flights will start six months later.

Disaster Management

USE OF SATELLITE IMAGES IN PREVENTION AND MITIGATION OF DISASTERS IN MEXICO

Eng. Ricardo de la Barrera Santa Cruz

CENTRO NACIONAL DE PREVENCIÓN DE DESASTRES (CENAPRED)
Av. Delfín Madrigal 665, Colonia Pedregal de Santo Domingo, Delegación Coyoacán, 04360 México, D.F.
Phone: 606-8111, Fax: 606-1608, E.mail: cstrdlb@cenapred.unam.mx

ABSTRACT

CENAPRED has incorporated the use of satellite images to complement results of studies of fenomena liable to cause disasters. In seismic risks, a seismic intensity recording system will be shown, and a system to evaluate physical damage and reconstruction cost. "French Spot" will show seismic risks in cities.

"Landsat Pancromatic", and "Landsat TM" will show images of topography of Popocatepetl and location of close by cities and different topographycal areas, communication routes, airports and infrastructure to use in disasters.

In analytical studies, two packages will be presented a graphic one to evalute trajectories of flows and risks based on these trajectories; and another to evaluate spreading of ashes.

In hydrometeorological risks, "Goes" will show Hurricane Roxane, and subsequent analytical studies to determine pluviometric characteristics; it will be shown the correlation between the incidence of hurricanes in Atlantic and Pacific coasts and the penomenon "El Niño

Images of the earth, taken from the moon, will be shown, as a reflexion on the philosophy of using space technology, with comments on "Gea Theory".

CENAPRED, a technical advisory organism of the National System for Civil Protection in Mexico, has incorporated the use of satellite images to complement the results obtained in studies made on phenomena feasible to cause disasters.

In geological risks of seismic type, an interactive program of seismic risk diagnose is shown, based on the Mercalli scale with some modifications of seismic data received from the whole Mexican Republic starting at the end of last centruy up to now, also a second system on evaluation of losses by earthquakes in Mexico will be shown. This package is in operation for the cities of Colima and Mexico, and it is being prepared to be used in Acapulco.

"French Sport" satellite images of Mexico City will be shown to illustrate applications of seismic risks in cities which will permit to corroborate analytical results.

In volcanic type risks, "Landsat PANCROMATIC" images of Popocatepetl Volcano will be shown where the topography and location of closeby cities, such as Amecameca and Ozumba in the State of Mexico, Cuautla and Cuernavaca in the State of Morelos, and Atlixco and Puebla will appear , this volcano has shown a remarkable increase in its activity in the last years.

"Landsat TM" images will be shown where it will be possible to appreciate the glaciar, wooded, and sandy areas of the volcano as well as the commucation routes, airports and possible infrastructure to be used in case of disaster.

From the point of view of analytical studies, a graphic package will be presented to evalute trajectories of flows and evaluation of risks based on these trajectories according to direction of flows, population concentrations and distances to main and secondary roads, it will also be shown another package that will enable to evaluate spreading of ashes according to volume of exhalations, velocity and predominant direction of winds.

Based on the above mentioned results, it has been possible to conform a map showing the areas of high, medium and low risks of the Popocatepetl Volcano.

In hydrometeorological type risks, images of satellite "Goes" will be shown when Hurricane Roxane was drawing near Yucatán, and the subsequent analytical studies that determine the pluviometric characteristics by areas.

As an important result in this area, it will be shown the correlation between the incidence of hurricanes in the coasts of the Atlantic and Pacific Oceans and the atmospherical penomenon called "El Niño" in the upper

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

part of the Southamerican Continent and the Caribbean region.

Images of the earth, taken at a height of five, fifty and one hundred km and from the moon will be shown, as a final reflexion on the philosophy of the use of space technology, with comments on the "Gea Theory" regarding the fact that our planet is a living organism which is irreversible damaged due to our carelessness.

Interactive Program of Seismic Risk Diagnose

Mexico is subject to the influence of big earthquakes which generate in its occidental coast, from Jalisco down to Chiapas, in the inner part of the continent as in the cases of Puebla and Veracruz and in the northern part of the Peninsula of Baja California. These phenomena have caused, in many occasions, great disasters with losses of human lives and material resources.

The basic information to prepare the Interactive Program of Seismic Risk Diagnose are the 49 maps of "ISOSISTAS" (lines that separate areas of same intensity) elaborated for earthquakes occurred between April 7, 1845 and September 19, 1985. The magnitudes of such events go from 6.4 to 8.1 degrees (Ritcher Scale)

The "ISOSISTAS" maps were made based on several reports of damages and effects of earthquakes received from peope of affected places, except in the case of Baja California where there are no "ISOSISTAS" maps, and where national and international sources were checked, finding very little historical data of 19 events in the period of 1845-1985 which were used to conform the map.

With the information obtained from the mentioned sources, an intensity degree was evaluated for each site using the Modified Mercalli Scale, which is a version that eliminates ambiguities in descriptions and permits a higher accuracy in results.

It must be kept in mind that the maximum intensities shown in the program could be surpassed in the future, in any place, as the period of 140 years used is limited in terms of geological time.

With the satellite images of the various areas of the Mexican Republic, degrees of seismic intensity by site can be referenced, with the type of orography and population concentrations and existing infrastructure which change, at a medium term, with the economic and tecnological progress.

Evaluation system for losses due to earthquakes in the Mexican Republic

This system has been developed, in principle, for the cities of Colima and Mexico, with results highly reliable.

In the case of Mexico City, the studied area was divided in 751 cells, with an average dimension of 500 meters. In this division it was attempted to make the existing constructions in each cell as homogeneous as possible, and to follow the natural boundaries of sreets, parks, auditoriums, etc.

A statistic population density can be determined for each cell, and the map can show the main avenues of the city.

Constructions have been divided in 14 classes considering the differences with regard to dynamic response and vulnerability. An important aspect in the definition of the response is the fundamental period of vibration of the building which depends on its height and its structuring system.

The following paremeter to be defined is the spectral acceleration, selecting the direction and period and the value of it which is in a closed interval [0,5].

Finally, the "ISOPACAS" map is considered which indicates the space distribution of the thickness of the clay layer in each polygon.

With all these elements, the system can evaluate the damage index by polygon, or also the expected loss in each area.

Based on the satellite images, the simulated areas can be referenced and verify the types of existing infrastructure, population density and the type of services that can be used in emergencies (hospitals, firemen, shelters to be used, etc.).

Following is a chart with the satellite images that have been requested for studies of volcanic, seismic and hydrometeorologic risks.

Monitoring of Popocatepelt Volcano with satellital support.

At present, CENAPRED has established a monitoring network for Popocatepetl Volcano to determine the existing risk the 24 hours a day all year long; this way, it can provide recommendations to the National System for Civil Protection through an Advisory Scientific Committee where the best volcanology specialists participate.

The premonitory parameters which were taken in consideration are: recordings of local seismic activity through accelerographs, deformations of the external layer through inclinometers, measurement of gas concentration belched out such as sulphur dioxide and carbon dioxide, detection of ash exhalations through the Dopplee radar, and visual checking of behavior through a video camera directed to the upper part of the crater.

At presente, all this information is obtained by 15 stations installed nearby the Popocatepetl Volcano and transmitted to CENAPRED through radio frequencies.

In the attached diagram, the proposal to carry out this interconnexion, via satellite, is shown; leaving the other network as a redundant system.

SOLICITUD DE IMAGENES DE SATELITE PARA CENAPRED

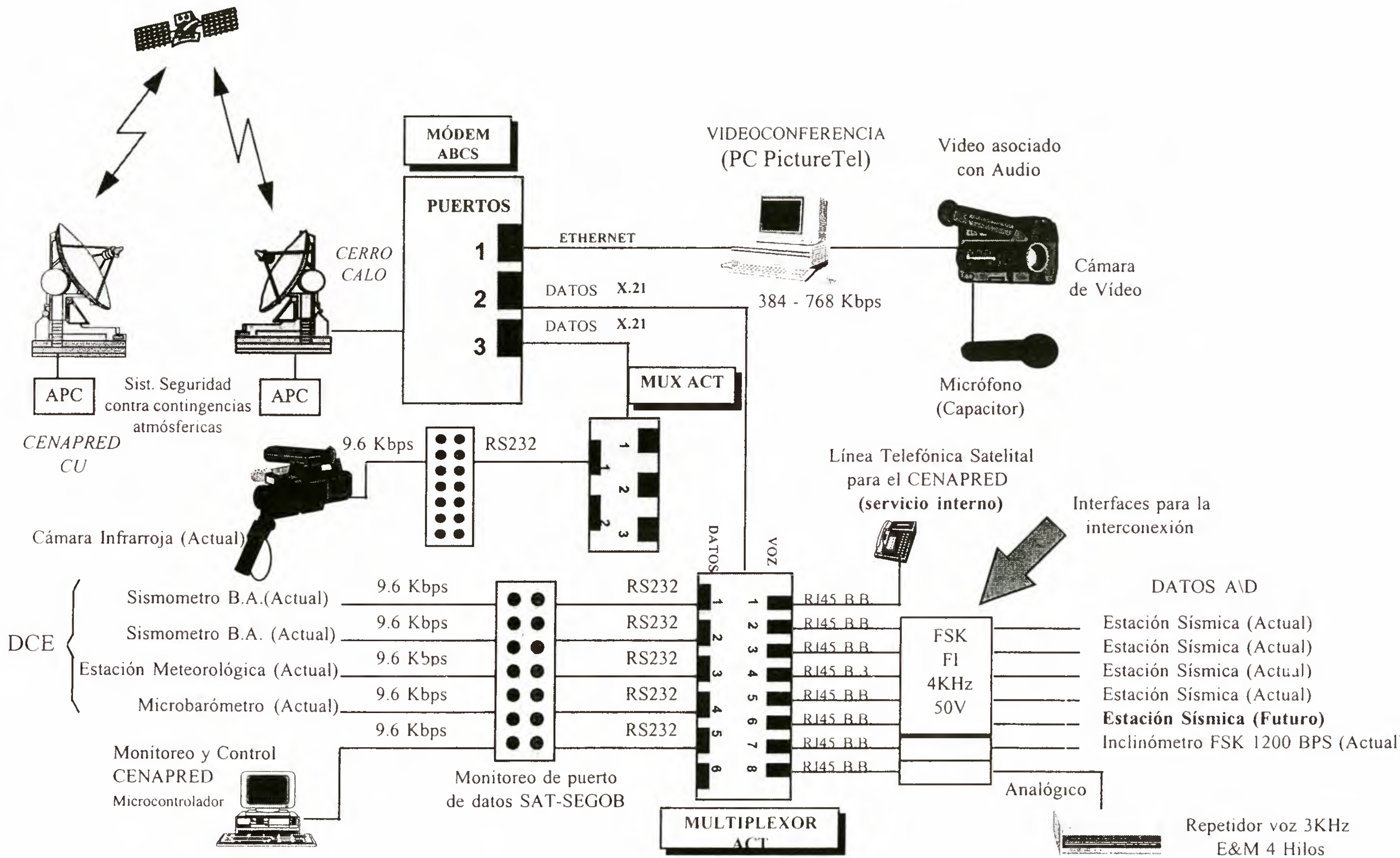
	IMAGEN	OBJETIVO	POSICIONAMIENTO PUNTO CENTRAL	FECHA	TIPO DE IMAGEN	PROCESAMIENTO
1)	POPOCATEPETL	ESTUDIO VULCANOLOGICO	19° 01'N 98° 37'W	MAS RECIENTE (SEP 1996)	TM (FRAME COMPLETO)	DATOS CRUDOS
2)	PICO DE ORIZABA	ESTUDIO VULCANOLOGICO	19°01'N 97°16'W	MAS RECIENTE (SEP 1996)	TM (FRAME COMPLETO)	DATOS CRUDOS
3)	VOLCAN DE COLIMA	ESTUDIO VULCANOLOGICO	19°31'N 103°37'W	MAS RECIENTE (SEP 1996)	TM	DATOS CRUDOS
4)	CD. DE MEXICO (ZONA URBANA)	ESTUDIO RIESGO SISMICO	19°22'N 99°08'W	MAS RECIENTE (SEP 1996)	PANCROMATICA IRS-1C	DATOS CRUDOS
5)	ACAPULCO	ESTUDIO RIESGO SISMICO	16°53'N 99°50'W	MAS RECIENTE (SEP 1996)	PANCROMATICA IRS-1C	DATOS CRUDOS
6)	CANCUN	ESTUDIO RIESGO HIDROMETEOROLOGICO	21°N 87°W	AGOSTO 1988 ANTES DE GILBERTO	TM	DATOS CRUDOS
7)	CANCUN	ESTUDIO RIESGO HIDROMETEOROLOGICO	21°N 87°W	MAS RECIENTE (SEP 1996)	TM	DATOS CRUDOS
8)	LOS CABOS	ESTUDIO RIESGO HIDROMETEOROLOGICO	23° 27'N 110°W	OCT 1993 (DIAS ANTES DE NOV 1993)	TM	DATOS CRUDOS
9)	LOS CABOS	ESTUDIO RIESGO HIDROMETEOROLOGICO	23° 27'N 110°W	DIC 1993 (DIAS DESPUES DE NOV. 1993)	TM	DATOS CRUDOS

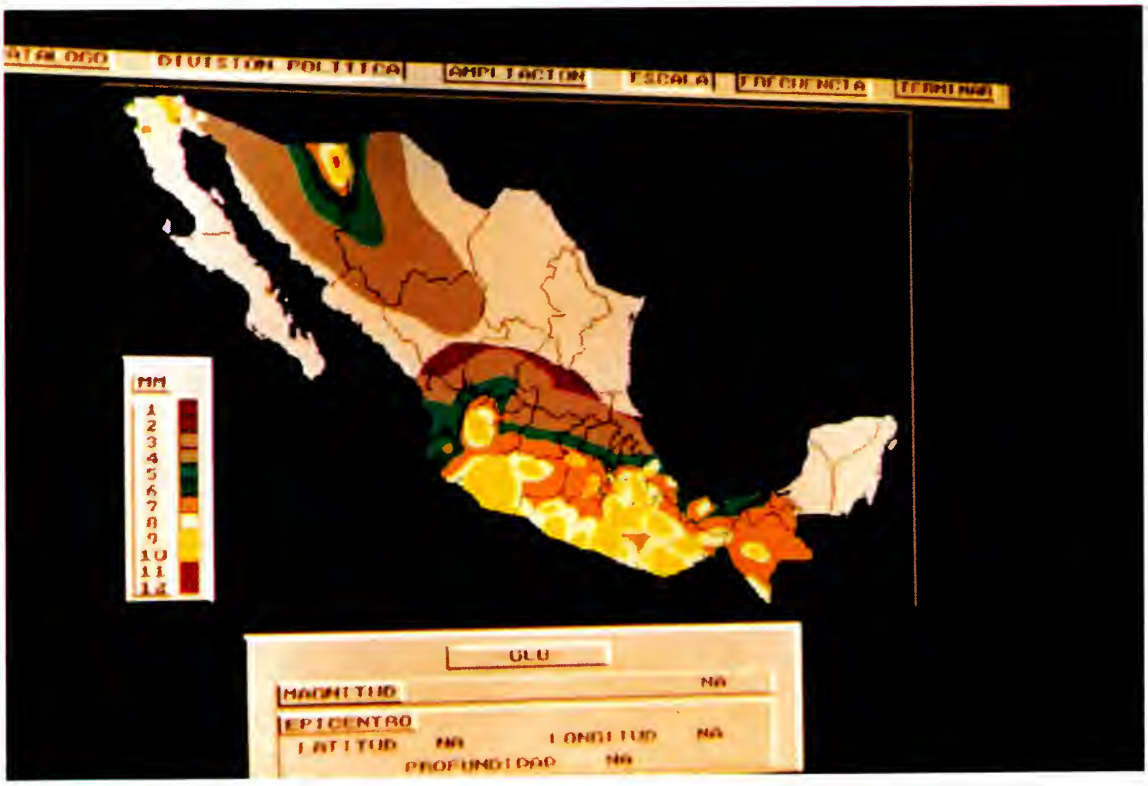
CRITERIOS DE PREFERENCIA DE IMAGENES :

1. QUE SEAN LO MAS RECIENTE POSIBLE (CON EXCEPCIONES INDICADAS EN LA TABLA)
2. QUE NO TENGAN NUBES O UNA NUBOSIDAD MINIMA (10% MAXIMO)
3. ALREDEDOR DEL MES DE SEPTIEMBRE.

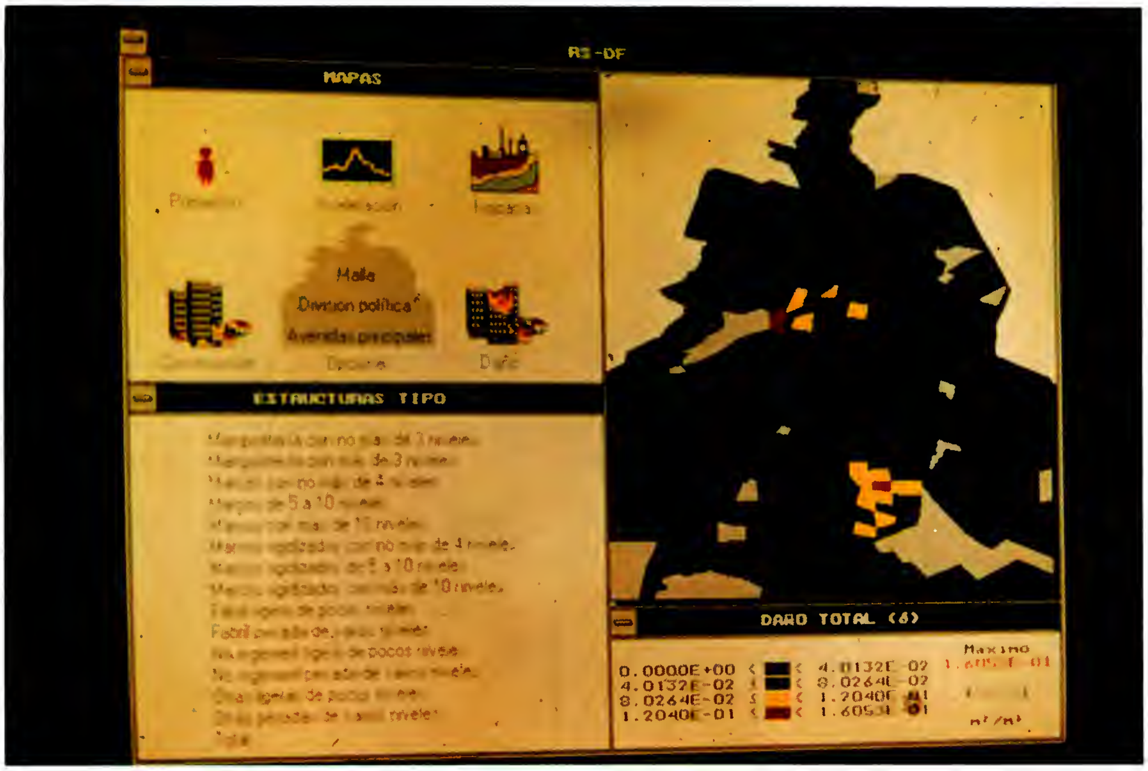
LOS CRITERIOS 1 Y 2 SON EQUIVALENTES MIENTRAS QUE EL 3 ES ALGO MENOS IMPORTANTE.

PROPUESTA DE INTERCONEXIÓN PARA EL "CENAPRED".

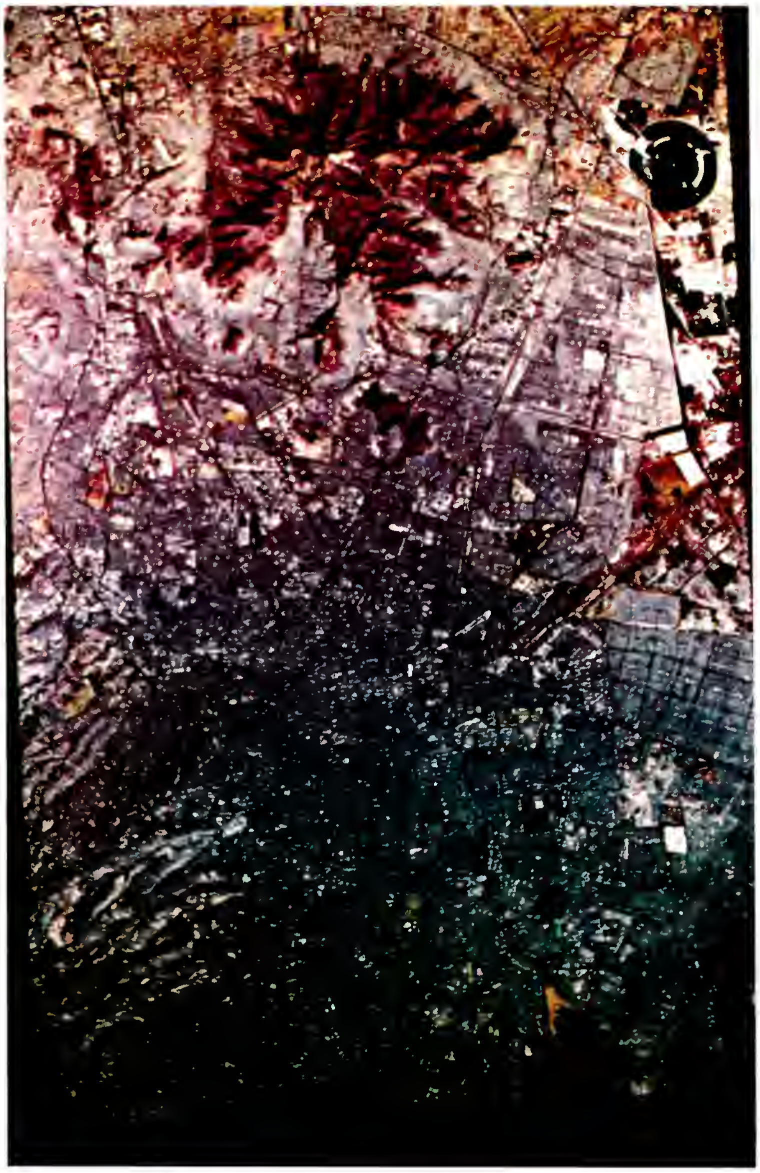




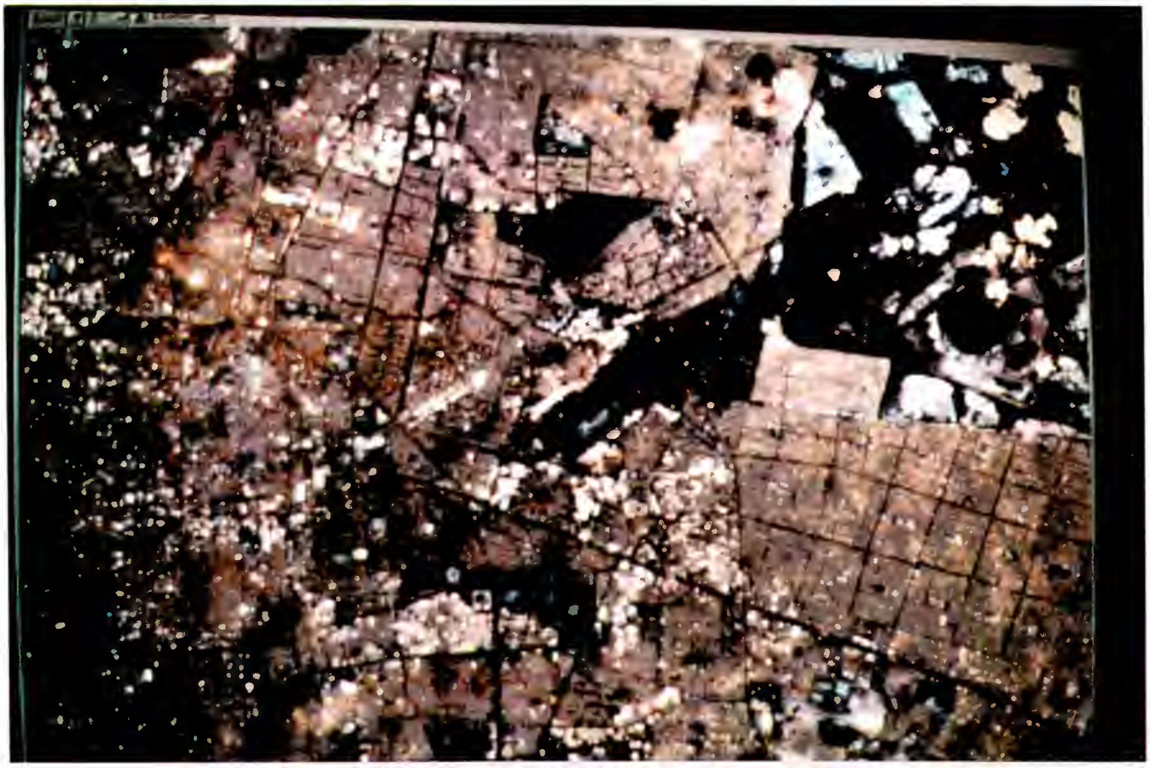
INTERACTIVE PROGRAM OF SEISMIC RISK DIAGNOSE



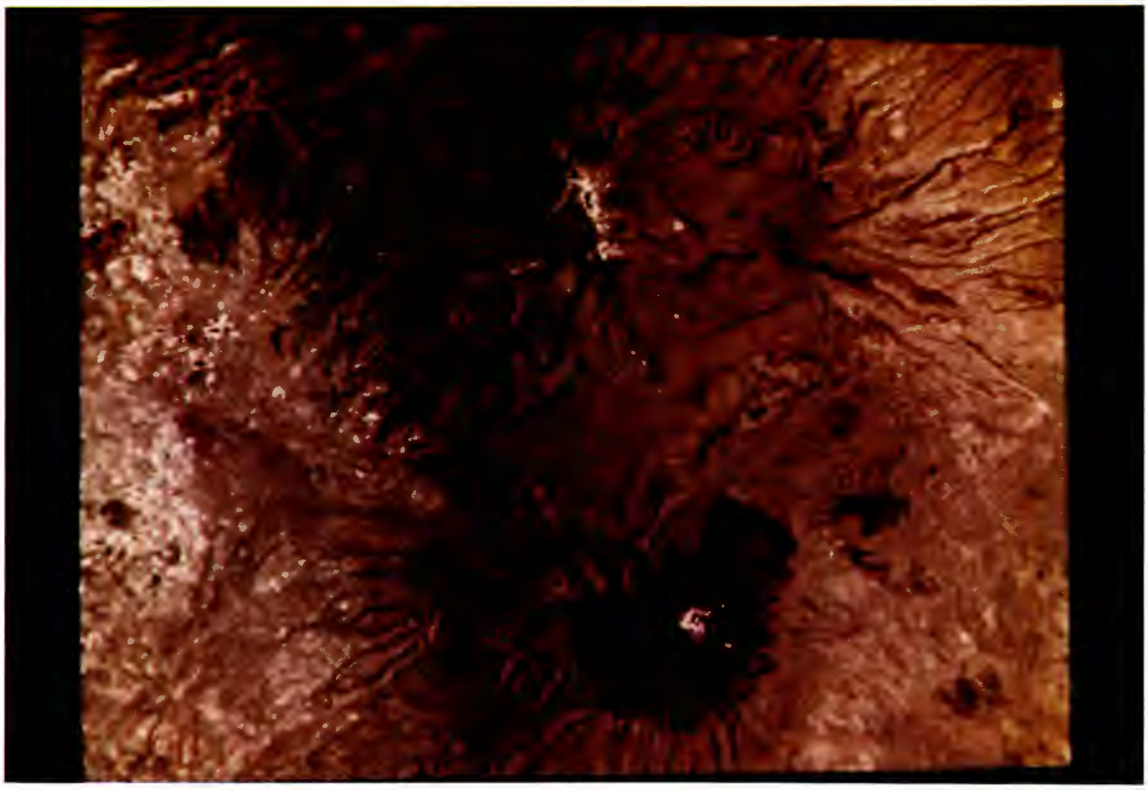
EVALUATION SYSTEM OF LOSSES DUE TO EARTHQUAKES IN THE MEXICAN REPUBLIC



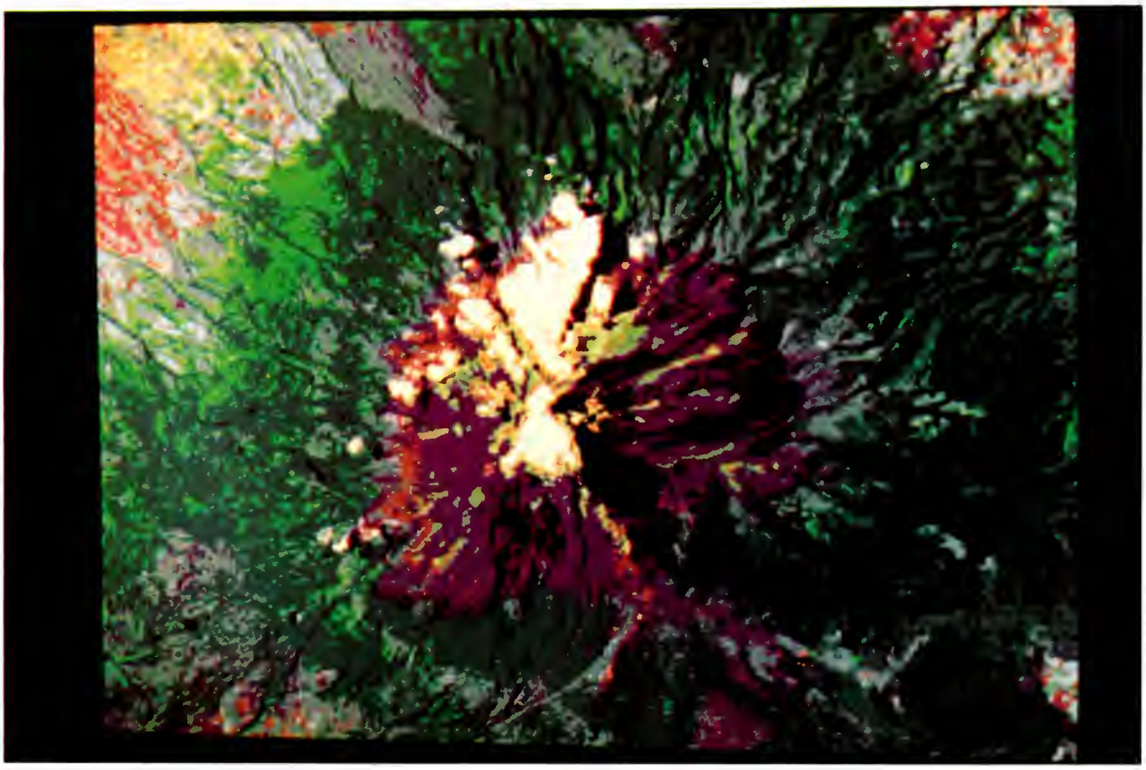
SPOT IMAGE OF MEXICO CITY'S METROPOLITAN AREA



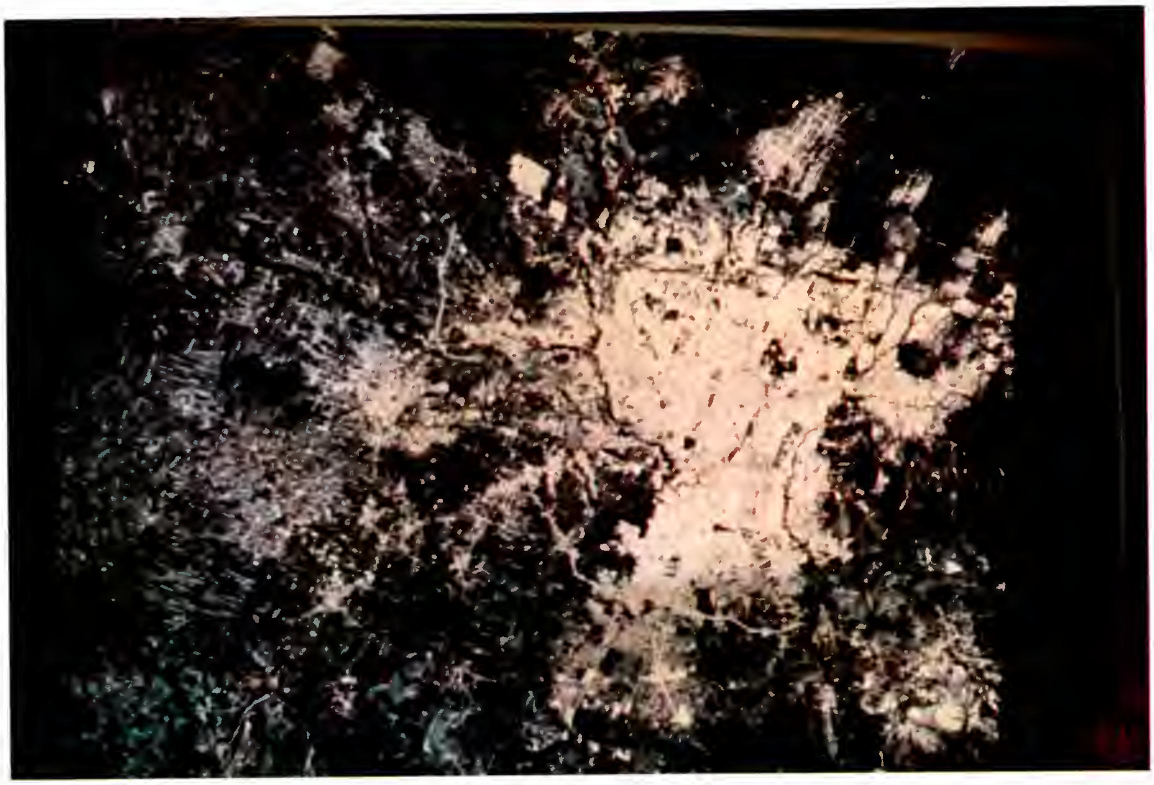
SPOT IMAGE OF A CLOSE UP OF NORTHERN AREA NEAR MEXICO CITY'S AIRPORT



LANDSAT PANCROMATIC IMAGE OF VOLCANOS IZTACCIHUATL AND POPOCATEPETL SHOWING OROGRAPHY OF THE AREA

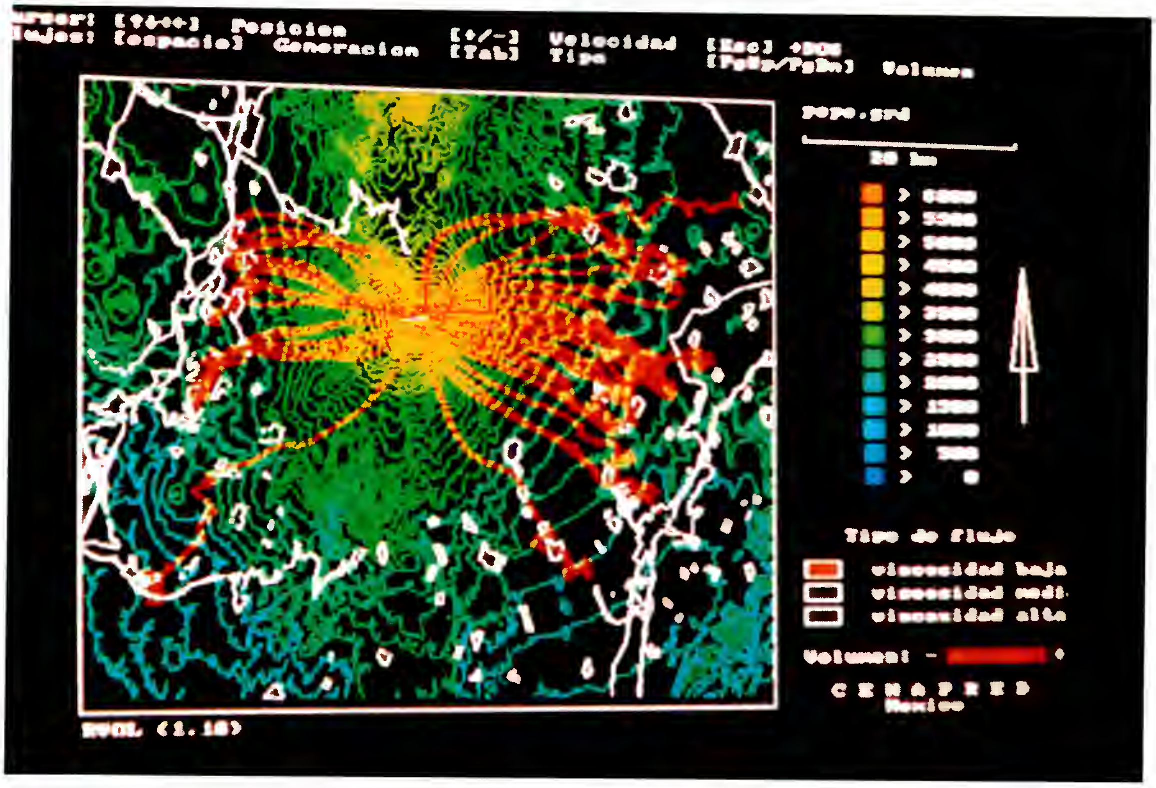


LANDSAT IMAGE OF POPOCATEPETL VOLCANO, FALSE COLOR



LANDSAT IMAGE (TM) OF RISKS OF VOLCANO RAINFALL ASHES IN PUEBLA CITY

LANDSAT IMAGE (TM) OF AMECAMECA CITY CLOSE TO POPOCATEPETL VOLCANO



GRAPHIC COMPUTER SYSTEM FOR SIMULATION OF POPOCATEPETL'S VOLCANIC FLOWS

GRAPHIC COMPUTER SYSTEM FOR SIMULATION OF RAINFALL ASHES NEAR POPOCATEPETL VOLCANO

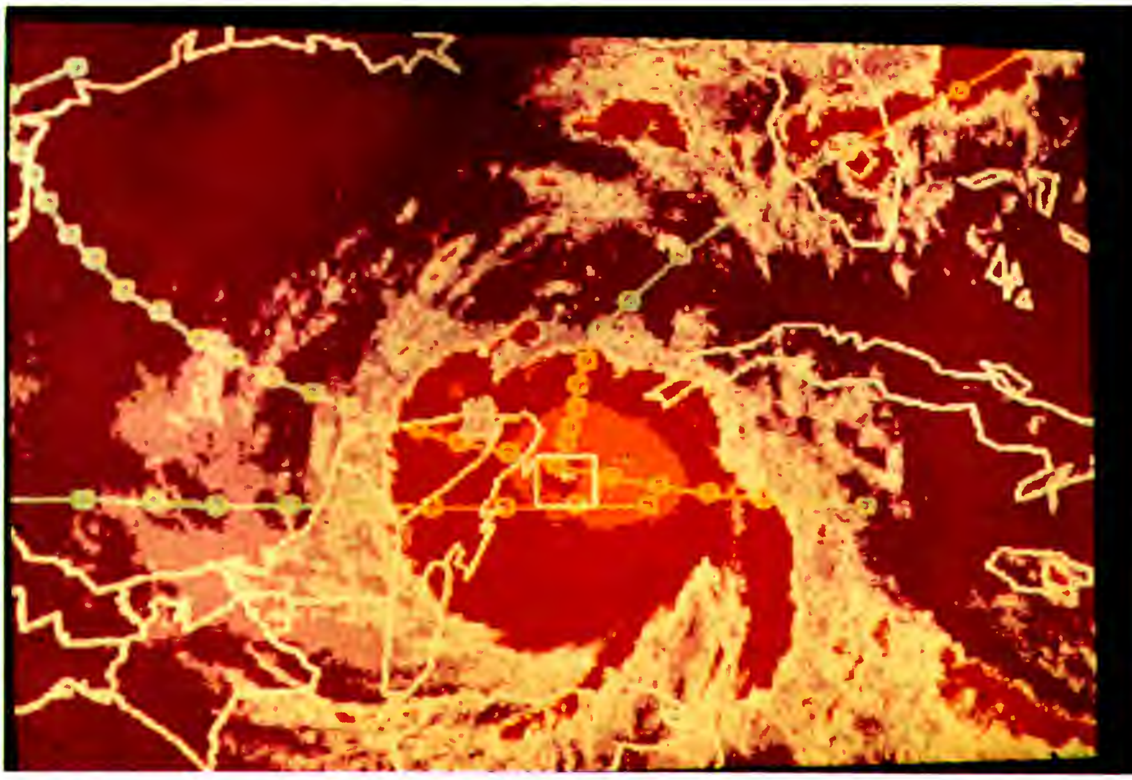
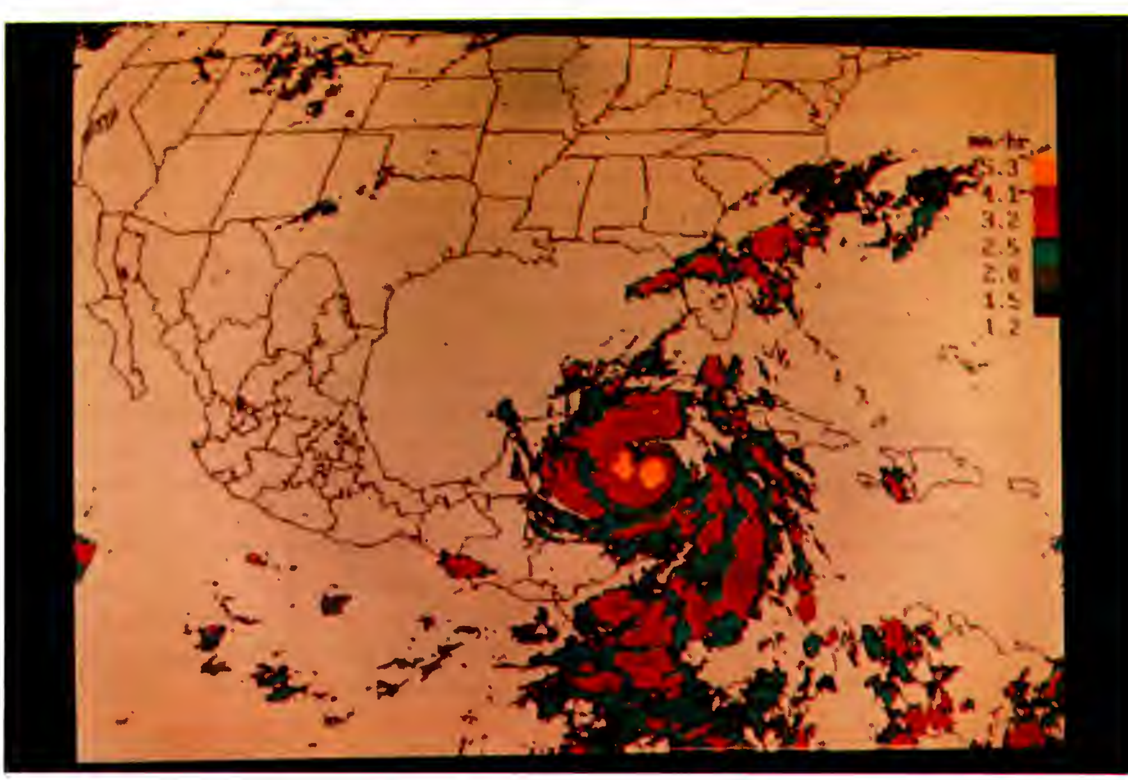
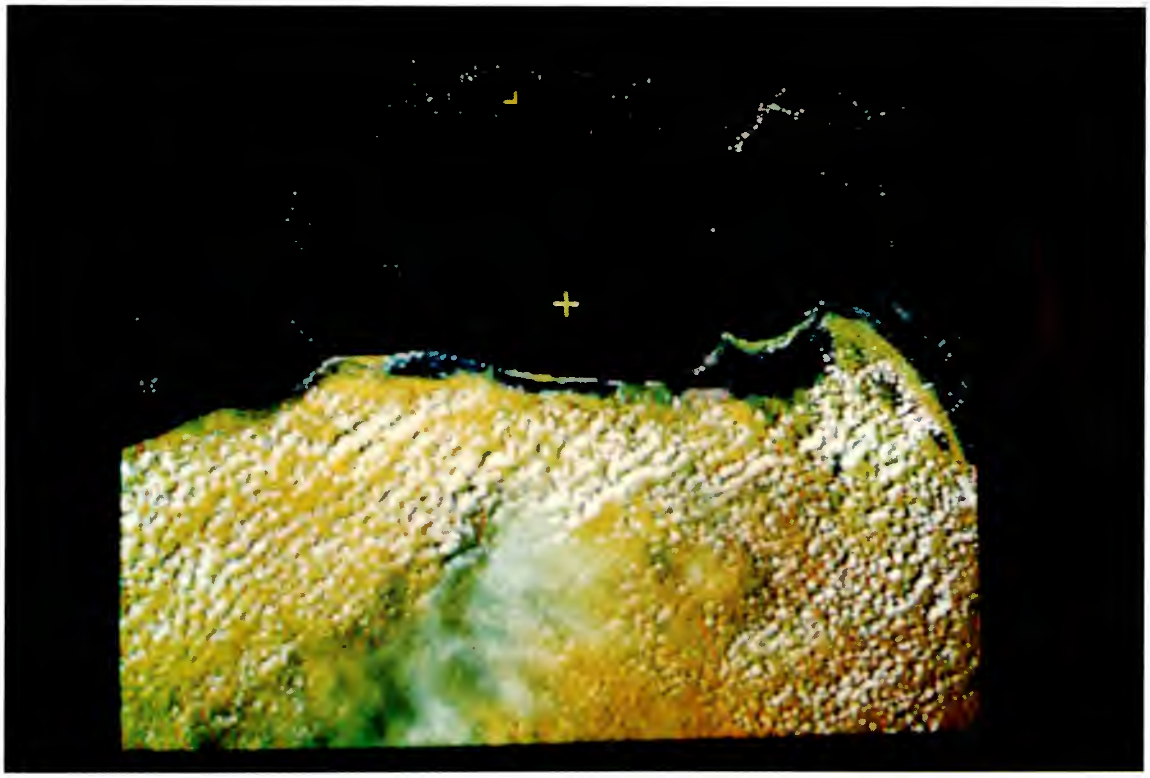


IMAGE OF METEOROLOGIC SATELLITE "GOES" AT THE TIME HURRICANE ROXANES IS DRAWING NEAR YUCATAN PENINSULE

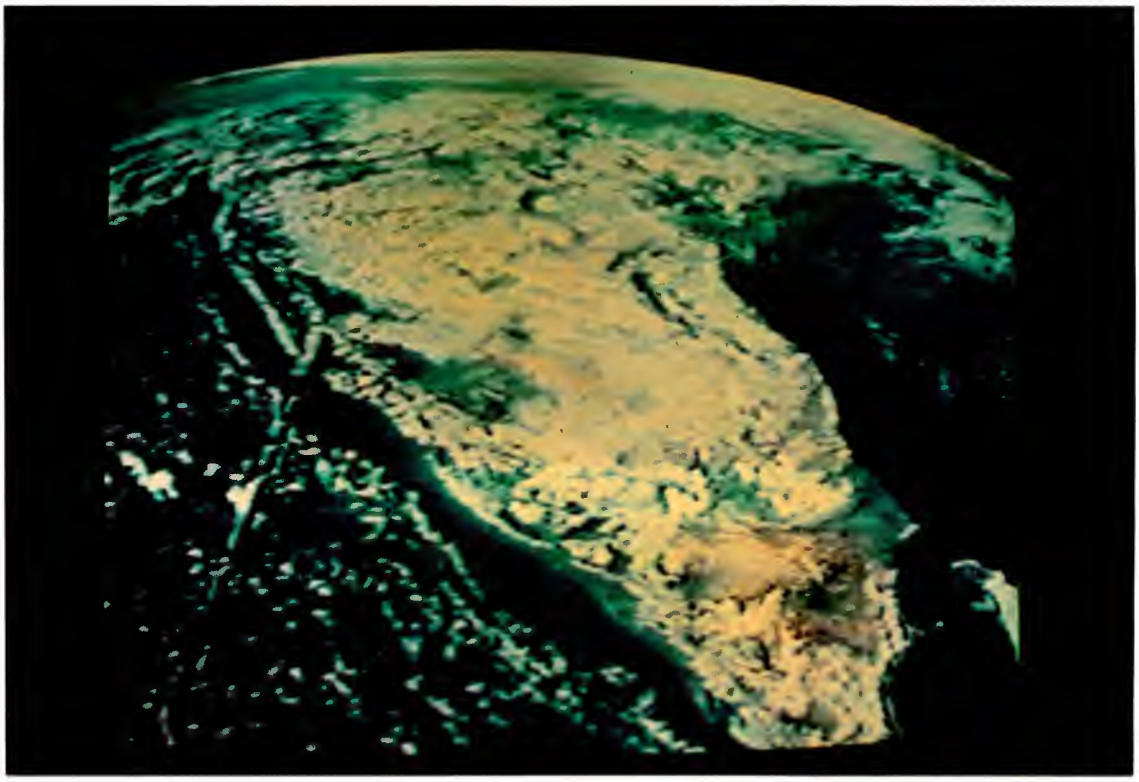


GRAPHIC COMPUTER SYSTEM TO DETERMINE PLUVIOMETRIC CHARACTERISTICS CAUSED BY HURRICANE ROXANE



LANDSAT IMAGE (TM) OF NORTHERN PART OF YUCATAN PENINSULE

LANDSAT IMAGE (TM) OF FURTHEST SOUTHERN PART OF BAJA CALIFORNIA PENINSULE



SATELLITE IMAGE OF OUR PLANET AT A HEIGHT OF 100 KMS

A DESCRIPTIVE PICTURE OF OUR PLANET AS A LIVING BEING AND WITH BOTH GLOBAL INTERACTION AND BRAIN

DISASTER MANAGEMENT - ESA's INITIATIVE

G. Naja

ESA, Paris, France

Since 1987, the Council of Europe manages an Intergovernmental Agreement on the management of natural and technological risks : the EUR-OPA agreement.

The parties to that agreement asked the European Space Agency in May 1994 to perform a study on the possibility to use space technologies to improve the prevention, detection and management of major risks, as well as the organisation of the rescue.

A preliminary study was performed from May to September 1994, on two examples : chemical risk and earthquakes. Its conclusions were very encouraging and it was thus decided to perform a detailed study on the contribution of space to overall risk management.

This detailed study was finished in July 1996. It was complemented by concrete demonstration projects.

The study was divided into four phases:

- The first phase consisted in identifying all the needs related to the management of major hazards.
- The second phase aimed at making the inventory of the relevant satellite resources available or planned in the Greater Europe.
- The third phase of the study consisted in comparing the needs identified within phase 1 with the available and planned resources identified within phase 2. The compliance between needs and resources was analysed along the risk type and the different space systems.
- The fourth phase of the study consists in evaluating the impact, on the prevention and management of major hazards, of the space systems and associated ground facilities defined within phase 3, in cooperation with civil protection organisations. This fourth phase is mostly being achieved through small and concrete pilot projects, two of which are on-going, regarding plain floods and earthquakes.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

Advantages of space technologies in the management of major risks

- Earth observation satellites allow to have detailed cartography of risk areas, to assess emergency situations and to evaluate the damage.
- Data collection and localisation satellites allow to monitor potentially dangerous zones.
- Navigation satellites support the organisation of rescue.
- Meteorological satellites provide support data and help foresee the evolution of catastrophes.
- Telecommunications satellites replace the damaged ground infrastructure and support the organisation of rescue.

Space means do not replace, but complement, existing ground or plane-based means.

WHY OBSERVE FROM SPACE ?

- Globality, thanks to the altitude; possibility to have a synoptic view, for the observation of large-scale phenomena
- Repetitiveness - especially for long-term monitoring
- Access to hostile or difficult areas - oceans, polar caps...
- Military observation
- Consistency of measurements - possibility for comparisons
- Objectivity of measurements

SUMMARY RESULTS OF PHASE 1

IDENTIFIED USER NEEDS

KNOWLEDGE AND PREVENTION PHASE

- Models (e.g. hydrological)
- Risk area cartography and vulnerability maps
- Routine monitoring
- Weather forecast

WARNING AND CRISIS PHASE

- Alert monitoring (i.e. with increased frequency)
- Cartography of damage
- Models simulating the disaster with real data in comparison to prevention models
- Management of means and rescue
- High-quality weather forecast

POST-CRISIS

- Damage assessment
- Feedback of disaster data in existing models

MAIN CONCLUSIONS

- There is a great convergence between countries regarding the expressed needs and wishes for information and service needs. There is also a general feeling that risk management could be improved and space technologies could contribute to such improvement.

- All data should be transmitted to responsible operational people under a format adapted to their needs, through already existing organisations.

- Cost will be a key issue in the use of space systems for risk management.

- In order to be efficient, the use of space technologies in risk management should involve training and information, as well as available expert teams in the technical and scientific fields related to the considered risk.

SUMMARY OF PHASE 2 RESULTS

SPACE RESOURCES INVENTORY

Present space systems already offer a large number of potential risk management applications, in particular in the fields of communications, meteorology, navigation and data collection. Earth observation resources provide a huge number of imaging data with different spatial resolutions and in different spectral channels. Some limitations in this field can be due to the fact that, in the warning and crisis phase, products are required "on the spot".

Future space systems will offer an even larger number of applications. Global communications systems will ease the information exchange between risk management authorities and field operations teams. Future meteorological products will provide improved land surface and cloud cover maps. Commercial Earth observation systems with high spatial resolution will improve the product quality and possibly also the data distribution situation.

PHASE 3 STUDY

METHODOLOGY FOR COMPLIANCE ANALYSIS

The compliance analysis was performed for three scenarios:

- Scenario 1: Use of currently existing space resources
- Scenario 2: Use of existing and planned space resources
- Scenario 3: Use of existing and planned resources, and assessment for need of new space-based services.

It must be highlighted that the compliance analysis allows to indicate where space-based resources can meet user needs, but not whether they are the most cost-effective.

OVERALL RESULTS OF COMPLIANCE ANALYSIS

Currently existing space-based resources cover approximately 60% of the user needs. This percentage varies considerably according to the risk type and to the resource type (meteo, comms, observation, etc.)

When taking into account planned space-based resources, the degree of compliancy rises to approximately 80%.

Some parameters, especially in the field of Earth observation, are technically but not operationally compliant, which could be improved by better data handling and delivery. Some other, in that same field, cannot be obtained due to poor spatial resolution, e.g. for water temperature or topographic height, or to missing knowledge, e.g. soil moisture.

In the field of meteorology, non-compliancy is due to a very local need (area of a few kilometres) which cannot be satisfied. Finally, some parameters cannot be obtained from space using available or planned techniques, such as frozen soil depth or detection of windy zones.

ASSESSMENT BY SPACE RESOURCE

- Current meteorology resources can cover about 80 % of the needs. The only needs that cannot be covered are those expressed on local scale.

- Current telecommunications and localisation systems can already fully cover the user needs.

- Existing data collection systems can meet 50% of the user needs but this can be improved to 80 % with planned systems.

- Earth observation current systems can cover about 45 % of the user needs. This could be improved to almost 80% with a radar satellite constellation.

HOW TO IMPROVE THE SITUATION?

There is a need to bridge the gap between the space data and service providers on the one hand, and the "users" - civil protections, government authorities involved in risk management... - on the other.

This requires to inform and convince the authorities of the usefulness of space techniques in support of risk management.

This requires to mitigate the feeling that "space is expensive", by reducing the cost of space data and services through a centralised procurement.

This requires to ensure that operational people can use space data and services by guaranteeing the quality and delivery of products that they need.

----> These improvements can be brought about by a Space Information Service System, which would inform and train the people in charge of risk management of the potentialities of space resources, and which would ensure the availability within the relevant delay of the space products required for risk prevention and management.

Conclusions

- The study has allowed to demonstrate the usefulness of space technologies in major risks management and that they are complementary to other means, ground and plane-based. Satellite products can already be fully used for the prevention phase and the post-crisis phase, in particular for damage assessment. For the crisis phase, considering the unpredictability of most disasters, space means need to assure global and continuous coverage, which requires a better coordination between existing space means.

- The use of space technologies for risk management does not require the development of new space systems : it relies on existing or planned systems, and it replies to the needs expressed by civil protection services.

- The on-going study as well as the demonstration projects will allow to assess, qualitatively and quantitatively, the feasibility and benefits of coordinating space systems for this essential application.

- Organisational questions still have to be solved as regards the integration of space products in national command chains for disaster mitigation.

PILOT PROJECTS

The objective of a pilot project is to establish a pre-operational system and to test it during a limited duration of time in a realistic operational context. At the completion of the work, end users taking part into the project have the possibility to judge the value of the service for their operational needs, and to evaluate its advantages. Service providers thus have the possibility of better understanding the end user needs.

In the frame of the exploitation of the two radar satellite missions ERS-1 and ERS-2, a number of such pilot projects related to disaster monitoring have been carried out by ESA, for flood monitoring, landslides, environmental monitoring.

ESA has currently initiated two pilot projects, on plain floods and earthquakes.

Plain Floods Pilot Project

* identification of the data products responding to the user (Civil Protections) requirements, concerning information contents, delivery delay, means of dissemination and support, formats.

* establishment of a user request procedure, including the requested information products, temporal window, cloud cover during flood crisis, precise geographical coverage, delivery delay.

* validation of the data procurement, interpretation and distribution of data and products through alert exercises (conducted on the Allier and Arno river basins, in France and Italy, respectively).

* establishment and validation of products and services for prevention, crisis and post-crisis, in relation to the user requests.

* validation of the overall pilot project activities in close cooperation with the users (return of experience).

Earthquakes Pilot Project

- selecting a real earthquake case (the 1980 Irpinia earthquake in Southern Italy), and defining a particular area, affected by the earthquake, including a small town (S. Angelo dei Lombardi) which suffered severe damage during the event.

- analysing the availability of remote sensing data before and after the event.

- In the crisis and post-crisis phases, products are used for the estimation of co-seismic movements (landslides) derived from differential SAR interferometry, and to estimate the possibility of an early assessment of damages, particularly of buildings (volume variations) and infrastructure.

Earth Watching

Earth Watching is a service provided by the ESRIN centre of ESA, in cooperation with EURIMAGE. It provides the capability of locating, acquiring, processing, and supplying to users Earth Observation data and products related to emergency situations.

An Earth Watching action is triggered by a request from interested parties, or by an internal action (meteorological forecasts, information media, request from Public Relations). After activation, Earth Watching acts as a crisis unit, searching for available data (mainly from ERS, JERS, RADARSAT, LANDSAT, SPOT), and re-planning image acquisition by ERS. Production and distribution requests are then submitted to the relevant suppliers, the data are acquired, and a Reference Archive for the event on hand is set up at ESRIN.

For the application in a crisis situation, processed SAR images (low-resolution) can be distributed by Earth Watching to users about 5 to 8 hours after acquisition, while high-resolution images become available 1.5 to 3 days after acquisition.

OTHER ACTIVITIES

ISIS

ESRIN is involved as a partner in the development of the Interactive Satellite Image Server (ISIS), a EC-sponsored activity aimed at demonstrating the benefits of high-performance computing and networking technologies in support of Earth Observation, for efficient on-line data processing and supply.

EMERGESAT

It consists of a prototype development, technical verification and validation of a satellite-based communication system for managing emergency situations involving the use of Earth observation techniques. It shall qualify this satellite communication platform as a cost-effective and modular system for near-real-time data dissemination.

Wireless/Satellite Communications for Emergency Management

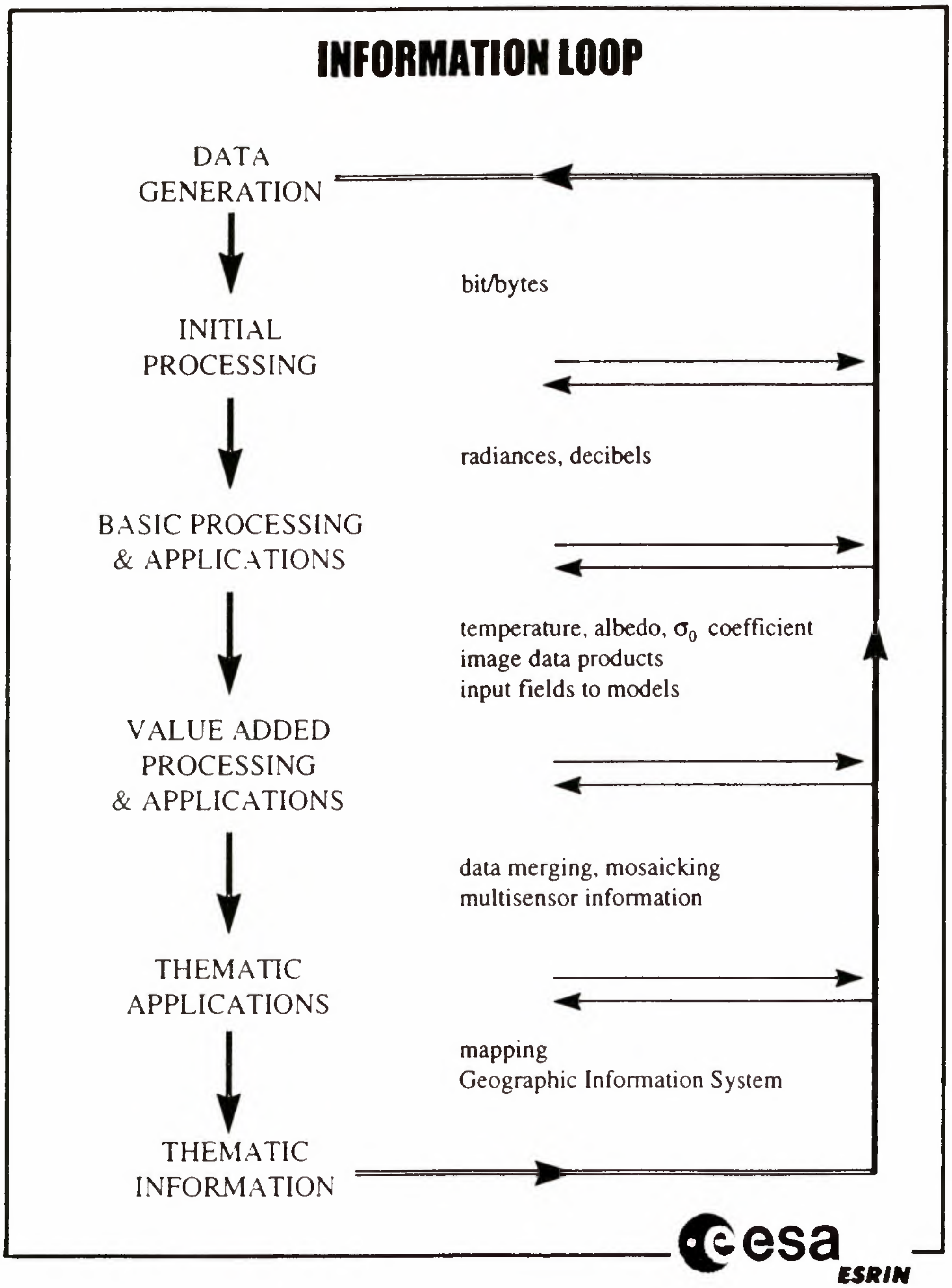
Design and demonstrate an integrated system for communications and localisation services in emergency situations, e.g. fire fighting.

MAJORISK Database

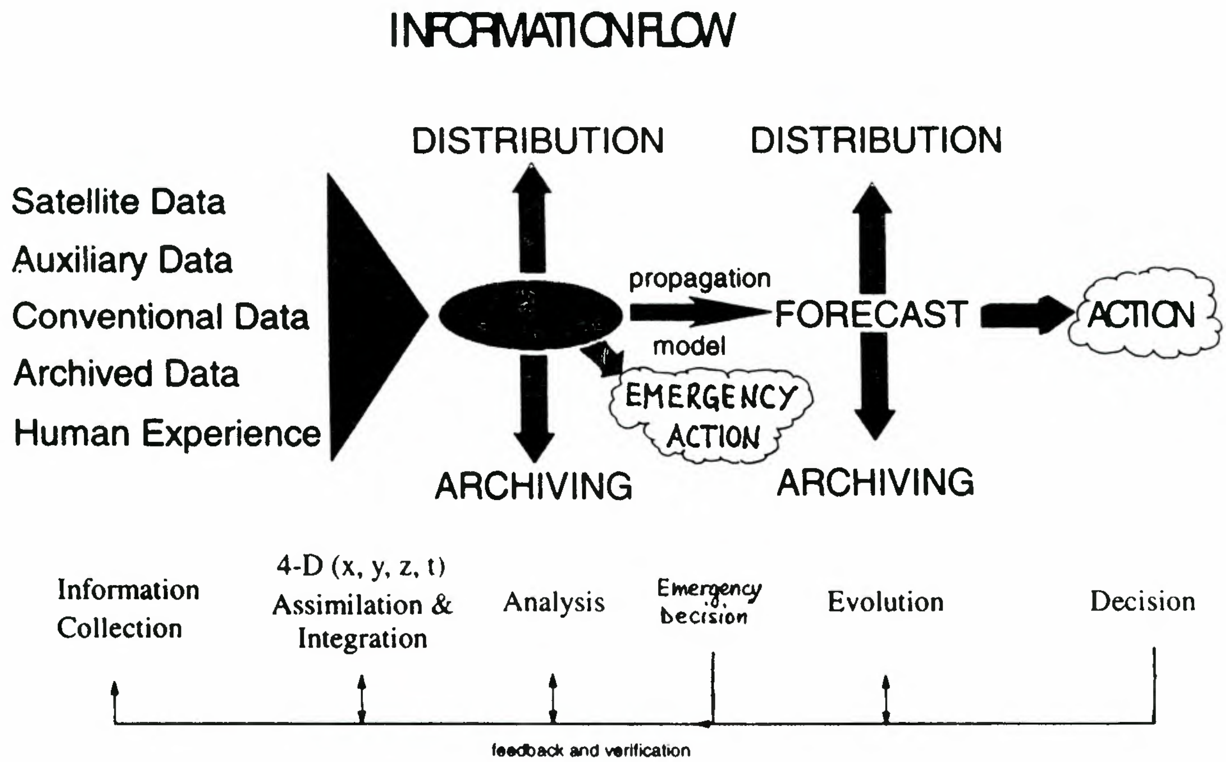
COMO LOS SATELITES PARA LA OBSERVACION DE LA TIERRA DE LA ESA PUEDEN CONTRIBUIR A LAS ACTIVIDADES DE PROTECCION Y DEFENSA CIVIL EN LAS REGIONES LATINO AMERICANAS Y DEL CARIBE

Maurizio Fea

Directorate of Applications – European Space Agency
ESRIN, via G. Galilei, Frascati (Italy)
ph.: +39.6.94180.940 - fax: +39.6.94180.280 - e-mail: mfea@esrin.esa.it



Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).



SECTORES ESPACIALES QUE PUEDEN BRINDAR UNA CONTRIBUCION A LAS ACTIVIDADES DE PROTECCION CIVIL

- TELECOMUNICACIONES
  sistemas satelitales permiten tanto comunicaciones a cualquier escala como la transmisión de datos, de textos y de imagenes, y unos las comunicaciones con estaciones mobiles también

- NAVEGACION y LOCALIZACION
  sistemas satelitales a escala global aseguran una localización precisa

- BUSQUEDA y SOCORRO
  satélites en orbita polar tienen como cargo de pago operativo aparatos para la localización de barcos en caso de accidente

- PERCEPCION REMOTA
  varias misiones satelitales, naves y estaciones espaciales transportan cargos de pago tanto para la observación de la Tierra y del Medio Ambiente como para el llevantamiento de medidas de parametros geofisicos

UTILIZACION DE LOS SISTEMAS SATELITALES DE PERCEPCION REMOTA EN LA GESTION DE CATASTROFES

Los datos de los satélites de observación de la Tierra son útiles ANTES, DURANTE Y DESPUES de un evento:

- ANTES para:
  - conoscer y modelar las condiciones antes del evento
  - evaluar la presión antrópica y su evolución
  - simular una situación de catástrofe (prevención)
  - sensibilizar y educar a todos los niveles
- DURANTE para:
  - observar la evolución de la catástrofe
  - evaluar el impacto del evento sobre el territorio
- DESPUES para:
  - evaluar el efecto final de la catástrofe
  - medir la área envuelta por el evento
  - actualizar el model y los parametros relacionados
  - sensibilizar y educar a todos los niveles.

SISTEMAS ESPACIALES DE PERCEPCION REMOTA UTILES PARA LAS ACTIVIDADES DE PROTECCION CIVIL

- SATELITES: meteorológicos, tanto en orbita geoestacionaria como en orbita casi-polar, para el análisis del tiempo y de las perturbaciones, en particular de las tormentas, para la medida de temperatura de la superficie del mar, el calculo de indeces de vegetación y la identificación de fuegos de bosque

  ambientales, en orbita casi-polar, con alta resolución geométrica, para el monitoreo del estado y de los cambios del medio ambiente, del suelo y de la superficie del mar (topografia, viento, olas, sedimentos, contaminación por aceite), del fundo del mar acerca de la costa y del tráfico de barcos
- NAVES y ESTACIONES espaciales, en varias orbitas relativamente bajas, para el monitoreo del medio ambiente, en particular de la superficie del suelo y del mar

¡ MUY IMPORTANTE !

LA MEJOR MANERA DE UTILIZAR LA PERCEPCION REMOTA ES LA DE INTEGRAR LOS DATOS DE CADA BANDA ESPECTRAL CON LOS DATOS CONVENCIONALES Y CON INFORMACION COMPLEMENTARIA

¡ aprovechando de las características de cada sistema satelital !

PARAMETROS QUE SE PUEDEN MEDIR CON LOS SENSORES DE PERCECION REMOTA

- REFLECTIVIDAD (ALBEDO) — se mide la cantidad de luz solar reflejada por los blancos (no señal a noche y en dias nublados se vee solo la cumbre de las nubes); util para análisis multiespectral y clasificación, monitoreo de la desertificación y mapeo del territorio
- TEMPERATURA SUPERFICIAL — se mide la emisión termica y se genera un mapa de la temperatura superficial (nublado => no suelo); util para identificar fuegos de bosque
- RUGOSIDAD y HUMEDAD — se mide la energia retrodispersada por los blancos iluminados por las impulsiones en microondas del radar (que pasan a través de las nubes también); util para analizar el estado de la superficie del suelo (y generar *DEMs* también) y del mar (olas, viento, helo, topografia del océano, manchas de aceite) y sus cambios, y a veces para sacar información batimétrica

SISTEMA SATELITAL DESARROLLADO POR LA ESA PARA LA OBSERVACION DE LA TIERRA (operado por EUMETSAT desde el noviembre de 1995)

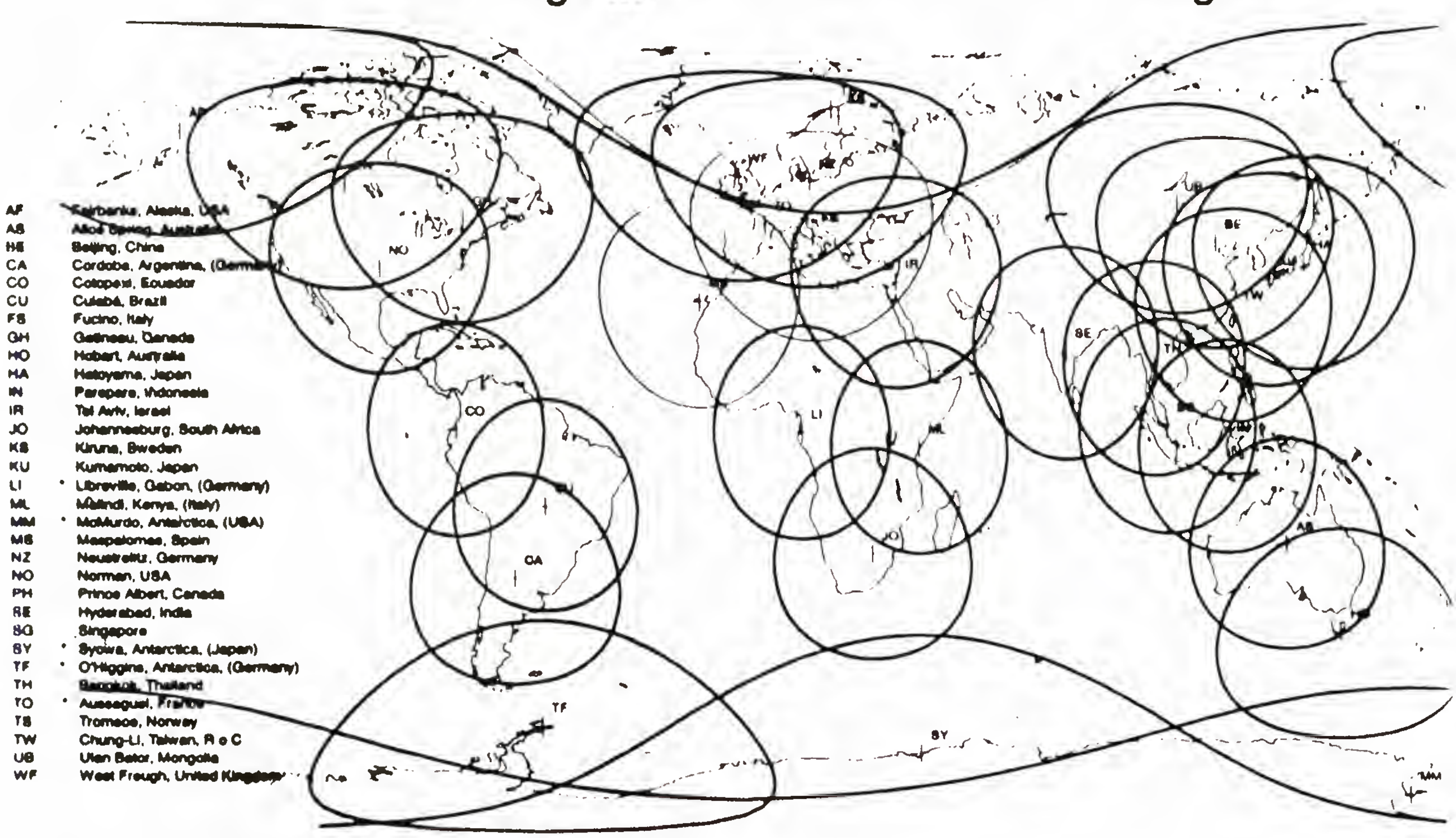
- METEOSAT
  - satélites para la meteorología y la climatología
  - desarrollados y lanzeados por la ESA,
  - operados por EUMETSAT desde el 1995 (antes por la ESA)
  - a 35.800 Km de altura, en orbita ecuatorial geo-sincrona
  - frecuencia temporal de observación: 30 min
  - tipo de observación: mono-sensor
multi-espectral (3 bandas [VIS, IR, WV])
  - resolución geométrica: 2.5 Km en VIS, 5 Km en IR y en WV
  - util para: monitoreo de los sistemas de nubes y tempestas
medida de: altura de la cumbre de nubes
temperatura superficial del mar
viento en la media y alta tropósfera

  \+ DCP (transmisión de datos de las estaciones automáticas)

SISTEMA SATELITAL DE LA ESA PARA LA OBSERVACION DE LA TIERRA

- ERS-1 ERS-2
  - satélites para los recursos de la Tierra y el Medio Ambiente
  - desarrollados, lanzeados y operados por la ESA
  - a 780 Km de altura, en orbita casi-polar elio-síncrona
  - frecuencia temporal de observación: 35 días
  - tipo de observación: multi-sensor (4 herramientas) multi-espectral (7 bandas [2 VIS, 4 IR, 1 MW])
  - resolución geométrica: ***25 m en MW** (SAR)*, 1 Km en VIS y IR
  - util para: monitoreo de la superficie, incluso en días nublados (inondaciones, humedad, cambios,..)
    medida de: viento sobre la superficie del mar
    temperatura superficial del mar
    topografía del mar, altura de las olas
    generación de modelos digitales del suelo (DTM)
    y medida de movimientos verticales del terreno

ERS SAR Image Mode Ground Station Coverage



* available during campaign periods

5° antenna elevation | ESA Ground Stations —— | Others ——

ESA/ESRIN - APP-RS - Sept. '97

SISTEMAS SATELITALES FUTUROS DE LA ESA PARA LA OBSERVACION DE LA TIERRA

- ENVISAT-1
  - satélite para los recursos de la Tierra, el Medio Ambiente y la atmósfera terrestre, que la ESA está desarrollando
  - a 780 Km de altura, en orbita casi-polar elio-síncrona
  - frecuencia temporal de observación: 35 días
  - tipo de observación: multi-sensor (6 herramientas)
multi-espectral (bandas en VIS, IR, MW)
multi-polarización (HH, VV, VH, HV)
  - resolución geométrica: ***25 m en MW*** (SAR), 350 m en VIS e IR
  - util para: monitoreo de la superficie, incluso en días nublados (inondaciones, humedad, cambios,..)
evaluación del color del océano
generación de modelos digitales del suelo (DTM) y medida de movimientos verticales del terreno
estudio de la fisica y quimica de la atmósfera
  - año de lanzamiento: 1999

SISTEMAS SATELITALES FUTUROS DE LA ESA PARA LA OBSERVACION DE LA TIERRA

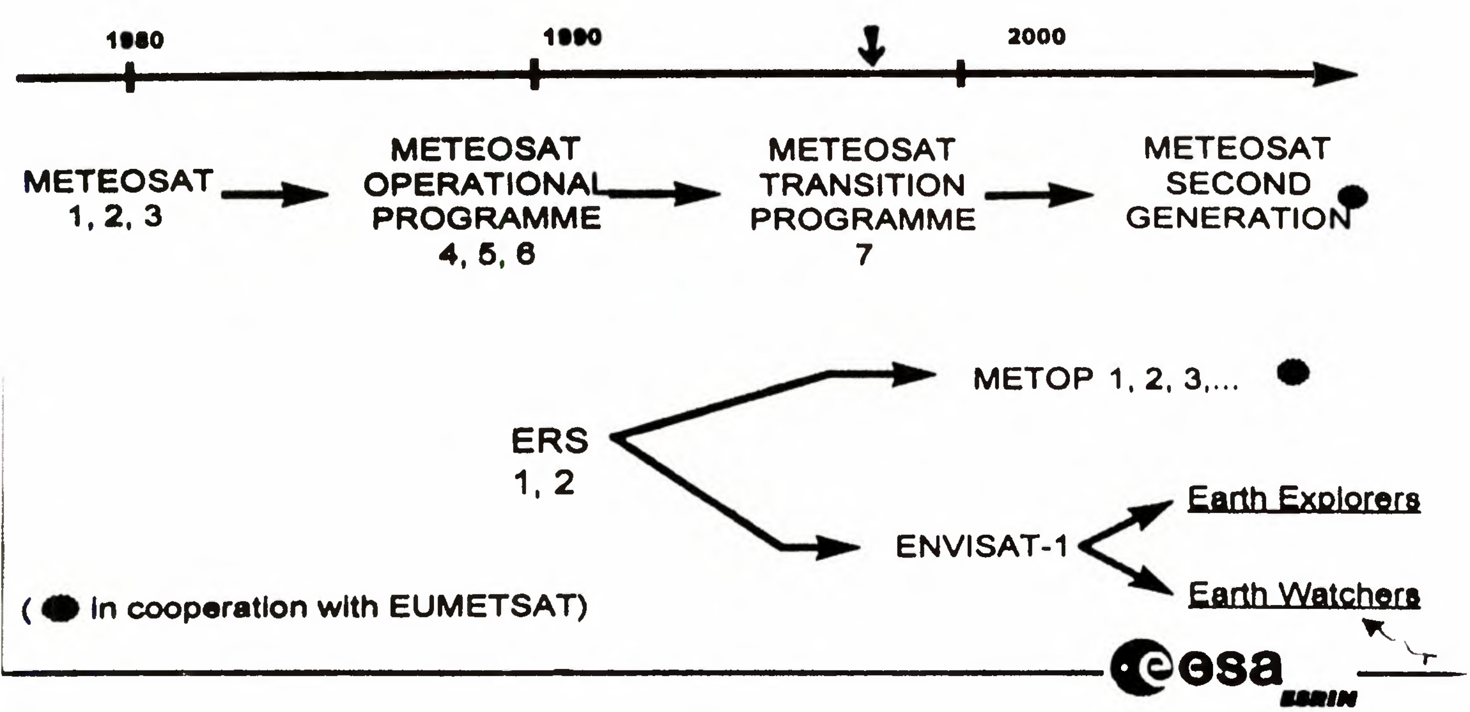
- METOP-1
  - satélite para la meteorología y la climatología
  - a 800 Km de altura, en orbita casi-polar elio-síncrona
  - contribución europea a la orbita de la manana de los satélites polares cuando la NOAA interumpirá el NOAA A.M.
  - frecuencia temporal de observación: 12 horas
  - tipo de observación: multi-sensor (7 herramientas)
multi-espectral (4 bandas [VIS, IR, MW])
  - resolución geométrica: 1 Km en VIS y IR
  - util para: monitoreo de los sistemas de nubes y tempestas
medida de: altura de la cumbre de nubes
temperatura superficial del mar
viento sobre la superficie del mar
evaluación global del estado de la vegetación
identificación de fuegos de bosque
  - año de lanzamiento: 2001

SISTEMAS SATELITALES FUTUROS DE LA ESA PARA LA OBSERVACION DE LA TIERRA

TERCERA GENERACION

- EARTH EXPLORERs — satélites para investigación y demostración
- EARTH WATCHERs — satélites para temáticas pre-operativas, para que luego entitades operativas tomen el cargo de las operaciones

The ESA EARTH OBSERVATION PROGRAMME



VENTAJA Y DESVENTAJA PRINCIPALES DE LOS SISTEMAS SATELITALES A ALTA RESOLUCION

- VENTAJA - los datos satelitales tienen una resolución geométrica alta, entonces permiten una visión regional objectiva bastante detallada y sistemática

- DESVENTAJA - los satélites actuales a alta resolución pasan sobre el mismo lugar (con la misma geometria) cada muchos días, lo que no permite de hacer el monitoreo de eventos rápidos

A NOTAR: a la fecha, ningun sistema satelital para la percepción remota ha sido desarrollado para proporcionar un servicio adecuado a las necesidades de la protección civil, sobre todo en lo que es la respuesta temporal entre dos visitas sucesjvas (misma geometria) y la entrega de datos. Las proximas misiones satelitales a resolución geométrica muy alta (1-2 metros) tendran un carácter tipicamente comercial.

CONCLUSIONES

- DESAFIO - desarrollar un sistema satelital que sirva *especificamente* las necesidades de la protección y defensa civil a escala global para cualquier pais (como para la meteorologia)
  => brindar productos y servicios específicos

- POSIBILIDAD - al momiento se puede utilizar un conjunto de equipos, herramientas y datos integrados que permita de sacar información util a este tipo de actividades

- OPORTUNIDAD - considerar la posibilidad de orientar el desarrollo de una de las misiones futuras, por ejemplo de la ESA, para que pueda offrecer informaciones especificas adecuadas a las necésidades de la protección y defensa civil.

Studying and monitoring natural hazards with satellite technology

- CLS general information
- Satellite monitoring tools
- Applications

CLS: Collecte Localisation Satellites

- **Created in 1986 with:**

  The French Space Agency, CNES
  The French Ocean Agency
  A consortium of French banks

- **Objectives:**

  Be the Argos worldwide operator,
  Operate, promote & develop satellite-based systems related to:
  - data collection
  - location
  - oceanography

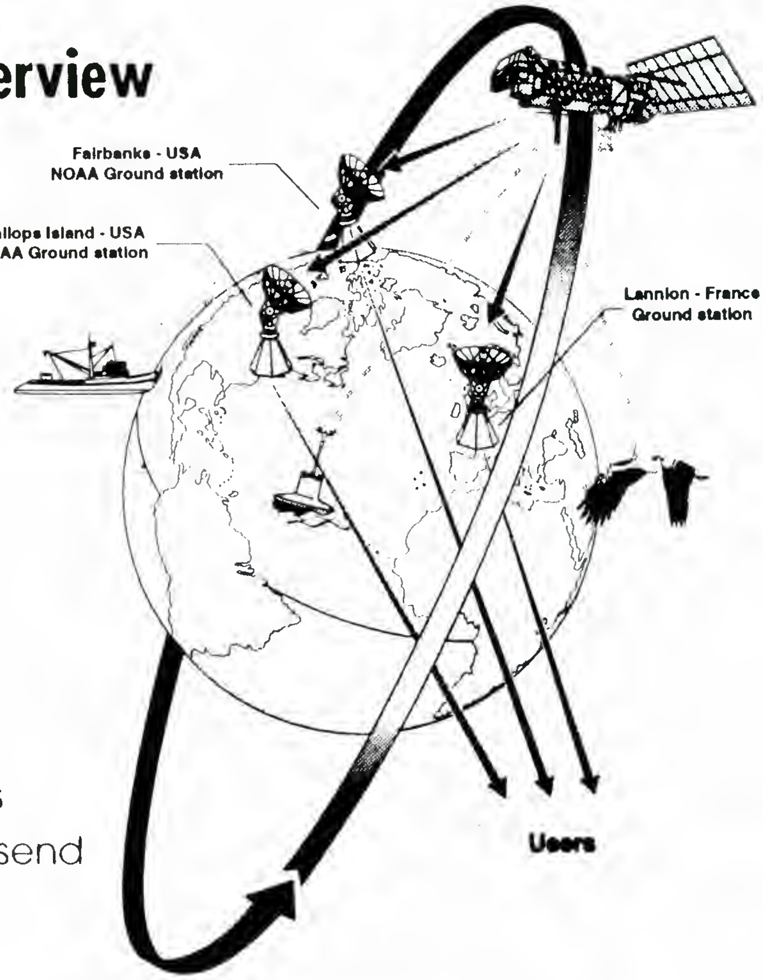
Collecting and distributing scientific data

CLS has continually improved and extended the range of complementary products and services:

- **Argos:** Location and data collection service
- **Cospas-Sarsat:** Search & rescue operation support
- **Doris:** Accurate orbitography and positioning
- **Space oceanography:** Altimetry (ERS-1, Topex/Poseidon)
- **Consulting & engineering**

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

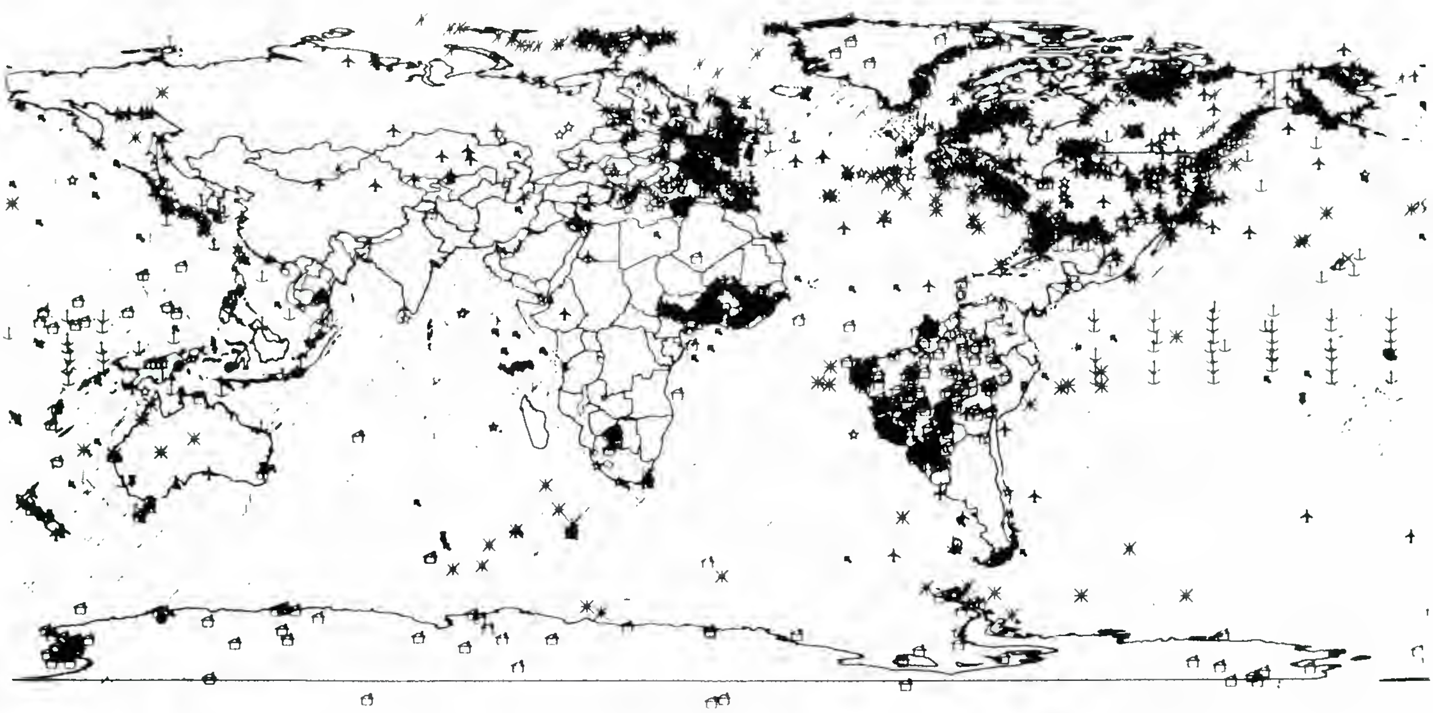
Argos system overview



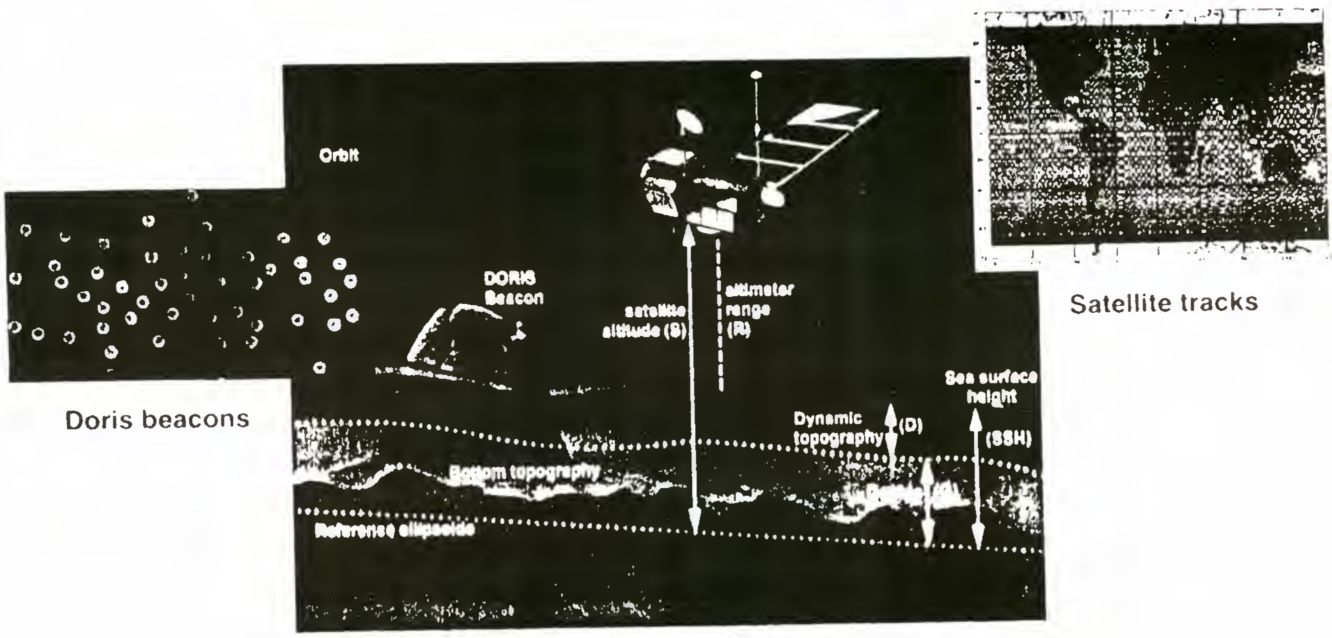
Argos worldwide system:

locates transmitters

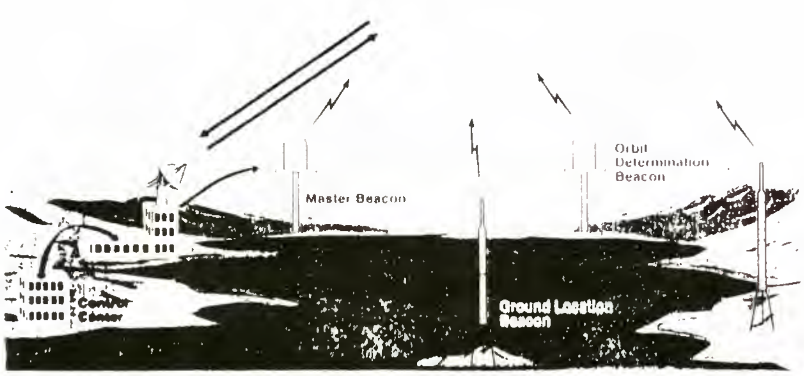
collects data they send

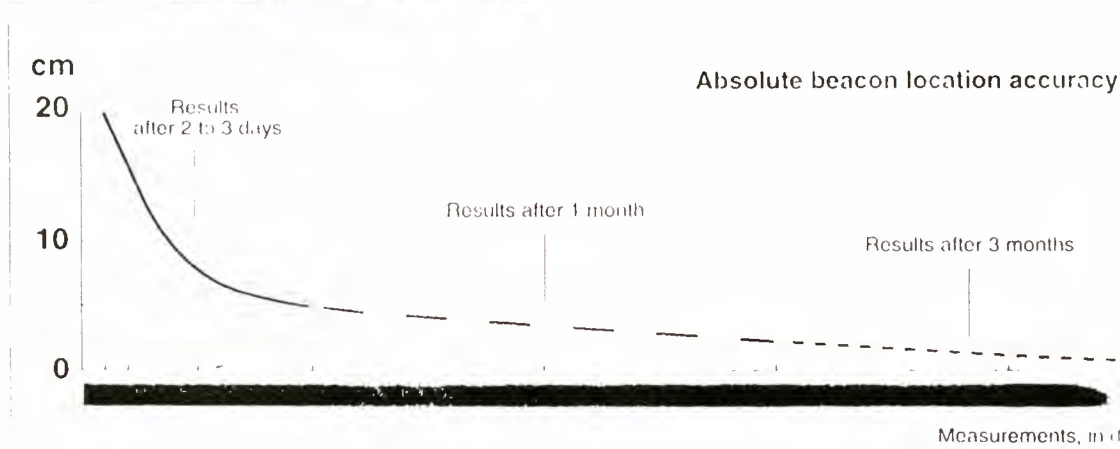


Altimetry principle



Doris system and performance overview

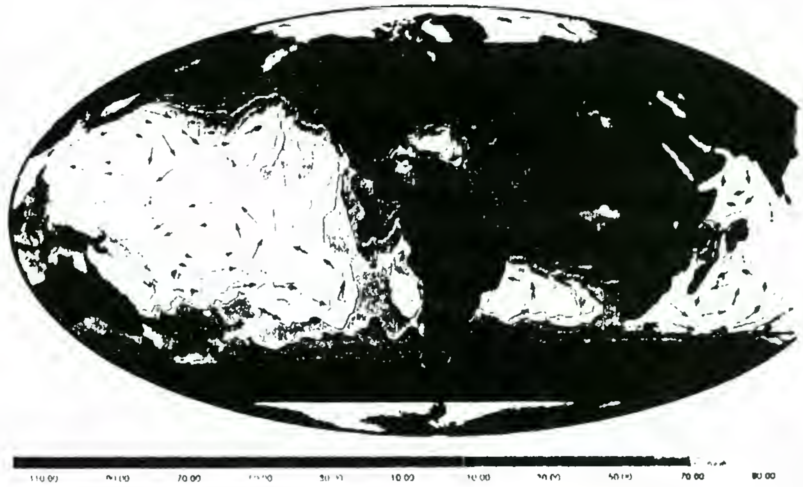




- Climate changes
- Hydrology and floods
- Volcano
- Earth deformation and landslide

Altimetry applications

Sea surface dynamic topography as observed by Topex/Poseidon

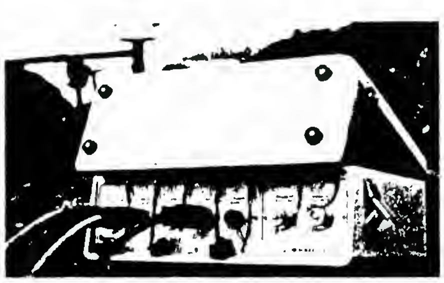


Oceanics currents

Marine meteorology: winds and waves

Ocean-atmosphere exchange and climate

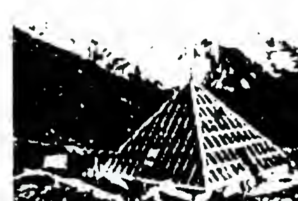
Doris: operational accurate location service



Geodesy

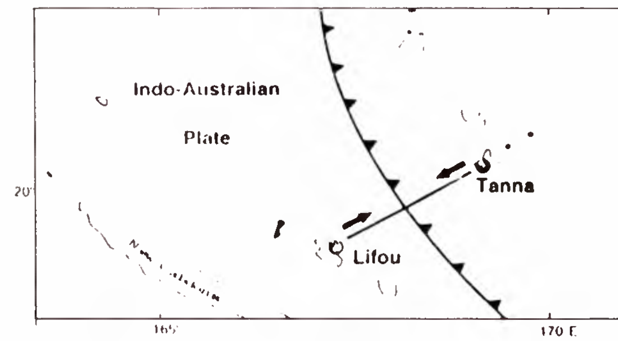
Geophysics

Geotechnics



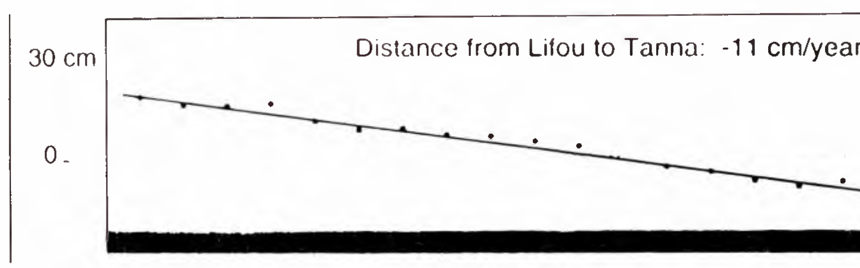
Earth deformation monitoring with Doris

> **Geophysics**
> activity seismic zones,
> rifts, volcanoes, glaciers...



Subduction around the New Hebrides trench

Studying
the seismic cycle
in Chile



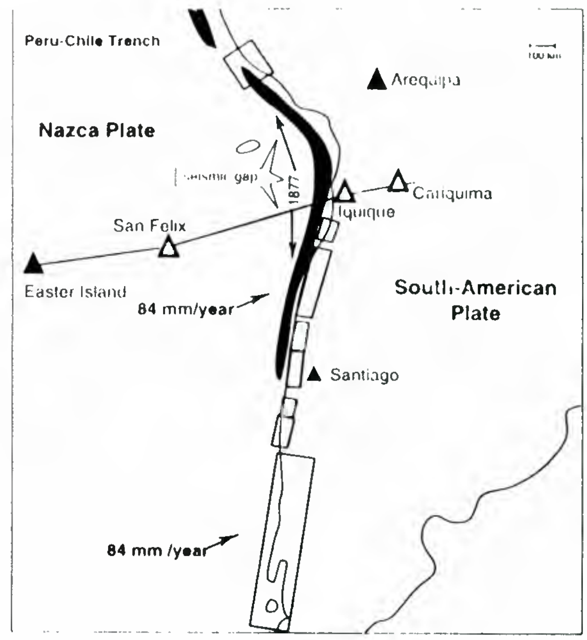
> **Geotechnics**
> areas with accurate locations and meteorological
> data also send via satellite

Landslide at Boulc, Southern France

Doris seismic application in Northern Chile

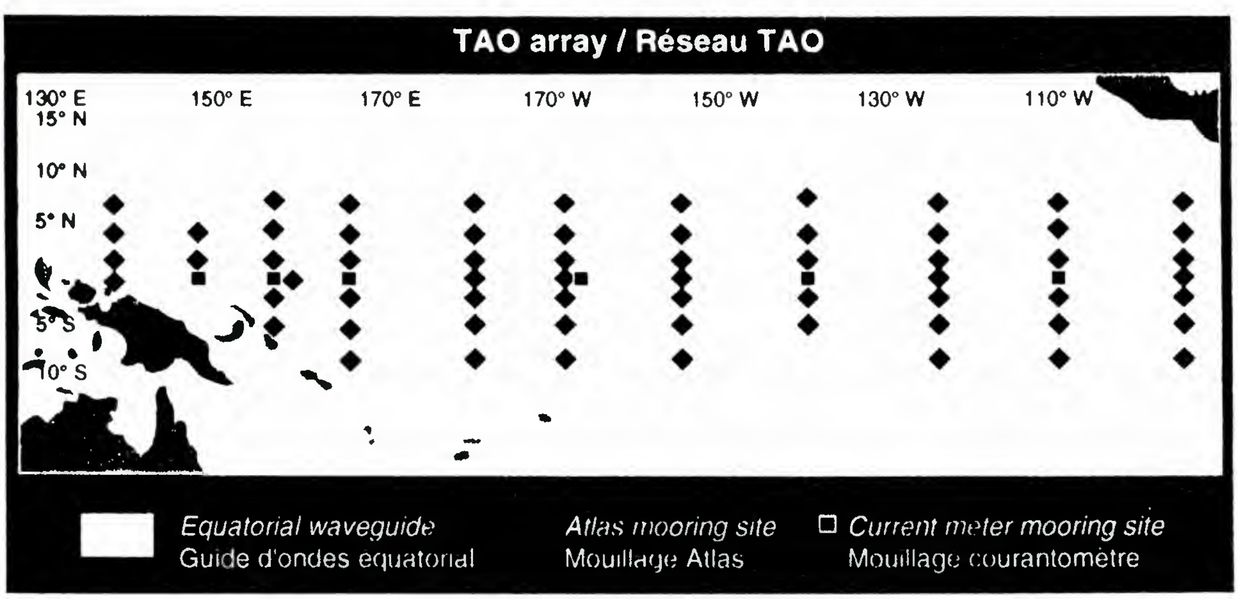
in collaboration with:
IPGP, CNES, INSU, GRGS

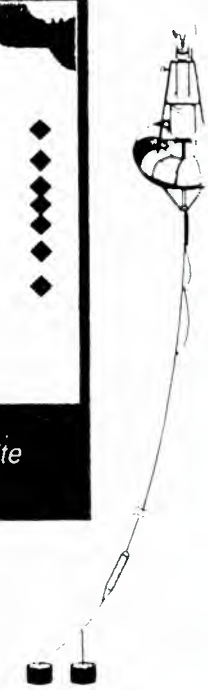
Doris results:
Easter Island — Iquique: -8 cm/year
Iquique — Cariquima: -1.5 cm/year



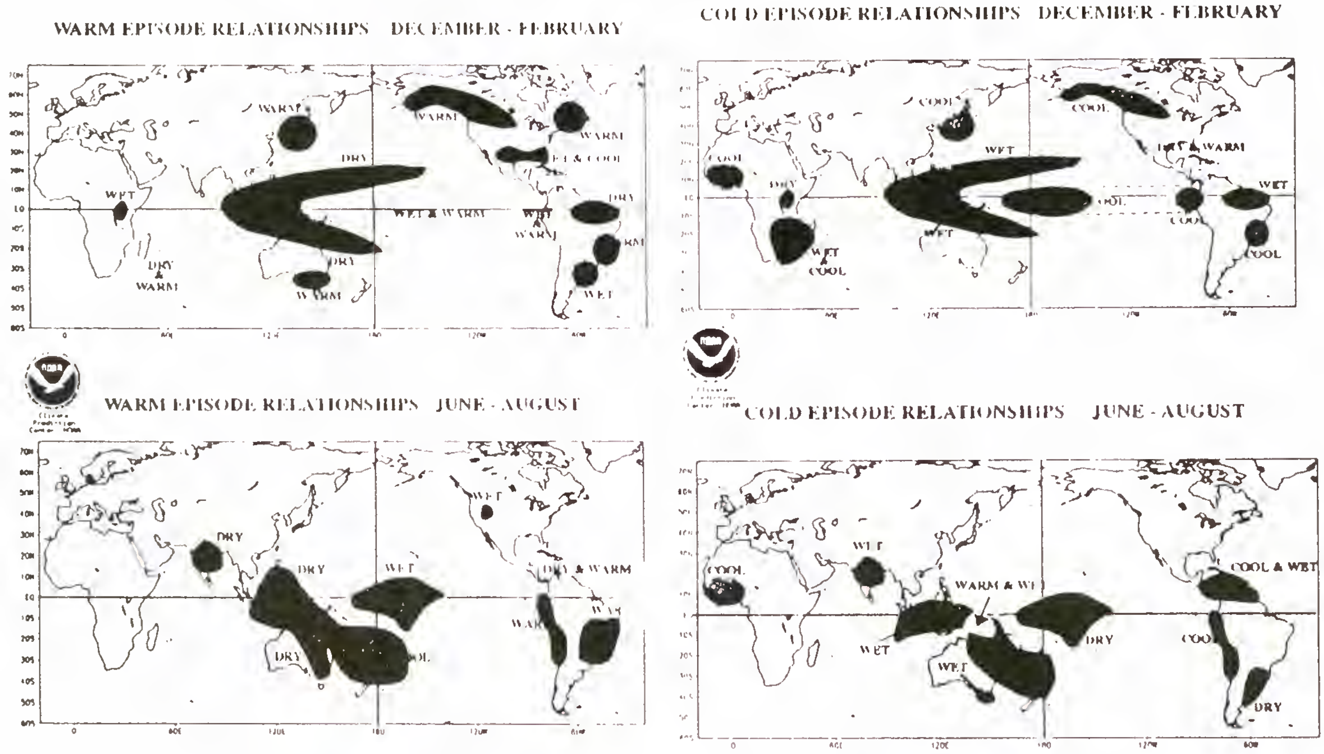
- ☐ Last century seismic rupture zones (MS>8 3)
- ▲ Doris Orbit Determination Stations
- △ Doris Ground Location Stations (since 1992)

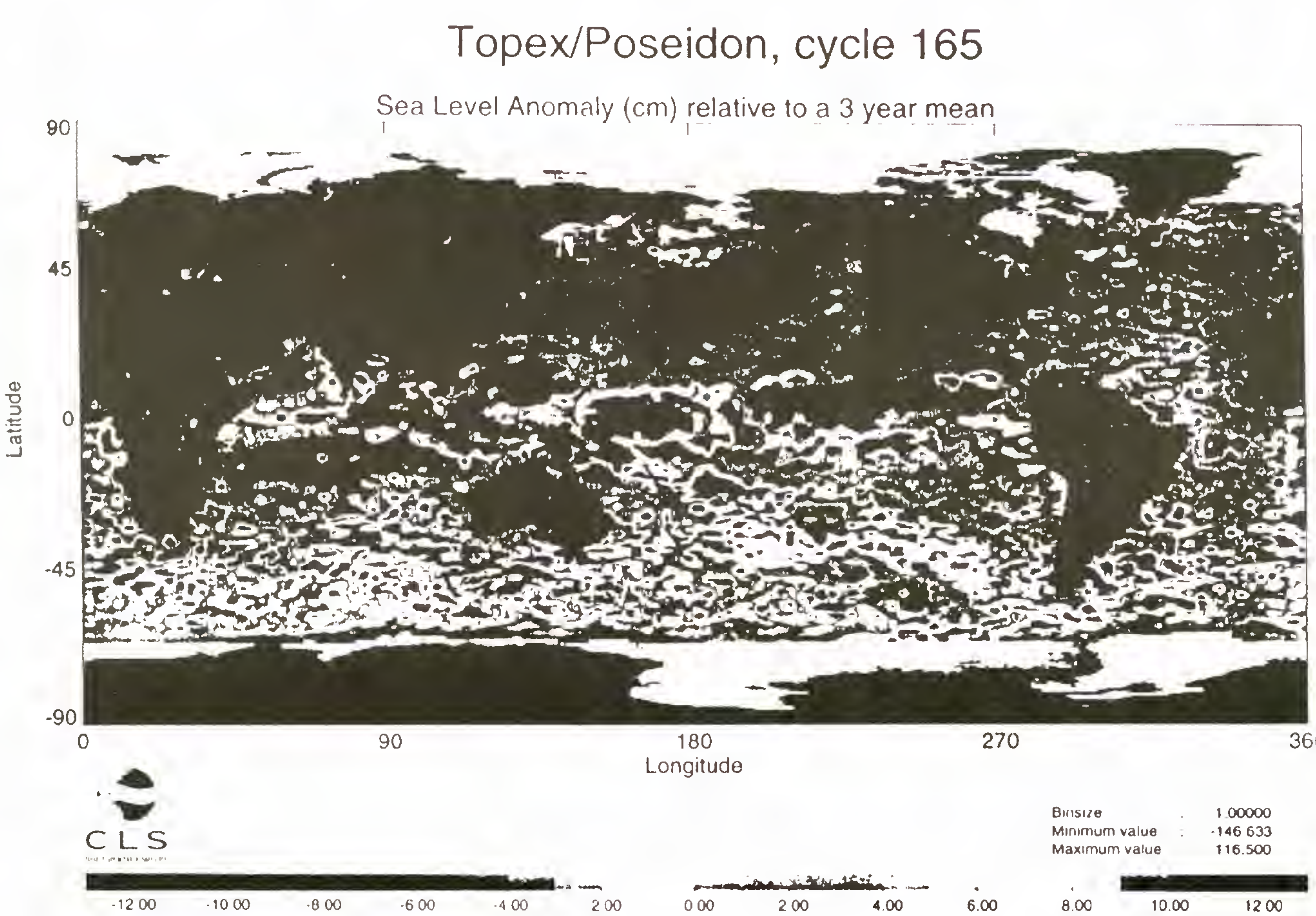
Pacific TAO deep sea moorings

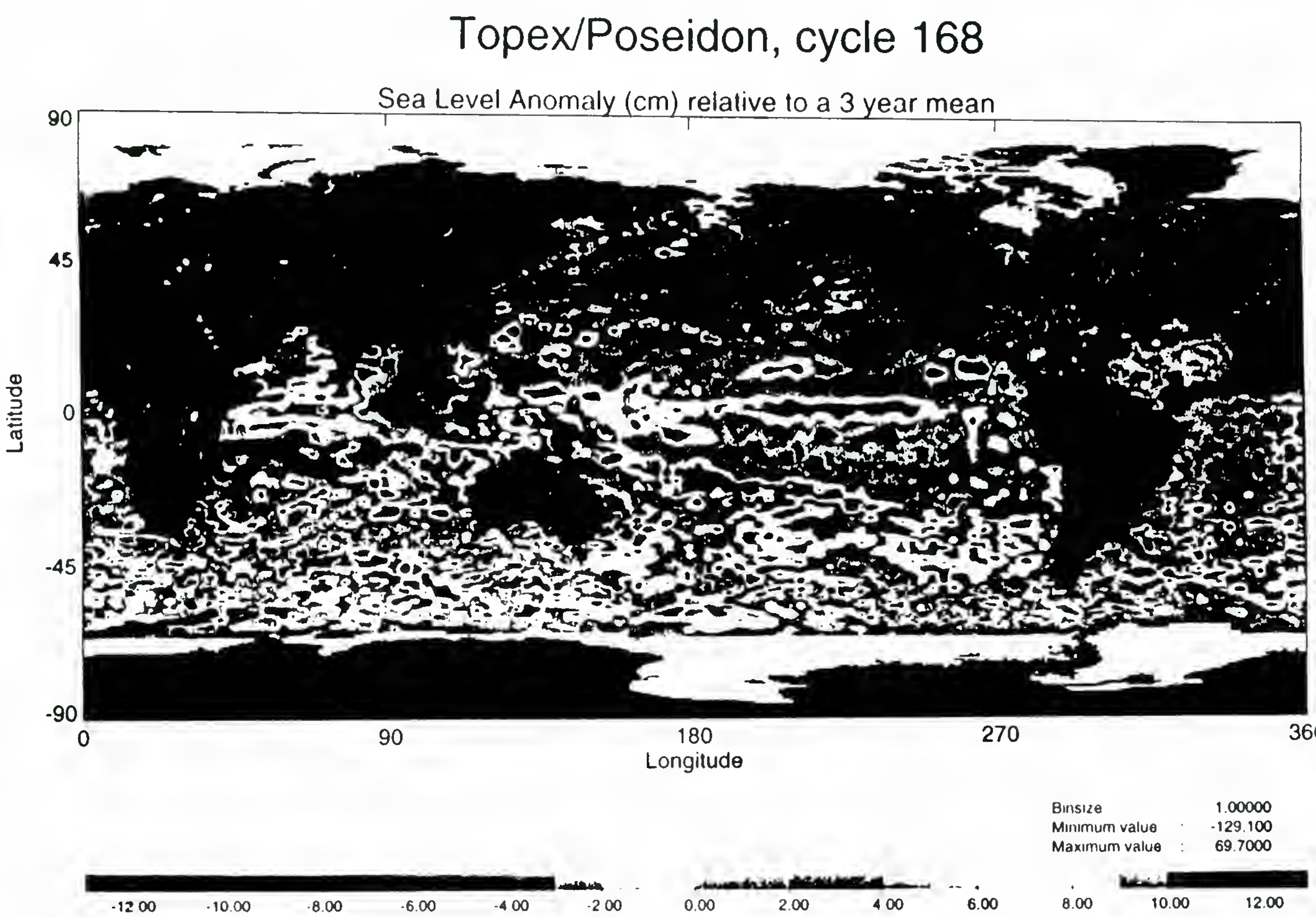


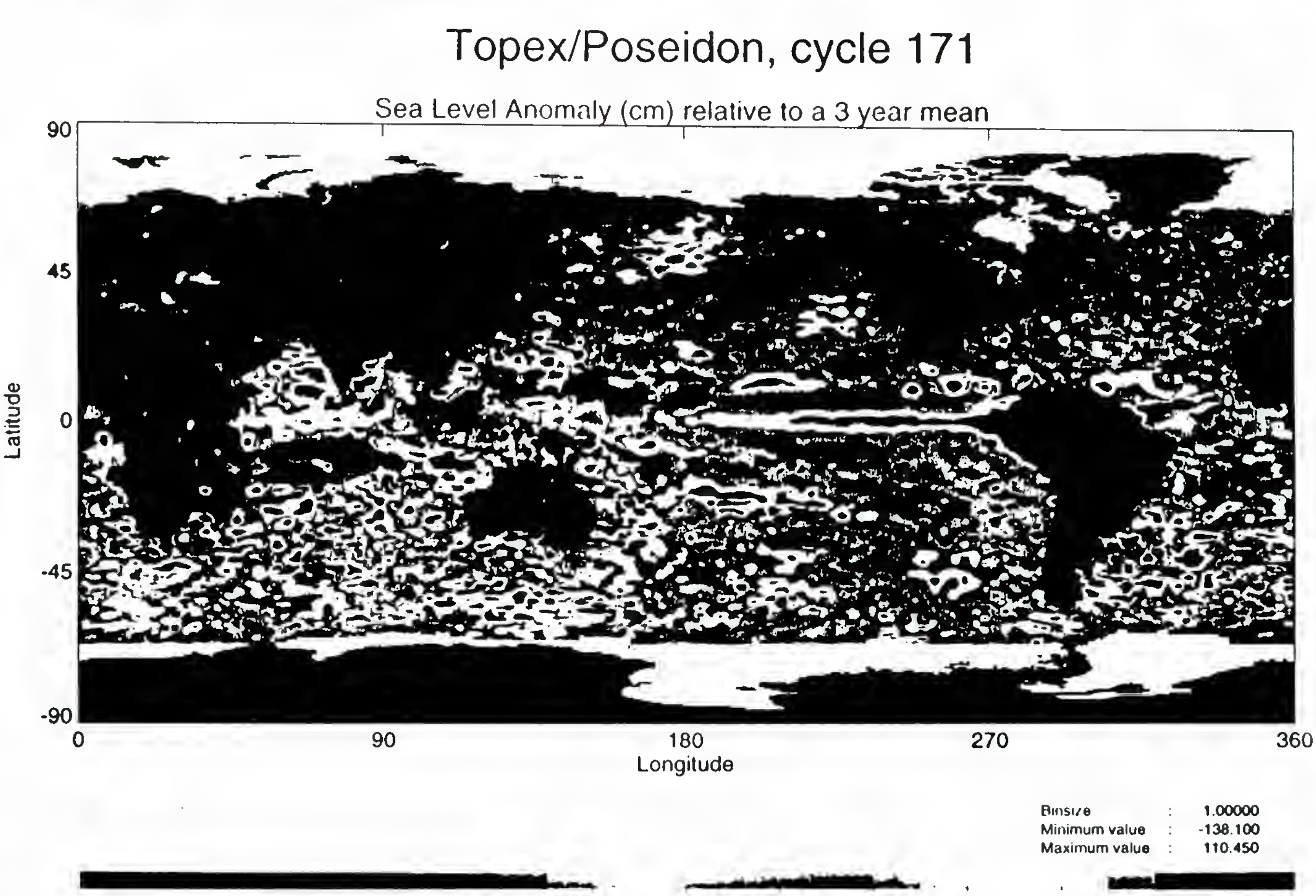


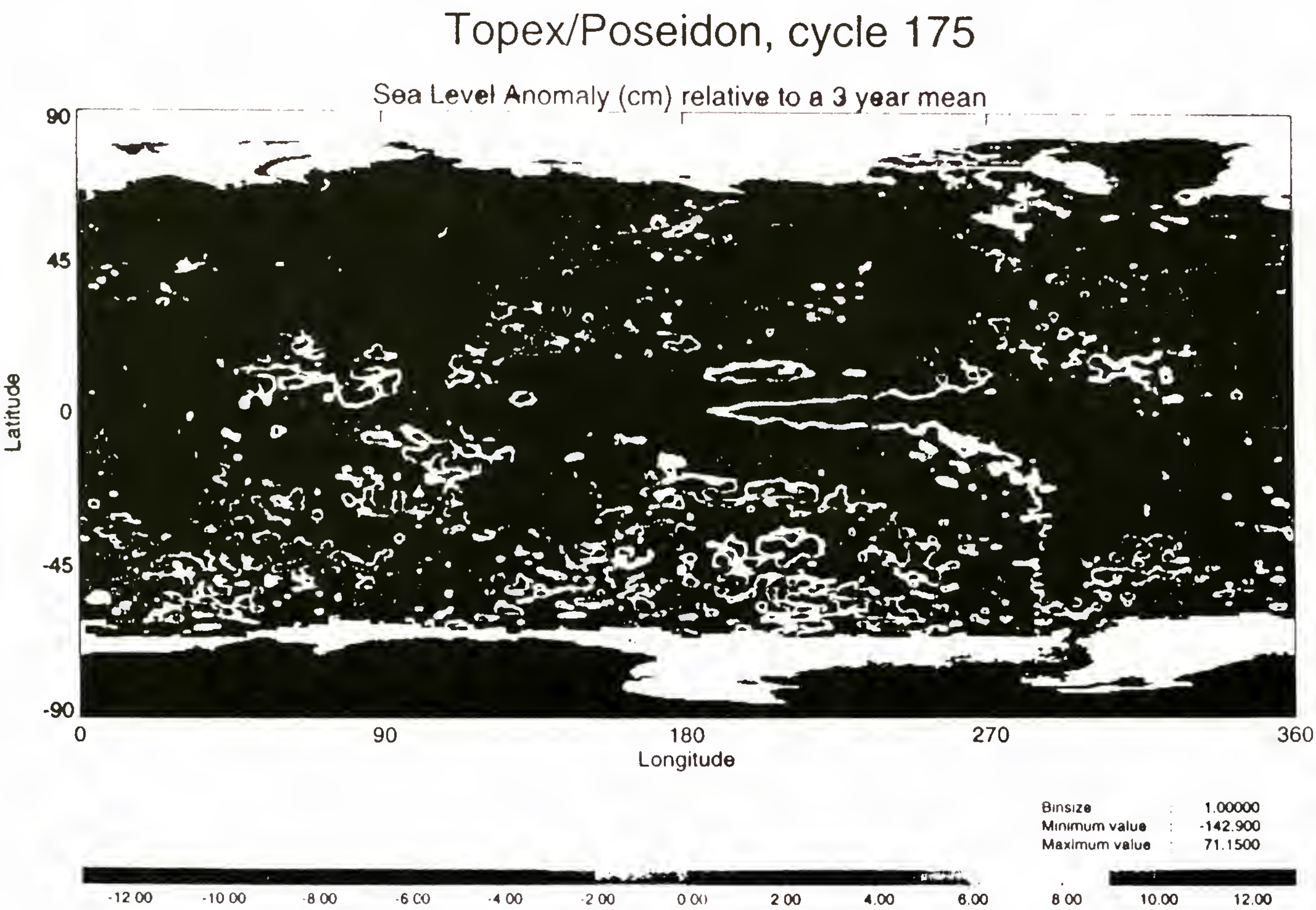
Impact of El Niño on climate






Topex/Poseidon, cycle 168
Sea Level Anomaly (cm) relative to a 3 year mean
Latitude
90
45
0
-45
-90
0
90
180
270
360
Longitude
Binsize 1.00000
Minimum value -129.100
Maximum value : 69.7000
-12.00
-10.00
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00


Topex/Poseidon, cycle 171
Sea Level Anomaly (cm) relative to a 3 year mean
Latitude
90
45
0
-45
-90
0
90
180
270
360
Longitude
Binsize : 1.00000
Minimum value : -138.100
Maximum value : 110.450
-12.00
-10.00
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00


Topex/Poseidon, cycle 175
Sea Level Anomaly (cm) relative to a 3 year mean
Latitude
90
45
0
-45
-90
0
90
180
270
360
Longitude
Binsize : 1.00000
Minimum value : -142.900
Maximum value : 71.1500
-12.00
-10.00
-8.00
-6.00
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0.00
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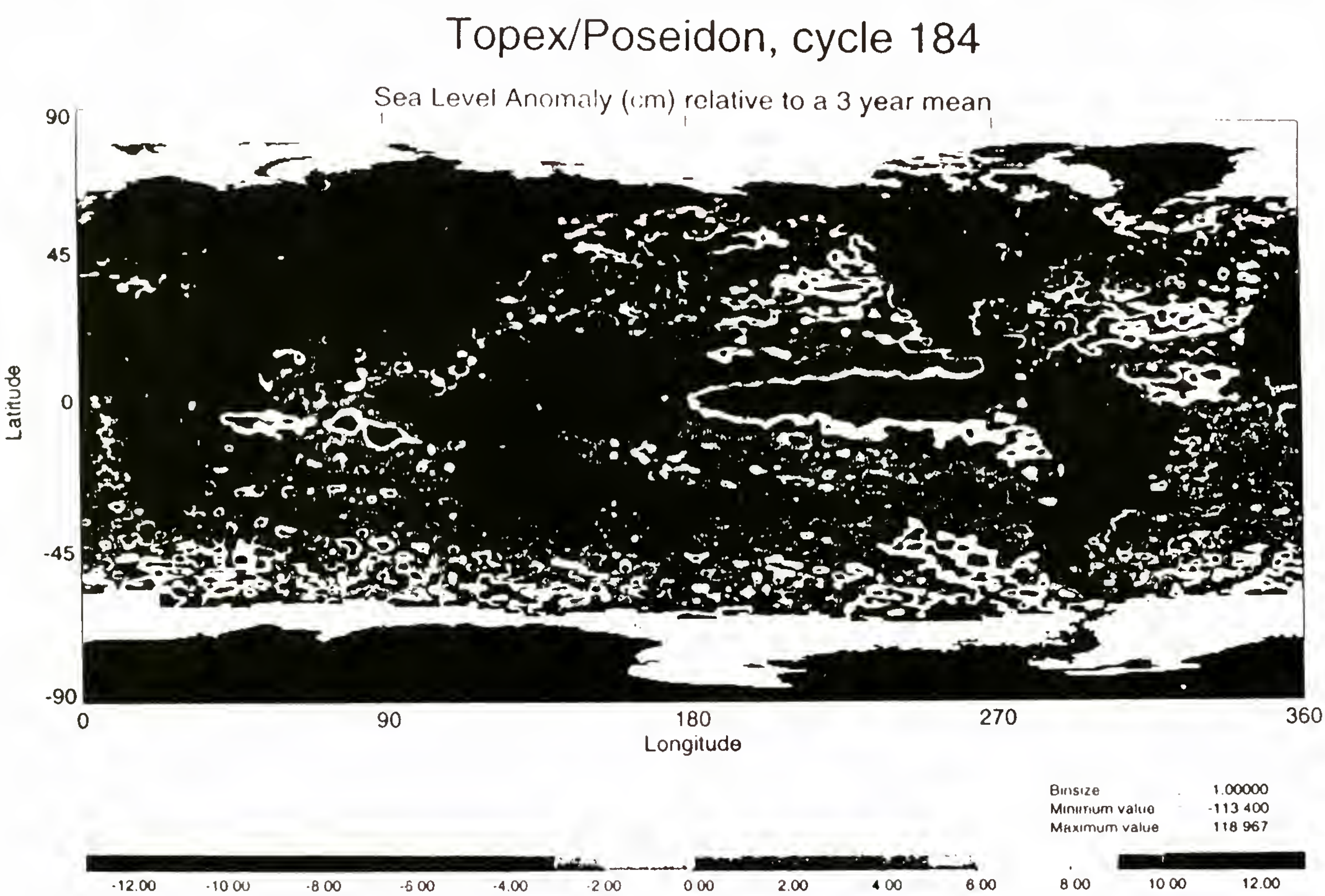
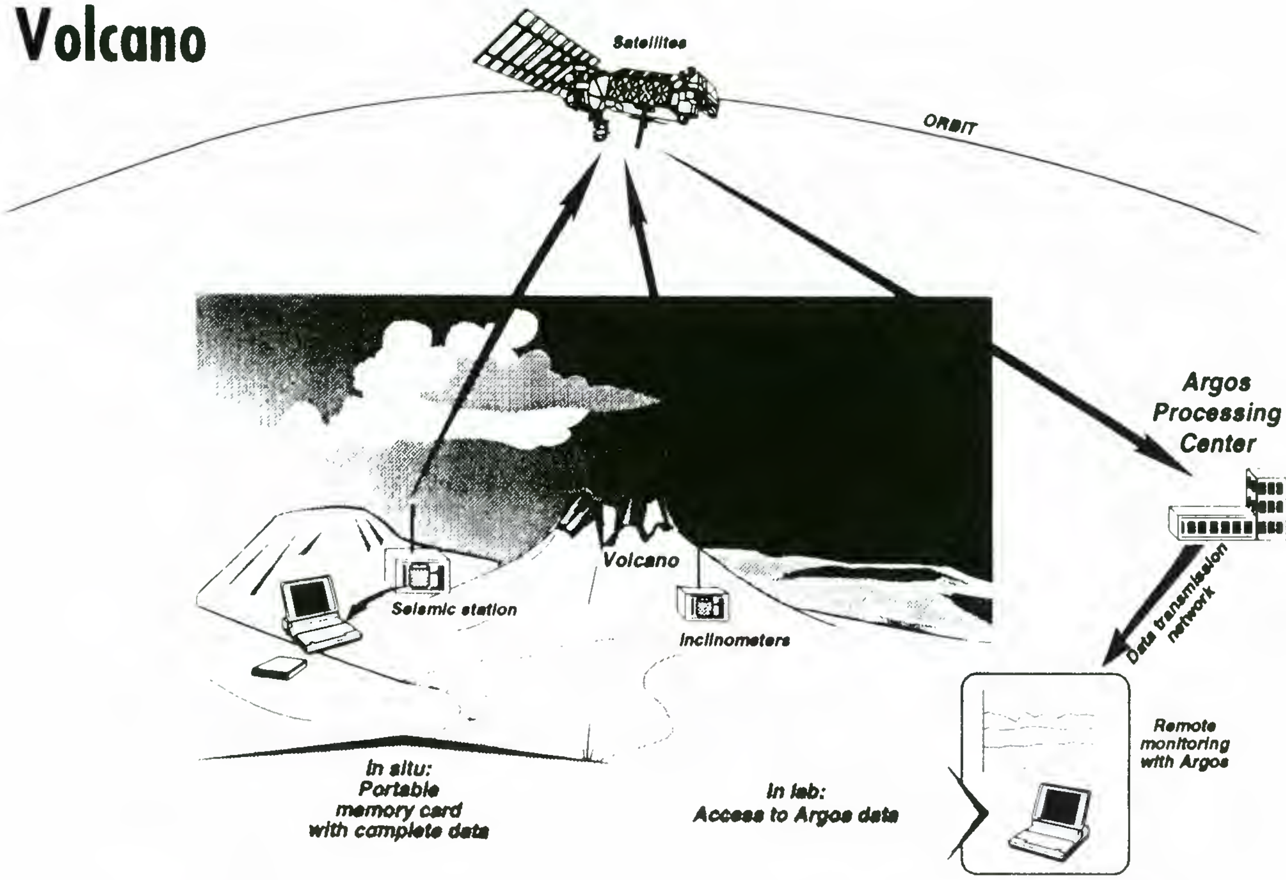
4.00
6.00
8.00
10.00
12.00

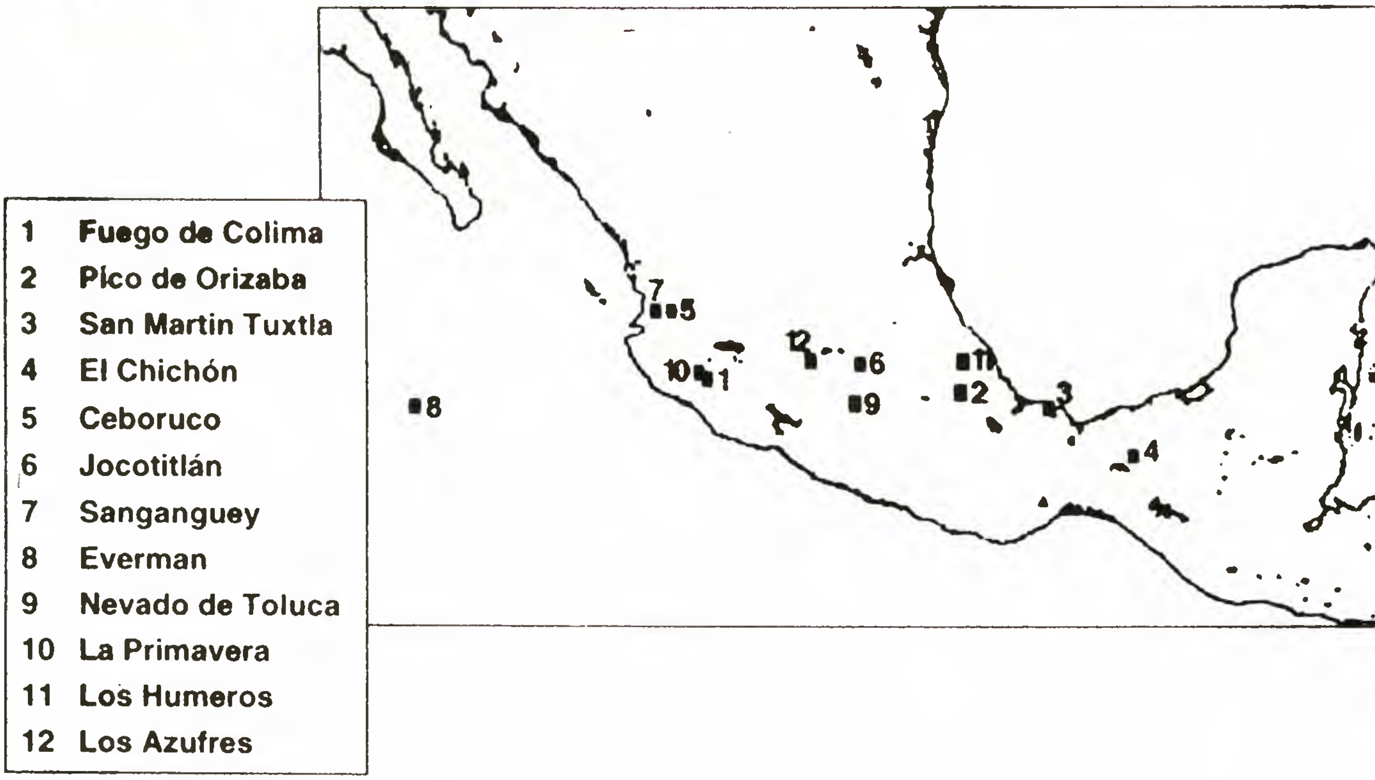

Topex/Poseidon, cycle 184
Sea Level Anomaly (cm) relative to a 3 year mean
Latitude
90
45
0
-45
-90
0
90
180
270
360
Longitude
Binsize 1.00000
Minimum value -113.400
Maximum value 118.967
-12.00
-10.00
-8.00
-6.00
-4.00
-2.00
0.00
2.00
4.00
6.00
8.00
10.00
12.00

Volcano

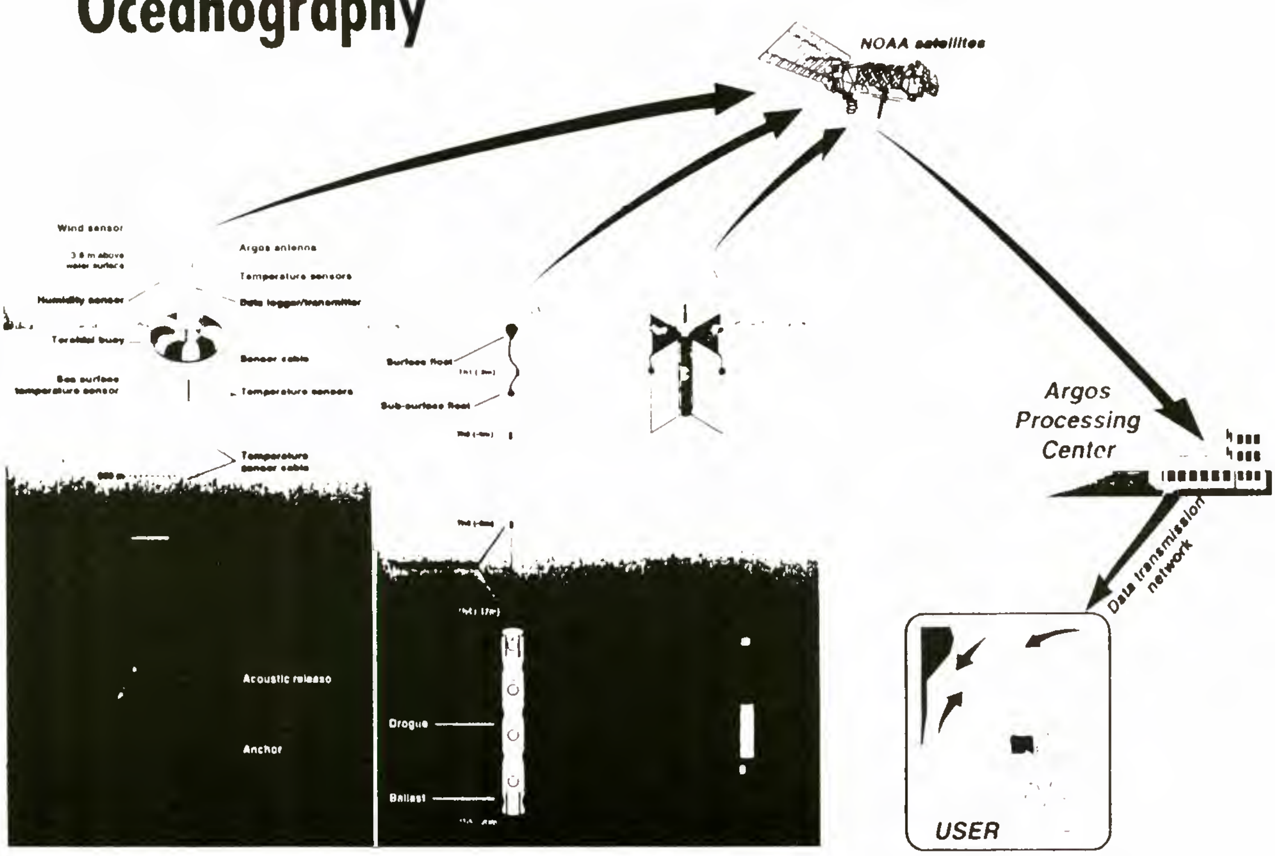


Les volcans indonésiens surveillés par le système Argos (proposition SATTIN)

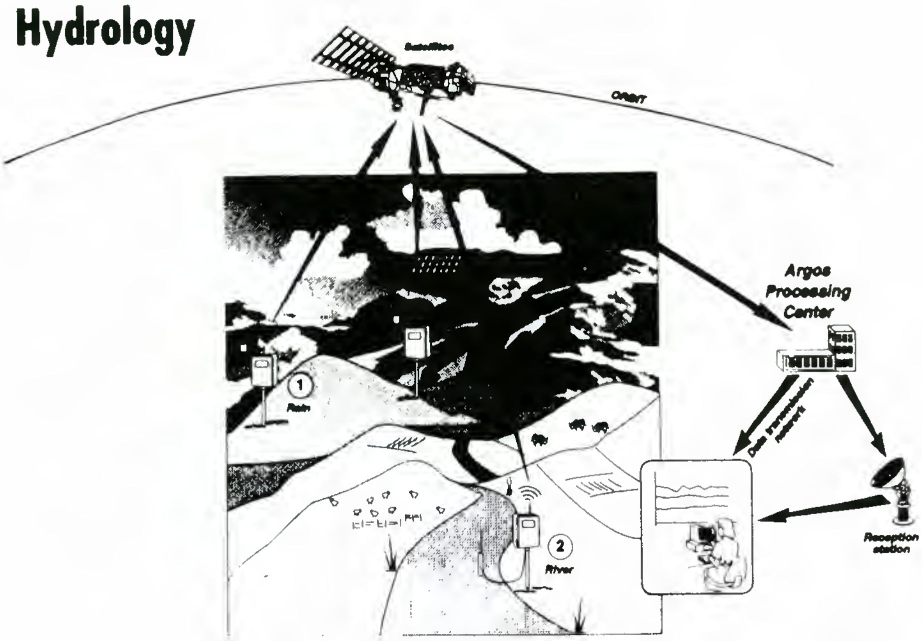
Volcano monitoring in México

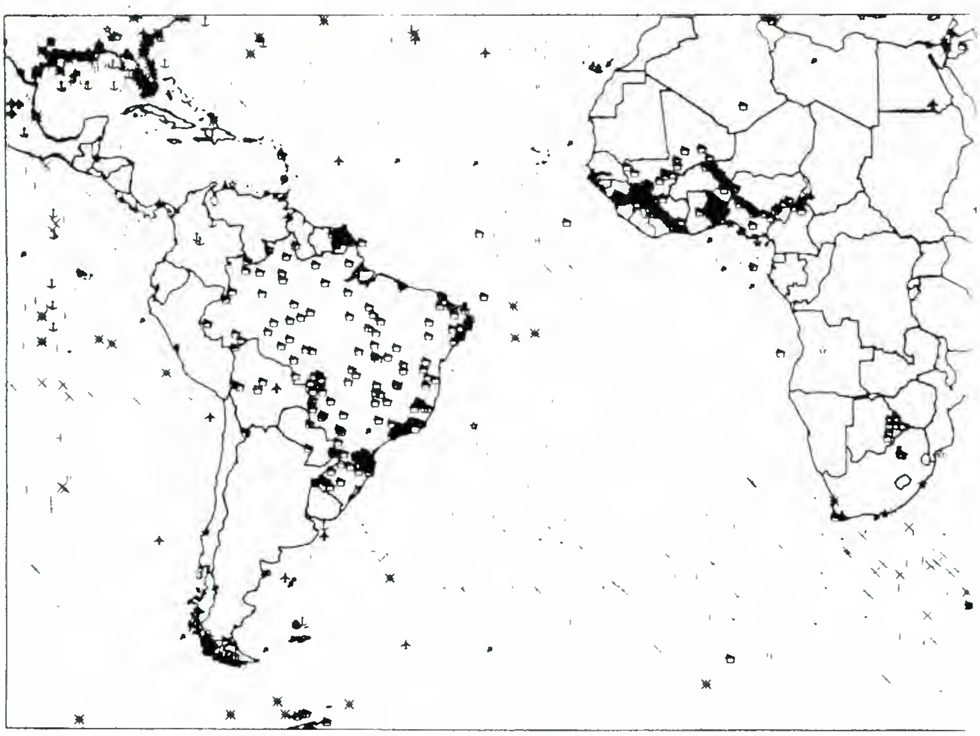


Oceanography



Hydrology





Processed payloads each day

ARGOS	NOAA - D NOAA - J NOAA - H NOAA - G
DORIS	SPOT 2 SPOT 3 TOPEX-POSEIDON
Altimetry	TOPEX-POSEIDON

OPTICAL , RADAR IMAGERY AND DIGITAL ELEVATION MODELS FOR NEOTECTONC STUDIES AND GEOLOGICAL HAZARDS ASSESSEMENT : DIVERSITY , COMPLEMENTARITY OF SPATIAL DATA AND ADEQUACY WITH STUDIED PHENOMENONS

Richard Guillande

Géosciences Consultants s.a.r.l
157 rue des Blains, 92220 Bagneux, France
phone : 33 1 46646060, fax : 33 1 46646161
e-mail : RG_GSC@compuserve.com

ABSTRACT

We present here summarised examples of geological hazards mapping in different geographical and tectonic contexts. The use of complementary data such as space optical (SPOT) and radar (ERS) imagery coupled with other techniques based on hydrologic networks anomalies and DEM derived products is analysed in each case and could be recommended systematically. Each sensor with its specific characteristics or properties reveals phenomenon's in specific conditions (geography, topography, orientation of structures, climate) and up to a scale limit. Beyond such limits, artefacts due to processing or geocoding method, nature of signal or size of observed geological objects, can forbid the extraction of good information's. With the multiplication of sensors and the always increasing spatial resolution, a real preparation of project is now required to select the type of data in adequacy with the objectives and the kind of phenomenon to study.

INTRODUCTION

Geological hazards can be partly studied with space imagery or monitoring techniques (GPS, ARGOS, interferometry, etc..). Active seismic faults identification, landslides inventory are currently extracted now from optical or radar space imagery at small (1/250000) to medium (1/25000) scales. The study of some phenomenon's (analysis of instability factors, buried active faults) requires more detailed data including very precise DEMs and to reach the magnification limit of most of the present day commercial products (SPOT, ERS). In such cases complementarity of images or data from different sensors can compensate the intrinsic limits of each one.
We present here briefly three studies in which the understanding of phenomenon's was brought by complementarity of sensors and/or very high resolution DEMs which allow to detect unknown geological features.
The first case is the study of an underground gas storage in a salt layer in France. The second one concerns slope instabilities in Greece. The third present the discovery of active fault based on morphoneotectonics in the seismic area of the Southern Rhine graben near the city of Basel (border between France and Switzerland).

FIRST CASE : STRUCTURAL AND NEOTECTONIC STUDY OF AN UNDERGROUND GAZ STORAGE IN FRANCE.

In this example, we use the morphoneotectonic analysis technique to detect geological structures reaching the surface or buried at shallow depth above an shallow depth underground gas storage in salt layer (cavity of dissolution). The area is located in the Sologne Region of France (150 km south of Paris), in very flat marshes and woods area. The objective fixed by GDF (French National Gas Company) was to complete the knowledge provided by wells and geophysics on the superficial structures (folds, faults, etc..) which could affect the retention properties, in this area where almost no outcrops of geological basement exists and where no morphology really expresses emerging structures. The study area has a size of 20x20 km.
The analysis was based on :

- aerial photos and SPOT XS imagery;
- hydrologic network anomalies detection and analysis (base on the 1/25000 topographic map);
- Digital elevation models analysis.

The imagery shows the improper land-use , unsuitable with a geological mapping (figure.1) mostly composed of forests, crops and villages. Only uncertain lineaments and some colour variations of the ground radiometry after numeric processing seem to indicate the location of an anticline above the storage.

More interesting results are obtained from the use of DEM by producing slope maps and shaded view with very low angle of incidence which enhance significantly the smooth shapes of the topography (figure 2).

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

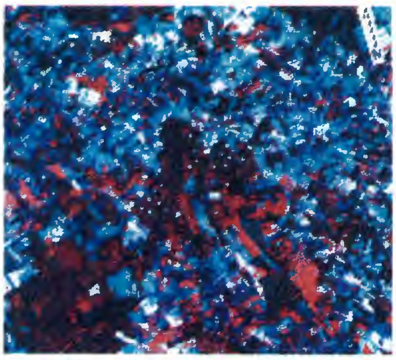


Figure 1 : SPOT XS image of the Soing storage site showing the land-use mostly composed of crops and forest.

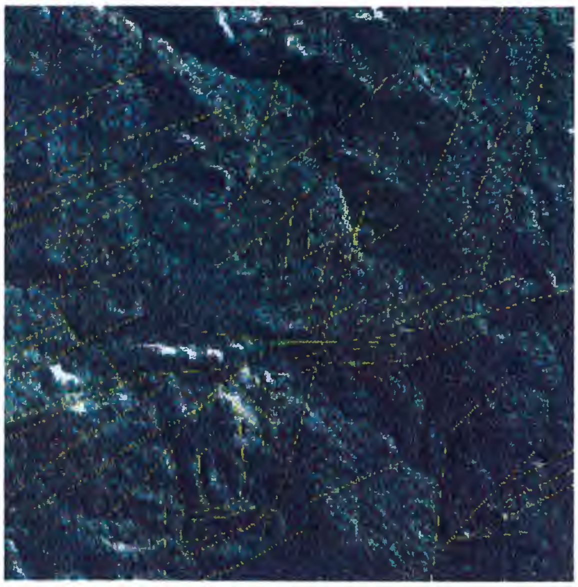


Figure 2 : DEM view showing structures enhancement with a low incidence angle shading.

The extraction of the drainage network and the detection of anomalies ("incompatible drainages", not flowing toward the greater slope direction) is also carried out. A synthesis of these anomalies and structures is produced and overlaid on the plan of seismic lines (Figure 3).
On these seismic lines have been drawn the supposed intersection between the surface and the projection to the surface of faults seen on the seismic lines (small lines perpendicular to seismic lines). We correlate then the different kind of anomalies detected on the various data (images, DEM, anomalies). The following results are obtained :

- detection of tectonic structures reaching the surface (faults, folds, lithologic morphology).
- reveals the trend of some of the faults observed on seismic lines;
- allows to correlate faults from one seismic section to the other;
- Suggest fault presence at surface or shallow depth invisible on the field or on the seismic sections.

Among the detected superficial topographic anomalies detected, some of them could not be correlated to anything known on the geological maps or on geophysics. Three faults directions known in the area are likely to reach the surface. Among the set of anomalies detected 50% could be correlated to two faults directions and 27% to the third one.

In such a context, we see how, the imagery is not able to provide a good geological and tectonic view of which structures reaches the surface. Nevertheless, by completing the imagery interpretation with DEM derived products, and hydrologic network anomalies we can have a clear image of the main structures reaching the surface and have a good correlation with deeper structures. Thus the superficial gap on seismic lines where no signal appear is compensated. The cost of such an application is nearly negligible compared to the cost of geophysical campaigns (close to 0.01 percent of total cost of field exploration).

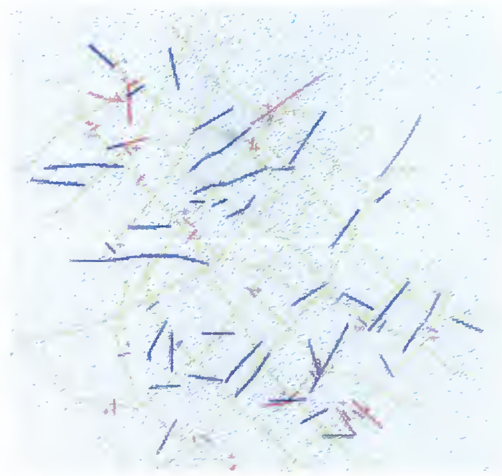


Figure 3 : overlay of anomalies (intermediate length lines) on the seismic lines plan (longest lines) with projection of faults observed on seismic sections (smallest lines).

SECOND CASE : SLOPE INSTABILITIES INVENTORY AND LANDSLIDES MONITORING BY DIFFERENTIAL INTERFEROMETRY.

This second example is taken from a European Commission DG XII project (Ref. EV5V-CT94-0452) named : " Natural processes inducing slope instability and erosion in two Mediterranean regions in Italy and Greece" which involved several partners from Italy, Greece, Belgium and France (Ref 4). The goal was to study the causes of declared instabilities and to produce potential instabilities maps induce by climatic, geologic or human causes.

Two main objectives were assigned to the remote sensing approach of the area :

- produce a landslide inventory and maps of all possible factors of instability such as faults , slopes, etc.. using standard images and data (SPOT, ERS, DEM, aerial photos) and a GIS.
- monitor two selected active landslides by differential interferometry for ground movement detection and quantification.

Mapping

A landslide inventory was produced in order to classify the different mass movements types and their corresponding causes.
Due to a varied land-use ranging from almost bare soils to forest covered areas, the three kinds of available images (SPOT, ERS, aerial) were used to produce different regional and local maps : landslides inventory and classification, updated geological-geotechnic map and fault map, slope maps, land use maps, etc...
DEMs with pixel sizes ranging from 50x50 m to 8x8 m were used for derived data extraction (slopes, aspects, etc...). After the regional inventory and analysis, we focused on smaller areas to analyse the threshold of detection of structures and instability factors, on previously studied ground movements.
Spatial data were pushed to their maximum magnification levels and allowed to discover unmapped unstable areas, and to discover factors of this instability which were not supposed on former data or studies (ex : aerial photos anterior to instabilities start).
The finest accuracy DEMs and 3D views allowed to detect an active fault plan, not visible on the imagery neither on the field, on which one of the selected test landslides was installed
In order to assess the advantages and drawbacks of ERS imagery for landslide and structural mapping, compared to the known performances of SPOT imagery, we controlled the visibility of landslides, faults and geological structures on different ERS images magnifications and with or without ortho-rectification and at different scales using a GIS.
The geocoding procedure do not bring significant improvement for the interpretation of ERS imagery, but gives the possibility of overlaying this images with other data such as optical or DEM derived layers and any other maps. It appears more interesting to geocode the interpretation, firstly to make a control of interpreted features which can be confused with non geological objects and secondly to produce real usable maps from interpretations.
We pushed the interpretation of ERS PRI images to the maximum possibility of zoom by integrating a geocoded ERS image on a database of our test sites (figure 4) with a corresponding pixel size of 8 metres. The results (figure8 (8)) shows that once reached a certain level of magnification, interpolation artefacts of the geocoding algorithm create a lining effects that forbid any interpretation and do not enhance nor outline the studied landslide which is hardly visible on the non geocoded image. The same results was observed on the other test site. Only one big landslide, visible on the non geocoded image was better outlined on the geocoded image, but staying at a low level of zoom.

Monitoring by Interferometry.

Interferometry on ERS1 and tandem data sets was carried out by the SAI-JRC Ispra of European Commission on ERS images. Among the 4 interferogrammes produced on the area, the first set could not be used because of a large baseline between images and a two long period between the acquisition inducing a bad correlation between the images except on stable urbanised areas and rocky river beds. Prior to the processing, we produced simulation of ERS images using our most accurate DEMs of the two test sites to analyse the visibility of the landslides in the specific geometry. This revealed that one of the orbit would give to narrow fringes to be unwrapped, the active surface being in a foreshortening area..
A last interferogramme was produced using ERS1-ERS2 tandem data set acquired in 1995 (Ref 6). The resulting interferogramme was of very good quality. The small baseline value and the corresponding wide ambiguity height allowed a comparison with a simulated interferogramme using a DEM in order to obtain a differential interferogramme supposed to show heights variations between the acquisitions on two monitored active landslides. Unfortunately, no movement was detected because of the too short time interval of one day between the two acquisition (1 day) which did not let occur a detectable movement of a few millimetres.
In addition to such a problem of adequacy between the velocity of the studied phenomenon and frequency of acquisition, can also appear a problem of atmospheric perturbation which is difficult to control and to extract, can require numerous interferogrammes to detect them and can induce great uncertainties on the value of the results, as shown for example in the interferometric study of Etna volcano eruption in (Ref. 3).

THIRD CASE : DETECTION OF ACTIVE SEISMIC ACCIDENTS WITH MORPHONEOTECTONIC STUDIES IN THE SOUTHERN RHINE GRABEN REGION.

This study was carried out for the Institut de Protection et de Sureté Nucléaire (IPSN) of France which is in charge of safety control on all nuclear installations in France and the CNES.

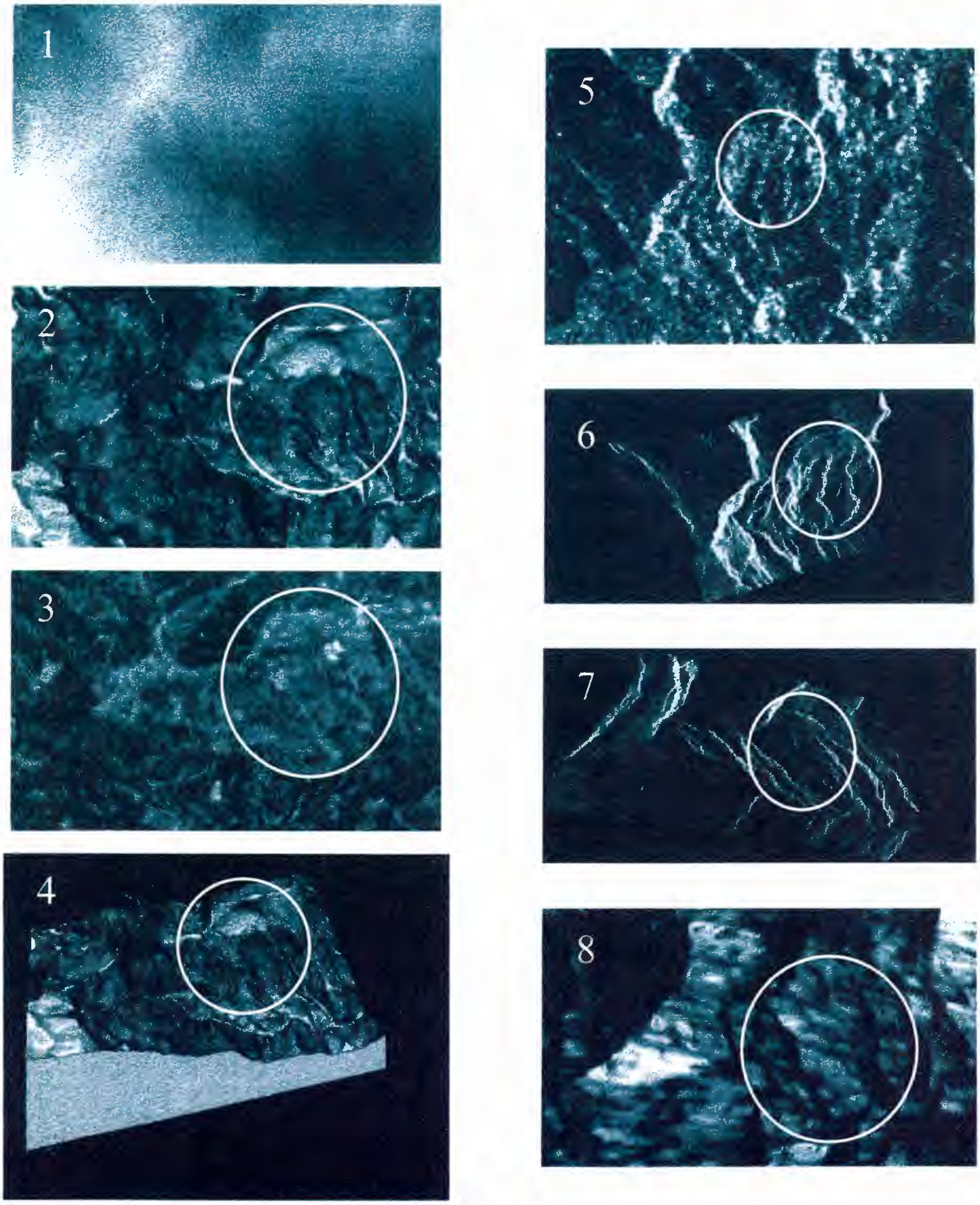


Figure 4 : Different view of the same area (2x1.5 km) : (1) - DEM (8x8 m pixel), (2) - shaded view, (3) - SPOT P view, (4) -view with shaded view draped on DEM, (5) - ERS 1 image, (6) - ERS image simulation of the same area, (7) - simulation in opposite orbit, (8) - geocoded ERS image. Circle shows the area of monitored landslide.

The objective was to detect active faults in this moderate seismicity area where took place in 1356, one of the strongest historic earthquake recorded in Occidental Europe (MSK intensity VIII).
We used or produced DEMs at different pixel sizes (75 m to 10 m) to compare the threshold of detection of known faults and try to detects new active faults (buried or at surface), hoping to detects the one at the origin of the 1356 earthquake.
A regional map of the deformation front was produced (figure 5) and push to relocate farther north the first signs of active deformation due to the progression of

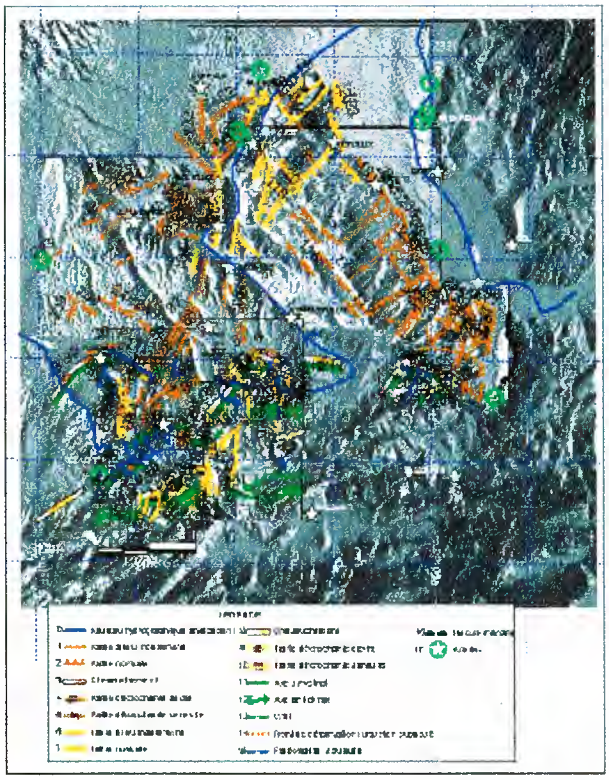


Figure 5 : Regional map of neotectonic indices and lineaments.

the Jura mountains front toward the North. The DEM analysis was completed by an extraction and analysis of the hydrologic network anomalies.
The study showed that the highest resolution DEMs (from a 1/25000 topographic map) provided a new view and allowed to discover several recent tectonic features, probably of quaternary age, south of the city of Basel which had never been mapped before (figure 6). Topographic profiles across these newly identified structures and 3D view clearly revealed superficial deformation zones which are probably related to recent (quaternary ?) movements. These structures where hidden below a densely urbanised area and invisible on all other images (stereoscopic SPOT pairs, aerial photos). A stereoscopic pair of SPOT images was used for a structural interpretation and the production of the DEM. The land-use ,mostly composed of urbanised areas, forest and crops) affected the quality of the DEM and the interpretation of the images. The smooth and low structures detected on the most detailed DEM (10x10m resolution) were not clearly detectable on the stereo pair neither on the SPOT DEM because of this unsuitable land-use. Nevertheless, the pair remained necessary to complete and extend the interpretation outside the area of the most accurate DEM area. A pair of ERS images in opposite orbites was also processed. Surprisingly, one of the images revealed quite well the morphology of the neotectonic structures discovered with the most accurate DEM, despite a lower resolution when the other orbit acquisition gave an image where urbanised areas and forest were extremely expressed and raised out from their environment compared to the morphology (except in the most mountainous area).
We also observed in several cases that lineaments and some topographic scarps can be confused or mistaken with forest limits. Such confusions can only be eliminated by a constant reference to other data, specially topographic maps which allow to identify land-use limits and topographic changes at the same time.
Further studies will be carried out around the new neotectonic structures discovered with the final objective to locate the best place for palaeo-seismicity trenching. This case revealed the necessity of complementarity of optical, radar images and accurate DEMs for the detection of smooth or recent structures of small amplitude with a weak topographic expression. The two main reasons are :

- in the area of work, showing very different land-uses masking totally the soils, small topographic structures may not appear in one of the spatial data or existing maps.
- there may be confusion between land-use limits and topographic or morphologic limits on radar images. This requires to analyse the images with complementary data (optical images or photos, topographic maps).
- Despite their different resolutions radar images and DEM can reveal very small structures not detectable on optical images, an lineaments narrower than the pixel size.
- The geometric deformations on radar images can induce severe interpretation errors when done by a non specialists or without complementary data.

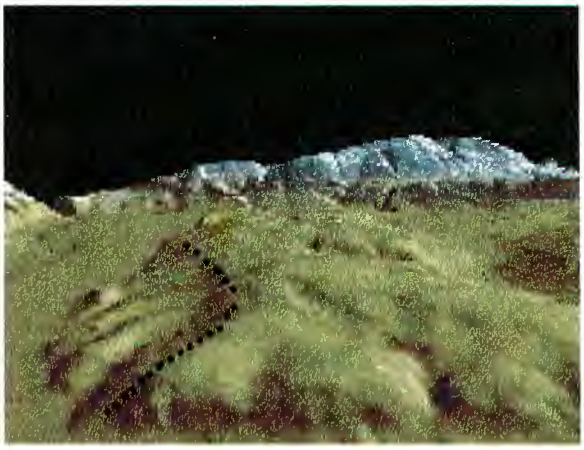


Figure 6 : 3D view with overly of shaded view on a 10x10 m pixel DEM

DISCUSSION : SCALE LIMITS AND ADEQUATION OF DATA SET TO LOCAL CONTEXT AND OBJECTIVES.

We can appreciate with these different examples, that no constant rule can be deduced in geomorphological or

geological mapping applications on which DEM or spatial images is the best to reach the objective. The adequacy between the used data and the results of the interpretation depends upon the geographical, land-use, topographical contexts on one side but also on orbital and geometric characteristics of used spatial data on another side.
Obviously, the higher is the spatial resolution, the better should be the result of morphological interpretation. Nevertheless, when reaching a certain degree of spatial resolution for the DEM or images of space origin , the information revealed is more related to the land-use than the real geomorphology, slopes or heights (specially for radar imagery). This is the case for our example in the Jura mountains.
Confusions can be withdrawn only by a cross analysis of different spatial data and existing, geological land-use of topographic maps. Such databases can be handled by GIS but a contradiction appears when using ERS images for which ortho-rectification is required before overlay on other maps when one works in an area with contrasted topography. Such corrections may induce artefacts on the corrected images which affects the interpretation. Interpretation on non-corrected images seems better but makes impossible a cross analysis in a GIS with other maps. This is partly false when working at very small scales on flats regions where geometric deformations are small and a simple geocoding can be used.
We also saw that in some cases, a single type of data may provide a fundamental information, factor or criteria, not accessible through the other data, and can change significantly the interpretation of an object or dynamic process. This means that a complete Remote sensing analysis may be false if the wrong kind of data is used or not correctly processed.

CONCLUSION

For geological hazards, very accurate DEMS seem to be promised to an increasing use specially for geomorphological applications. The high resolution provides a kind of information's which can be fundamental for the understanding of even very local phenomenon's which are not detectable on other kinds of data or from field studies. Interferometric DEMs generated from ERS imagery or SPOT are not suitable for such detailed studies which require photogrammetric DEMs of at least 1/25000 topographic maps for digitisation.
The intrinsic properties of radar imagery (all sensors included) make them a very useful as complementary data but cannot be considered as good enough to be used as a unique base for detailed or local mapping at very high spatial resolutions, specially in mountainous areas. Geocoding generates artefacts that limits the possibility of zooming on small areas.
In our cases of geological hazards, Digital elevation models remain the best base which can be completed by space imagery.
Nevertheless, with the multiplication of sensors and the availability in a near future of very resolution optical image will allow production of DEMs with small pixel size.
The wider choice of sensor will oblige projects managers in Earth observation to a very detailed study of the most suitable data to get the expected results, analysing in an early stage the geography of the study area, climatic conditions, size and trend of the studied structures with respect to the satellite, and its radiometric and spatial resolution and for dynamic processes, the frequency of acquisition.
The simulation (when possible, as a DEM is frequently required) can be in some cases a necessary tool to analyse feasibility and visibility of dynamic processes in the specific geometry of radar images (Ref.5).
Considering the diversity of geographical contexts and sensors now available and the availability of new data with very high resolution in a close future, any geological or natural hazards project will require a feasibility study in which the following parameters will be taken into account :

- objective of the imagery analysis within the project;
- geographical and topographical contexts of the studied area;
- spatial and spectral resolution;
- stereoscopy possibilities and possible derived products (digital elevation models for example);
- geometric deformations of the space products and geocoding difficulty and cost;
- complementarity needs and requirements;
- frequencies of acquisition and adequacy with evolution for dynamic processes studies.
- Interest of images simulations for sensors with multiple resolution and/or multiple incidence angles to select the best configuration (specially for radar imagery).

Such parameters are very likely to be also important for other thematic studies in land-use mapping, oil and mine exploration, agriculture and forestry, other non geological natural hazards (floods).

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USE OF SPACE TECHNIQUES FOR FLOOD MANAGEMENT PROJECT - APPLICATION TO RECENT FLOOD CASES -

Gerard Tarel
Alcatel Espace, 26 av. J.F. Champollion, B.P. 1187, 31037 Toulouse Cedex, France
Phone: +33-05- 6119 5810, Fax: +33-05-6119 5190, E-mail: gtarel@compuserve.com

Philippe Puyou-Lascassies
Scot-Conseil, Parc Technologique du Canal, 8-10 rue Hermès, 31526 Ramonville Cedex, France
Phone: + 33-05-6139 4600, Fax: +33-05-6139 4610, E-mail: philippe.puyou@scot.cnes.fr

ABSTRACT

Floods are one of the most frequent natural disasters and increase more rapidly than any other disasters in the world. This is more often due to non-sustainable development practices. Consequently, the vulnerability of social and economic systems is increasing more and more, even in highly industrialised countries.

An efficient way for mitigation and relief of disasters effects is to drastically improve the availability, dissemination and effective use of information on disaster areas, during crisis and post-crisis events. It is shown hereafter how information from space systems can effectively contribute to a better management of flood disasters. Several European pilot projects have been performed in 1997, through an ESA Contract. Results & conclusions are presented herein .

Earth Observation from space is, firstly, very useful for risk map assessment and watershed modelling of risk geographical area. Also, a combination of meteorological, space communications, and Earth Observation systems is essential for improving the crisis and post-crisis management . For making an effective use of space data, we propose to implement at national or regional levels, dedicated space based information Systems for the acquisition, selection, decentralised processing &.dissemination of information to the relevant international & national users community.

1. INTRODUCTION

Some people still believe that very little things can be done for mitigation and relief of natural disasters like floods, cyclones, droughts... Yet the economic cost of disasters has quadrupled since the 60s, a rise too steep to attribute only to natural forces. Non-sustainable development practices are now considered as a major factor in the rise of natural disasters to the point where experts frequently ask whether "natural" disasters are "acts of God" or "acts of Man".

Floods are one of the most frequent natural disasters and increase more rapidly than any other disaster in the world.

Disaster research has demonstrated that increasing hazard and vulnerability patterns are clearly related to flawed non-sustainable forms of development. Many hazards, such as floods, landslides, droughts... are related to patterns of human intervention. So, the vulnerability of social and economic systems is increasing, even in highly industrialised countries.

In the United States, the heavy damages made by hurricane Andrew have shown that *development* does not mean an eradication of vulnerability. Again, the nearly $20 billions in losses, from recent Oder floods in Germany and Poland, have drastically affected both insurance market and the whole economy of the countries. In some less developed regions, the economic losses may be lower, but the cumulative effect of thousands of small- and medium-scale disasters, occurring annually, may be even greater than a single large catastrophe jeopardising the lives and livelihoods of a large number of people.

2. NEEDS FOR INFORMATION RISK MANAGEMENT APPROACH

As more flood disasters impact people, economical assets and Organisations, disaster management has become an important issue for the governmental bodies at local, regional and national levels.

To fulfil their responsibilities, Officials must become better informed about what happens before, during and after the disaster. Efficiency of disaster management depends on the availability, dissemination and effective use of information. So, the ability to manage flood disaster rather than react to crisis only, is essentially depending on the availability of a dedicated and integrated risk management approach.

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

Several recent studies performed, at European level, have clearly highlighted the fact that space techniques including Earth Observation, Meteorology, Telecommunications and Localisation systems could be effectively used on a true operational basis for supporting the management of all phases of major risks (preparedness and prevention, crisis and post-crisis).

3. PREPAREDNESS AND PREVENTION PHASE

The mitigation of flood disasters is based first on a proper preparedness & establishment of comprehensive prevention plans. These tasks are currently under the full responsibility of the national Authorities in charge of risk prevention.

The Prevention plans needs the availability of many geographical information, which are useful for :

- implementing the relevant '***Risk maps***',
- watersheds '***Modelling***'.

The space Earth Observation techniques have the capability to deliver such geographical information, in complement of other relevant sources.

So, for the implementation of risk maps on a given watershed, the needed information are:

- Topographic information, such as Digital Elevation Model (DEM) and derived information (slopes, exposures, sub-basins);
- Historical data about the previous extent of past floods over the watershed;
- Land use & vegetal cover, arranged in few classes : urban, water bodies/rivers, arable land, forest cover, natural area;
- Human presence : housing, civil infrastructures, location of vulnerable sites (hospitals, chemical factories, hazardous materials storage area...).

The current need for scale of risk maps is a minimum of: 1:50000. However, in small geographical area a scale of 1:10000 even better, is expected by the Authorities in charge of risk prevention. This is typically the case in Italy, Spain, France...

The current commercial satellites have a scale capability limited to 1:50000, as for SPOT satellites. Military satellites have a better resolution but are not accessible on a commercial way. However, in the near future (1998), some new set of high-resolution satellite imaging systems with a spatial resolution of about 1 to 3 m , will start to be operated. The scale map capability will be in the range of 1:10000 to 1:5000. This will certainly boost the use of the satellites images for the risk management applications.

The watershed modelling techniques require also the availability of geographical information, of the same nature than those given above, in particular:

- Morphological data,: confluence order, river basin average slopes, water profiles, drainage density...
- Biophysical data: soil moisture , soil capability of water absorption...
- Anthropological data : human presence...

The possibility to use the Earth Observation information from space, in complement to traditional ground or airborne data is now technically proven and already well accepted by the end users, as shown throughout recent studies conducted in Europe on behalf of the Space Agencies. However, the operational use of the space techniques has still to be developed by governmental users. The use of space data should be considered by them as an integral part of an overall governmental risk prevention policy, and should be included in the preparedness procedures and rescue operations.

Beside the use of Earth Observation satellites, it should be emphasised that space communications systems have also a strong potential for a larger operational use. For example, satellite systems like Argos, Inmarsat... can be effectively used for flood monitoring by using their capabilities to collect hydrological parameters of watersheds like: height of water, water flow...

All these parameters can be fed up into hydrological models when used for flood extent forecast, alert and flood simulation.

We can expect in the near future that most of the space techniques will become more and more attractive both on economical and technical performances point of view and by using friendly user interfaces, allowing a true generalisation of such applications for major risks management. We should remind that space meteorology has already paved the way for space applications in the area of disasters mitigation and relief.

4. FLOOD CRISIS PHASE

In this phase of Risk, the space techniques can efficiently contribute to the crisis management, through :

- Meteorological satellites, which are currently used for weather forecasts over disaster area through the world-wide meteorological network. However, the forecast ability on a small geographical area is still too limited.
- Communications satellites could be used, more extensively, for collecting physical ground data in

order to monitor continuously the flood event and give alert when thresholds are over. Near real-time satellite system is requested .That implies a data acquisition rate better than or equal to 15 minutes, as an average.

- The geographical positions of rescue teams & vehicles or planes, when equipped with GPS receivers can easily be transmitted through Communications satellites to the operational co-ordination Centres which are often located far from the disaster theatre. Such information can save some logistical costs and lives.
- Earth Observation satellites are able to supply required data for making and updating flood expansion maps on a regular basis. The limits of the flood extent can be found by direct extraction of flood contours from image processing. The evolution of flood extent is often made by combining several multitemporal satellites data on the same topographic map in the background.

Satellites with optical sensors like SPOT, IRS... are able to deliver very high quality images but they have limited operational capabilities for supplying data at night or with dense cloud cover.

Radar satellites, like ERS, Radarsat... are quite more efficient for supplying data images during the crisis, due to their all weather, day and night capabilities.

However, the existing Earth Observation systems still have technical and operational limits. The delivery time of satellite data during crisis are a little bit too far from the current users requirements (few hours to a maximum of one day), due to their technical constraints on :

- Revisit period which remains between 1 to 5 days in average for a single satellite system,
- Time spent for satellite 'mission planning' and/or re-planning in case of emergency,
- Time necessary for data processing, image interpretation and dissemination to end users.

Recent real-time exercise as conducted during the last Germany and Poland Oder floods (July-August 1997), has shown that there is a high probability of getting satellite images during the flood event (typically between 1 to 3-days period), if all current Earth Observation satellite systems are mobilised during the crisis period. As the timely availability of information is crucial during a crisis, our last exercise has highlighted that the delivery time of satellite images is drastically reduced if an operational procedure between end users and satellite data providers is put in place before the crisis phase. Also, we are convinced that operational performances of Earth Observation systems can be well improved by complementing the existing systems by a new constellation of small radar satellites.

5. POST-CRISIS PHASE

Sometimes during a long period after the crisis phase, it is mandatory to restore and maintain basic communications services on the disaster area until nominal telecommunications services are re-established. Satellite communications systems could be used for that purpose due to their capabilities to :

- cover a large geographical area,
- to be deployed in a short time on disaster site.

The Earth Observation data could contribute to the assessment of damages after the crisis event. They have capability to provide very valuable information for a proper understanding of the entire crisis evolution. As most of the satellite data are presented on a digital format , their entries into dedicated databases are quite easy and economical. More and more users are equipped with such database tools for management purpose. Such databases could be used as 'learning base' for post-crisis analysis, return on experience and further training of rescue teams.

We should point out that 'damages assessment usually requires very high resolution images (1 to 3 m). Such space resolution is not currently available on a commercial basis, except for some images coming from Russian camera satellites (2-3 m) and for which the delivery time is often too long.

However, next year, very high resolution images (1 to 3 m) should be made available on a full commercial basis.

After the crisis, the satellites data can seriously help the end users to identify, analyse, and record any physical changes on the disaster area, such as landslide, heavy mud coverage, change of river bed...

All these information are also very important for updating the « risk maps », and the hydrological models. This has been demonstrated in our last pilot project conducted for ESA and in which several governmental users were duly involved (French Ministry of Environment, Italian Civil Protection, Spanish and French civil Protections).

6. INFORMATION SYSTEM CONCEPT

For flood risk management, as for other major hazards, the Earth Observation space resources and techniques which could be mobilised are numerous, various and complex. So, it is surely not easy for an end-user to directly access the space data and to master their processing and interpretation techniques, especially in an emergency situation. Also, we strongly believe that some dedicated space-based Information Systems should be created at a national or regional level by Authorities in charge of risks appraisal & management. Such Information system should interface with both world-wide satellite operators and end users. This system should operate as an information *server*. Any end user request should be taken into account by this server. The required space information should be delivered and controlled through the server in full compliance with the users requirements.

The main functions of this information server should be to:

- receive the end-user request made at one single access point,
- analyse the request and mobilise the relevant satellite resources,
- acquire the satellite data,
- process the data through one or several thematic units specialised by risk area,
- control the information quality,
- disseminate the information to end users through proper data communications networks.

7. CONCLUSIONS

The United Nations have declared the 1990's as the International Decade for Natural Hazards Reduction (IDNDR) due to the permanent increase of natural disasters in the world. Since a few years the European countries are paying more and more attention to the management of major hazards, and in particular to the floods. Most national economic development models and projects have not factored in Hazards or vulnerability areas and have then contributed to increase the susceptibility to disasters and to the degradation of natural resources. Sometimes they have even endangered the overall economic sustainability of the nation. We are convinced that Investment in disaster reduction sector can help to provide a more secure environment for investment by reducing insurance losses and avoiding the need to divert public funds from social development purposes to emergency relief.

The potential use of space techniques have now been investigated since 1994 by the European Space Agency (ESA), under the request of the Council of Europe acting in the framework of the Eur-Opa Agreement on Major Hazards and in full co-ordination with the French Space Agency (CNES) and several major European Civil Protections like Italy, Belgium, Spain and Russia.

Results got from our *pilot projects* on floods management are encouraging enough for now envisaging real applications to operational cases in complement of other traditional techniques. In order to facilitate the current use of the space tools, more awareness on space techniques, demonstration projects and training actions still to be conducted with the full involvement of operational users. In addition, we believe that the existing systems should be completed by small satellites constellation in order to increase their operational capabilities in particular during the crisis phase. Relevant space based Risk Information Systems have also to be progressively built by the end users, as basic risk management tool.

This is the way for any future progress in disasters reduction at the full benefit of the mankind.

Insurance Implications

SETTING-UP A RISK MANAGEMENT PLAN

A CRITICAL BROKER TASK

By Philippe MONTPERT and Benoit CONDROYER

International Space Brokers

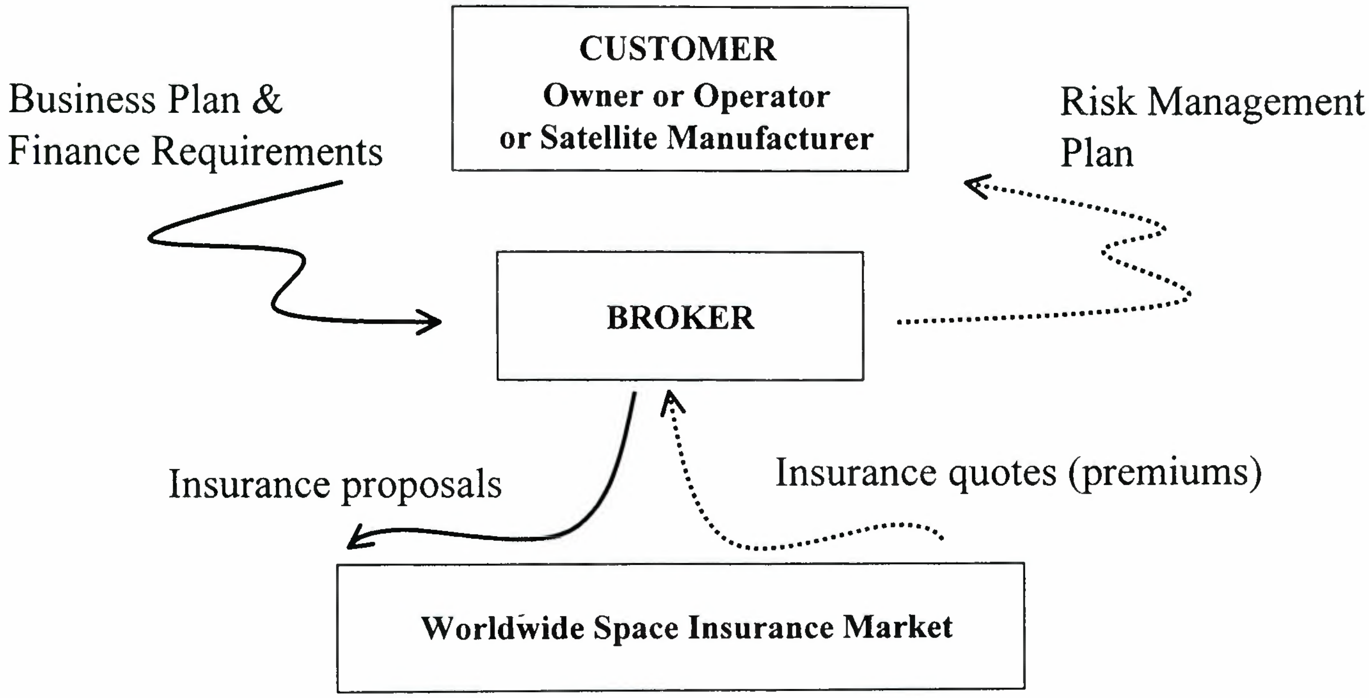
I - RISK MANAGEMENT ANALYSES

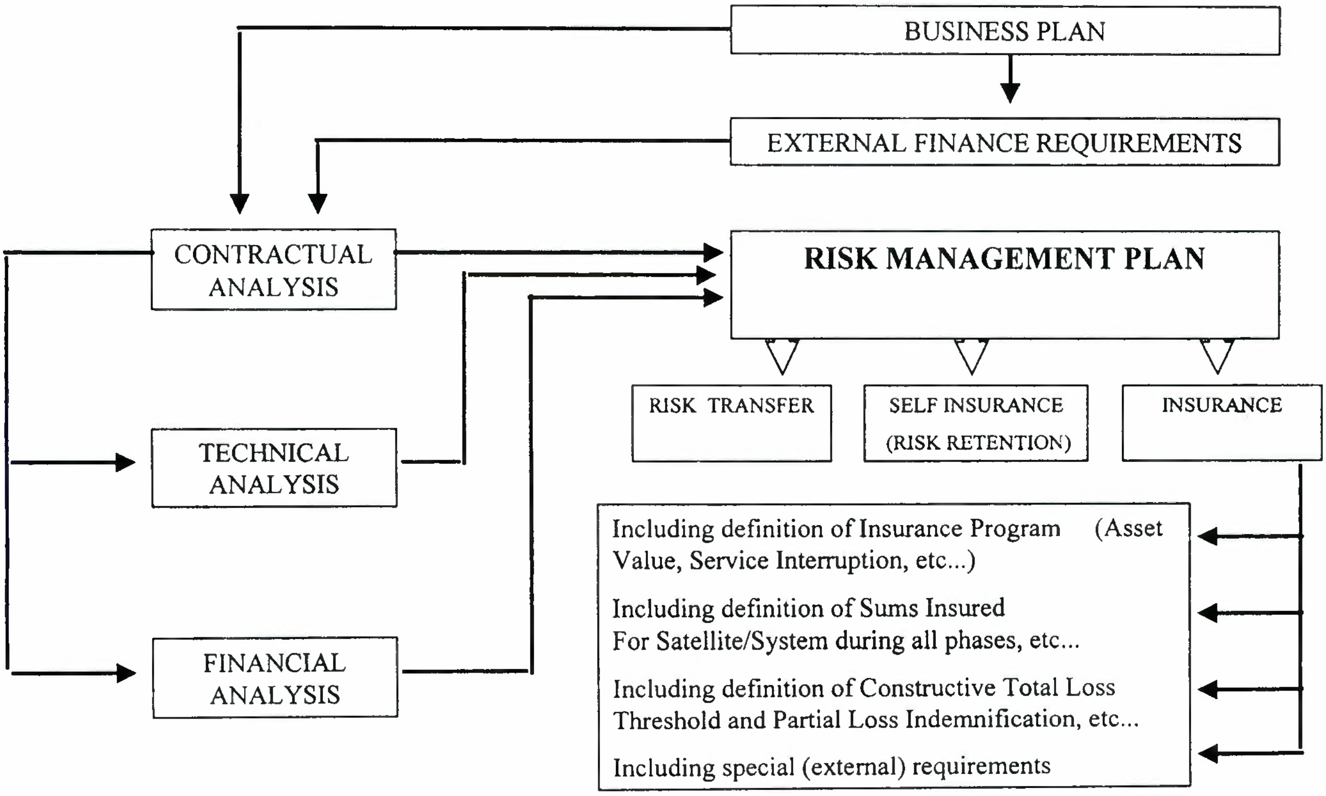
SPACE INSURANCE : THE PLAYERS

CUSTOMER	The **Owner / the Operator** **or** The **Satellite Manufacturer**
BROKER	**Risk management partner** **Customer' s representative**
INSURERS	**Specialized insurers in space**

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

SPACE INSURANCE : THE PLAYERS





RISK MANAGEMENT PLAN OBJECTIVES

- COMPLEMENT BUSINESS PLAN OBJECTIVES
- ENSURE FINANCIAL STABILITY
- ENHANCE PROGRAM FINANCING EFFORTS
- IMPROVE CLIENT'S MARKETING EFFORTS

STRATEGIC ELEMENTS OF RISK MANAGEMENT PLAN

- QUALIFY AND QUANTIFY EXPOSURES
- DEVELOP RISK TREATMENT OPTIONS
- OPTIMUM SOLUTION
- IMPLEMENTATION
- PROGRAM MONITORING

ANALYTICAL TOOLS / PROCEDURES

ANALYSES

RISK MANAGEMENT MATRIX

BROKER'S DATA BASES

RISK MANAGEMENT MATRIX

	PRE-LAUNCH PHASE	LAUNCH / DEPLOYMENT PHASE	COMMISSIONING / EARLY OPERATIONS PHASE	IN-ORBIT OPERATIONS PHASE
Financial Exposures	• **S/C Asset Value** . **(Transit / storage)** - Contract Obligations • **Liability** - Launch Site - Other • **Program Delay** - Debt Service - Operating Expenses - Extra Expenses - Revenue Loss - Contract Obligations	• **Asset Value** - Spacecraft Cost - Launch Vehicle Cost - Insurance, Other Capital Costs • **Revenue Loss / Extra Expenses** • **Third Party Liability** • **Manufacturer Incentives** (Pre-Separation)	• **Same as with Launch Phase**	• **Same as with Launch Phase** (Exclusive of Incentives)
Perils	• **Physical Damage** . **(A.V. & Delay)** • **Force Majeure (Delay)** • **Political Risk** • **Program / Technical (Delay)** • **Major Exclusions** - War Risk - Radioactive Contamination - Financial Insolvency	• **L/V + Propulsion Performance . Failure** • **Spacecraft Endurance** • **Deployment Hardware / Procedure** **Space Environment** • **Operator Error** • **Major Exclusions** - As with Pre-Launch - Intentional Acts	• **Spacecraft Commissioning &** . **Infant Mortality** • **Space Environment** • **Collision / Debris** • **S/C Control Center Failure** • **Operator Error** • **Major Exclusions** - As with Launch / Deployment Phase	• **Same as with Launch /** . **Deployment Phase** (Exclusive of L/V Performance, Propulsion, Commissioning, and Infant Mortality)
	T - (24 months) Satellite Contract Signing	T - 0 Launch (Intentional ignition or Lift-off)	T + (Deployment, approx. 30-60 days but usually including one eclipse	T + approx. 180 days (design life 12-17 yrs - longer fuel life)

T + __ yrs
End of Life

CONTRACTUAL ANALYSIS

- **OBJECTIVE - DETERMINE RISK EXPOSURES TO PARTIES**
- **TYPE OF CONTRACTS**
- **KEY CONTRACT CLAUSES**

  TRANSFER OF TITLE/RISK OF LOSS

  FORCE MAJEURE

  DELAY/TERMINATION

  WARRANTIES

  INCENTIVE PAYMENTS

  INTER-PARTY WAIVERS

TECHNICAL ANALYSIS OBJECTIVES

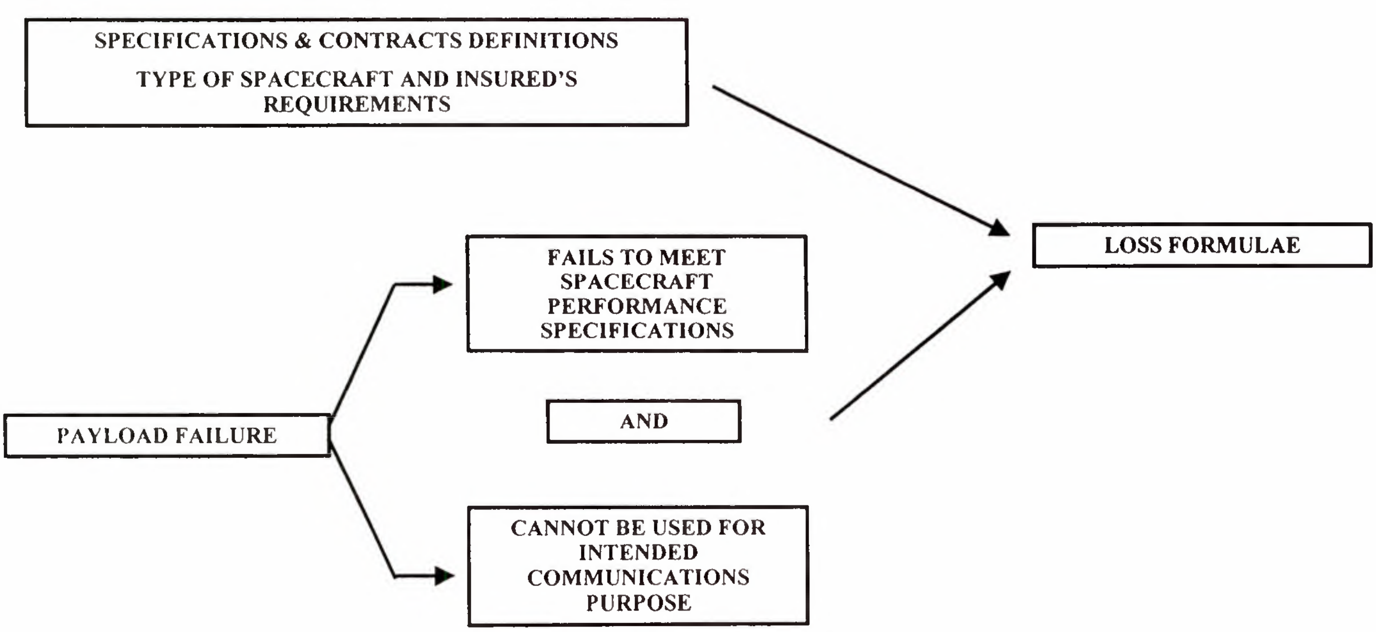
➡ Before the launch of the satellite

- UNDERSTAND THE SPACE AND THE GROUND SEGMENT.
- DESIGN POLICY DEFINITIONS TO ADEQUATELY COVER THE INSURED'S EXPOSURE
- BRIEF UNDERWRITING MARKETS.

➡ After the launch of the satellite

- KEEP MARKETS ADVISED OF ANY DESIGN CHANGES
- PROVIDE REGULAR HEALTH STATUS REPORT TO UNDERWRITERS.

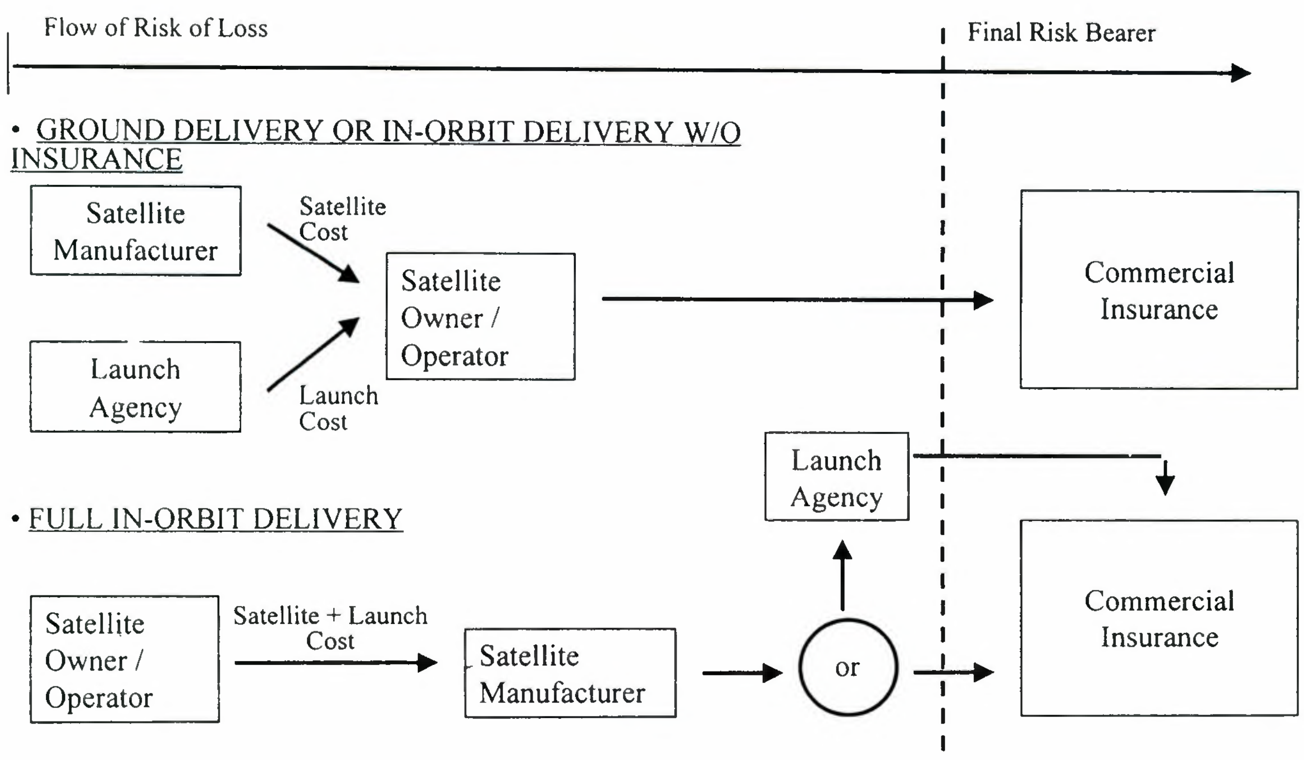
TECHNICAL ANALYSIS LEADING TO LOSS FORMULAE DEFINITION



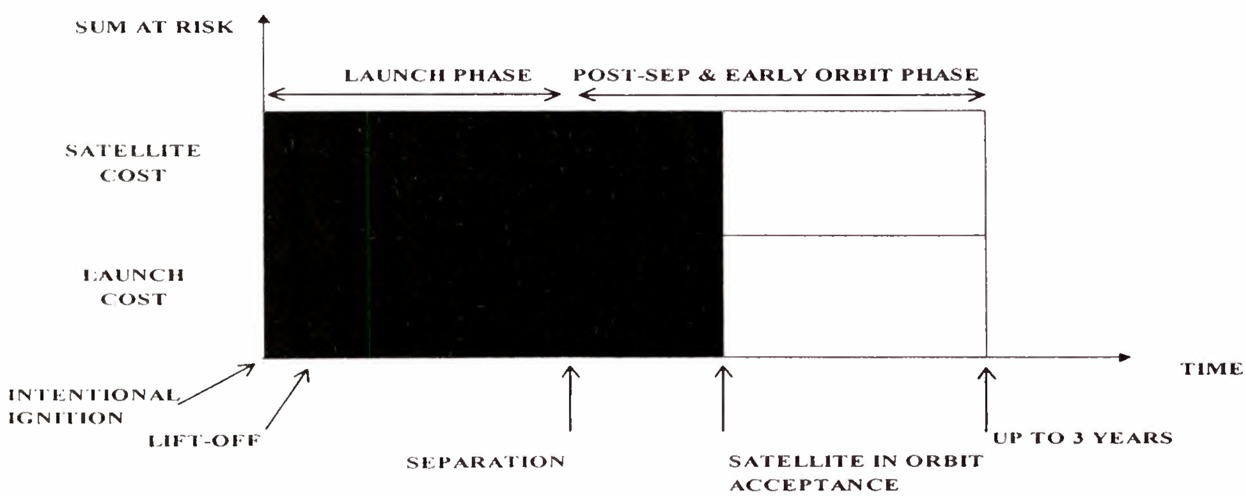
FINANCIAL ANALYSIS OBJECTIVES

- WORK WITH FINANCE GROUP TO IDENTIFY ALL PROGRAM FINANCIAL EXPOSURES
- ASSESS THE FINANTIAL CONSEQUENCES OF ANY SELF INSURANCE OPTIONS
- ADAPT THE SUMS INSURED AND THE PREMIUM PAYMENT SCHEME
- IDENTIFY THE USUAL EXCLUSIONS OF COVER IN THE SPACE INSURANCE MARKET.
- IDENTIFY THE CLAUSES USUFUL FROM A FINANTIAL POINT OF VIEW BUT FOR WHICH THERE NO (OR EXTREMELY LIMITED) INSURANCE MARKET.

RISK TRANSFER PROCESS
(Launch Risks)



RISK TRANSFER PROCESS



SELF-INSURANCE

- **OBJECTIVES**

  ASSESS FINANCIAL CAPACITY IN ORDER TO ABSORB LOSSES

  ANALYZE TRADE-OFF WITH OTHER OPTIONS

- **SELF-INSURANCE OPTIONS**

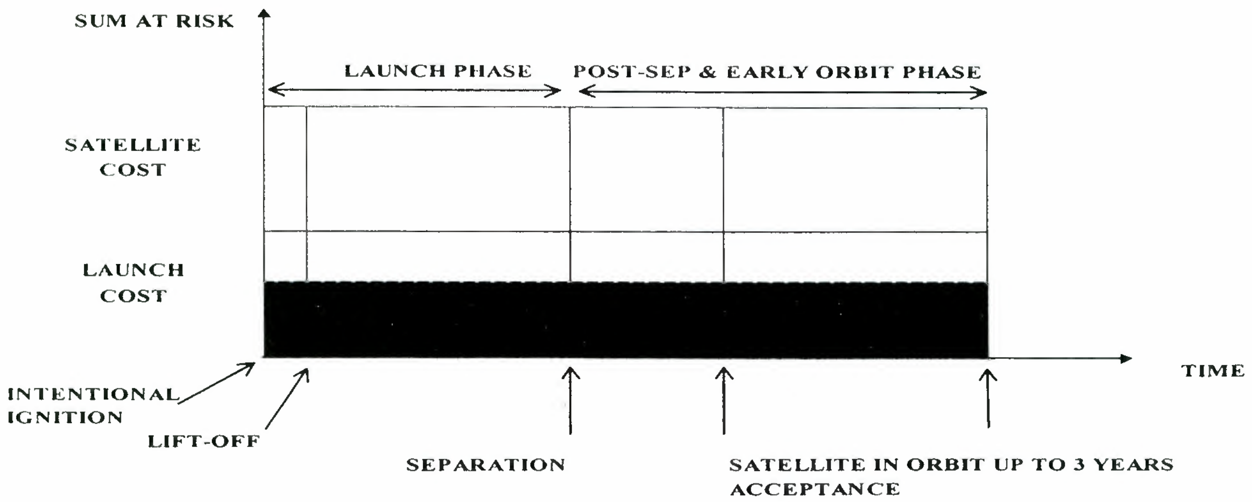
  PARTIAL LOSS DEDUCTIBLE AND OR FRANCHISE

  COINSURANCE

  LAUNCH FAILURE DEDUCTIBLE

II - RISK TREATMENTS

SELF-INSURANCE CHARACTERISTICS



COVERAGES OVERVIEW

- **PRE LAUNCH**
- **TERMINATED IGNITION**
- **LAUNCH AND COMMISSIONING**
- **IN-ORBIT LIFE**
- **THIRD PARTY LIABILITY**
- **POLITICAL RISKS**

LAUNCH & COMMISSIONING INSURANCE

- **INTEREST**
- **SUM INSURED**
- **SCOPE OF COVER**
- **PERIOD**
- **RATE / MARKET CAPACITY**

IN-ORBIT INSURANCE

- **INTEREST**
- **SUM INSURED**
- **SCOPE OF COVER**
- **PERIOD**
- **RATE / MARKET CAPACITY**

INTERNATIONAL SPACE BROKERS GROUP

ISB France
134 rue Danton
F 92304 Levallois Perret Cedex

Tel : (33) (0) 1 47 59 11 11
Fax : (33) (0) 1 47 59 93 82

ISB Washington
1300 Wilson Boulevard
Suite 990
Rosslyn, VA 22209, USA

Tel : (1) (703) 841 1334
Fax : (1) (703) 841 0525

ISB UK
America House
America Square
London EC3N 2AH

Tel : (44) (171) 488 1414
Fax : (44) (171) 265 1453

CASIOPEA RE IN THE SPACE AREA

J. Navas Oloriz

Casiopea Re

1. CASIOPEA RE

1. Breve historia
2. Situación financiera
3. Ramos y clientes

2. ¿POR QUÉ EL SECTOR ESPACIAL?

1. Pertenencia al Sector de Telecomunicaciones
2. Resultados técnicos del sector

3. EXPERIENCIA DE CASIOPEA RE EN EL SECTOR ESPACIAL

1. Lanzamientos Hispasat 1A y 1B
2. Colocación vida en Orbita:1995, 1996 y 1997
3. Aceptaciones facultativas: Lanzamientos y vida en órbita
4. Programas espaciales: SCOR, Generali

4. RESULTADOS TÉCNICOS DE CASIOPEA RE EN EL SECTOR

I. CASIOPEA RE

1. BREVE HISTORIA

Constitución: 9 de Junio de 1988

Sede Social: 73, Rue du Fort Neipperg

L-2230 LUXEMBURGO

Ejercicio: del 1 de Enero al 31 de Diciembre

Capital Social: 3,600.000 - ECU's

Accionistas: Telefónica de España (100%)

Auditor Externo: KPMG Peat Marwick

Telemóvil de El Salvador

Telecom de Colombia

COCELCO (Colombia)

Telefónica del Perú

CRT (Brasil)

Telefónica Móviles

TTD (Unisource España)

RIESGOS ESPACIALES

Hispasat

Contratos con SCOR y Generali

RIESGOS MARÍTIMOS Y OTROS

TEMASA (Buques Cableros)

Torres de Telecomunicaciones (Torre de Collserola, S.A.)

II. ¿POR QUÉ EL SECTOR ESPACIAL?

1. Pertenencia al Sector de Telecomunicaciones

1.1. Accionista: Telefónica de España, empresa líder en Telecomunicaciones.

1.2. Conocimiento técnico y tecnológico del sector.

2. Resultados técnicos del Sector

Coberturas de lanzamiento y de vida en órbita

III EXPERIENCIA DE CASIOPEA RE

EN EL SECTOR ESPACIAL

1. Lanzamientos Hispasat

1A

Fecha de lanzamiento: 11/9/92

Suma Aseguradora: 116 Mll. US$

Aceptación: 73,50%

Cesión: Mercado internacional liderado por Lloyd´s, Generali, Intec y Munich Re

1B

Fecha de Lanzamiento: 22/7/93

Suma Aseguradora: 134 Mll. US $

Aceptación: 86,30%

Cesión: Mercado internacional liderado por Lloyd´s, Generali, Intec y Munich Re

2. Colocación vida en órbita Hispasat 1A y 1B

1.995:

Aceptación: 87%

Cesión: 85,50%

1996:

Aceptación: 76%

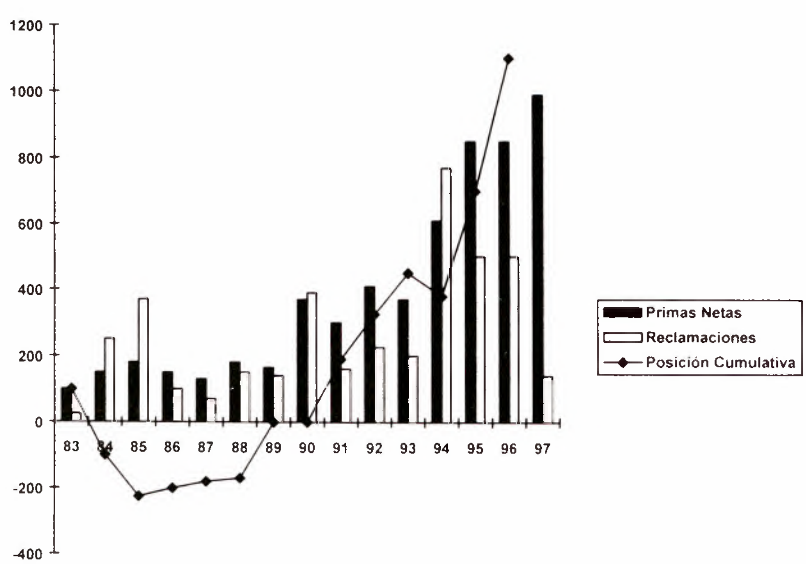
Cesión: 75%

1997:

Aceptación: 74%

Cesión: 73%

Cobertura de lanzamiento y de vida en órbita



Fuente: ISB

3. Aceptaciones facultativas: lanzamientos y vida-en-órbita

Brasilsat	Astra
Orion	Intelsat
Telecom	Panamsat
Motorola (Iridium)	Solidaridad 1 y 2
	Etc

4. Programas Espaciales

Son contratos obligatorios en los que Casiopea Re subscribe un porcentaje de las aceptaciones subscritas por otras reaseguradoras. En la actualidad, Casiopea Re tiene dos programas en vigor, subscritos con SCOR y Generali.

2. SITUACIÓN FINANCIERA (en ECU´s)

	1994	1995	1996
ACTIVOS TOTALES	85,434.796	102,638.575	110,163.427
RESERVA ESTABILIZACIÓN	64,951.369	77,888.799	84,817.799
INVERSIONES	59,562.353	72,297.936	86,902.599
PRIMAS EMITIDAS	24,767.200	23,914.650	32,152.918
EXCEDENTE ANUAL	5,592.689	12,937.430	8,089.358

HISPASAT Y EL DESARROLLO DE LA OFERTA AUDIOVISUAL EN ESPAÑA Y AMÉRICA

J. Jesus-Garcia

Hispasat

GENÉSIS Y CARACTERÍSTICAS

- Durante varios años, a finales de los ochenta y principios de los noventa, España era el mayor consumidor de capacidad espacial en Eutelsat (alrededor del 22% del sistema).

- La mayor parte de esta capacidad se consumía en aplicaciones domésticas:
  - Distribución de TV terrestre
  - Transporte TV a Canarias
  - Enlaces de respaldo

- Por lo que se identifica la necesidad de contar con un sistema de comunicaciones por satélite doméstico.

- Esa necesidad abría paso a un conjunto de oportunidades
  - Nuevos servicios
  - Nuevas tecnologías
  - Nuevos mercados

HISPASAT HOY

- Los dos satélites que conforman el sistema fueron lanzados respectivamente:

  - HISPASAT 1A: SEPTIEMBRE 1992
  - HISPASAT 1B: JULIO 1993

- La vida útil de los satélites excederá los 10 años previstos.

- Todos los complementos de redundancia están disponibles.

- La gestión y operación del sistema la realiza HISPASAT desde su CCS con total autonomía.

EL SISTEMA HISPASAT

DIFUSIÓN DIRECTA

- 5 transpondedores de alta potencia usando las asignaciones de frecuencia españolas de la CAMR-77.

SERVICIO FIJO

- 16 transpondedores de media potencia con cobertura sobre Europa occidental. Dos de ellos permitiendo transmisiones América-Europa.

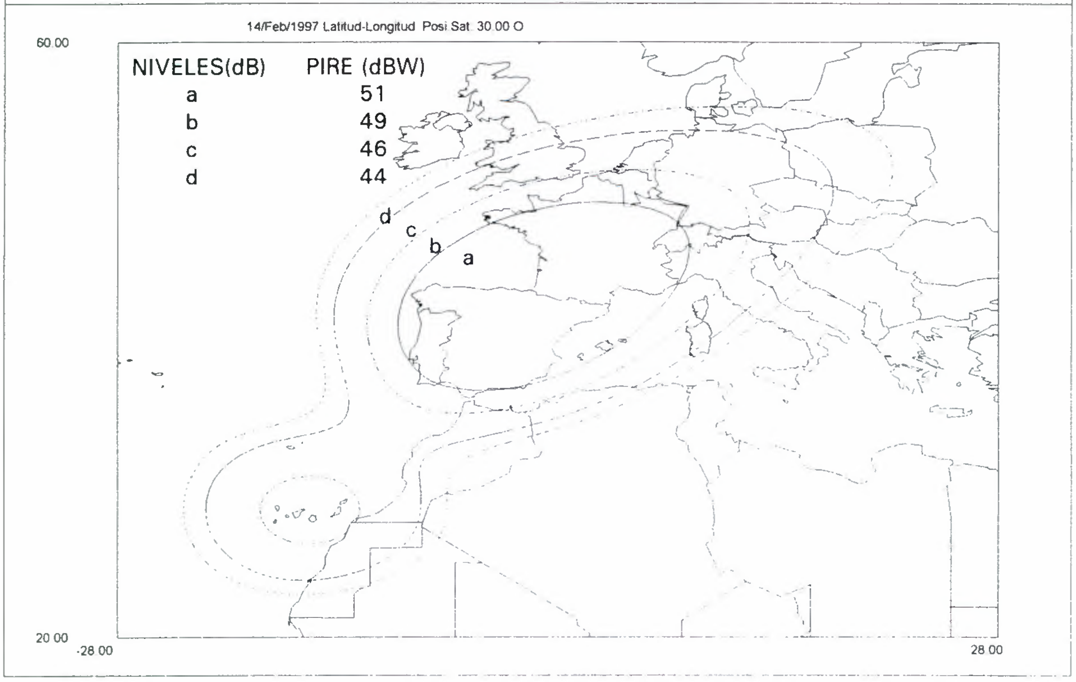
TV AMÉRICA

- 2 transpondedores para la distribución-difusión de TV sobre América.

GUBERNAMENTAL

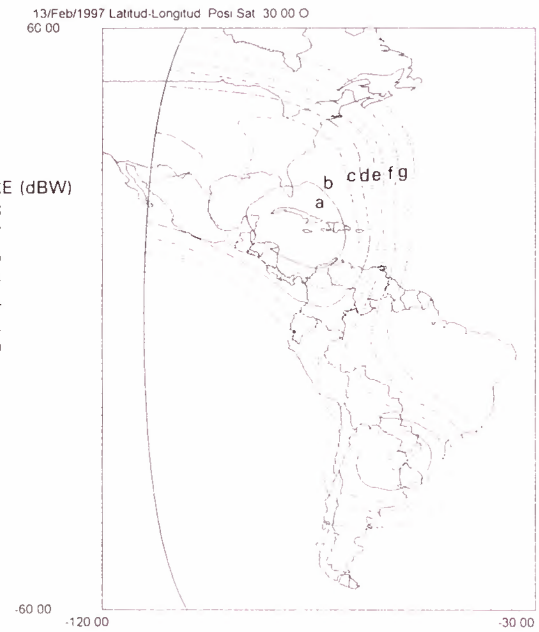
- El sistema está formado por 2 satélites cosituados en 30° Oeste.

COBERTURA SFS DEL SISTEMA HISPASAT-1



COBERTURA SOBRE AMERICA DEL SISTEMA HISPASAT-1

NIVELES(dB)	PIRE (dBW)
a	48
b	47
c	46
d	45
e	44
f	42
g	39



PRESTACIONES DEL SISTEMA HISPASAT

• Las prestaciones ofrecidas por el sistema están satisfaciendo ampliamente los requisitos de los clientes para la explotación de sus servicios.

•Las prestaciones de HISPASAT han permitido establecer relaciones comerciales y desarrollar el mercado en Europa Occidental.

•Todos los servicios:

- Difusión
- Transporte
- Contribución
- Empresariales
- Enlaces con la Red Pública

se diseñan con la mejores prestaciones en el área de cobertura de HISPASAT.

SITUACION DE OCUPACION ACTUAL DE HISPASAT

OCUPACION

SFS: 15 DE 16 CONTRATADOS COMPLETOS POR TODA LA VIDA UTIL.
- TRANSPONDEDOR 18: CONTRATADO A MEDIO PLAZO

SRS: CONTRATADOS POR TODA LA VIDA UTIL.

TVA: CONTRATADOS POR TODA LA VIDA UTIL.

GUBERNAMENTAL: CONTRATADO POR TODA LA VIDA UTIL.

EL VOLUMEN DE LO CONTRATADO A LARGO PLAZO SUPERA EL 99% MIENTRAS QUE CON LOS COMPROMISOS A MEDIO PLAZO SUPONE EL 100%.

UTILIZACIÓN ACTUAL (I)

RADIO Y TELEVISIÓN

- Difusión
- Distribución
- Transportes y
- Contribución

De prácticamente la totalidad de los productos audiovisuales españoles (tanto en analógico como en digital)

UTILIZACIÓN ACTUAL (II)

REDES DEDICADAS

Cerca de 40 redes con más de 4000 terminales

- Impresión de periódicos
- Agencias de noticias
- Sistemas de radiobúsqueda
- Redes de monitorización
- Teleenseñanza
- Telemedicina
- Otros

REDES PÚBLICAS

Sistemas troncales de capacidad media

SERVICIOS DE HISPASAT

- **ALQUILER DE TRANSPONDEDORES A LARGO PLAZO**
- **PORTADORAS DIGITALES**
  - No normalizadas
  - Redes normalizadas
  - Fracción de transpondedor
- **SERVICIOS NO PERMANENTES**
  - Ocasionales
  - Reserva por suscripción
  - Alquiler a medio plazo
  - Tiempo compartido

LA TV DIGITAL: UNA PROMESA HECHA REALIDAD

- La mayor parte de la carga útil civil de HISPASAT está dedicada a servicios de televisión y radio (= 80%).

- Es, por tanto, fundamental para HISPASAT el seguimiento de la evolución tecnológica, comercial y regulatoria de estos servicios. En particular, todo lo que concierne a la digitalización de la señal de televisión.

- Esta preocupación afecta a todas las aplicaciones, pero particularmente a la distribución y difusión de las señales.

- Por tanto, HISPASAT ha participado activamente en la elaboración de la norma europea de televisión digital y ha desplegado un importante número de actuaciones promocionales en coordinación con los operadores y la industria, a fin de desarrollar este mercado.

¿QUÉ OFRECE DE ESPECIAL LA TV DIGITAL?

CAPACIDAD

- Entre 6 y 9 canales de TV digital ocupan la misma capacidad que uno de TV analógica.
- HISPASAT 1A / 1B acomoda 90 canales de TV en su cobertura España/Europa y 20 canales sobre América.
- HISPASAT 1C continuará el desarrollo de una oferta audiovisual

NEGOCIO DE TELEVISIÓN

- La oferta adicional implica:
- Canales de pago (suscripción, PPV)
- Canales temáticos
- Nvideo on demand

OTROS NEGOCIOS

- Distribución de datos/software/videojuegos
- Distribución productos multimedia

HISPASAT Y LA OFERTA DTH

- Tanto los transpondedores de SRS de HISPASAT, como los transpondedores del SFS de 36 MHz (contiguos al SFS), permiten distribuir cerca de 40 Mbit/s a antenas de un tamaño no superior a 50 cm de diámetro (DVB, QPSK, FEC 3/4).

- Según la naturaleza del programa la codificación MPEG-2 puede exigir entre 4-6-8 Mbit/s para cada señal.

- Por tanto, HISPASAT está en condiciones de ofrecer de manera inmediata capacidad para una oferta de entre 13 y 15 transpondedores y por tanto, satisfaciendo el requisito de difusión de entre 80 y 150 canales, que podrían recibirse conjuntamente con una antena de menos de 60 cm. Actualmente se ofrece la programación de VIA Digital en 11 Transpondedores.

EL MERCADO ESPAÑOL: VALORES DE SATURACIÓN (I)

HIPÓTESIS

- Si cada segmento del mercado dedique un 20% de su capacidad de gasto/ocio a la nueva oferta de TV.

- Si los costes de suscripción al paquete básico no supera las 24.000 pts/año (IVA incluido).

- Si el coste del paquete premium es 48.000 pts/año, y 72.000 pts/año si se incluye el gasto de "pago por visión".

EL MERCADO ESPAÑOL: VALORES DE SATURACIÓN (II)

- El 65% de los hogares españoles disponen de capacidad de gasto para acceder a la TV de pago.
- El 40% de los hogares estaría en condiciones de suscribir canales premium.
- El 20% de los hogares contrataría regularmente servicios de pago por ver.
- Pero solamente el 25% de las familias estarían dispuestas a invertir 75.000 pts en la adquisición del equipo de recepción.
- El mercado potencial podría exceder 318.000 Mpts al año, pero sería necesario incentivar la compra de los receptores.

POTENCIAL DEL NEGOCIO TV DTH DIGITAL EN ESPAÑA

SITUACIÓN CONSOLIDADA

- Índice de penetración sobre total hogares ➪ 25%
- Gasto medio familia/año ➪ 48.000 Ptas. (iva incluido)
- Índice de penetración sobre mercado accesible ➪ 40 - 50%
- Volumen negocio anual ➪ 120 Millardos (pesetas de 1.996)

EL MERCADO LATINOAMERICANO

- De los 115 millones de hogares Latinoamericanos 37 disponen de capacidad financiera para suscribir TV de pago. (De 3000 a 3500 pesetas/mes).

- El crecimiento previsto para este mercado alcanzaría 45 millones de hogares hacia el año 2005. De ellos más del 30% se espera que suscriban a sistemas DTH.

- El mercado de servicios hacia el año 2005 alcanzaría 2.5 Billones de pesetas.

- HISPASAT desde su posición orbital en 30° Oeste está en condiciones de servir como vehículo para una parte significativa de la oferta de servicios dirigida a América Latina.

LA TV DIGITAL EN AMÉRICA LATINA

- El tamaño del mercado en América Latina permite la existencia de varias plataformas.

- La capacidad actual de HISPASAT permite la difusión de 20 canales europeos sobre toda Latinoamérica.

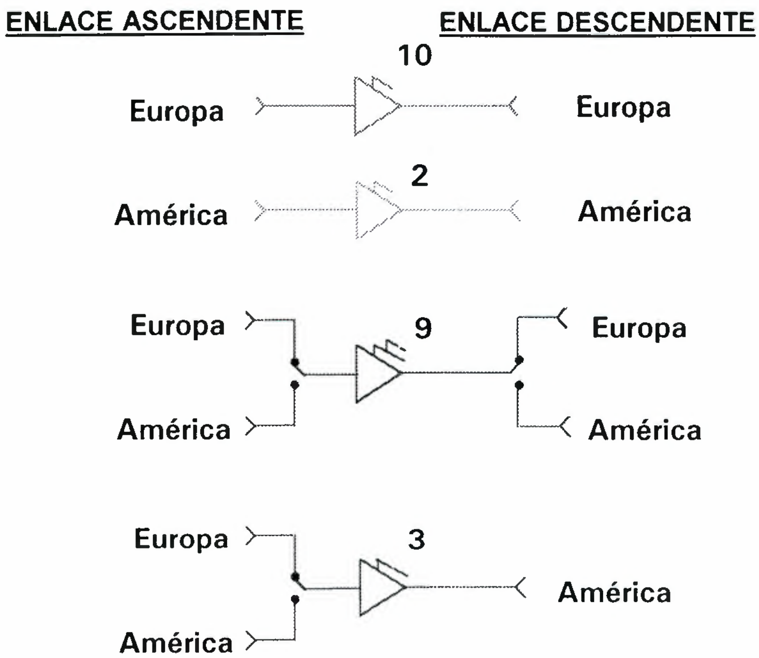
- El desarrollo del mercado se favorecería mediante una acción coordinada entre los proveedores de servicio.

HISPASAT 1C

- HISPASAT, S.A. ha tomado la decisión de poner en operación un tercer satélite en la misma posición geoestacionaria: 30° Oeste.

- HISPASAT 1C ofrecerá su capacidad: 24 transpondedores para dar servicios
  - Europa - Europa
  - Europa - América
  - América - Europa
  - América - América

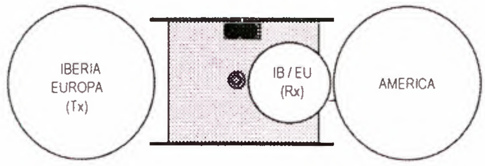
- HISPASAT 1c será lanzado a finales de 1999



Resultando:

Máximo Europa - Europa	=	19
Máximo Europa - América	=	12
Máximo América - Europa	=	9
Máximo América - América	=	14

HSA-1C : Configuración



- Posición Orbital: 30° W
- Frecuencias:
  - ✓ E. Ascendente: Europa+Iberia: 13.75-14.00 GHz
    12.75-13.25 GHz
    America: 13.75-14.50 GHz
  - ✓ E. Descendente: Europa+Iberia: 11.70-12.50 GHz
    10.70-10.95 GHz y
    11.20-11.45 GHz
    America: 11.70-12.20 GHz
- Canales:
  - ✓ Máxima conectividad entre coberturas
  - ✓ Ancho de banda: 36 MHz
  - ✓ 24 canales activos simultáneamente
- PIRE:
  - ✓ 44 a 56 dBW sobre Europa + Iberia
  - ✓ 44 a 47 dBW sobre América Hemisférica
- G/T:
  - ✓ 0 a +9 dB/K sobre Europa + Iberia
  - ✓ -5 a -2 dB/K sobre América

- Calendario de Entrega en Tierra: 24 meses
- Vida Útil (fiabilidad 0.75): 15 años
- Repetidor: 32 : 24 TOPs de 110 W
- Masa Seca:
  - ✓ Antenas: 111 kg
  - ✓ Repetidor: 197 kg
  - ✓ Plataforma: 901 kg
  - ✓ Capacidad de Propulsante: 1,756 kg
- Potencia:
  - ✓ Consumo carga de pago: 4,380 W
  - ✓ Consumo plataforma: 411 W
  - ✓ Potencia Paneles Solares : 4,790 W
  - ✓ Capacidad de Baterías: 2 X 118 A-h
- Masa de Lanzamiento:
  - ✓ ARIANE 4 (15 años): 2,800 kg
  - ✓ ARIANE 5 (15 años): 2,750 kg
  - ✓ ATLAS IIA (15 años): 2,950 kg

OBJETIVOS DE HISPASAT 1C

• Hacer frente a la demanda previsible para el desarrollo de la Plataforma de TV digital.

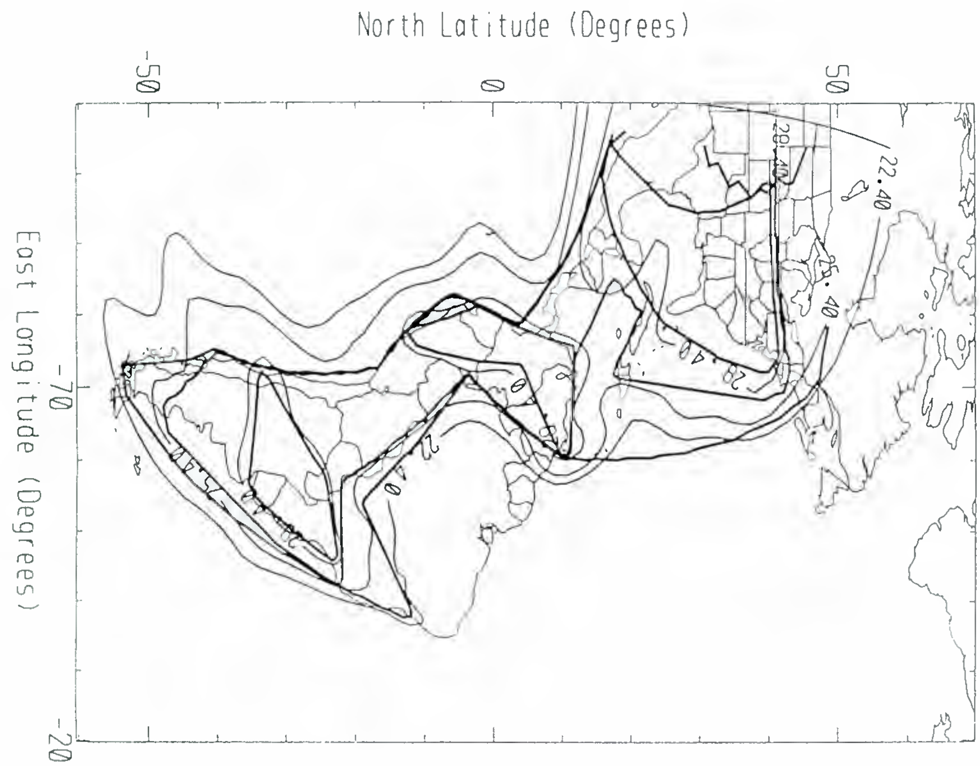
• Estar en condiciones de resolver las necesidades de capacidad espacial para distribución a redes de cable o a televisiones locales.

• Satisfacer la creciente demanda de capacidad para los diferentes servicios motivada por la liberalización: Garantizar que HISPASAT sigue siendo el proveedor principal de los operadores españoles.

• Facilitar, suavizar y simplificar el tránsito de servicios a la segunda generación

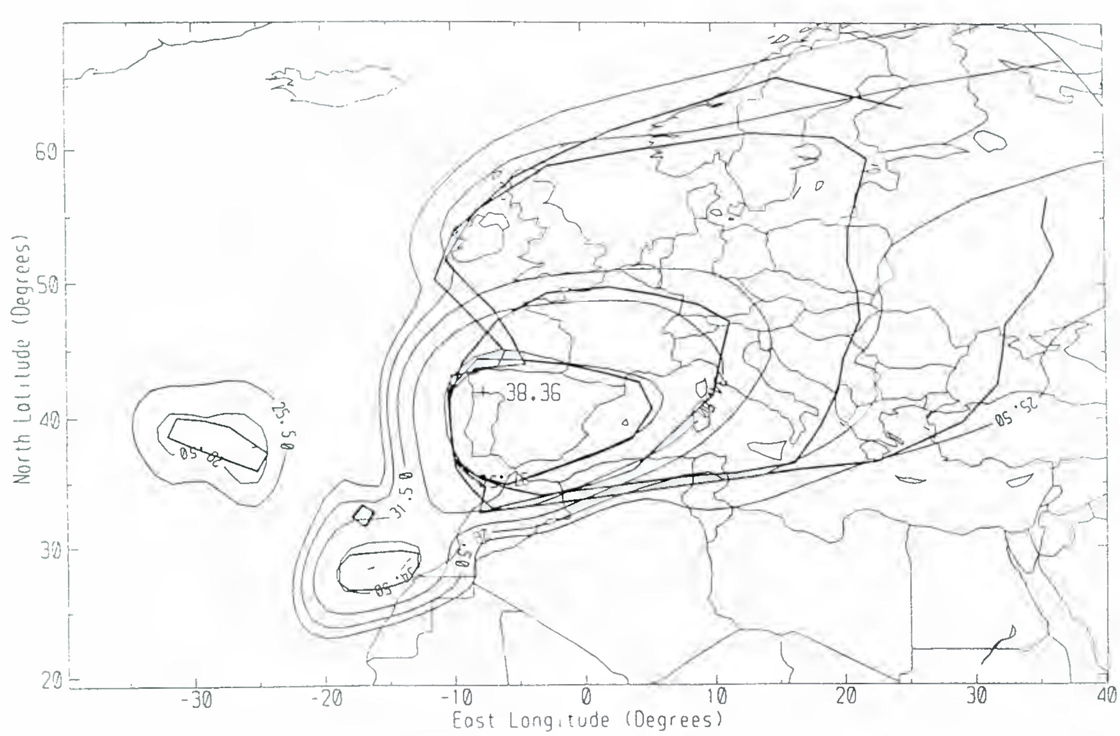
•Garantizar capacidad de respaldo en situaciones de emergencia.

•Reforzar y consolidar la posición estratégica de HISPASAT como proveedor de servicios en el ámbito latinoamericano..



EIRP = GAIN + 18,65
(dBW)
G/T = GAIN -27,55
(dB/K)

IBERIA/EUROPE TX GAIN



EIRP = GAIN + 18,65
(dBW)

Solidaridad : Example of an Insured Satcom Programme

EDMUNDO VILLASANA MUNGUIA
DIRECTOR SPECIAL ACCOUNTS
SEGUROS COMERCIAL AMERICA, S.A. DE C.V.

JUAN MANUEL ZAMUDIO ZEA
DIRECTOR OF SATELLITE OPERATIONS ENGINEERING
SATELITES MEXICANOS, S.A. DE C.V.

BACKGROUND.

- Satellite communications have always been viewed as a strategic area by the Mexican government and as an ideal means for bringing the population together in order to promote the country's economic, social and cultural development. In 1995, the process of involving private investment in the satellite sector was initiated. This process culminated with the sale of 75% of the stock in the recently established Mexican satellite company known as SATMEX S.A. de C.V. to Autrey (Mexico) and Loral (U.S.A.)

- Mexico has been a member of Intelsat since 1967. In 1968, a control center was installed in order to gain access to this worldwide system for use in televising the XIX Olympic Games.

- In 1980, INTELSAT placed a Series IV satellite for Mexico's exclusive use in the position 53°W (307°E). A transponder for SCPC telephone channels provides service to geographically inaccessible areas and, for the first time, Mexico's three major television networks can be seen throughout the entire country.

- In 1985, Mexico's Morelos I and II satellites were put into operation on the C and Ku bands, in orbital positions 113°W and 116.8° W. In order obtain a third position (109.2°W) it was necessary to reach an international agreement with respect to the relocation of several nearby satellites.

- In November 1993, prior to the end of the service life of Morelos I, the Solidaridad I was launched to occupy the position 109.2°W. Upon the de-orbiting of Morelos I, in March 1994, its orbital position was occupied by Solidaridad 2 (113.0°W).

- The Solidaridad satellites have greater coverage and power and operate on 3 frequency bands: C, Ku and L. They are equipped with beams directed toward Central and South America, as well as cities with large Hispanic populations on the East and West Coast of the United States.

SOLIDARIDAD I and II.

On 3 December 1990, the Mexican Communications and Transportation Ministry, through Telecomunicaciones de México, published an international request for bids directed toward companies specializing in the construction of telecommunications satellites. Among other things, the request for bids included the following specifications:

1. SOLIDARIDAD SATELLITES

Two similar telecommunications satellites with triaxial stabilization and a minimum operational service life of 10 years, using the same configuration, to be quoted on the basis of two versions:

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

- Version A: two satellites, each with 18 active transponders on the 6/4 Ghz band (C Band), 12 active transponders on the 14/12 GHZ band (Ku Band), operating on the basis of multiple frequency re-use schemes with linear orthogonal polarization, and one active transponder on the 1.6/1.5 Ghz band (L Band), with right circular polarization and the corresponding back-ups.

- Version B: two satellites, each with 18 active transponders on the 6/4 Ghz band (C Band) and 14 active transponders on the 14/12 GHZ band (Ku Band), operating on the basis of multiple frequency re-use schemes with linear orthogonal polarization, including the corresponding back-ups.

2. CONTROL CENTERS
Including a primary control center and the establishment of an alternate control center with the functions associated with the placement in orbit phase, plus all the main functions for maintaining the geo-stationary orbit of both satellites.

3. DYNAMIC SIMULATION AND PAYLOAD TEST LABORATORY
The principal objective of which is to analyze normal and abnormal conditions with respect to the operation of the SOLIDARIDAD satellites, on the ground.

4. PARTICIPATION, TECHNOLOGY TRANSFER, TRAINING, INSTRUCTION AND TECHNICAL ASSISTANCE PROGRAMS
Programs which allow for the participation of Mexican scientists, engineers and technicians in the various stages of the Solidaridad project:

4.1 Program for the participation of Mexican Personnel
4.2 Technology transfer program
4.3 Training, instruction and technical assistance program

5. MAINTENANCE, SPARE PARTS AND BACK-UP FOR THE PRIMARY AND ALTERNATE CONTROL CENTERS
For the proper operation of the primary and alternate control centers in the event of a contingency, throughout the entire life of the satellites.

In conjunction with the foregoing, on 12 December of the same year, the Telecommunications Department once again requested the involvement on the part of what was then Aseguradora Mexicana (currently, Seguros Comercial América, División ASEMEX) which respect to insurance coverage and the design of a Risk Management program so as to provide for the adequate coverage of the property and services during the construction of the Solidaridad I and Solidaridad II satellites, the primary and alternate control centers, as well as the launch and operation of the aforementioned satellites. At the same time, it was requested that a confidentiality agreement be signed between the two entities.

In fact, relations between Telecomunicaciones de México and the former Aseguradora Mexicana began in mid-1983, with the development of the MORELOS I and II satellites, i.e., first generation of satellites in the Mexican Satellite System.

Between 1983 and 1985, executives from TELECOMM and ASEMEX held frequent meetings in order to approach the reinsurance market, design, prepare and negotiate the best terms and conditions available at that time in the market.

Unfortunately, during this period of time three telecommunications satellites were lost and this resulted in a decrease in the capacity of the reinsurance market and, consequently, launch insurance costs increased significantly.

With respect to the second generation of satellites, SOLIDARIDAD I y II, ASEMEX, signed the aforementioned contract for the rendering of technical-professional services in connection with the review of the Risk Management program for the supply, launch and commissioning for service of the satellites, including an analysis and evaluation of the proposals with respect to Risk Management programs presented by the bidders in connection with the construction and launch of the satellites.

The Risk Management program proposed by Aseguradora Mexicana (currently, Seguros Comercial América, División ASEMEX) consisted of three stages:

First stage: Preparation of the bidding specifications.
Preparation of the wording with respect to the Risk Management section in the bidding specifications.

Second stage: Analysis and evaluation of the proposals.
- Analysis and evaluation of the proposals presented by the bidders.
- The design of the questions in this regard to be formulated to each one of the bidders in order to fully understand the details of their proposal.
- The preparation of draft of the corresponding policies, containing the contractual wording to be agreed upon with the winning supplier and launcher, so as to achieve an optimum Risk Management program.

The strategy to be followed during this second stage is principally oriented toward a comparison between the proposals presented and the programs which were in effect so as to evaluate the actual possibilities of those proposals whose creativity and/or aggressiveness might go beyond the real capacity of the satellite insurance market.

Third stage: Review of the final contracts.
Review of the satellite supply and launch contracts, prior to their signing, so as to detect any anomalies in the wording and guarantee that the terms and conditions agree upon during the course of the negotiations are included in the final documents.

In this regard, a schedule of activities was prepared with a duration of approximately four months, leading to the final delivery of a document to be included as an attachment to the bidding specifications.

THE RISK MANAGEMENT PROGRAM.

1. Contractor-supplied insurance.

The contractor must obtain, at their own expense, without limitation, the following insurance coverages. This, however, does not relieve the contractor from total liability for the coverage of all the risks inherent in the supply of the system, as of the date on which the contract is signed and until final delivery.

1.1 Full coverage insurance (ALL RISK)

1.1.1 The full coverage (all risk) insurance policy/policies must be worded on forms authorized by TELECOMM and must insure the contractor, subcontractors and suppliers, as well as TELECOMM, with respect to any possible loss or damage, payable to the beneficiaries as their corresponding interests may appear or in accordance with their instructions.

1.1.2 The insurance must cover the property manufactured and/or supplied by the contractors, subcontractors and suppliers at their respective plants or installations, or any other work site which may be used or operated by the contractor for purposes of construction or storage. The policy must also cover the transit and transport of the property forming the subject matter of the supply contract, as well as any other activity which takes place until the lift-off of the launch vehicle.

1.1.3 The sum insured must be sufficient to cover the replacement value of the property to be supplied, i.e., both the property forming part of the control centers, as well as the SOLIDARIDAD satellites.

1.1.4 The policy/policies must insure the loss of or damage to the property manufactured, built and/or supplied, forming the subject matter of the respective contract, as of the date on which work begins at the contractor, subcontractor or supplier's plant or installations, and must remain in effect until such time as the liability of the aforementioned parties has expired, in accordance with the terms established in the supply contract for the SOLIDARIDAD satellite system.

1.1.5 The supplier will be liable for the payment of the deductibles, as well as for any loss which is not covered under the terms of the policy/policies, without any limitation whatsoever.

1.1.6 The policy/policies must include the following clause:

"In the event any payment is made under the terms of this policy, the Company shall be subrogated in all the beneficiary's rights of recovery which may exist against any person or organization, and the beneficiary must deliver and execute any type of instrument or document and carry out all the acts necessary to enforce such recovery rights. The company agrees not to enforce or assign to any third party said subrogation rights against:

A. Any corporation, partnership, firm, individual or interest with which the Insured, prior to the occurrence of the loss or damage, has agreed to waive liability with respect to such loss or damage or has agreed to include as additional insureds, nor against any subsidiary or any other company managed by the beneficiary;

B. Any third party, as established in the contractual dispositions applicable to the supply of the SOLIDARIDAD satellite system;

C. Contractors, subcontractors and carriers who have agreed or signed contracts to supply work or services with any of the entities to which reference is made in this Risk Management Program and, particularly, in this section; and

D. Other users of the respective launch services and/or their contractors, subcontractors and carriers.

1.2 TRANSPORT INSURANCE.

1.2.1 For purposes of this section, "transport" is deemed to be the movement of the property forming the subject matter of the contracted supply, from the construction site to the location designated for the launch or storage of the said property.

1.2.2 The transport insurance policy must provide full coverage, i.e., it must grant all risk coverage and must include all the clauses which are characteristic of policies of this type. The policy must be in a form approved by TELECOMM. The policy must insure the loss of the property forming the subject matter of the contract for the supply of the SOLIDARIDAD satellite system.

In the event of any accident resulting in the loss of the property forming the subject matter of the contract, the corresponding indemnity will be paid to the contractor and TELECOMM, as their interests may appear or in accordance with the instructions issued to the Company.

1.2.3 Coverage under the terms of this policy will take effect as of the start of the loading operations in connection with the property forming the subject matter of the contract on board any vehicle or means of transportation and will remain in effect while the property is in transit or in the custody of any carrier or bailee.

1.2.4 The sum insured must be equal to the replacement cost of the property to be supplied in connection with the SOLIDARIDAD satellite system which is being transported or which is in transit both to its final destination and to the launch site.

1.2.5 The insurance must be subject to the application of a deductible and must cover the risks to which reference is made in this program, as well as any others which may arise as of the signing of the contract for the supply of the property, and until the lift-off of the launch vehicle.

1.2.6 The insurance policy must include the clauses to which reference is made above in section 1.1.6 of this Risk Management Program.

1.3 GENERAL LIABILITY.

1.3.1 The general liability insurance policies must be worded on forms expressly authorized by TELECOMM and must include the contractor, TELECOMM and their agents as insureds.

1.3.2 The insurance to which reference is made in this section must take effect as of the awarding of the contract and must remain in effect until the contractor removes their launch support crew at the designated launch site, after having properly placed the equipment and satellites at the place designated for this purpose by TELECOMM.

1.3.3 The General Liability policies shall not be subject to the payment of a specific amount in the form of a deductible.

1.3.4 The liability insurance obtained by the supplier will be subject to a combined limit of no less than US$ (to be proposed by the bidder) and must include bodily injury and property damage arising from any type of risk.

1.3.5 The policy/policies to which reference is made in this section must include the following coverages:

A. Bodily injury to third parties.

B. Third party property damage.

C. Contingent employer's liability.

D. Contractual or extracontractual liability with respect to the supply of the SOLIDARIDAD satellite system.

E. Liability (broad) for the use of non-owned vehicles.

F. Cross liability clause.

G. "Other insurance clause" which must establish that these policies are primary with respect to any other insurance obtained by TELECOMM.

H. The policy/policies must include the clause to which reference is made above in section 1.1.6 of this Risk Management Program.

The policy/policies must include an express agreement by the parties with respect to the waiver of liability which may arise between the insured parties at the launch site.

1.4 Insurance covering delay in the delivery of the property and services forming the subject matter of the contract for the supply of the system.

The contractor will be under the obligation to obtain insurance which indemnifies TELECOMM for the damage and loss caused by delay in the delivery of the property and services forming the subject matter of the respective supply contract.

2. INSURANCE OBTAINED BY TELECOMM.

TELECOMM will obtain, provide and maintain the following insurance at its own expense:

2.1 GENERAL LIABILITY INSURANCE.

2.1.1 The general liability insurance policy will be worded on a form developed expressly by TELECOMM and will be specifically applicable to the launch of the satellites at the designated launch site, and will include all the pre-launch operations carried out at the launch site and which are required by the launch agency and/or the government of the country in which the launch takes place.

2.1.2 The policy will name the contractors, subcontractors and/or suppliers as beneficiaries and must include the cross liability clause, as well as the agreement by the parties to waive liability between the insured parties.

2.1.3 This insurance will take effect as of the start of the launch support services and the arrival of the property forming the subject matter of the supply contract with respect to the SOLIDARIDAD satellite system to the designated launch site, and shall remain in effect for a period of thirty days after the launch date.

2.1.4 This policy will not be subject to any deductible whatsoever.

2.1.5 The liability coverage obtained by TELECOMM under the terms of this policy must be sufficient to meet the requirements of the launch agency and/or the government of the country in which the launch takes place.

3. GENERAL INSURANCE REQUIREMENTS.

The contractor, within thirty days as of the signing of the contract, must provide

TELECOMM with the insurance certificates issued by the insurer(s) in connection with the coverage of the risks to which reference is made in this document. In the event the policies have been obtained by the contractor specifically in connection with the supply of the SOLIDARIDAD satellite system, TELECOMM must be provided with certified copies of the policies.

4. INVOICES WITH RESPECT TO THE PROPERTY TO BE SUPPLIED IN CONNECTION WITH THE SOLIDARIDAD SATELLITE SYSTEM AND THE RISK OF LOSS OR DAMAGE.

4.1 The partial invoices with respect to the property forming part of the supply, which is delivered and forms the subject matter of the periodic payments established under the terms of the supply contract, must be sent to TELECOMM and must be free of any claim or liability, lien, charge or impediment, regardless of the fact that TELECOMM has acquired ownership of the property. The presentation of partial invoices shall not constitute final acceptance of the deliveries in question and shall not release the contractor from the obligations agreed upon in the contract.

4.2 The invoices in connection with the partial deliveries agreed upon in the contract and established in the respective work schedule shall only be obligatory with respect to TELECOMM insofar as the acceptance thereof is concerned.

4.3 TELECOMM may request that the contractor store the property forming the subject matter of the respective supply contract, upon completion of the property's manufacture or construction, prior to its transport to the launch site, and the contractor shall assume all the risks with respect to damage to or the partial or total loss of the aforementioned property during the storage period.

4.4 The contractor shall be liable for the damage to or the partial or total loss of the property forming the subject matter of the respective supply contract during the transport thereof to the launch site and its subsequent storage, as well as during the launch support services, whether such transport is carried out by the contractor or is subcontracted to a third party, caused by any individual or entity and arising from any cause, whether due to negligence or any other cause, until the lift-off of the launch vehicle.

4.5 With the exception of the terms established above in sections 4.3 and 4.4 and below in section 5, the contractor will be liable for any damage to or partial or total loss of the property forming the subject matter of the respective supply contract up until the lift-off of the launch vehicle and with respect to all the property supplied until the delivery thereof in accordance with the terms agreed upon in the respective contract.

5. LIABILITY INSURANCE FOR DAMAGE AND TOTAL OR PARTIAL LOSS.

5.1 The contractor must indemnify and hold TELECOMM, its officers, employees, representatives and agents harmless against any loss, damage, liability or expense arising from property damage including, without limitation, property owned by TELECOMM, and with respect to bodily injury, including death, sustained, without limitation, by the employees of the contractor, their subcontractors, TELECOMM and the employees of any other person involved in the execution and supply of the property or services forming the subject matter of the respective contract, arising in connection with any accident or occurrence caused by a negligent act or omission or otherwise attributable to the contractor, their subcontractors, employees, agents or all of them, and at their own expense shall respond to and defend any legal action initiated against TELECOMM, its directors, technicians, employees or agents, jointly or separately, relating to the contract for the supply of the SOLIDARIDAD satellite system, and shall pay all the related expenses and discharge the liabilities arising in connection with such legal actions, incurred by or attributable either individually or collectively to the aforementioned persons.

TELECOMM and the contractor agree and acknowledge that the stipulations contained in this section shall not be applicable to the launch support services provided by the contractor in accordance with the terms established in the respective supply contract requiring that personnel or materials to be contracted or utilized by the contractor at the designated launch site.

Clarification to the bidder.

The parties involved in a discharge of liability agreement must take into consideration that any final agreement or contract will contain the provisions established below in section 5.2.

Regardless of the fact that that the contents or wording employed below in section 5.2 are affected by the stipulations or clauses contained in the contract for the rendering of launch services signed by TELECOMM, this must be understood as follows:

5.2 TELECOMM and the contractor agree to sign a hold blameless and waiver of subrogation agreement, releasing the parties from liability, under the terms of which each party assumes liability for any damage caused as the result of the damage to or total or partial loss of their property and affecting their respective employees, including death, arising from the launch operations in or around the designated launch site, whether such damage or total or partial loss is imputable to or caused by both the contractor and TELECOMM, the launch contractor or a third party involved in said launch operations, and regardless of whether the damage or total or partial loss arises as a consequence of negligence or any other cause, and it is the intention of the parties to this waiver of liability agreement that it be interpreted broadly so as to achieve its intended purpose.

For purposes of this section 5.2 both parties further agree that if they subcontract with third parties with respect to the rendering of services which require the presence of said third parties at the designated launch site, the contractor or TELECOMM, as the case may be, acknowledge and agree that the aforementioned subcontractor will be required to sign a hold blameless and waiver of subrogation agreement, releasing the parties from liability, containing the immunity with respect to damages and total or partial loss as established in this section.

In the event that TELECOMM or the contractor fails to obtain from their subcontractors the liability release agreement to which reference is made in this section, the parties shall mutually indemnify and hold each other and all the other users of the launch services and their respective contractors and subcontractors at the designated launch site harmless against any actions initiated against the contractors and/or subcontractors of TELECOMM and/or the contractor, with respect to damage to or the total or partial loss of the property, bodily injury to or the death of the employees of said subcontractors at the designated launch site who are carrying out activities or operations in connection with the launch.

5.3 The contractor and TELECOMM will obtain and maintain in effect the applicable insurance, at their own expense, in accordance with the stipulations established in this Risk Management Program which forms an integral part of both the bidding specifications for the supply of the SOLIDARIDAD satellite system, as well as the corresponding contract. Furthermore, the contractor must include in any subcontract, the price of which exceeds US$ 1 million, relating to the construction, manufacture or rendering of services in connection with the contract for the supply of the SOLIDARIDAD Satellite System, the obligation to obtain and maintain in effect insurance coverage which is similar to that obtained and maintained by the contractor, in accordance with the terms of this Risk Management Program. If the subcontractor for any reason fails to obtain and maintain the aforementioned insurance in effect, the subcontractor will be under the obligation to guarantee that the manufacture, construction, supply or rendering of services relating to the contract for the supply of the SOLIDARIDAD Satellite System is duly insured for the benefit of TELECOMM in accordance with the terms established in this Risk Management Program.

5.4 Independently of any of the terms or stipulations set out in the contract for the supply of the SOLIDARIDAD Satellite System, section 5 shall be applicable to and binding upon the parties involved in the aforementioned contract.

CONCLUSIONS.

The launch phase is the most critical of all the phases, due to the fact that it is at this point that the satellites are exposed to the greatest risk and the possibility of total loss is particularly high. The possibility of a total loss during the launch phase will largely depend upon the type of launch vehicle.

Despite the improvements which are constantly being made in the design of the vehicles, there remains a margin for possible failure. One of the reasons for this is that, in general, the technical improvements are designed to increase the efficiency of the launch vehicle, rather than to increase the safety margins. Consequently, it is necessary to transfer this margin of failure to the insurance market.

In summary, it is necessary to make use of a launch vehicle with a proven track record and to obtain first rate insurance coverage involving the participation of an insurance company with broad experience in the coverage of launch and in-orbit risks, given that the complexity and the amounts involved in a claim are very high.

Financing of Space Projects

Accessing the Public Equity and Debt Markets

Carol S. Goldstein
Executive Director

MORGAN STANLEY DEAN WITTER

OVERVIEW

- 1997 has been an exciting year in the world of satellite financing
- Over $240 million raised in equity markets
- Over $3.4 billion raised in high yield markets
- Innovative financing in bank markets

Market Drivers

- Data transmission
- Internet growth
- Subscriber line penetration
- Growing cellular subscribers
- Cellular coverage
- Technology improvements

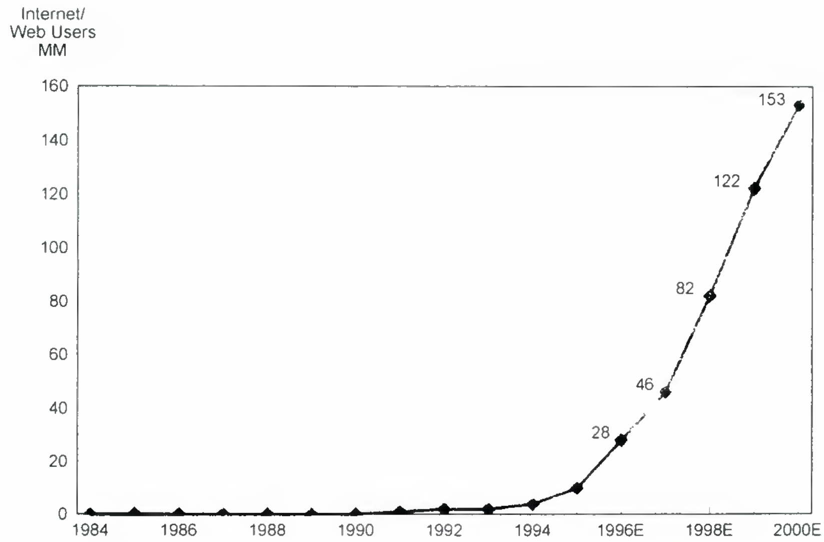
Data Transmission Growth

- Data and Network Services market
  - 1995E: $32.5 B
  - 1996E: $37.7 B (16% growth)
  - 1997E: $48.8 B (21% growth)
- Drivers: CAD/CAM, Distance Learning, videoconferencing, telemedicine, etc.

Source: 1997 Data Comm Market Forecast, Dec 96, includes leased lines, X.25, FR, internet services, ISDN, network service and support

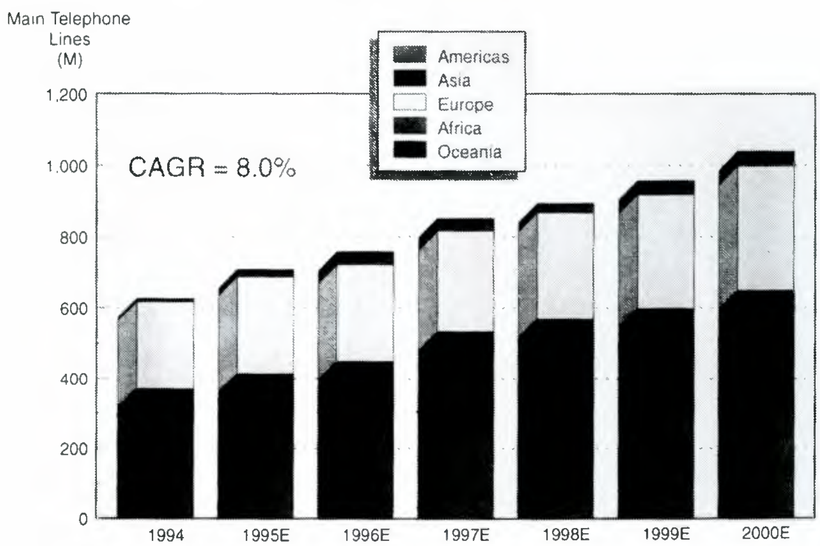
Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

Estimated Internet User Growth



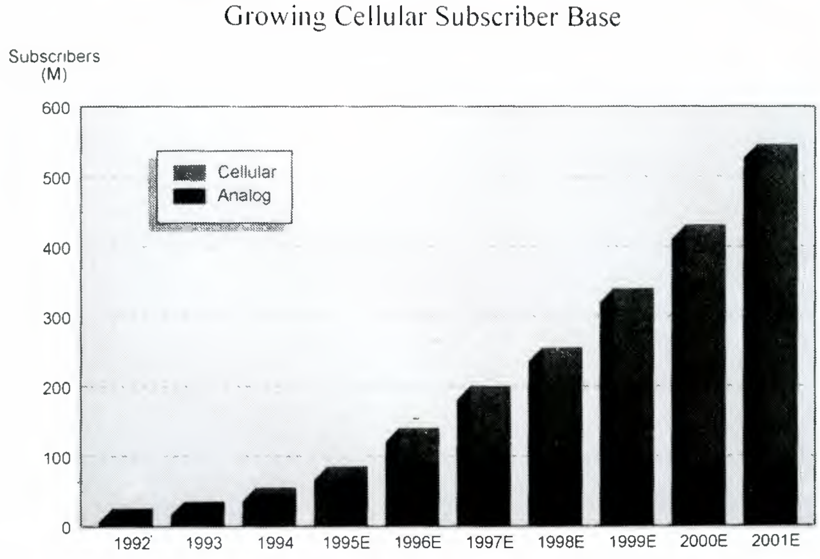
Source: Morgan Stanley research

Global Wireline Growth



Source: ITU

Growing Cellular Subscriber Base



Source: DataQuest

HIGH YIELD CAPITAL MARKETS

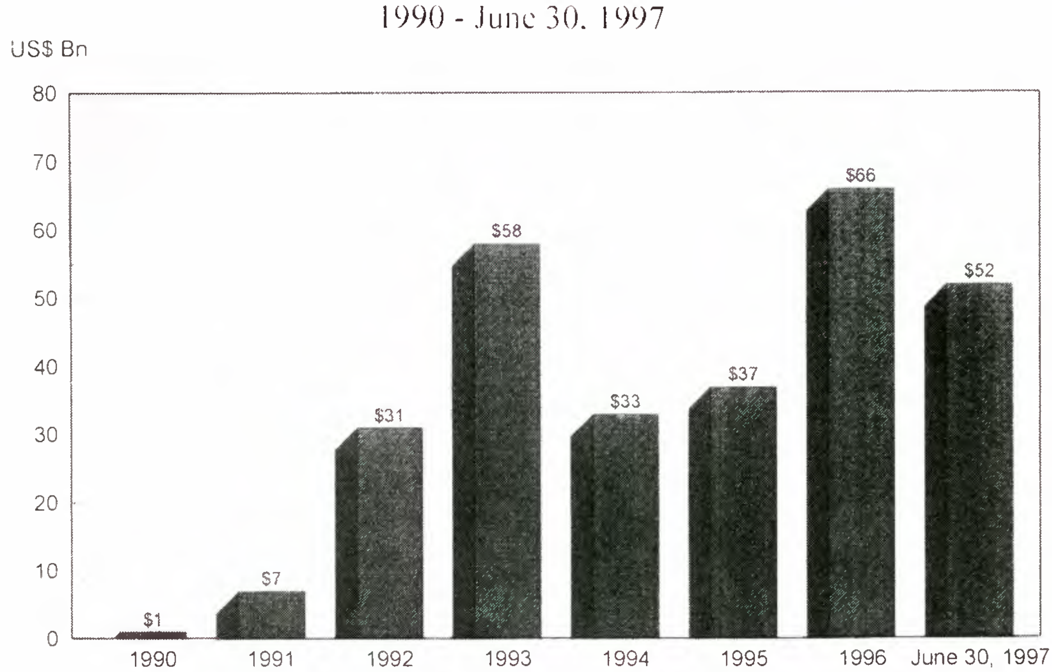
High Yield is Well Suited for Satellites

- Securities issued by companies rated below investment grade (BB or lower)
- High Yield financing options include
  - Cash coupon bonds
  - Zero coupon bonds
  - Bonds with warrants/equity features
  - Preferred Stock
  - Common Stock
- Yields/Total Investor Returns normally 10-15%
- Long-Term Capital for emerging growth companies
- Innovative and Flexible – High Yield can do anything

Global High Yield Market Overview

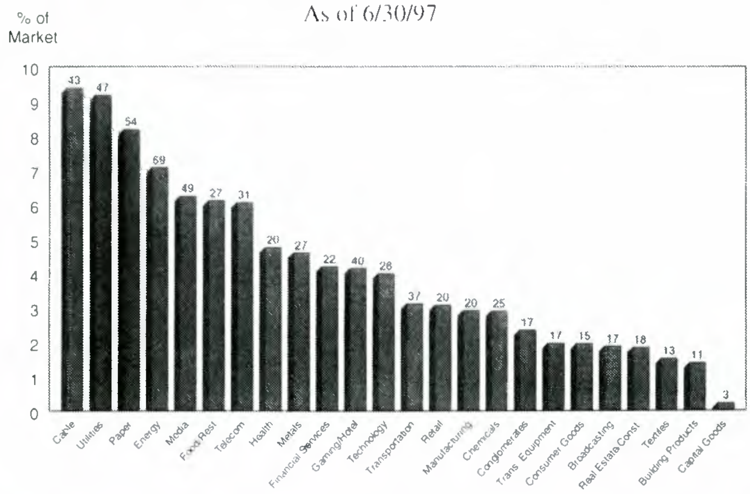
- $470 billion market – 31% annualized growth in 1997
- Investors dominated by mutual funds
- Increasingly global issues and investors
- Media/telecommunications sectors are 20% of the market
- Satellite securities represent 1% of the market

U.S. High Yield New Issue Volume
1990 - June 30, 1997



Source: Morgan Stanley, Securities Data Company, Inc

Percentage of High Yield Issues by Sector
As of 6/30/97



- Media & telecommunications issuers represent 22% of the market
- Satellite companies represent 1% of the market

Innovative Satellite Financings[1] in the High Yield Market During 1997

Date	Company	Rating at Issue	High Yield Securities	Gross Amount Raised
January, 1997	Orion Network Systems	B2/B B2/B	"Overfunded" Sr. Notes due 2007 with warrants Sr. Discount Notes due 2007 with warrants	$445 MM $265
February, 1997	Globalstar	B3/B	Sr. Notes due 2004 with warrants	$500
March, 1997	EarthWatch	NR	"Overfunded" Sr. Notes due 2001 with warrants	$50
June, 1997	Globalstar	B3/B	Sr. Notes due 2004	$325
June, 1997	EchoStar	NR/B-	"Overfunded" Sr. Secured Notes due 2002	$375
July, 1997	Iridium LLC	B3/B- B3/B-	Sr. Notes due 2005 with warrants Sr. Notes due 2005	$300 $500
October, 1997	Globalstar	B3/B	Sr. Notes due 2004	$325
October, 1997	Iridium LLC	B3/B-	Sr. Notes due 2005	$300
				$3,385 MM

Note: (1) Includes facilities based companies

Innovative Satellite Financings in the High Yield Market

	Deals	Amount	Securities Issued (17 Total)				
			Better Than B3/B-	Debt	Equity Related	Secured	Zero/ Overfunded
1993	1	$435MM	2	2	0	1	1
1994	1	$335	0	0	1	1	1
1995	1	$275	0	1	0	0	0
1996	3	$590	0	1	2	1	2
1997 YTD	8	$3,385	3	5	5	1	4
	14	$5,020MM	5	9	8	4	8

Case Study - Orion Network Systems, Inc.: January 1997

- ★ **Successful return of Orion to the market after failed high yield transaction in late 1995**
- ★ **Largest public market satellite financing**
- ★ **Large zero coupon issue**

Objectives/Use of Proceeds:

- Refinance current bank facility to relieve partners of debt guarantees and facilitate partnership roll-up
- Fund the construction and launch of Orion 2 and Orion 3 satellites

Transaction:

Issue Date: January 28, 1997

Type of Security: Two tranches of Senior Notes and Senior Discount Notes

	Senior Overfunded Notes	Senior Discount Notes
Size:	Gross: $445.0MM Net: $311.1MM	Proceeds: $265.4MM Face: $484.0MM
Price Talk:	11.25 – 11.50%	12.50 – 13.00%
Coupon:	11.25%	0/12.50%
Spread to UST:	+462 basis points	+587 basis points
Warrants:	1.415% of the company	1.205% of the company
Maturity:	January 15, 2007	January 15, 2007
Ratings:	B/B2	B/B2

Case Study - PanAmSat Corporation: April 1995

- ★ **Successful return of PanAmSat to the high yield market after failed launch and failed IPO**
- ★ **Largest Single B Preferred issued in capital markets at the time**
- ★ **Largest PIK Preferred at the time**

PanAmSat

Objectives/Use of Proceeds:

- To obtain long term capital without violating covenants
- To fund the construction and launch of new satellites

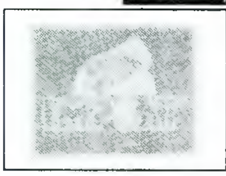
Transaction:

Type of Security:	Mandatorily Exchangeable Senior Redeemable Preferred Stock
Maturity:	April 15, 2005
Ratings:	B3/B-
Size:	$275MM
Price Talk:	12.875-13.125%
Dividend Yield:	12.75%, PIK option for the first 5 years
Mandatory Exchange:	Will be exchanged for Sr. Sub Notes September 30

MORGAN STANLEY DEAN WITTER GLOBAL TELECOM

Case Study: IMPSAT Corporation

- **The first Argentine "emerging company" issue ever in high yield market**
- **The longest Argentine maturity since the Mexican devaluation**
- **The deal was heavily oversubscribed ($200MM plus in orders) although the Argentine market was undergoing severe volatility due to rumors of Cavallo resignation**



Objectives/Use of Proceeds:

- Repay higher cost, short-term debt
- Stabilize the capital Structure in order to focus on growth of business
- Obtain sufficient funding to finance future capital expenditures
- Introduce the Company's credit to a new universe of investors ensuring future access to long-term capital
- Extend maturities to better match and liabilities

Transaction:

Issue Date:	July 25, 1996
Distribution Method:	144A with Registration Rights
Type of Security:	Senior Guaranteed Notes
Size:	$125MM
Price Talk:	12.50%-12.75%
Dividend Yield:	12.125%
Maturity:	July 15, 2003
Ratings:	B2/BB-

Transaction Highlights:

- Priced successfully despite difficult market conditions due to impending Cavallo resignation
- Company accessed 7-year money, the longest maturity for an Argentine issue since the Mexican devaluation
- Aggressive pricing pushed out "emerging market" buyers
- Company lowered its long-term cost of capital from an expected 13% at the beginning of the roadshow to 123.125%, the final pricing achieved

HIGH YIELD CAPITAL MARKETS

Case Study - Innova, S. de R.L.: March 1997

- ★ **Largest single B Mexican Corporate issue since devaluation of Mexican Peso**
- ★ **First-ever Mexican Start-up issuer**

SKY ENTERTAINMENT SERVICES

Objectives/Use of Proceeds:

- Fund the launch of the Mexican DTH Service
- Acquire Medcom

Transaction:

Issue Date:	March 26, 1997
Distribution Method:	Rule 144A with Registration Rights
Type of Security:	Senior Overfunded Notes
Size:	Gross: $375.0MM
	Net: $242.3MM
Price Talk:	12.75 – 13.00%
Coupon:	12.875%
Yield:	13.000%
Spread to UST:	+622 basis points
Maturity:	April 1, 2007
Ratings:	B2/B-

EQUITY CAPITAL MARKETS

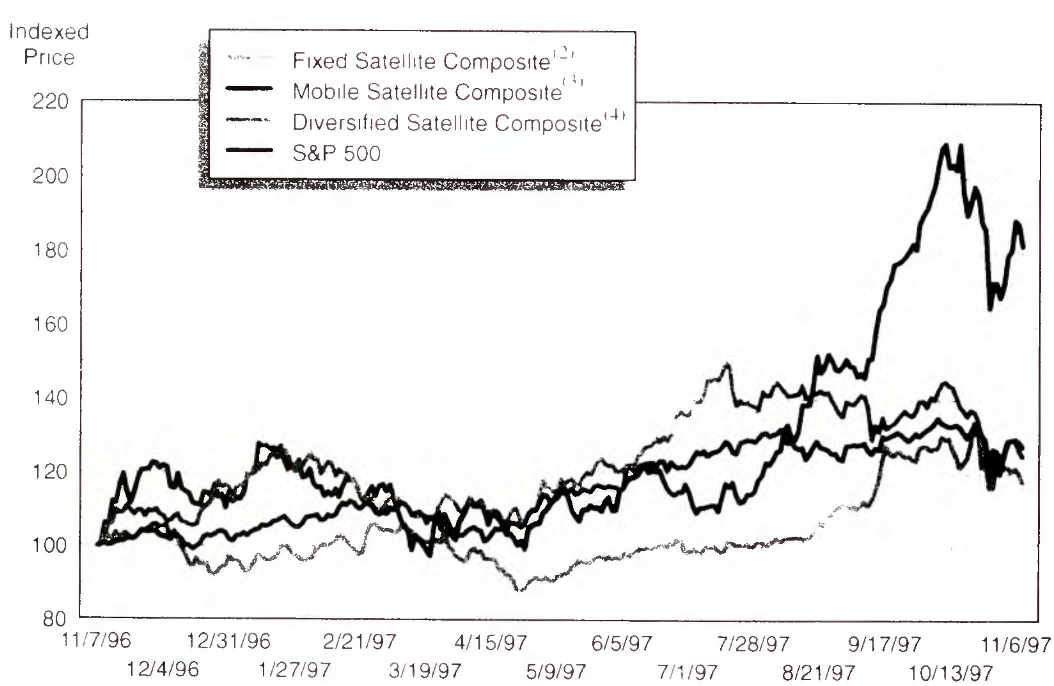
Satellite Financing in the Equity Markets

Date	Issuer	Amount ($MM)	Security
June 1997	Iridium	$240	Common
December 1996	APT Satellite	184	Common
November 1996	Loral Space	500	Convertible Pref.
June 1996	AsiaSat	277	Common
June 1996	PSN	73	Common
March 1996	Globalstar	275	Convertible Pref.
January 1996	USSB	224	Common
September 1995	PanAmSat	321	Common
September 1995	British Sky Broadcasting	808	Common
August 1995	Orion Network Systems	56	Common
January 1995	EchoStar	68	Common
February 1995	Globalstar	200	Common
December 1994	British Sky Broadcasting	1,400	Common
September 1994	CD Radio	7	Common
		$4,633	

EQUITY CAPITAL MARKETS

Relative Price Performance

Last Twelve Months[1]



Notes: (1) As of November 7, 1997.
(2) Composite comprises APT Satellite, AsiaSat, PSN, PanAmSat, Comsat and Orion.
(3) Composite comprises American Mobile Satellite, CD Radio, Globalstar and Iridium.
(4) Composite comprises Loral, Lockheed Martin, GM Hughes, Orbital Sciences, Qualcomm, Motorola and Trimble Navigation.

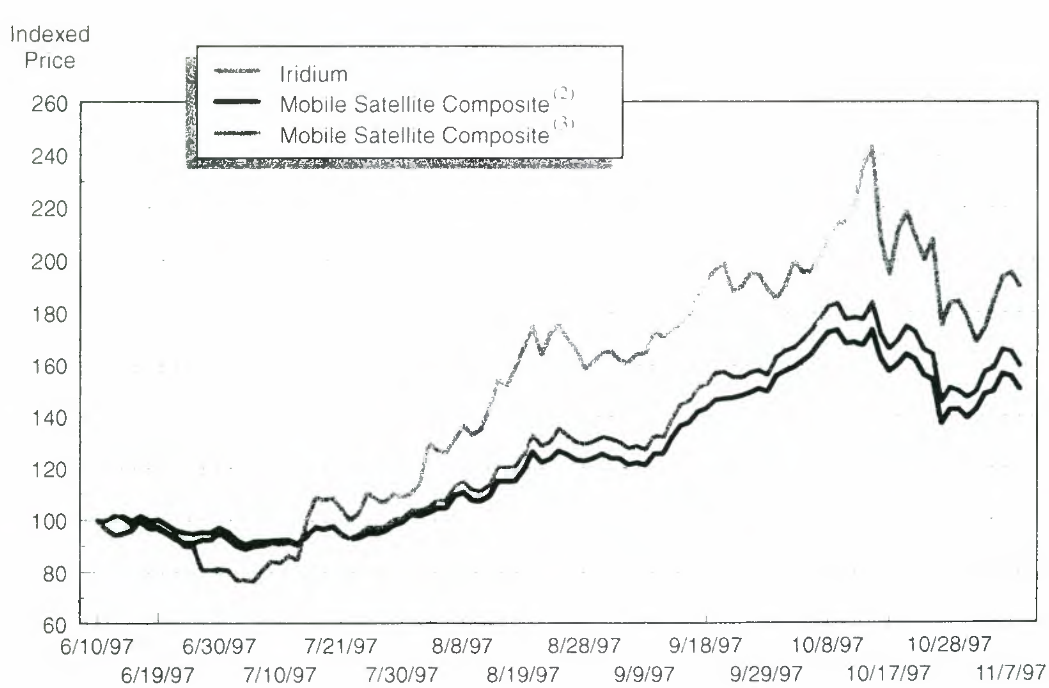
EQUITY CAPITAL MARKETS

Case Study: Iridium World Communications, Ltd.

Initial Public Offering

Offering Price:	$20 per share
Amount Raised:	$240MM (8.5% of Iridium LLC)
Implied Value of Iridium LLC:	$2,824MM
Milestones:	- 5/66 satellites launched - 8/66 satellites produced
Expected Date of Commercial Operations:	September 1998

Relative Price Performance Analysis
Since Iridium IPO on June 10, 1997 [1]

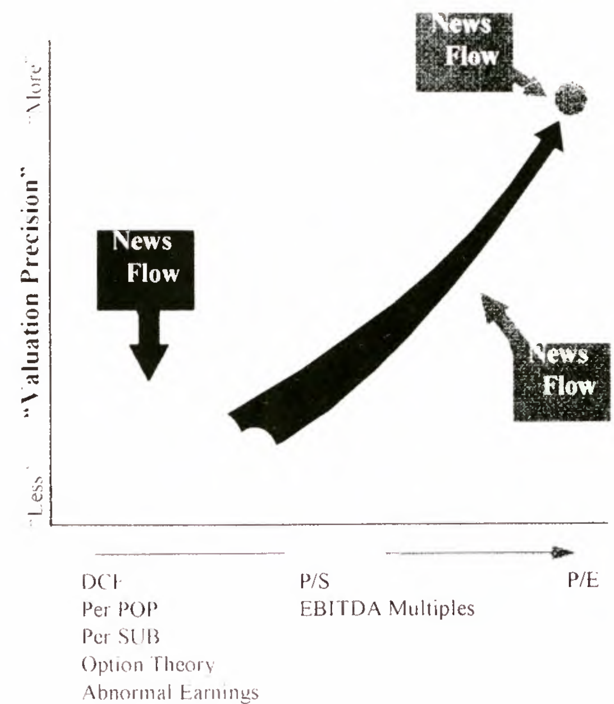


Notes: (1) $42.25 per share as of November 7, 1997, representing a 111% increase in share price since IPO.
(2) Composite comprises American Mobile Satellite, CD Radio, Globalstar and Iridium.
(3) Excludes American Mobile Satellite.

EQUITY CAPITAL MARKETS

How do Capital Intensive Stocks Trade?

"Mature"	Net Inc. = (+)
"Growth"	EBITDA = (+)
"Concept"	Revenue = 0



Valuation Methodology

Quantitative

- Addressable market
- Industry penetration
  - Take up curve
- Market share
- Discount rates
  - Multi-stage FCFF or FCFE

Intangibles

- Sponsorship
- Strength of business plan
- Ability to finance
- Distribution strategy
- Management
  - Track record
  - Flexibility

Trading Statistics of Selected Satellite Companies

Company	Price (1)	Equity Value ($MM)	Aggregate Value ($MM)	Agg. Value/ Book Cap.	Agg. Value / EBITDA 1997E	1998E	1999E	2000E
APT	$16.00	$840	$939	2.7x	17.0x	9.0x	8.3x	6.6x
AsiaSat	23.69	924	1,104	4.2	10.7	8.0	7.5	5.8
Orion (3)	12.25	343	1,051	1.2	115.5	59.1	13.8	8.7
PanAmSat (2)	39.20	5,846	8,296	2.9	16.7	12.4	9.4	7.5
PSN	17.75	464	488	3.8	40.2	16.9	10.1	5.1
			Mean:	3.0x	40.0x	21.1x	9.8x	6.7x
			Median:	2.9x	17.0x	12.4x	9.4x	6.6x

Notes: (1) As of 11/07/97. Estimates from selected analysts.
(2) Book Capital adjusted to reflect tangible capital only.
(3) Pro forma for high yield offering and for roll-up of partnership: fully-diluted basis. Price as of 8/15/97 (pre-takover rumors).

CONCLUSIONS

- Both debt and equity markets can be used to raise substantial capital

- The key success factors are:
  - Sponsorship/strategic partners
  - Credibility of business plan
  - Time to market
  - Ability to capture imagination of investors

Morgan Stanley is the Leading Banker to the Satellite Industry

Morgan Stanley

Lead-Managed Financings

Client	Amount Raised ($MM)	Product
Orion	$710	HY
Innova	375	HY
PanAmSat	597	IPO, HY
IMPSAT	125	HY
EarthWatch	120	HY
Total	**$1,927**	

Advisory Assignments

Client	Transaction Value ($MM)	Transaction
Orion	$1,213	Sale of Co.
PRIMESTAR	1,998	Merger of Partnership Interests
PRIMESTAR	1,100	Purchase of American Sky Broadcasting
PanAmSat	6,000	Sale of Co.
Total	**$10,311**	

STRUCTURING BANK FINANCING FOR SATELLITE VENTURES

CREDIT LYONNAIS

Jean-Pascal Orcel
Head of the Telecoms/Satellites Financing

SOURCES FOR THE FINANCING OF SATELLITE PROJECTS

- Sponsors
- High yield debt providers
- Suppliers
- Commercial banks
- Export credit agencies and Multilateral agencies
- Capital markets

KEY ASPECTS OF THE BANKERS'PERCEPTION OF SATELLITE PROJECTS

- Sponsors : Financial commitment
  Strategic commitment
  Know how transfer (new markets / new technologies)
- Country risk : Revenues in local currencies
  Regulatory risk (i.e. global projects)
  Political risk
- Project economics
- Degree of innovation
- Management quality
- Marketing quality : (market risk projects) Market study
  Distribution strategy
  Pricing strategy
- Financing plan quality and first steps of implementation
- Credit enhancements: Off-takers commitments
  Standby Equity support
  Turnkey construction contracts

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

KEY STRUCTURE ELEMENTS IN A SATELLITE PROJECT BANK FINANCING

- **Equity/Debt ratio :** Depends on project risks & credit enhancements
  Typically in the 25% to 50% range
  Subordinated/unsecured debt may be accounted in equity to some extent

- **Maturity:** Determined by project economics and country risk typically 5 to 10 years

- **Prioritization of cash outflows :** Progressive repayment profiles
  Early free cash flow to repay debt in priority to dividends and subordinated debt principal
  Ratios governing dividend payments

- **Main securities:** 1st ranking lien on the satellite and TTC&M station
  Assignment of main contracts
  Pledge of project revenues and accounts
  Assignment of insurance proceeds

MAIN ISSUES IN ARRANGING A SATELLITE PROJECT FINANCING STRUCTURE - PROJECT ECONOMICS

- Typical project parameters to be tested through sensitivities :
  - Opex
  - Capex
  - Satellite occupancy rate
  - Market size and market share
  - Revenue per subscriber
  - Delay due to launch failure
  - Macroeconomic parameters (exchange rate, inflation, interest rate)
  - Insurance premium

- Sensitivities will help determine :
  - If credit enhancements are necessary, and their amounts,
  - Financial ratios to include in covenants

MAIN ISSUES IN ARRANGING A SATELLITE PROJECT FINANCING STRUCTURE - COUNTRY RISK

- Country risk may affect:
  - The operation of the project (incorporation, orbital slot, license, tax, ...)
  - The project revenues (currencies, political risk, ...)
  - The macroeconomic environment of the project

- Examples of instruments to mitigate country risks are:
  - Revenues from creditworthy lessees paid on off shore project accounts,
  - Export credit agencies : political risk cover
    commercial risk partial cover
  - Multilateral agencies ("umbrella effect"): IFC
  - Currency swap

MAIN ISSUES IN ARRANGING A SATELLITE PROJECT FINANCING STRUCTURE - INSURANCE REQUIREMENTS

- Commercial general liability insurance
- Property damage insurance (for property other than the satellite)
- Launch and initial operations insurance
- In orbit insurance
- Third party liability insurance
- Terms to include Banks named as additional insured and loss payees

MAIN ISSUES IN ARRANGING A SATELLITE PROJECT FINANCING STRUCTURE - INTERMEDIARY SITUATIONS

- A start up satellite company may rapidly turn out to have a corporate profile
- Launching a new satellite may have a severe impact on the financial ratios of a two-satellites company
- There is a need to consider some intermediary stage companies from a different angle than pure project financing, which means :
  - more flexibility on debt/equity, dividends, and the global covenants and security package
  - some control through financial ratios, limitation on indebtedness, and some preferential access to free cash flows

FINANCING SATELLITE VENTURES
A CHALLENGE TO THE TRADITIONAL BANK FINANCING APPROACH

- Accelerating technological evolution
- New markets: TV broadcasting
  Radio broadcasting
  Mobile telephony & data
  Internet
  Multimedia & high speed services
- More risks and larger projects :

GEO	M$ 200
MSS	M$ 800
LEO	B$ 3
MULTIMEDIA	B$ 10

- More entrepreneurial ventures

Financing for Satellite Projects

Leonard Shavel

BABCOCK & BROWN

Contents

Privatisation of Space

The past decade has witnessed an explosion in private sector space activity in what used to be exclusively a government and parastatal domain...

Incorporation	Company
❑ 1983/4/5	Columbia Communications, Panamsat, SES Astra, Thaicom
❑ 1991/2	Thaicom, Optus (ex O-Star), Rimsat
❑ 1993	Japan Satellite Systems Inc, Satelindo
❑ 1994	Orion, Mabuhay
❑ 1995/6	APT, USSB, Echostar, Asiasat, Indostar
❑ current	Globalstar, Iridium etc

... today, even the parastatals such as Intelsat, Inmarsat and Eutelsat are focussing on increased private sector participation.

What's driving this growth?

- Deregulation of telecommunications and broadcast markets
  - Private investment possible and rewarding (eg Panamsat)
  - Growth in new services made possible (eg VSAT)
  - Ever increasing technical capability encouraged (eg high powered DBS)
- Improved technology and knowledge
  - Improved satellite reliability and power
  - Better understanding of launch risks
  - Suitability of space for broadcasting and growth in programme demand
- Deregulation and globalisation of capital markets
  - Growth in equity markets for space ventures (especially US)
  - High yield markets
  - Wider range of financial products

Third Euro-Latin American Space Days, Proceedings of an International Conference held in Mexico City, 10-14 November 1997 (ESA SP-412, May 1998).

What happens next?

As the industry matures, it will face a number of challenges ...

- ❑ **Deregulation is spreading**
  - markets becoming highly competitive
  - slot values increase (eg $682m from FCC DBS auction to MCI)
  - long distance terrestrial transmission costs are tumbling towards marginal costs
  - satellites will find it harder to compete against terrestrial broadband capacity (telephone and broadasting)
- ❑ **Digitalisation**
  - analogue broadcasting accounts for approximately 50-60% of satellite capacity
  - digitalisation and compression could significantly reduce the demand for transponders
  - will increased programming (VOD and near VOD) and other capacity demanding services (eg Internet) be sufficient to fill the gap?
- ❑ **Too much capacity?**
  - payload sizes are increasing
  - the number of planned or in-construction systems is higher than it has ever been
  - will the retirement of older systems compensate?

... and looks like developing into a commodity market.

Satellite Financing: Theory and Practice

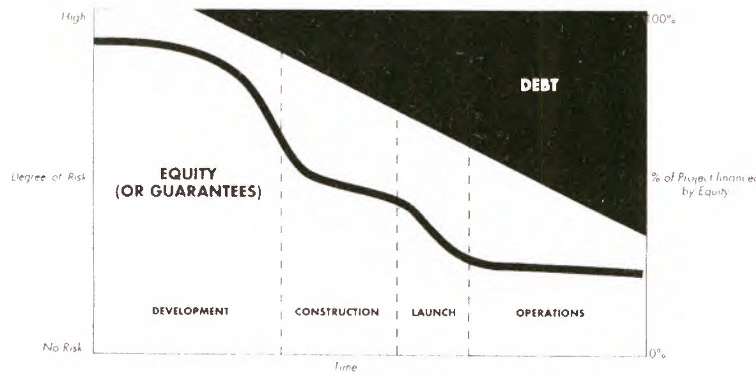
- ❑ **In theory, satellite based businesses should attract debt and equity financing early**
  - growing demand for capacity and more applications
  - proven track record of reliability and success
  - value of a satellite in orbit far exceeds its cost
- ❑ **In practice, there are barriers to obtaining finance at the time when promoters of businesses need it most**
  - perceived level of risk
  - lack of knowledge
  - business plans not finalised until shortly before launch
  - collateral value of satellites not accepted/proven
  - absences of licences/permits/approvals
- ❑ **To date, most pre-operating satellite financings have relied largely on equity funding and shareholder supported debt.**

Satellite Risk Profile

PRE-LAUNCH	LAUNCH & COMMISSIONING	OPERATIONS & MARKETING
Construction • delay • performance and technical **Launch** • delay/failure **Business Plan** • partners • marketing/customers • transponder leases • authorisations • financial projections **Regulatory** • licences • ITU procedures	**Satellite Performance** **Technical** **Launch Vehicle Performance**	**Satellite Performance** • delay • performance and technical **Technical** • delay **Business** • customers/transponder leases • market **Business** • regulatory • ownership

Satellite Finance has hardly been leading edge

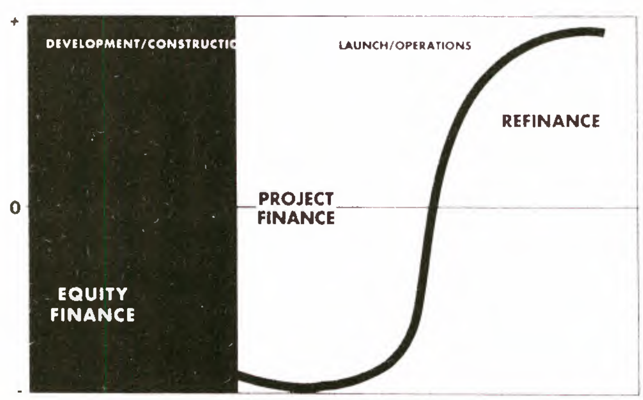
Space projects are dynamic: risks change rapidly ...



... and so are difficult to finance

Space Projects are not typical of Project Finance Ventures

... until its too late.



Prefinancing Cash Flow

Financing options will follow industry trends ...

As the industry matures ...

- Start-up Satellite platform businesses less likely
- Consolidation: vertical and horizontal (eg Panamsat, Loral)
- Service providers rather than space platforms will drive funding
- Increasing premium for financing efficiency
- Commodity and other financing techniques added to traditional space finance methods

... and fall into two general categories ...

- Basic funding: sponsor(s) needs money
  - certainty of raising capital is primary
  - other concerns (such as accounting, tax efficiency) are secondary
  - timing and status of project usually dictates type of financing
- Opportunistic financing: sponsor(s) choosing among several alternatives
  - desire for tax advantaged or otherwise attractive funding
  - only in some cases, is the goal to minimise balance sheet exposure
- Distinction is generally credit driven but also relates to stage of project and type of business

... reflecting market segmentation

	Corporate Financing	Asset or Project Financing
Service Providers	- Specialised satellites eg LEO, MEO - Earth sensing/Navigation	- Regional GEO telephony - Rural telephony - Dedicated broadcast platforms
Commodity Businesses	- Speculative satellite networks - Consolidated business	- Operating lessors - Residual value players
	Financial products increasing available	Traditional satellite financing techniques

Greater financial innovation and sophistication likely

- A market for residual value
- Increased operating leasing of satellites and satellite capacity
- Financial engineering more important
- Derivative financial products increasingly likely
- Tax products increasingly relevant
- Project Financing in specialised cases only

Collateral Value

Valuing collateral will allow greater access to limited recourse debt and other financing products

- Satellites have a quantifiable and realisable value as an asset
  - The value of the asset can be disassociated from the viability of the business (eg Aircraft and other asset finance products which rely on asset value)
- Project finance relies on future business performance and shareholder support
- Satellite financing combines these two disciplines
  - Geostationery satellites can be remarketed and sold if the original business is not successful
  - Lenders can rely on the sales proceeds for security
  - Limited precedent

... but registering charges is difficult without an international register.

Summary

- Space business is changing rapidly
- Participants have adapted accordingly but face greater challenges
- Financial innovation and creativity will be key as margins on capacity fall, the industry moves towards a commodity market in space, and specialised services on the ground

Participants

HARTLEY CHRIS
ANITE SYSTEMS
Tel: 54-547-260-47
Fax: 00 54 547 26047
e_mail: 104637.2252@compuserve.com
Alvarez Igarzabal 915
Córdoba
ARGENTINA

SÁNCHEZ PEÑA MIGUEL
Asociación Argentina de Ciencias Espaciales
Tel: 54 1 792 34 18
Fax: 00 541 792 3418
e_mail: miguel@unlv.01.edu.ar
Paunero 13821 (1640)
Martínez
ARGENTINA

DEL VALLE HÉCTOR FRANCISCO
CENPAT
Tel: 54-965-736-80
Fax: 00 54 965 51543
e_mail: delvalle@cenpat.edu.ar
C.C. 128
Puerto Madryn (Chubut)
9129 ARGENTINA

ALONSO CARLOS
Comisión Nacional de Actividades Espaciales
Tel: 54 1 33 1 0074 EXT. 218
Fax: 00 54 1 331 01 89
e_mail: calonso@conae.gov.ar
Paseo Colón 751
Buenos Aires
1063 ARGENTINA

COLOMB FERNANDO RAÚL
Comisión Nacional de Actividades Espaciales
Tel: 54 1 331 0074
Fax: 00 54 1 331 3446
e_mail: rcolomb@conae.gov.ar
Paseo Colón 751
Buenos Aires
1063 ARGENTINA

HISAS RAÚL FERNANDO
Comisión Nacional de Actividades Espaciales
Tel: 54-1-331-00-74
Fax: 00 541 331 3446
e_mail: fhisas@conae.gov.ar
Paseo Colón 751
Buenos Aires
1063 ARGENTINA

AGUGLINO L. RUBÉN LUIS
Director
DIRECCIÓN DE APLICACIÓN DE IMÁGENES SATELITARIAS
Tel: 54-21-29-49-51
Fax: 54 21 29 49 52
e_mail: capdis@isis.unlp.edu.ar
Calle 7 No. 1267 - Piso 2
La Plata
1900 ARGENTINA

SOLARI GIORGIO
EUROPEAN TRIPARTITE GNSS SECRETARÍAT
Tel: 32-3-230-90-39
Fax: 00 32 2 230 90 81
e_mail: gsolari@estec.esa.nl
Rue de la loi 223
Bruxelles
B-1040 BÉLGICA

CASSIDY JEFFREY
ACE INSURANCE CO.
Tel: 1-441-299-92-16
Fax: 00 1 441 292 2527
e_mail: acejsc@mail.ace.bm
30 wood bourne Avenue
Hamilton
HM08 BERMUDA

FORTES LAURO
AGENCIA ESPACIAL BRASILEIRA AEB
Tel: 55-61-325-12-50
Fax: 00 55 61 325 1249
e_mail: fortes@dem.inpe.br
SBN. Ed. Eng. Paulo Maurício. Sala 1401
Brasília D.F.
BRASIL

BOGOSSIAN OTAVIO LUIZ
INPE
Tel: 55-12-345-61-53
Fax: 00 55 12 345 61 63
e_mail: bogossia@dss.inpe.br
Av. Dos Astronautas 1758
Sao José dos Campos
515 BRASIL

NERI JOSÉ ANGELO
INPE
Tel: 55 12 34 6221
Fax: 00 55 12 345 6225
e_mail: neri@dca.inpe.br
Av. Dos Astronautas 1758
Sao José dos Campos - SP
515 BRASIL

RUDORFF BERNARDO
INPE
Tel: 55 12 345 6447
Fax: 00 55 12 345 6460
e_mail: bernardo@ltid.inpe.br
Av. Dos Astronautas 1758
Sao José dos Campos - SP
515 BRASIL

DA SILVA TEIXEIRA PAULO
MINISTRO DE AERONÁUTICA BRASIL
Tel: 55-21-220-07-14
Fax:
e_mail:
BRASIL

SOUZA DE OLIVEIRA ROBERTO
MINISTRO DE AERONÁUTICA BRASIL
Tel: 55-21-240-74-76
Fax:
e_mail:
BRASIL

LARSON WADE
Gestionnaire Organisations Internationales
CANADIAN SPACE AGENCY
Tel: 001 514 926-4329
Fax: 00 1 514 926 4362
e_mail: wade.larson@space.gc.ca
6767 Route de l'Aeroport Saint-Hebert
Québec
J3Y 8Y9 CANADÁ

ST-PIERRE MARCEL
CANADIAN SPACE AGENCY
Tel: 514 926 44 16
Fax: 00 1 514 926 4433
e_mail: MARCEL.ST-PIERRE@space.gc.ca
6767 Route de l'Aeroport Saint-Hebert
Québec
J3Y 8Y9 CANADÁ

PAVA CAMELO ALVARO
Miembro del Consejo
COMISIÓN NACIONAL DE TELEVISIÓN
Tel: 0057 1635 22 40
Fax: 00 57 1 257 2446
e_mail:
Calle 93 No. 16-25
Santa fe de Bogotá. D.C.
COLOMBIA

BARES PETR
SCIENCE SYSTEM
Tel: 00420-2-361-000
Fax: 00 420 2 361 934
e_mail: petr@compuserve.com
CHECOSLOVAQUIA

CASTRO RÍOS ROBERTO
UNIVERSIDAD CATÓLICA DE CHILE
Tel: 56-2-553-29-00
Fax: 562 553 29 00
e_mail: rcastro@sas.puc.cl
Av. Vicuña Macken 4 4860
Santiago
CHILE

MORALES ALVAREZ RICARDO
CLIRSEN
Tel: 593 2 581-064
Fax: 586 1066
e_mail: clirsen@uio.satnet.net
Estación Cotopaxi. Panamericana sur, km. 55, Páramo Romerillos
ECUADOR

VASCONEZ CISNEROS BYRON ALBERTO
CLIRSEN
Tel: 593 02 58 10 64/582-447
Fax: 00 593 02 581066
e_mail: clirsen@uio.satnet.net
Estación Cotopaxi. Panamericana sur, km. 55, Páramo Romerillos
ECUADOR

OCAMPO TORRES FRANCISCO
Centro de Investigación Científica y de Educación Superior de Ensenada
Tel: 52 61 745050 EXT. 24051
Fax:
e_mail: ocampo@Centro de Investigación Científica y de Educación Superior de Ensenada.mx
Km.107 Carretera Tijuana - Ensenada
Ensenada B.C.
MÉXICO

DE MATEO GARCÍA MARI LUZ
AENA
Tel: 00 341 321-34-34
Fax: 00 341 321 3119
e_mail: mdemateo@ugdna.aena.es
ESPAÑA

AGUILAR REYES
CDTI
Tel: 34-1-581-55-94
Fax: 34 1 581 55 94
e_mail: rar@cdti.es
Paseo de la Castellana 141
Madrid
28046 ESPAÑA

BUENO BANDERA EMILIA
CDTI
Tel: 34 1 581-55-63
Fax:
e_mail: ebb@cdti.es
Paseo de la Castellana 141
Madrid
28046 ESPAÑA

GÓMEZ VICENTE
CDTI
Tel: 341 581-55-11
Fax: 00 341 581 55 11
e_mail:
Paseo de la Castellana 141
Madrid
28046 ESPAÑA

ALVAREZ GASCÓN LUIS FERNANDO
Grupo de Marketing
Grupo de Mecánica de Vuelo
Tel: 91 807-21-00
Fax: 00 91 807 21 99
e_mail: lalavarez@gmv.es
Isaac Newton II P.T.M. Tres Cantos
Madrid
28760 ESPAÑA

MAYO MUÑIZ LUIS ANTONIO
Grupo de Mecánica de Vuelo
Tel: 34 1 807 21 00
Fax: 34 1 807 2199
e_mail: lmayo@gmv.es
C. Isaac Newton 11, Tres Cantos
Madrid
E - 28760 ESPAÑA

DÍAZ ARGUELLES JOSÉ
HISPASAT
Tel: 34 1 372-9000
Fax: 00 341 307 77 05
e_mail:
Gobelas 41-45
Madrid
28080 ESPAÑA

GARCÍA JUAN JESÚS
HISPASAT
Tel: 34-1 3729 000
Fax: 00 341 307 7705
e_mail:
C. Gobelas 41-43
Madrid
28080 ESPAÑA

ALFONSO FERNÁNDEZ RANGEL
INDRA ESPACIO
Tel: 91-396-39-11, 91 396-33-33
Fax:
e_mail:
Mar Egeo 4, Pol. Ind. no. 1, San Fernando de Henares
Madrid
28850 ESPAÑA

FERNÁNDEZ RANGEL ALFONSO
Dirección de Desarrollo Estratégico
INDRA ESPACIO
Tel: 91-396-39-11
Fax: 00 91 396 3912
e_mail: afer@mdr.indra-espacio.es
Mar Egeo 4, Pol. Ind. no. 1, San Fernando de Henares
Madrid
28850 ESPAÑA

GARCÍA ESCOBAR FELIPE
INDRA ESPACIO
Tel: 34 1 396 3911
Fax: 00 341 396 3412
e_mail: rbar@indra-espacio.es
Mar Egeo 4, Pol. Ind. no. 1, San Fernando de Henares
Madrid
28850 ESPAÑA

GONZÁLEZ FERNANDO
INSTITUTO NACIONAL DE TÉCNICA AEROESPACIAL
Tel: 34 1 520-19-47
Fax: 34 1 520 1384
e_mail: gonzalezgf@inta.es
C. Ajalvir Km. 4, Torrejón de Ardoz
ESPAÑA

RODRÍGUEZ GARCÍA JUAN BAUTISTA
INSTITUTO NACIONAL DE TÉCNICA AEROESPACIAL
Tel: 34 1 520 19 38
Fax: 00 34 1 6777 3986
e_mail:
Carretera de Ajalvir Km. 4 Torrejón-Madrid
Madrid
28850 ESPAÑA

HERNÁNDEZ ARIÑO SANTIAGO
SENER
Tel: 91-807-73-04
Fax: 00 91 807 72 01
e_mail:
Severo Ochoa 4 P.T.M. Tres Cantoa
Madrid
28760 ESPAÑA

EYMAR PATRICK
Corporate Director Sales and Marketing
AEROSPATIALE
Tel: 33-1-34-92-35-83
Fax: 00 33 1 34 92 2445
e_mail: patrick.eymar@espace.aerospatiale.fr
66 Route de Verneuil - BP 2
Les Mureaux Cedex
78133 FRANCIA

RITCHIE BRUNO
AGF
Tel: 33 14486-76-02
Fax: 00 33 1 44 86 7602
e_mail: ritchie@agf.fr
87 Rue de Richelion
Paris
75002 FRANCIA

TAREL GERARD
ALCATEL
Tel: 05 61 195 190
Fax: 00 33 5 61 19 58 10
e_mail:
B.P. 1501
Toulouse
31601 FRANCIA

ALBRECHT PATRICE
Vice-President Communications and International Relations
ARIANESPACE
Tel: 33 0160-87-60-09
Fax: 00 33 1 60 87 63 04
e_mail:
Boulevard de l'Europe B.P. 177
Evry Cedex
91006 FRANCIA

BOURDELIER FRÉDERIC
Marketing Communications Exhibits Manager
ARIANESPACE
Tel: 33-1 60-87-12
Fax: 00 33 1 60 87 63 04
e_mail: f.bourdelier@arianespace.fr
Boulevard de l'Europe B.P. 177
Evry Cedex
91006 FRANCIA

GOJAT PIERRE
ARIANESPACE
Tel: 33 0 1 60 87 62 19
Fax: 00 33 1 60 87 62 70
e_mail:
Boulevard de l'Europe B.P. 177
Evry Cedex
91006 FRANCIA

JORY PHILIPPE
ARIANESPACE
Tel: 60 87 64 51
Fax:
e_mail: pjory@arianespace.fr
Boulevard de l'Europe B.P. 177
Evry Cedex
91006 FRANCIA

LARCHER PATRICE
ARIANESPACE
Marketing Manager
Tel: 33 1 60 87 62 33
Fax: 00 33 1 6087 6270
e_mail:
Boulevard de l'Europe B.P. 177
Evry Cedex
91006 FRANCIA

LAFUMA PIERRE
C.N.O.S.
Tel: 612-73-131
Fax: 00 33 5 61 273111
e_mail: Pierre.Lafuma@cnes.fr
18, Av. Edouard Beliv
Toulouse
FRANCIA

GUERNIER-PUECH JACQUELINE
CNES
Tel: 447 67 725
Fax: 00 331 44 76 78 49
e_mail: Jacqueline GuernierPuech@CNES.FR
2 Place Inamice Quentin
Paris
7500 FRANCIA

ORCEL JEAN PASCAL
CREDIT LYONNAIS
Tel: 33-1-42-95-07-82
Fax: 00 33 1 42 95 03 82
e_mail:
1 Rue des italiens
Paris
75009 FRANCIA

GUILLANDE RICHARD
ESA
Tel: 33 1 53 69 76 54
Fax: 33 1 53 69 75 60
e_mail:
8-10 Rue Mario Nikis
Paris
FRANCIA

NAJA LORBIN GERALDINE
ESA
Tel: 331-53-69-75-32
Fax: 33 1 53 69 73 82
e_mail: gnaja@hq.esa.fr
Rue Mario Nikis
Paris
FRANCIA

PARÍS JEAN PIERRE
G.D.T.A.
Tel:
Fax:
e_mail:
8-10 Rue Hermès
Ramonville
31526 FRANCIA

CONDROYER BENOIT
INTERNATIONAL SPACE BROKERS
Tel: 47-59-10-21
Fax: 00 33 1 47 59 10 21
e_mail: BCondroyer@Compuserve.com
134 rue Danton, Levellois Berret
92000 FRANCIA

MONTPERT PHILIPPE
INTERNATIONAL SPACE BROKERS
Tel: 33 1 47-59-10-72
Fax:
e_mail: phmontpert@compuserve.com
134 rue Danton, Levellois Berret
Paris
92000 FRANCIA

MARCE JEAN LOUISE
INTESPACE
Tel: 33-5-61-28-11-50
Fax:
e_mail:
FRANCIA

BUCHWALTER HERVÉ
MATRA MARCONI SPACE
Tel: 33 562-19-67-41
Fax: 33 5 62 19 51 10
e_mail: herve.buchwalter@tls.mms.fr
Rue des Cosmonauts, Z.I. du Palays
Toulouse
31000 FRANCIA

LESBRE DIDIER
MATRA MARCONI SPACE
Tel: 33 1 348 84 362
Fax: 33 1 34 88 43 62
e_mail: didier.lesbre@vlz.mms.fr
37 Avenue Louise Breguet - BP 1
Vélizy-Villlacoublay Cedex
78146 FRANCIA

TORRES CLAUDE
MATRA SYSTEMES & INFORMATION
Tel: 33 5 62 19 59 31
Fax: 00 33 5 62 19 59 59
e_mail: torre@matra-mszi.fr
18 rue des Cosmonautes
Toulouse
31402 FRANCIA

LEURENT ARNAUD
MATRA SYSTEMES & INFORMATION
Tel: 33 1 346 37 530
Fax: 00 33 1 34 63 7660
e_mail: a.leurent@matra.mszi.fr
78 Velizy Villacoliblay
FRANCIA

CERF-MAYER ERIC
PROSPACE
Tel: 331-44-76-77-70
Fax: 00 33 1 44 76 78 47
e_mail:
25 Rue du Pont Neuf
Paris Cedex 01
75039 FRANCIA

PARSOIRE DIDIER
SCOR
Tel: 33 14 69-87-006
Fax: 00 33 1 47 670409
e_mail:
1 Avenue du Polt Wilson, La Defence
Paris
92076 FRANCIA

PESKINE JEAN SEBASTIEN
SEP
Tel: 331 4728 6538
Fax: 00 33 1 47 72 0796
e_mail:
BP 303
Suresnes Cedex
92156 FRANCIA

HIERSO LAURENCE
SOTEREM
Tel: 33 5 627 19 060
Fax: 33 5 627 190 69
e_mail: soterm@starway.tm.fr
ZI de VIC BB 97
Toulouse
31500 FRANCIA

AUMONIER FRANÇOIS
SPOT IMAGE
Tel: 33 0 5 62 19 40 38
Fax: 00 33 5 62 19 40 51
e_mail: François.Aumonier@spotimage.fr
5, rue de Satellites BP 4350
Gerente Comercial para América Latina
Toulouse Cedex 4 FRANCIA

VIENNE BRIGITTE
ARIANESPACE
Tel: 33 1 60-87-62-35
Fax: 00 331 6087 6488
e_mail: b.vienne@arianespace.fr
Boulevard de l'Europe B.P. 177
Evry Cedex
91006 FRANCIA

ALVARENGA PEÑA NEFTALÍ
C.N.S.S.P.
Tel: 3902-89
Fax: 00 504 34 0946
e_mail:
Paseo Virgilio Zelaya Rubí, Bloque F, Col. Castaños Sur
Tegucigalpa
HONDURAS

CUTTER MICHAEL
SIRA LTD
Tel: 44-181-462-26-36
Fax: 00 44 181 467 6515
e_mail: Mike-Cutter@siraco.co.uk
South Hill, Chisluturst
Kent
INGLATERRA

XEFTERIS PANAGIOTIS
ALENIA SPAZIO
Tel: 0039 6 41 51 4186
Fax: 00 39 6 4151 2171
e_mail:
Via Saccomuro 24
Rome
ITALIA

FEA MAURICIO
ESA
Tel: 39-6-94-18-09-40
Fax: 00 39 6 94 18 02 80
e_mail: mfea@esrin.esa.it
ESRIN, CP 64
Frascati
00044 ITALIA

TRIVUIZIO AUGUSTO
FIAR
Tel: 39-2-3579-30-362
Fax: 00 392 3579 0052
e_mail: fiarskco@iol.it
Via Montefectro, 8
Milano
20156 ITALIA

FABRIZI ANTONIO
FIAT AVIO
Tel: 396-97-29-22-35
Fax: 00 39 6 9729 2738
e_mail:
Corso Garibaldi 22, Colleferro
Roma
00034 ITALIA

PIAGGESI DANILO
NUOVA TELESPAZIO
Tel: 39 6 793235
Fax: 00 396 teo 73 238
e_mail: danilo_piaggesi@telespazio.it
ITALIA

FERRUCCI FABRIZIO
PROTEZIONE CIVILE/PRESIDENZA DEL CONSIGLIO
Tel: 39-6 68-20-299
Fax: 00 396 682 0313
e_mail: faber@ccisc1.unical.it
11, Via Ulpiano
Rome
00193 ITALIA

MOREAU SOFÍA
ABTEMA
Tel: 591 2 315220 Y 355824
Fax: 00 591 2 31 5220
e_mail: Casilla 14248
La Paz
LA PAZ BOLIVIA

GONZÁLEZ JOSÉ MARÍA
CASIOPEA RE
Tel:
Fax:
e_mail:
LUXEMBURGO

NAVAS F. JAVIER
CASIOPEA RE
Tel:
Fax:
e_mail:
rue du Fort Nipperg
Luxemburgo
LUXEMBURGO

RANGEL MORALES RENÉ SANTIAGO
AEROMÉXICO
Tel: 398-15-41
Fax:
e_mail:
Av. Fuerza Aérea Mexicana
MÉXICO

PONTVIANNE JACQUES
ARIANESPACE
Tel: 250-71-22
Fax: 203 9485
e_mail:
Ejercito Nacional 579-73
D.F.
MÉXICO

MALDONADO REYNOSO NORMA PATRICIA
ASOCIACIÓN MEXICANA DE INVESTIGACIÓN DE LAS COMUNICACIONES
Tel: 674-26-07 688-90-04
Fax: 688 9004
e_mail: par@mail.ulanet.mx
San Simón #129B-4 Col. San Simón
D.F.
03660 MÉXICO

ARREOLA LOURDES
AXIS AGENTE DE SEGUROS Y FIANZAS
Tel: 257-71-00
Fax: 257 71 22
e_mail: axis@infosel.net.mx
Prol. Paseo de la Reforma No. 61, 4o. Piso. Col. Paseo de las Lomas
D.F.
MÉXICO

MARTÍNEZ DE VELASCO GUILLERMO
AXIS AGENTE DE SEGUROS Y FIANZAS
Tel: 257-71-00
Fax: 257 7122
e_mail: axis@infosel.net.mx
Prol. Paseo de la Reforma #61 4° piso, Col. Paseo de las Lomas
D.F.
MÉXICO

PACHECO VIVERO KARIM JOSÉ
CENTRO CULTURAL DE LA CD. DE MÉXICO
Tel: 541-01-47
Fax:
e_mail:
MÉXICO

PACHECO ENRIQUE
Centro de Investigación Científica y de Educación Superior de Ensenada
Tel: 61 74 50 50
Fax: 01 61 750549
e_mail: epacheco@Centro de Investigación Científica y de Educación Superior de Ensenada.mx
Km. 107 Carrretera Tijuana-Ensenada
Ensenada, B.C.
MÉXICO

ALVAREZ MIGUEL
Centro de Investigación en Tecnología Digital-IPN
Tel: 66 23-13-44
Fax: 01 66 23 12 88
e_mail: malvarez@Centro de Investigación en Tecnología Digital.mx
Av. del Parque 1310 Mesa de Otoy
Tijuana, B.C.
MÉXICO

LÓPEZ BONILLA ROMÁN
Centro de Investigación en Tecnología Digital-IPN
Tel: 66 23 1344
Fax: 01 66 23 13 88
e_mail: rlopez@Centro de Investigación en Tecnología Digital.mx
Av. del Parque 1310 Mesa de Otoy
Tijuana, B.C.
MÉXICO

DE LA BARRERA SANTACRUZ RICARDO
CENTRO NACIONAL DE PREVENCIÓN DE DESASTRES
Tel: 606-81-11
Fax: 606 1608
e_mail: rbs@cenapred.unam.mx
Delfín Madrigal No. 665, Col. Pedregal de Santo Domingo
D.F.
MÉXICO

SALAS MARCO ANTONIO
CENTRO NACIONAL DE PREVENCIÓN DE DESASTRES
Tel: 606-95-20
Fax:
e_mail: mass@cenapred.unam.mx
Delfín Madrigal No. 665, Col. Pedregal de Santo Domingo
D.F.
MÉXICO

SANSÓN LEODEGARIO
CFE-IPN
Tel: 230-92-36
Fax: 230 9236
e_mail: lsanson@cfe.gob.mx
Oklahoma 85 1er. piso, col. Napoles
MÉXICO

SHIRASAGO BERNARDO
CICIMAR - INSTITUTO POLITÉCNICO NACIONAL
Tel: 01-112-253-44
Fax: 112 253 22
e_mail:
Av. Instituto Politécnico Nacional s/n
La Paz, B.C.
23050 MÉXICO

OREA MAGNOLIA
CIIEMAD-INSTITUTO POLITÉCNICO NACIONAL
Tel: 729-60-00 EXT. 53013
Fax:
e_mail: morea@vmredipn.ipn.mx
Av.IPN s/n y Av. Sierra Vista, Col Lindavista
D.F.
07300 MÉXICO

ROMERO VALLEJO SERGIO
CIIEMAD-INSTITUTO POLITÉCNICO NACIONAL
Tel: 754-02-06
Fax: 754 0206
e_mail: svallejo@vmredipn.ipn.mx
Av.IPN s/n y Av. Sierra Vista, Col Lindavista
D.F.
07300 MÉXICO

CORTES CARLOS
COLEGIO DE INGENIEROS MECÁNICOS ELÉCTRICOS
Tel: 595-39-17
Fax:
e_mail:
Cda. Banderillas #9
D.F.
MÉXICO

GARCÍA GONZÁLEZ GABRIELA NATAXA
COLEGIO LAGOS
Tel: 573-52-79
Fax:
e_mail:
MÉXICO

ALANÍS ORTEGA ROSA MARÍA
Comisión Federal de Telecomunicaciones
Comunicación Social
Tel: 261-42-08
Fax: 259 15 29
e_mail:
Bosque de Radiatas #44 4o. Piso. Col. Bosques de las Lomas
D.F.
MÉXICO

GÓMEZ GONZÁLEZ AMANDA
Comisión Federal de Telecomunicaciones
Tel: 261-58-30
Fax: 606 3002
e_mail: amandag@verona.fi-p.unam.mx
Radiatas 44 Col. Bosques de las Lomas
D.F.
MÉXICO

LODIGIANI ARMANDO
COMISIÓN FEDERAL DE TELECOMUNICACIONES
Tel: 261-42-60
Fax:
e_mail:
Radiatas 44 Col. Bosques de las Lomas
D.F.
MÉXICO

PERALTA HIGUERA JOSÉ LUIS
Comisión Federal de Telecomunicaciones
Tel: 261-42-56
Fax: 261 4042
e_mail: jperalta@cft.gob.mx
Radiatas 44 Col. Bosques de las Lomas
D.F.
MÉXICO

RUELAS HERRERA MA. DEL SOCORRO
Comisión Federal de Telecomunicaciones
Tel: 629-13-54
Fax: 624 13 10
e_mail:
CONTEL Iztapalapa, Av. de las Telecomunicaciones s/n Col. Leyes de Reforma
D.F.
09310 MÉXICO

MOMPALA SEBASTIÁN
COMPU CONTACTO
Tel: 703-33-16
Fax: 703 3316
e_mail:
Amado Nervo No. 34-1
D.F.
MÉXICO

PADILLA GONZÁLEZ JUAN MANUEL
COMPU CONTACTO
Tel: 703-33-16
Fax: 703 3316
e_mail:
Amado Nervo #34-1
MÉXICO

JIMÉNEZ J. RAMÓN
CON ARTE
Tel: 545-28-93
Fax: 545 28 93
e_mail:
Aniceto Ortega # 263
D.F.
MÉXICO

FLORES GRECIA MARGARITA
CON ARTE
Tel: 753-17-53604-32-28
Fax: 604 32 78
e_mail:
Aniceto Ortega #1063 Col. del Valle
D.F.
MÉXICO

GALICIA ESTRELLA ERNESTO
DAYTI
Tel: 785-67-56
Fax: 785 6756
e_mail:
norte 188 #632
D.F.
MÉXICO

HERNÁNDEZ ALPIDE JOSÉ LUIS
DAYTI
Tel: 551-01-34 551-19-95
Fax:
e_mail:
Nte 188 # 632
MÉXICO

CORTES ÁNGEL
DESPACHOS ADUANALES
Tel: 551-01-34
Fax: 551 19 95
e_mail:
Norte # 632 Col. Peñón de los Baños
D.F.
MÉXICO

GONZÁLEZ PÉREZ ALEJANDRO
DIRECCIÓN DE EDUCACIÓN SECUNDARIA
Tel: 420-62-63
Fax:
e_mail:
MÉXICO

Espinoza Soriano Jorge Hebert
Director de Secundarias Diurnas
Tel: 420 62 50
Fax: 420 52 51
e_mail:
Fray Servando # 127 5o. Piso
D.F.
México

MOYA FLORES ARELI
EMBAJADA BRITÁNICA
Tel: 207-20-89 ext. 3254+E197
Fax: 207 25 30
e_mail:
Rio lerma 71. Col. Cuauhtémoc
D.F.
MÉXICO

RAMÍREZ RUBIO PALOMA
ESCUELA SECUNDARIA 55
Tel: 341-17-58
Fax:
e_mail:
MÉXICO

ZORRILLA FLORES MA. DEL PILAR
ESCUELA SECUNDARIA LOGOS
Tel: 524-95-67
Fax:
e_mail:
López Cotilla 1822
D.F.
MÉXICO

MARTÍNEZ GUERRERO FERNANDO
ESCUELA SUPERIOR DE FÍSICO MATEMÁTICAS IPN
Tel: 897-23-59
Fax:
e_mail:
MÉXICO

DOLORES RIVERO JAVIER
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA IPN
Tel: 770-45-40
Fax:
e_mail:
Av. Ticomán No. 600, Col. San José Ticomán, Del G.A. Madero
D.F.
MÉXICO

MONTAÑO ZARATE VICTOR ANTONIO
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA IPN
Tel: 751-99-12
Fax:
e_mail: vmontaño@redipn.ipn.mx
D.F.
MÉXICO

NAVARRETE VICTOR
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA IPN
Tel:
Fax:
e_mail: vnavarre@vmredipn.ipn.mx
MÉXICO

PADILLO LOREDO ANABELL DEYANIRA
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA IPN
Tel:
Fax:
e_mail:
MÉXICO

CORTÉS ASUR
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel: 676-04-92
Fax: 586 33 94
e_mail: ascorg8@hotmail.com
Av. Ticomán # 600, Col. San José Ticomán
D.F.
MÉXICO

DELGADO RAMOS GUILLERMO
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel:
Fax:
e_mail:
Av. Ticomán No. 600, Col. San José Ticomán, Del G.A. Madero
D.F.
MÉXICO

DÍAZ GARCÍA HÉCTOR
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel: 729-6000 EXT. 56077
Fax: 586 3394
e_mail: hdgarcia@vmredipn.ipn.mx
Av. Ticomán No. 600, Col. San José Ticomán, Del G.A. Madero
D.F.
MÉXICO

MARAVILLA VARGAS SAÚL
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel:
Fax:
e_mail:
Av. Ticomán No. 600, Col. San José Ticomán, Del G.A. Madero
D.F.
MÉXICO

MARTÍNEZ VARGAS SAÚL
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel:
Fax:
e_mail:
Av. Ticomán No. 600, Col. San José Ticomán, Del G.A. Madero
D.F.
MÉXICO

PONOMAROV VLADIMIR
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel: 729-60-00 EXT. 56056
Fax:
e_mail: vponomar@vmredipn.ipn.mx
Av. Ticomán No. 600, Col. San José Ticomán
D.F.
MÉXICO

RIVERA SERGIO
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel: 729-60-00
Fax:
e_mail:
Av. Ticomán No. 600 Col. San José Ticomán
D.F.
MÉXICO

RODRÍGUEZ ROMÁN CARLOS
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel: 557-18-53
Fax:
e_mail:
MÉXICO

ROJAS HERNÁNDEZ GABRIEL
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel: 391-02-28
Fax:
e_mail:
Atolón No. 26 Col. Acueducto de Guadalupe, Del. G.A. Madero
D.F.
07279 MÉXICO

SADOVNITECHII SEGEI
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel: 729-60-00 EXT. 56056
Fax:
e_mail: sadovnic@vmredipn.ipn.mx
Av. Ticomán No. 600, Col. San José Ticomán
D.F.
MÉXICO

VÁZQUEZ FLORES J. FELIX
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel: 586-33-94
Fax: 586 33 94
e_mail:
Av. Ticomán No. 600, Col. San José Ticomán
D.F.
MÉXICO

VIZUET TOBIAS ARMANDO
ESCUELA SUPERIOR DE INGENIERÍA MECÁNICA Y ELÉCTRICA TICOMÁN IPN
Tel: 839-03-75
Fax:
e_mail:
Lago Gran Esclavo #19 Col. Jardines de Morelos, Ecatepec
Ecatepec, Edo. de México
55070 MÉXICO

JACOBS CARMEN
FROST & SULLIVAN
Tel: 629-98-00 CLAVE 151164
Fax: 574 56 59
e_mail:
Diagonal 27
D.F.
MÉXICO

ZAMUDIO PIÑA GERARDO ALBERTO
GLOBAL TELEFONÍA
Tel: 251-06-20
Fax:
e_mail:
Bosques de Franceros 194-001, Col. Bosques de las Lomas
D.F.
MÉXICO

FLORES MARTÍNEZ RAFAEL
GRUPO RADIOCENTRO
Tel: 259-27-11
Fax: 259 27 11
e_mail:
Constituyentes 1154, Lomas de Chapultepec
D.F.
MÉXICO

ORRICO MIGUEL
I.A.F. INTERNATIONAL ASTRONÁUTICA
Tel: 520-49-76
Fax:
e_mail:
MÉXICO

AGUILAR ROBERTO
INFOTEC
Tel: 628-73-45
Fax:
e_mail:
MÉXICO

TALID HIND
INSTITUTO DE GEOGRAFÍA UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO
Tel: 622-43-24
Fax:
e_mail: htaud@igius.igeograf.unam.mx
MÉXICO

ORTUÑO ARZATE SALVADOR
INSTITUTO MEXICANO DEL PETRÓLEO
Tel: 52-5-567-82-61
Fax:
e_mail:
MÉXICO

GARCÍA PRIMO MIGUEL
INSTITUTO NACIONAL DE TÉCNICA AEROESPACIAL
Tel: 341-520-19-51
Fax:
e_mail:
MÉXICO

AGUIRRE AGUILAR AZAID
Instituto Politécnico Nacional
Tel: 342-04-14
Fax:
e_mail:
Av. Instituto Politécnico Nacional
D.F.
MÉXICO

ALMIRALL SANDY
Instituto Politécnico Nacional
Tel: 586-54-51
Fax:
e_mail:
Calle del país 329, Colonia Ticomán
D.F.
MÉXICO

BARRERA MARTÍNEZ JOSÉ LUIS
Instituto Politécnico Nacional
Tel: 729-60-00 EXT. 56077
Fax:
e_mail: jBarrerM@vmredipn.ipn.mx
Av. Ticomán # 600, Col. San José Ticomán
MÉXICO

CAMARILLO ENRIQUE
Instituto Politécnico Nacional
Tel: 729-60-00 EXT. 55017
Fax:
e_mail: ecamar@esfm.ipn.mx
Unidad Profesional Adolfo López Mateos, Edif. Col. Lindavista
D.F.
MÉXICO

GIL ANDRÉS ARTURO
Instituto Politécnico Nacional
Tel: 729-60-00 EXT. 55077
Fax:
e_mail: agilf@vmredipn.ipn.mx
Av. Ticomán No. 600, Col. San José Ticomán, Del G.A. Madero
D.F.
MÉXICO

GONZÁLEZ MORA ENRIQUE
Instituto Politécnico Nacional
Tel: 842-00-68
Fax:
e_mail:
MÉXICO

HERNÁNDEZ TAMAYO JORGE
Instituto Politécnico Nacional
Tel: 729-60-00 EXT. 56077
Fax: 586 3394
e_mail: jtamayo@vmredipn.ipn.mx
Av. Ticomán No. 600, Col. San José Ticomán, Del G.A. Madero
D.F.
MÉXICO

MALDONADO REYNOSO JAIME ALBERTO
Instituto Politécnico Nacional
Tel: 519-55-24
Fax: 519 5524
e_mail: jaimal@supernet.com.mx
Av. hidalgo No. 132, Col. Sta. Anita
D.F.
MÉXICO

ROCH JAVIER
Instituto Politécnico Nacional
Tel: 618-74-90
Fax: 618 7490
e_mail: javier_roch@hotmail.com
Av. Ticomán No. 600 Col. San José Ticomán
D.F.
MÉXICO

SAEZ ANASTASIO
Instituto Politécnico Nacional
Tel: 729-60-00
Fax:
e_mail:
Av. Ticomán No. 600, Col. San José Ticomán
D.F.
MÉXICO

SERRANO RÍOS CRUZ
Instituto Politécnico Nacional
Tel: 729-60-00
Fax:
e_mail:
MÉXICO

SORIANO LÓPEZ CESAR
Instituto Politécnico Nacional
Tel: 729-60-00
Fax:
e_mail:
Av. Ticomán No. 600, Col. San José Ticomán
D.F.
MÉXICO

SOSA PEDROZA JORGE
Instituto Politécnico Nacional
Tel: 729 60 00 EXT. 54904
Fax: 7296000 ext. 54904
e_mail: jsosa@vmredipn.ipn.mx
U. P. Adolfo López Mateos edif. 5, 3er. Piso, Av. IPN s/n Col. Lindavista
D.F.
MÉXICO

VALLE FRANCISCO
Instituto Politécnico Nacional
Tel: 558-59-43
Fax:
e_mail: fvalle@vmredipn.ipn.mx
Calle 87 No. 39 Col. Puebla
D.F.
15020 MÉXICO

ZIMAN DAVID
Instituto Politécnico Nacional
Tel: 52 5 5 74 30 17
Fax: 574 56 59
e_mail:
Amsterdam 180-201
D.F.
MÉXICO

VILLA LÓPEZ FRANCISCO JAVIER
INSTITUTO TECNOLÓGICO AUTÓNOMO DE MÉXICO
Tel: 628-48-00 EXT. 36-05
Fax: 616 22 11
e_mail: fvilla@lamport.rhon.itam.mx
Rio Hondo No. 1
D.F.
MÉXICO

BUSTAMANTE ROGELIO
INSTITUTO TECNOLÓGICO DE ESTUDIOS SUPERIORES DE MONTERREY
Tel: 525-48-32-202
Fax: 673 25 00
e_mail: rbustama@campus.ccm.itesm.mx
Del Puente 222, Col. Ejidos de Huipulco
D.F.
MÉXICO

SUJO YOK
INSTITUTO TECNOLÓGICO DE ESTUDIOS SUPERIORES DE MONTERREY
Tel: 343-07-00
Fax: 572 7745
e_mail: al444592@cadim01.cem.itesm.mx
Fuente de la Luna #38. Fuente de la Luna #38. Fuentes de Satélite, Atizapan
Edo. de México
MÉXICO

MÉNDEZ GARCÍA JULIO
LATTICE TELECOMUNICACIONES PERSONALES S.A. DE C.V.
Tel: 682-80-40 687-87-12
Fax: 669 2679
e_mail: jmendez@solar.sar.net
Calle Diagonal No. 27 Col del Valle
D.F.
03100 MÉXICO

ALVAREZ VILLASEÑOR ALEJANDRA
NOTIMEX
Tel: 420-11-00
Fax:
e_mail:
MÉXICO

CELIS ESTHER
PCI GEOMATICA S.A. DE C.V.
Tel: 52-5-685-75-90
Fax: 685 76 43
e_mail: celis@instantmex.com
Camino Real a Sn. Lorenzo # 263
D.F.
MÉXICO

RIVEROLL FUSTER ERIK
INSTITUTO TECNOLÓGICO DE ESTUDIOS SUPERIORES DE MONTERREY
Tel: 379-34-68
Fax:
e_mail: al444187@acadenet.cem.itesm.mx
Hacienda de Canndapaz #11, Lomas de la Hacienda, Atizapan
Edo. de Mex.
D.F.
MÉXICO

MARTÍNEZ PIÑÓN FERNANDO
Gerente de Relaciones con la Industria
IUSACELL, S.A DE C.V.
Tel: 525-500-05-50 EXT. 3244 CELULAR 525-504-00-92
Fax: 272 2477
e_mail: fermtz@iusa.net.mx
Lateral Sur S/N Frente Grupo 40, Mz. 4 Unidad Habitacional Santa Fé
D.F.
01170 MÉXICO

SALDIVAR D. JOSÉ LUIS
NO TIENE
Tel: 280-62-23
Fax:
e_mail:
MÉXICO

CABRERA SÁNCHEZ ALMA LUZ
PCI GEOMATICA S.A. DE C.V.
Tel: 686-42-55
Fax:
e_mail:
Camino Real a Sn. Lorenzo # 263
D.F.
MÉXICO

MENDOZA ARTURO
PETRÓLEOS MEXICANOS
Tel: 938-112-15
Fax: 01 938 112 15
e_mail: arturom@mne.pep.pemex.com
Calle 31 s/n
Cd. del Carmen. Camp.
MÉXICO

VILLARREAL ERNESTO
PROEZA
Tel: 52-8-346-96-99
Fax: 01 528 346 9713
e_mail: uirmareut@infosel.net.mx
Constitución 405 Pte. piso 1
Monterrey, N.L.
64000 MÉXICO

BISIACCHI GIANFRANCO
PROGRAMA UNIVERSITARIO DE INVESTIGACIÓN Y DESARROLLO ESPACIAL UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO
Tel: 550-13-50
Fax: 616 01 07
e_mail:
Circuito exterior s/n. Ciudad Universitaria
D.F.
MÉXICO

LIBERMAN DAVID
PROGRAMA UNIVERSITARIO DE INVESTIGACIÓN Y DESARROLLO ESPACIAL UNIVERSIDAD NACIONAL AUTÓNOMA DE MÉXICO
Tel: 550-13-50622-86-11
Fax:
e_mail: liberman@aleph.cinstrum.unam.mx
Circuito exterior s/n. Ciudad Universitaria
D.F.
MÉXICO

ARRAS LEÓN DIONISIO
REDSAT
Tel: 568-35-46
Fax: 568 22 82
e_mail: darras@redsat.com
Av. México 516, San Jerónimo Aculco
MÉXICO

BARRERA DÍAZ CYNTIA
REUTERS
Tel: 728-95-49
Fax: 540 30 01
e_mail: cyntia.barrera@reuters.com
Monte Pelvoux # 110 Lomas de Chapultepec
D.F.
11000 MÉXICO

IANKOV KRASSIMIR
SAP
Tel: 514-68-25
Fax: 525 13 32
e_mail: sap@mpsnet.com.mx
Colima 220-307, Col. Roma
D.F.
MÉXICO

ZUÑIGA C. DIANA
SAP
Tel: 514-68-25
Fax: 252 12 32
e_mail: sapki@hotmail.com
Colima 220-307 Col. Roma
D.F.
06700 MÉXICO

BAÑOS AMADOR BENJAMIN
Satélites Mexicanos, S.A. de C.V.
Tel: 613-53-23
Fax: 6 13 53 23
e_mail:
Av. de las Telecomunicaciones s/n Col. Leyes de Reforma, Del. Iztapalapa
D.F.
09310 MÉXICO

BEAUJEAN PIER
Satélites Mexicanos, S.A. de C.V.
Tel: 629-17-53
Fax: 614 31 30
e_mail:
Av. de las Telecomunicaciones s/n Col. Leyes de Reforma, Del. Iztapalapa
D.F.
09310 MÉXICO

CABALLERO ACOSTA ADÁN
Satélites Mexicanos, S.A. de C.V.
Tel: 629-13-56
Fax: 629 13 56
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

CASTILLA JORGE
Satélites Mexicanos, S.A. de C.V.
Tel: 211.93-84
Fax: 211 9384
e_mail: jcastilla@vsat.com
Eje Central Lázaro Cárdenas 567, piso 15, Col. Narvarte
D.F.
03020 MÉXICO

CORTES MARISCAL DORA LUZ
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-21
Fax: 530-00-67
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

ESQUEDA IBARRA ADRIANA
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-21
Fax: 530 00 67
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

FLORES AGUILAR FERNANDO
Satélites Mexicanos, S.A. de C.V.
Tel: 613-53-23
Fax: 613 53 23
e_mail:
Av. de las Telecomunicaciones s/n Col. Leyes de Reforma, Del. Iztapalapa
D.F.
09310 MÉXICO

GALLEGOS JAVIER
Satélites Mexicanos, S.A. de C.V.
Tel: 613-53-23
Fax: 613 5323
e_mail:
Av. de las Telecomunicaciones s/n Col. Leyes de Reforma, Del. Iztapalapa
D.F.
09310 MÉXICO

GAMA ENRIQUE
Satélites Mexicanos, S.A. de C.V.
Tel: 519-66-17
Fax:
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

GARCÍA MARTÍNEZ FRANCISCO
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-60
Fax:
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

GARCÍA OROZCO JOSÉ FRANCISCO
Satélites Mexicanos, S.A. de C.V.
Tel: 629-13-41
Fax: 530 7927
e_mail: encervan@infosel.net.mx
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

GONZÁLEZ HERNÁNDEZ JOSÉ
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-56
Fax: 629 1356
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

GUTIÉRREZ SOLÍS GUADALUPE
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-21
Fax:
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

HERNÁNDEZ RODRÍGUEZ JOSÉ LUIS
Satélites Mexicanos, S.A. de C.V.
Tel: 629-13-56
Fax:
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

JAUREGUI NIETO ANA LUISA
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-21
Fax: 530 00 67
e_mail:
Eje Central Lázaro Cárdenas 567, piso 13, Col. Narvarte
D.F.
03020 MÉXICO

MELGAREJO TRUJILLO ARTURO
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-21
Fax: 530 00 67
e_mail:
Eje Central 567, Piso 13 norte, Col Narvarte
D.F.
03020 MÉXICO

MERLO MOJICA MARCO ANTONIO
Satélites Mexicanos, S.A. de C.V.
Tel: 629-13-41
Fax:
e_mail:
Eje Central 567, Piso 13 norte, Col Narvarte
D.F.
03020 MÉXICO

MORALES ADRIANA
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-00 EXT. 2261
Fax:
e_mail:
Eje Central 567, Piso 13 norte, Col Narvarte
D.F.
03020 MÉXICO

PACHECO HERNÁNDEZ CARLOS GABRIEL
Satélites Mexicanos, S.A. de C.V.
Tel: 629-16-16
Fax:
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

RÍOS PÉREZ JOSÉ LUIS
Satélites Mexicanos, S.A. de C.V.
Tel: 120-51-74
Fax:
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
03020 MÉXICO

ROMERO AGUILAR JOSÉ FRANCISCO
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-00 EXT. 4579
Fax: 614 31 30
e_mail: fromero@planet.com.mx
CONTEL Iztapalapa Av. de las Telecomunicaciones s/n, Col. Leyes de Reforma
D.F.
09310 MÉXICO

SALAZAR MUÑOZ SILVIA
Satélites Mexicanos, S.A. de C.V.
Tel: 629-12-49
Fax:
e_mail:
Eje Central Lázaro Cárdenas No. 567, Col. Narvarte
D.F.
03020 MÉXICO

SÁNCHEZ ORTÍZ DAVID
Satélites Mexicanos, S.A. de C.V.
Tel: 613 53 23
Fax: 614 3130
e_mail:
Av. Telecomunicaciones s/n Col. leyes de Reforma
D.F.
09310 MÉXICO

TAPIA LORANCA MA. BEGOÑA
Satélites Mexicanos, S.A. de C.V.
Tel: 629-12-53
Fax:
e_mail:
Eje Central Lázaro Cárdenas No. 567, Col. Narvarte
D.F.
03020 MÉXICO

TORRES JAVIER
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-81
Fax: 629 1356
e_mail:
Eje Central Lázaro Cárdenas No. 567, Col. Narvarte
D.F.
03020 MÉXICO

TUN MOLINA DIONISIO
Satélites Mexicanos, S.A. de C.V.
Tel: 629-16-56
Fax: 614 3130
e_mail: dmtun@TELECOMcx.com
Av. Telecomunicaciones s/n Col. leyes de Reforma
D.F.
09310 MÉXICO

ZAMUDIO ZEA JUAN M.
Satélites Mexicanos, S.A. de C.V.
Tel: 629-11-00 EXT. 4044 Y 4045
Fax: 629 1618
e_mail:
Av. Telecomunicaciones s/n Col. leyes de Reforma
D.F.
09310 MÉXICO

DORANTES PAZ ARMANDO
SECRETARÍA DE EDUCACIÓN PÚBLICA
Tel: 420-62-63
Fax: 420 6263
e_mail:
Fray Servando # 127
D.F.
MÉXICO

JIMÉNEZ FLORES LORENA EINGELI
SECRETARÍA DE EDUCACIÓN PÚBLICA
Tel: 753-47-63
Fax:
e_mail:
D.F.
MÉXICO

RAMÍREZ LINARES MA. DEL ROSARIO
SECRETARÍA DE EDUCACIÓN PÚBLICA
Tel: 577-08-55
Fax:
e_mail:
Av- San Juán de Arasus. Col. San Pedro el Chico
D.F.
MÉXICO

REYNA PINEDA MACARIO
SECRETARÍA DE EDUCACIÓN PÚBLICA
Tel: 649-6-13
Fax:
e_mail:
Av. Churubusco Esq. Canal de Tezontle
D.F.
MÉXICO

AGUIRRE GUADARRAMA FRANCISCO EZEQUIEL
SECRETARÍA DE LA DEFENSA NACIONAL
Tel: 557-72-35
Fax: 395 36 63
e_mail:
Periférico Nte. Esq. Av. Ind. Mil. Lomas de Sotelo
D.F.
MÉXICO

ALLENDE SANCHO
SECRETARÍA DE LA DEFENSA NACIONAL
Tel: 552-32-00 EXT.3912
Fax:
e_mail:
Periférico Nte. Esq. Av. Ind. Mil. Lomas de Sotelo
MÉXICO

CASARRUBIAS TACUBA SEBASTIÁN
SECRETARÍA DE LA DEFENSA NACIONAL
Tel:
Fax:
e_mail:
Periférico Nte. Esq. Av. Ind. Mil, Lomas de Sotelo
MÉXICO

GÓMEZ MARTÍNEZ MARTÍN
Dirección General de Cartografía
SECRETARÍA DE LA DEFENSA NACIONAL
Tel: 589-42-92
Fax: 589 4292
e_mail:
Periférico Nte. Esq. Av. Ind. Mil, Lomas de Sotelo
D.F.
MÉXICO

SOSA ORGANISTA JUAN MANUEL
SECRETARÍA DE LA DEFENSA NACIONAL
Tel: 557-45-00 5 57-32 00 EXT. 3365
Fax: 395 3663
e_mail: ssistema@compuserve.com.mx
Periférico Nte. Esq. Av. Ind. Mil, Lomas de Sotelo
D.F.
MÉXICO

FUCUGAUCHI JUANA
SECUNDARIA
Tel: 420-62-63
Fax: 420 6263
e_mail:
Fray Servando # 127 5o. Piso
D.F.
MÉXICO

VILLASANA M. EDMUNDO
SEGUROS COMERCIAL AMÉRICA
Tel: 727-10-41
Fax: 229 9533
e_mail:
Paseo de la Reforma No. 175, 5o. Piso, Col Cuauhtémoc
D.F.
06500 MÉXICO

TORRES GÓMEZ ROSALINDA
SEP
Tel: 719-07-29
Fax:
e_mail:
Fray servando Teresa de Mier No. 27
D.F.
MÉXICO

TRUJILLO BLANCAS MA. NOEMÍ
SEP
Tel: 7-94-75-80
Fax:
e_mail:
Av. 477 # 24 Unidad Aragón, Secc. VII
D.F.
MÉXICO

URQUIZA CUTBERTO
SEP
Tel: 571-41-62
Fax:
e_mail:
Reforma 57 Av. del Taller
MÉXICO

VELASCO OROZCO BENJAMÍN MANUEL
SEP
Tel: 551-26-66
Fax:
e_mail:
MÉXICO

VILLAGRÁN FRANCISCO JAVIER
SEP
Tel: 670-59-44
Fax:
e_mail:
Campesinos #256 Col. Progreso.
MÉXICO

RAMOS GONZÁLEZ VÍCTOR
SERVICIO METEOROLÓGICO NACIONAL
Tel: 626-86-00 EXT. 3426
Fax:
e_mail:
Av. Observatorio #192
D.F.
11860 MÉXICO

QUIROS FERNANDO
SOCIEDAD ASTRONÓMICA DE LA FACULTAD DE INGENIERÍA (SAFIR)
Tel: 684-67-40
Fax: 684 6740
e_mail: fquiros@servidor.unam.mx
Rancho del Gallego #21 Col. Prado Coapa
D.F.
MÉXICO

GAMA MIGUEL ÁNGEL
TELECOM-ICO
Tel: 629-11-57
Fax: 530 7530
e_mail:
Eje Central Lázaro Cárdenas 567, Col. Narvarte
D.F.
MÉXICO

ALARCÓN LEOPOLDO
Telecomunicaciones de México
Tel: 629-16-94
Fax: 6 29 16 94
e_mail:
Eje Central Lázaro Cardenas #567, Narvarte
D.F.
03020 MÉXICO

JIMÉNEZ JAVIER
Telecomunicaciones de México
Tel: 629-17-75
Fax: 629 1694
e_mail: huizar99@hotmail.com
Av. de las Telecomunicaciones s/n Col. Leyes de Reforma, Del. Iztapalapa
D.F.
09310 MÉXICO

PERUJO IÑAKI
SOCIEDAD ASTRONÓMICA DE LA FACULTAD DE INGENIERÍA (SAFIR)
Tel: 211-05-97
Fax: 553 4180
e_mail: jperujo@hermes.uninet.net.mx
Parque España 53-3, Col. Condesa
D.F.
MÉXICO

VIDAL TERESA
SOCIEDAD ASTRONÓMICA DE LA FACULTAD DE INGENIERÍA (SAFIR)
Tel: 671-32-17
Fax: 671 32 17
e_mail: iperukjo@hermes.uninet.net.mx
Rancho Panda #66 Col. Haciendas de Coyoacán
D.F.
MÉXICO

A. ISAAC ÁNGEL
Telecomunicaciones de México
Tel: 629-16-45
Fax: 629 26 94
e_mail: Angelesc@Hotmail.com
Av. de las Telecomunicaciones s/n Col. Leyes de Reforma, Del. Iztapalapa
D.F.
09310 MÉXICO

GUERRERO LUIS
Telecomunicaciones de México
Tel: 629-11-29
Fax: 519 1855
e_mail:
Eje Central Lázaro Cárdenas 567 Piso 9 Ala Sur, Col. Narvarte
D.F.
03020 MÉXICO

JIMÉNEZ SALAZAR ALMA XOCHITL
Telecomunicaciones de México
Tel: 629-12-58
Fax: 519 1855
e_mail:
Eje Central 567, Piso 9 sur, Col Narvarte
D.F.
03020 MÉXICO

LÓPEZ ARRIAGA ULISES
Telecomunicaciones de México
Tel: 629-16-94
Fax: 629 1694
e_mail: ulisesla@hotmail.com
Av. de las Telecomunicaciones s/n Col. Leyes de Reforma, Del. Iztapalapa
D.F.
09310 MÉXICO

MARTÍNEZ ESCOBAR MARTÍN
Coordinador de Desarrollo de Nuevos Servicios
Telecomunicaciones de México
Tel: 629-12-05
Fax: 519 1855
e_mail:
Eje Central Lázaro Cárdenas No. 567, Piso 9, ala Sur. Col. Narvarte
D.F.
03020 MÉXICO

RICO MERCEDES
Telecomunicaciones de México
Tel: 629-12-52
Fax: 519 1855
e_mail:
Eje Central Lázaro Cardenas #567, Narvarte
D.F.
03020 MÉXICO

ROBLES RENÉ
Telecomunicaciones de México
Tel: 629-12-01
Fax: 530 7530
e_mail:
Eje Central Lázaro Cardenas #567, Narvarte
D.F.
03020 MÉXICO

VALDÉZ MELCHOR
Telecomunicaciones de México
Tel: 629-17-76
Fax: 629 1694
e_mail:
Eje Central Lázaro Cardenas #567, Narvarte
D.F.
03020 MÉXICO

VIVEROS JOSÉ FRANCISCO
Telecomunicaciones de México
Tel: 52-5-629-16-40
Fax: 629 1694
e_mail: Fviveros@TELECOMex.com
Cda. Nicolas Bravo #5, Tepepan Xochimilco
D.F.
MÉXICO

CHAVIRA MARTÍNEZ ELSA
UNIVERSIDAD AUTÓNOMA DE PUEBLA
Tel: 22-44-39-49
Fax:
e_mail:
MÉXICO

PEDROZA MELÉNDEZ ALEJANDRO
UNIVERSIDAD AUTÓNOMA DE PUEBLA
Tel: 22-44-39-49
Fax:
e_mail:
MÉXICO

GANDARILLA OTHON
UNIVERSIDAD AUTÓNOMA METROPOLITANA
Tel: 724-46-30
Fax:
e_mail: oton@xanum.uam.mx
Av. Michoacan y Purísima S/N
D.F.
MÉXICO

RODRÍGUEZ AGUIRRE ARTURO JAVIER
UNIVERSIDAD IBEROAMERICANA
Tel: 688-90-04
Fax: 688 9004
e_mail: Pam@mail.ulanet.mx
Palomar # 43 Col. Gral. Anaya
D.F.
MÉXICO

ALVAREZ ROMÁN
Universidad Nacional Autónoma de México
Tel: 683-64-80
Fax: 616 21 47
e_mail: rab@igiris.igeograf.unam.mx
Ciudad Universitaria
D.F.
04510 MÉXICO

AVILA MARTÍNEZ GERARDO
Universidad Nacional Autónoma de México
Tel: 736-41-27
Fax:
e_mail:
UNAM Campus Aragón
MÉXICO

CARRASCO YEPEZ FRANCISCO EDUARDO
Universidad Nacional Autónoma de México
Tel: 389-44-14
Fax:
e_mail: edcaye@cancun.fi-a.unam.mx
Juárez 85-502 Col. Ex-hda. de Enmedio
D.F.
54170 MÉXICO

DIEZ BARROSO LUIS
Universidad Nacional Autónoma de México
Tel: 551-77-16
Fax:
e_mail:
Pekin # 65 Col. Romero Rubio. Del. Venustiano Carranza
D.F.
15400 MÉXICO

FLORIO JOSÉ S.
Universidad Nacional Autónoma de México
Tel: 592-13-97
Fax: 511 9120
e_mail: florio@servidor.unam.mx
Río Amazonas No. 57
D.F.
06500 MÉXICO

HERNÁNDEZ ALVAREZ EDITA CELIA
Universidad Nacional Autónoma de México
Tel: 573-87-73
Fax:
e_mail: editah@cosmeg.fi-a.unam.mx
Ed. Luis G. Valdez Vallejo. Fac. de Ing. C.U.
D.F.
04510 MÉXICO

IBARRA PEREYRA MARIO
Universidad Nacional Autónoma de México
Tel: 622-30-66
Fax: 622 30 50
e_mail: Marioa@aries-fi-b-unam.mx
C.U. Facultad de Ingeniería
D.F.
04510 MÉXICO

LÓPEZ RABADAN RICARDO
Universidad Nacional Autónoma de México
Tel: 756-48-89
Fax: 756 48 89
e_mail:
Simón Advenard # 72
D.F.
MÉXICO

LUJÁN CORTÉS LEONARDO
Universidad Nacional Autónoma de México
Tel: 394-54-76
Fax:
e_mail: isaragon@indy.aragon.unam.mx
V.H. El Rosario Croc II Edif 78, dpto. 402
D.F.
MÉXICO

LUNA LUIS
Universidad Nacional Autónoma de México
Tel: 782-16-70
Fax:
e_mail:
MÉXICO

MACÍAS GUZMÁN DEMETRIO
Universidad Nacional Autónoma de México
Tel: 688-69-36
Fax:
e_mail: MAGD68@Hotmail.com
Prolongación Tajín #901, Col. Sta. Cruz Atoyac
D.F.
MÉXICO

MARTÍNEZ FLORES JOSÉ LUIS
Universidad Nacional Autónoma de México
Tel: 622-31-19
Fax:
e_mail: baker@dctrl.fi-b.unam.mx
C.U., Facultad de Ingeniería
D.F.
04510 MÉXICO

MENDOZA ERIKA
Universidad Nacional Autónoma de México
Tel: 666-05-34
Fax:
e_mail: erikam@verona.fi-p.unam.mx
Cerro del tesoro 130, Col. Romero de Terreros, Coyoacán
D.F.
MÉXICO

MENDOZA ROSALES ROCÍO
Universidad Nacional Autónoma de México
Tel: 568-68-89
Fax:
e_mail: rociom@speech.fi-p.unam.mx
MÉXICO

OROPEZA RAMOS LAURA
Universidad Nacional Autónoma de México
Tel: 528-39-61
Fax:
e_mail:
Lázaro Cárdenas no. 152, San Bartolo
D.F.
07730 MÉXICO

PALACIO JOSÉ LUIS
Universidad Nacional Autónoma de México
Tel: 52-5-622-43-40
Fax: 616 2145
e_mail: palacio@servidor.unam.mx
C.U.
D.F.
04510 MÉXICO

PORTA ADRIANA
Universidad Nacional Autónoma de México
Tel: 622-30-55
Fax: 616 18 55
e_mail: adriana@verona.fi-p.unam.mx
Calle 71, Av. 6, edif B-4, Col Sta. Cruz M. Iztapapalapa
D.F.
MÉXICO

RODRÍGUEZ HELADIO
Universidad Nacional Autónoma de México
Tel: 622-30-25
Fax:
e_mail: heladior@verona.fi-p.unam.mx
MÉXICO

SÁNCHEZ JORGE
Universidad Nacional Autónoma de México
Tel: 622-31-13
Fax: 622 3113
e_mail: jorgsate@servidor.unam.mx
Calle de la Manzana #42 Col. Los Reyes Culhuacán, Iztapalapa
D.F.
MÉXICO

TÉLLES JUAN MANUEL
Universidad Nacional Autónoma de México
Tel: 622-31-13
Fax:
e_mail: juanma@servidor.unam.mx
Andador 3 #32 col. Juventino Rosas, Iztacalco
D.F.
08700 MÉXICO

VICENTE VIVAS ESAÚ
Universidad Nacional Autónoma de México
Tel: 622 81 28
Fax: 622 8091
e_mail: E V V@automatizacion.iingen.unam.mx
C.U. Av. Universidad s/n Coyoacán
D.F.
04510 MÉXICO

SÁNCHEZ VÍCTOR
UNIVERSIDAD TECNOLÓGICA
Tel: 373-87-78
Fax: 358 7931
e_mail:
Morelos 23-A Bosque de los Remedios. Naucalpan
Edo. de México
MÉXICO

CUÉLLAR RAMOS ANÍBAL
UNIVERSIDAD TECNOLÓGICA DE MÉXICO
Tel: 542-97-23
Fax:
e_mail:
MÉXICO

LÓPEZ GIRON JESÚS
UNIVERSIDAD TECNOLÓGICA DE MÉXICO
Tel: 756-65-77
Fax:
e_mail:
MÉXICO

REYES ANDRADE VÍCTOR MANUEL
UNIVERSIDAD TECNOLÓGICA DE MÉXICO
Tel:
Fax:
e_mail:
MÉXICO

ROCHA BUSTOS JUAN MANUEL
UNIVERSIDAD TECNOLÓGICA DE MÉXICO
Tel: 382-09-90
Fax:
e_mail:
MÉXICO

COLOMA RICARDO
Comisión Nacional de Investigación y Desarrollo Aeroespacial
Tel: 511-441-9081
Fax: 00 511 4419081
e_mail: rcoloma@conida.gob.pe
Felipe Villaran 1069
Lima
27 PERÚ

KIRKMAN ANDREW
REMOTE SENSING INSTRUMENTATION
Tel: 44 1252 39 5723
Fax: 00 44 1252 51 55 23
e_mail: askirkman@Meto.gov.uk
Building 470, Dera Farnborough Hampshire
REINO UNIDO

WRIGHT LOUISE
REMOTE SENSING INSTRUMENTATION
Tel: 44-1252-39-57-24
Fax: 00 44 1252 515523
e_mail: lawright@meto.gob.uk
Building 470, Dera Farnborough Hampshire
REINO UNIDO

LEGATE ELLA
MATRA MARCONI SPACE
Tel: 44 17 05 7045 33
Fax: 44 1705 70 82 80
e_mail:
Anchorage road Portsmouth
REYNO UNIDO

SAWYER GEOFF
MATRA MARCONI SPACE
Tel: 44 17 05 705 872
Fax: 00 44 1705 708 290
e_mail: geoff.sawyer@mmsuk.co.uk
Anchorage road Portsmouth
REYNO UNIDO

SAMOILOV STEPAN
EMBAJADA DE LA FEDERACIÓN DE RUSIA
Tel: 273-13-05
Fax: 202 1200
e_mail:
Av. José Vasconselos # 204
D.F.
RUSIA

HACKER PETER
SWISS RE NEW MARKETS
Tel: 411-28-555-57
Fax:
e_mail:
SUIZA

OPADEYI JACOB
CTU/UWI
Tel: 868 662 2002
Fax: 00 868 662 4414
e_mail: jopadeyi@eng.uwi.tt
University of the West Indies
Trinidad
TRINIDAD

RODRÍGUEZ BRIANZA CARLOS
SECRETARÍA PRO TEMPORE III CEA
Tel: 58 82 900 18 26
Fax: 00 5982 903 03 93
e_mail: IIICEA@MRREE.UY
URUGUAY

SHAVEL LEONARD
BABCOCK
Tel: 203-862-48-20
Fax: 203 862 4848
e_mail: lbs@babcockbraun.com
2 Soundview Drive, Greenwich CT
06830 USA

POTTS DANA
C.L.S.
Tel: 341-18-14
Fax: 301 341 2130
e_mail: dpotts@nacls.com
9200 Basil Court Suite 306
Largo
MD 21045 USA

AGUILAR JESÚS
H.S.C.
Tel: 310-364-71-85
Fax: 00 1 310 3 64 71 85
e_mail:
P.O. Box 80028
Los Angeles, Ca
90080 USA

LANDAZURI HELENA
IDB
Tel: 1 202 623 1872
Fax: 00 1 202 623 1417
e_mail: helenal@iadb.org
1300 New York Ave. Stop E-1500
Washington D.C.
USA

KHALIL MOHSEN
IFC WORLD BANK
Tel: 1-202-473-67-86
Fax: 00 1 204 974 4403
e_mail: MKhalil@IFC.org
2121 Pennsylvania Avenue
Washington, D.C.
20008 USA

HOGAN GLEN
INTERNATIONAL SPACE BROKERS
Tel: 703-841-13-34
Fax: 00 1 703841 0525
e_mail: glenh@isbworld.com
1300 wilson blvd. Suite 990
Rosslyn
VA 22209 USA

GOLDSTEIN CAROL
MORGAN STANLEY
Tel: (212) 761-03-74
Fax: 00 1 212 761 4364
e_mail: goldstein@ms.com
1585 Broadway
New York
USA

SALCEDO RAMIRO
FII- CPDI
Tel: 58 2 903 4666
Fax: 00 582 903 4781
e_mail: selper@telcel.net.ve
Apdo. Post. 40200
Carácas
1040-A VENEZUELA

HOOD VALERIE
ESA
Tel: 33 1 53 69 74 43
Fax: 33 1 53 69 75 60
e_mail: vhood@hq.esa.fr
8-10 rue Mario Nikkis
Paris

European Space Agency
Agence spatiale européenne

Contact: ESA Publications Division
c/o ESTEC, PO Box 299, 2200 AG Noordwijk, The Netherlands
Tel (31) 71 565 3400 - Fax (31) 71 565 5433