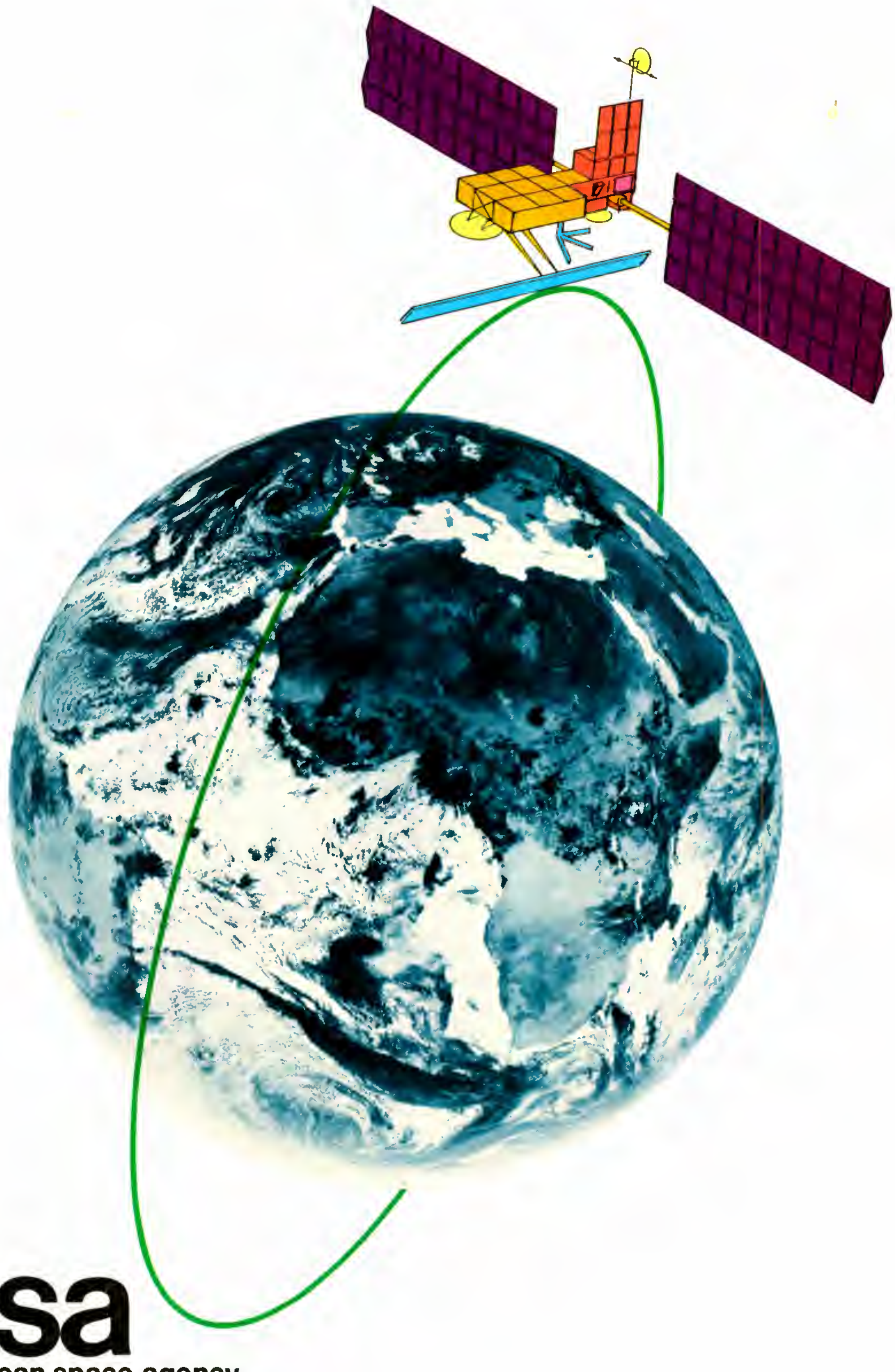
Report of the working group on

Earth Observation Requirements for the Polar Orbiting Platform Elements of the International Space Station



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EXECUTIVE SUMMARY

Polar Orbit Earth Observation requirements have been considered for the Space Station era. Candidate model payload groupings (both an initial set and an evolutionary growth) have been derived assuming the availability of serviceable permanent polar platforms, e.g. a "morning" platform provided by ESA, and an "afternoon" one by NASA.

The resulting generic payload requirements have been estimated, and at first sight appear to be consistent with the assumptions being made in the Columbus Polar Platform Phase B1 study. This study at present shows that such assumptions are close to what can be realised with the use of a single Ariane-5 or shuttle for launching the inital configuration and a single shuttle for augmenting it at servicing intervals.

The candidate model payloads represent a first but important step in converging towards a set of requirements agreed by the space agencies who would participate in the provision or contribution of platforms and/or payloads to realise such a capability.

1. INTRODUCTION

Satellites have been observing the Earth now for over 25 years. Technological advances have lead to dramatic improvements in the quality of the data acquired and in the end uses to which they are put.

We tend to take for granted the role that satellites play today. Weather forecasts are to a large extent based on the meteorological parameters routinely measured by a coordinated set of meteorological satellites (of which Europe has since 1977 contributed the METEOSAT series). The land areas have been observed by the LANDSAT satellites since 1972, and have recently been joined by the SPOT satellite; ocean and ice areas by SEASAT and NIMBUS 7, and in the future by ERS-1; the atmosphere is investigated by the NIMBUS satellite series; navigation and special satellites (e.g. LAGEOS) are used for solid earth research and applications.

All these satellites are expendable. They carry out their missions until degradation or failures reduce the usefulness of the mission to a point where they are no longer of value. In many cases a new satellite is then launched to take over and to continue the service.

The Earth Observation part of the European Long Term Plan, approved by the ESA Council meeting in Rome in January 1985 at Ministerial level, assumed the use of conventionalexpendable satellites.

At the same meeting the possibility of in-orbit servicing and repair of satellites has been favoured by the decision to participate in the international space station programme proposed by the United States by providing among others items a polar platform. The future space station (of which the European component will be called Columbus) in fact is based on permanent facilities maintained and improved in-orbit. The fact that a significant fraction of the observations of the Earth from space have been and still are done from satellites in rather similar near polar (in fact sun-synchronous) orbits has led the Space Agencies on both sides of the Atlantic to consider how a small number of permanent polar orbiting platforms could form the basis of almost all future satellites observations from polar orbit. As a consequence, the Earth Observation activities of ESA are in the process of being reoriented towards the use of this important space station element.

A basic scenario of two permanent platforms in sun-synchronous orbits, one in a so-called "morning" orbit (with a descending node in the late morning) and the other in an "afternoon" orbit (with an ascending node in the early afternoon) has been the subject of increasingly detailed consideration by many Space Agencies and Nations. These platforms would be permanent, serviced in-orbit and the payloads would be updated and augmented as time goes on.

The present stage of the Space Station studies (Phase B) conducted separately by the US and ESA includes Polar Platform elements. These studies aim at defining candidate platforms to satisfy model payload requirements which have been provided separately by the US and ESA as driving inputs for their own studies. It turns out that the Polar Platform users are predominantly from Earth Observation.

Most nations wish to make the same type of observations of the Earth, and since polar orbiting satellites provide coverage of virtually the whole globe (except for the poles), interest has been expressed in determining the extent to which such platforms and payloads could be provided and their use shared in a cooperative and coordinated way by the various Space Agencies and Nations.

As a first step towards improving the model payload generic requirements for further Polar Platform studies, ESA set up the Earth Observation Polar Orbiting Platform Element (POPE) Requirements Working Group. In this report the POPE Working Group has examined the requirements and priorities in the different areas of Earth Observation, drawing both on "Looking Down, Looking Forward" and on the Earth Observation part of the European Long Term Plan, in order to make a first assembly of payload groupings and to derive the resulting generic requirements for both initial and later Polar Platform configurations*. It has also addressed the possible role of other elements (e.g. a platform coorbiting with the Manned Space Station) and touched in a preliminary way on some of the operational aspects

At the same time this report will be of value to the ESA Executive for advancing the dialogue with other Space Agencies and Nations involved in Earth Observation activities in order to lead to a widely agreed set of technical requirements and representative payloads to be used as the basis for the development of internationally coordinated Polar Platform systems.

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* The following terms are used in this report:

IOC: Initial Orbit Configuration

MOC: Medium Term Orbit Configuration (a few years after IOC)

AOC: Advanced Orbit Configuration (a few years after MOC)

2. ASSUMPTIONS

The establishment of generic requirements for an ESA developed Polar Platform and a Co-orbiting Platform (a platform co-orbiting with the manned Space Station) has to take into account a number of constraints of a differing nature such as :

- mission and user-oriented, in order to fulfil the very wide and diverse requirements of the Earth Observation community;
- technical, for instance in looking at the cost-effectiveness of the proposed in-orbit servicing and maintenance capability;
- programmatic to match the overall time schedule proposed for the various elements of the ESA Earth Observation Long Term Programme;
- political, as agreed at the ESA Council Meeting at Ministerial level held in January 1985 in Rome, in particular as regards the cooperation with the USA for the Space Station;
- financial to be within the financial envelope adopted in Rome.

The assumptions made are given in more detail below.

2.1 Primary need for a Polar Platform

By far the most important users of a Polar Platform are the various disciplines (scientific and applications) of Earth observation, although its use may also be considered by life science disciplines communications, astronomy disciplines, etc.

The serviceable Polar Platform is assumed to be the in orbit infrastructure to replace expendable platforms such as that of SPOT used by the SPOT-series and ERS-1, and of TIROS-N used for the NOAA TIROS-N series of satellites, the latter platform being planned to be phased out after NOAA-K, L and M.

It should be recognised, however, that the use of a Polar Platform will not be the only means to fulfil the Earth observation needs. The Polar Platform mission will have to be complemented by other means, e.g.:

- geostationary Earth observation missions, such as the Second Generation Meteosat;
- high or very low altitude satellites for Solid Earth missions;
- missions utilising a retrievable carrier such as EURECA;
- Earth observation instruments on a possible Co-orbiting Platform;
- flights of opportunity on other missions (e.g. on microgravity, scientific or SPOT missions, or foreign missions (e.g. India)).

2.2 The ESA Long Term Plan

The ESA Long Term Plan provides guidelines with financial constraints on what can reasonably be achieved in the field of Earth observation. This plan calls for an upper annual financial limit available to Earth observation in the order 190-200 MAU (1984 economic conditions) over a period of about 11 years (1985-1996). Only a part of this budget will be available for Polar Orbit Earth observation missions as it also has to cover other activities, in particular the development of the Second Generation Meteosat and a Solid Earth mission.

Taking account of these other programmme requirements, the need for the order of 400 MAU for developing a set of instruments for a Polar Platform and of other assumptions given in 2.4 below, it is reasonable to plan for a launch of a first Polar Platform Earth Observation mission by the end of 1994, or beginning of 1995.

2.3 Economy of Servicing the Polar Platform

For this report, it is assumed that a serviceable Polar Platform concept is a cost-effective option with respect to expendable and retrievable platforms. The lifetime is expected to be of the order of 15 years with servicing missions being performed every 2-3 years. During servicing, new instruments will be added, others replaced, and the platform will be serviced and refuelled.

The strategy to perform servicing still needs to be investigated for several possible options :

- servicing at (or near) the platform altitude with the Hermès/Ariane-5 system or the OMV*/Shuttle system;

- servicing at the Shuttle altitude by de-orbiting the platform.

The merits of these options have to be studied in terms of technical feasibility, complexity, cost, operations and impact on services provided to users.

2.4 Interface with the ESA Columbus Space Station Programme

It is assumed that the Polar Platform will be developed as part of the ESA Columbus Space Station programme. The cost for the development, qualification, manufacture and launch of the first Polar Platform, the integration and test (checkout) of the Earth Observation payload together with the in-orbit checkout, operations and first servicing of the Polar Platform is therefore assumed to be borne by the Columbus Programme as part of the demonstration programme.

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* OMV = Orbital Manoeuvring Vehicle

2.5 Payload data acquisition, Pre-processing, Cataloguing, Archiving and Distribution

These tasks are assumed to be the responsibility of the Earth Observation activities of ESA, performed by the Earthnet Programme Office (EPO) in support of the Polar Orbit Earth Observation Programmes using the existing ground segment system adapted and complemented according to the needs of the user community.

The use of a European Data Relay Satellite (DRS), possibly developed by ESA, is assumed to be of benefit to the Earth Observation activities but its development is assumed to be at no cost to Earth Observation.

2.6 Polar Platform instrumentation

It is assumed that the payload complement of the initial orbit configuration will consist almost entirely of Earth observation instruments.

These will be a combination of ESA-provided and non-ESA provided multidisciplinary "core" instruments complemented by nationally provided instruments, the latter selected on the basis of an Announcement of Opportunity (AO). It is assumed that the integration and operation of the "core" instruments are ESA responsibilities, irrespective of whether they are developed by ESA or by other partners (e.g. US and Japan), who will in turn provide and operate platforms on the assumption that such partners provide similar flight opportunities to ESA on a reasonable equity and "no exchange of funds" basis.

The instruments of the core payload and those on the platforms belonging to other international partners are assumed to be selected through a closely coordinated Announcement of Opportunity (AO).

Funding for the ESA-provided instrumentation has been assumed to be of the order of 400 MAU.

2.7 Continuity of Scientific and Applications Data

The instrumentation is assumed to generate not only new but also existing types of data (although possibly enhanced) thus providing the European user community with the necessary continuity of access to data. Although the process of selection of instruments needs close coordination with the user community, the exact selection is not expected to drastically alter the general requirements on a Polar Platform.

2.8 Commercial Aspects

Commercial aspects (instruments provided and operated by private ventures) are assumed not to be part of the instrument payload of the initial orbit configuration (IOC).

2.9 Polar Platform Configuration at IOC

It is assumed that the Polar Platform system at IOC will consist of TWO (2) platforms, one provided by ESA and the other by an agency other than ESA (e.g. NASA, Japan) and deployed in a "morning orbit" for the former and in an "afternoon orbit" for the latter, with appropriate and phased repeat cycles. The various scenarios presented in Section 5 are based on the existence of such a 2-platform system. Should this assumption not be valid (e.g. only 1 platform at IOC), scenarios would be different.

2.10 Launchers

Two launch systems are currently under consideration, namely Ariane-5 and the Shuttle. Their expected capabilities for a sun-synchronous near-polar orbit configuration are given in Table 2.1. The choice of the launcher for the ESA-provided platform will depend on the availability of Ariane-5 at IOC. If this is not the case, the ESA platform may have to be Ariane **and** Shuttle compatible. In the event of a Shuttle launch, for both financial and technical reasonsit is assumed that it will be a **single-Shuttle** launch.

2.11 Technology trends

The development of advanced remote sensing sensors will require a major effort in the development of corresponding technologies. Priority areas for Europe include :

- laser (e.g. for lidar)
- large antenna (e.g. for microwave radiometer)
- high power amplifier (e.g. for SAR)
- cryogenics (e.g. for cooled limb sounder)

Table 2.1

LAUNCH CAPABILITIES OF ARIANE V AND SHUTTLE

SYSTEM	ORBIT ALTITUDE (km)	ORBIT INCLINATION (degrees)	MASS CARRYING CAPABILITY (kg)
ARIANE V	850	98	10,000
ARIANE V	276	98	13,000
Shuttle *	276	98	7,850
Shuttle **	276	98	10,250
HERMES (for servicing)	850	98	1,400 ***

* Normal performance but subtracting a payload mass margin of 1000 lb

** Enhanced performance version using so called "109% engines" but subtracting a payload mass margin of 1000 lb

*** Growth potential of ARIANE V might allow this to be increased

3. OBJECTIVES

3.1 Atmosphere Objectives

3.1.1 Current observational satellites

The first meteorological satellite was launched in 1960, and its potential for improving the understanding of the atmosphere and helping to improve weather forecasts was immediately recognised. Since that time the meteorological forecasting services have benefited greatly from the gradually increasing capabilities of these satellites, which have now become an integral and essential part of the meteorological global observing system. Image data from the TIROS-N series of NOAA polar orbiting satellites are used routinely for forecasting purposes at many hundreds of locations worldwide. Quantitative products from these satellites, such as sea surface temperatures and profiles of temperature in the atmosphere, are used routinely in near real-time as essential inputs to numerical forecast models. The high quality image data aids research concerning the atmosphere as well as in many studies of the surface of the ocean and the land. The data are used for monitoring purposes and contribute to the climatological data base.

The present NOAA TIROS-N series satellites are now an essential part of the global observing system and their capabilities must be maintained through the coming generations of polar platforms.

3.1.2 Improvements needed in observations

The need for improved observational data has increased as the understanding of the atmosphere grows. Current numerical forecasting models are already capable of forecasting the state of the atmosphere for several days with useful precision and accuracy. Economic arguments indicate the value of improving and extending this capability, and improvements in the observational data and suitable modification of models to exploit fully the type of data acquired are necessary to achieve this. The accuracy of existing satellite observations must be increased; some studies indicate that forecasts could be extended by another few days if the errors in the knowledge of the initial observed state could be halved.

Data from instruments developed for ERS-1 and similar satellites will make a contribution to the understanding of the lower atmosphere and boundary conditions, and should be made available on a routine basis. Novel instrumentation should be developed to help understand the atmospheric processes which are as yet poorly observed. The systems for transmitting the observational data to the forecasting services and to research centres, and the methods and systems used for extracting geophysical measurements from the raw data, must be further developed to improve the effectiveness of these valuable data. The evolving requirements for operational, research and monitoring purposes can only be met, therefore, by corresponding developments of the satellites and the ground based systems.

3.1.3 The hydrological cycle

One of the most important areas in which further advances are necessary relates to the observation of the hydrological cycle. The monitoring of total rainfall and soil moisture is essential for climatological studies and would assist in the understanding and prediction of rainfall fluctuations in arid zones. Observations of rainfall rate would be of direct assistance to the forecaster, would help to initialise numerical forecasting models and would contribute towards improvements in warnings of extreme rainfall leading to flooding. Soil moisture information would also be used in these models, as would improved atmospheric humidity fields.

3.1.4 The upper atmosphere

The troposphere is routinely monitored by meteorological instruments, but the key parameters of the upper atmosphere are not yet monitored in a systematic long term fashion. This is necessary because of the more and more evident role played by the upper atmosphere on the Earth's climate.

Some exciting instruments have been flown on an experimental basis on the Nimbus satellites or are planned for flight on the Upper Atmosphere Research Satellite (UARS). The expertise in instrument design gained from these short period experiments must be utilised to help specify a comprehensive programme of regular measurements of important parameters relevant to the upper atmosphere, including the stratosphere, mesosphere and thermosphere.

These atmospheric regions are attracting increasing attention because of concerns that minor constituents released as a result of human activity and natural evolution will have effects on the ozone layer, and more generally on the Earth's biospheric steady state aspects such as radiation input and output. The upper atmosphere is a region where there is a complex interplay between radiation, chemistry and dynamical effects (not yet fully understood) but it is also a region where adequate observational coverage over long periods cannot be achieved by conventional methods.

3.1.5 The Earth's climate

In order to understand properly our climate and its possible evolution it is essential to study the complex interactions between the individual components of the climate system.

The exchange of energy and momentum between the atmosphere, oceans, ice regions and land surfaces determines the thermodynamic equilibrium of our planet, its response to heating by solar radiation, and the natural statistical climatic fluctuations about this mean equilibrium state, as well as the predicted drift towards a new climatic state as a consequence of man's impact on the environment. These interactions are controlled by many different factors, including the distribution of atmospheric trace gases and pollutants, heat transport by ocean currents, the vegetation cover and moisture distribution on the Earth's surface, and the hydrological and biochemical cycles. The great power of satellite observations lies in their ability to provide both a global view of the planet and simultaneous measurements of the interactions between the many different components of the climate system.

Although some of the relevant parameters can already be and are being measured by satellite techniques (giving some insight into the complicated interactions taking place and possible future climatic evolutions) additional parameters need to be measured and all parameters require to be carefully and accurately monitored over long periods of time in view of the long time scales and time constants involved.

Such measurements required for studying and monitoring the Earth's climate on a continuing, comprehensive and global basis include measurement (in addition to the more conventional meteorological parameters) of atmospheric composition, incoming and outgoing radiation, ice cover, surface albedo, volcanic activity and the evolution of these. This will require careful attention to instrument calibration and stability over long periods.

3.1.6 Instrument development

Although more information could be extracted from present instruments through improved data access and processing algorithms, it is clear that further improvements in these instruments are needed and novel forms of instruments will be necessary if the observational requirements are to be met. Thus the Polar Platform programme must include provision for instrument development and for flying experimental instruments.

3.1.7 Instrument requirements

The instruments required to perform the basic meteorological observations from polar orbit, together with their principal characteristics, are given in table 3.1.1.

New major instruments required for the expanding atmosphere objectives and needs (including climatology) are given in table 3.1.2. Table 3.1.3 gives examples of smaller instruments which could contribute strongly to atmosphere objectives, and which are potential candidates for being provided nationally.

Table 3.1.1

OPERATIONAL INSTRUMENT REQUIREMENTS FOR ATMOSPHERE

NAME OF INSTRUMENT	PREFERRED ORBIT M OR A	ORBIT REPEAT 3/14 DAYS	OPERATIONAL DEMONSTRATION OR EXPERIMENT (O, D OR E)	IOC OR LATER	RELATIVE PRIORITY	POSSIBLE PROVIDER (US/ESA NATIONAL/OTHER)	MASS kg	POWER W	DUTY CYCLE %
AVHRR*	M + A	-	O	IOC	1	US	60	33	100
HIRS*	M + A	-	O	IOC	1	US	80	33	100
AMSU*	M + A	-	O	IOC	1	US + ESA	300	210	100
ARGOS	M + A	-	O	IOC	1	ESA	100	110	100
ERBI	M or A	-	O	IOC	?	US	55	50	100

* Fully redundant

Table 3.1.2

NEW INSTRUMENT REQUIREMENTS FOR ATMOSPHERE

NAME OF INSTRUMENT	PREFERRED ORBIT M OR A	ORBIT REPEAT 3/14 DAYS	OPERATIONAL DEMONSTRATION OR EXPERIMENT (O, D OR E)	IOC OR LATER	RELATIVE PRIORITY	POSSIBLE PROVIDER (US/ESA NATIONAL/OTHER)	MASS kg	POWER W	DUTY CYCLE %
ATLID	A or M or C	-	Exp.	IOC	1	) ESA could provide a basic facility with interfaces to allow enhancement	100	500	100
DIALID	A or M or C	-	Exp.	MOC	2	)	150	1000	100
RSR	A or M or C	-	Exp.	MOC	2	)	100	120	70
CLSR	A or M or C	-	Exp.	MOC	2	)	400	400	100
WPLID	A or M or C	-	Exp.	AOC	3	)	600	1500	100

Table 3.1.3

EXAMPLES OF A.O. INTRUMENTS FOR ATMOSPHERE

NAME OF INSTRUMENT	PREFERRED ORBIT M OR A	ORBIT REPEAT 3/14 DAYS	OPERATIONAL DEMONSTRATION OR EXPERIMENT (O, D OR E)	IOC OR LATER	RELATIVE PRIORITY	POSSIBLE PROVIDER (US/ESA NATIONAL/OTHER)	MASS kg	POWER W	DUTY CYCLE %
AMPS		-	E	IOC		OTHER	50	50	70
ERB-PACK		-	E	IOC		OTHER	100	70	100
MLS		-	E	IOC		OTHER	250	500	100
PDWS		-	E	IOC		OTHER	40	20	60
LIRS		-	E	IOC		OTHER	100	100	100
UV-VIS		-	E	IOC		OTHER	100	100	50
PMR		-	E	IOC		OTHER	20	20	20
GOMR		-	E	IOC		OTHER	40	12	100
SSLOR		-	E	IOC		OTHER	150	100	10
TSS		-	E	IOC		OTHER	10	30	100
							990		

3.2 Ocean / Sea Ice Objectives

In recent years, in addition to the demanding on-going requirements of operational agencies such as national meteorological organisations, many groups of leading world experts have drawn up detailed proposals for major long term programmes for monitoring and studying the oceans and polar regions in the disciplines of oceanography, climatology, ocean pollution and cryosphere studies. Moreover there is a substantial overlap with atmosphere programmes because of strong ocean - atmosphere - ice coupling.

These programmes include the World Climate Research Progamme (WRCP), the Tropical Ocean Global Atmosphere Programme (TOGA), the World Ocean Circulation Experiment (WOCE), the Programme for International Polar Oceans Research (PIPOR), Greenland Sea Project (GSP), the Wave Modelling Programme (WAM), the UN Environmental Programme (UNEP), Global Ocean Flux Programme (GOF), the Physical Oceanography of the Eastern Mediterranean Programme (POEM) and their successors.

All of these programmes require long-term continuity, simultaneous geographic and temporal observations by groups of inter-related and carefully calibrated instruments (synergy), and for most of them global coverage is essential. This can only be achieved by using space-borne instruments such as ERS-1 on a long term continuous basis.

Further programmes are needed to cover such important areas as ocean pollution, fishery forecasting, shiprouting, etc.

Many of the parameters needed for these programmes can be obtained by using either existing instruments or modifications to them. Others (e.g. rain-rate, ocean-atmosphere heat fluxes, etc.) require new concepts and new technologies.

This requires a programme balanced between the need for long-term continuity on the one hand, using instruments close in design to present ones, and research and development on new concepts and techniques, on the other hand. The latter is needed both to improve the accuracy/resolution of the measurement of sensitive parameters and to develop the ability to measure key parameters that cannot at present be obtained.

The principal objectives and the instruments needed to achieve these are listed in tables 3.2.1, 3.2.2, and 3.2.3.

Table 3.2.1

OCEAN/SEA ICE OBJECTIVES AND INSTRUMENT REQUIREMENTS

OBJECTIVES	INSTRUMENTS
A. RESEARCH	
1. Ocean Surface Characteristics (temperature, wind velocity, wave height and spectrum, salinity, phytoplankton) GSP WOCE WAM WCRP GOF	AVHRR AATSR WINDSCAT WAVESPEC OCM RA PBIMR SSTIMR MFIMR LASER-ALT
2. Large Scale Ocean Circulation (surface topography, geoid, currents) WOCE WCRP	AVHRR AATSR RA & PPS WINDSCAT ARA LASER-ALT
3. Mesoscale Ocean Features (fronts, eddies, internal waves, current shear zones, water mass boundaries, bottom water) PIPOR POEM WOCE WCRP UNEP GSP	AVHRR AATSR SAR RA ARA OCM PPS
4. Sea-Ice Characteristics (extent, concentration, age, thickness, velocity) PIPOR WCRP GSP	AVHRR AATSR SAR MFIMR
5. Air-Sea-Ice Interactions (surface heat and momentum fluxes, polar front, marginal ice zone dynamics, rain rate) TOGA PIPOR WCRP GOF POST-ALPEX GSP	AVHRR AATSR SSTIMR MFIMR RSR (air temp.) WINDSCAT WAVESPEC SAR RA
6. Ice Sheet and Shelf Ice Characteristics (measurement of ice sheet topography and motion) WCRP	RA LASER-ALT MFIMR PPS

Table 3.2.1, contd.

OBJECTIVES	INSTRUMENTS
B. APPLICATIONS	
7. Off-shore Activities (wave height, ice extent and movement, winds)	WINDSCAT WAVESPEC SAR RA ARA SSTIMR MFIMR
8. Ship Routing (wave height, ice extent and movement, winds)	WINDSCAT WAVESPEC SAR RA ARA SSTIMR MFIMR
9. Fisheries (primary production, upwelling, currents, fronts - temperature/chlorophyll, turbidity)	OCM AVHRR AATSR SSTIMR LIDAR
10. Pollution (oil, industrial effluents)	AVHRR AATSR OCM SSTIMR MFIMR SAR LIDAR
11. Coastal Calamities (storm surges, erosion)	SAR RA ARA OCM WINDSCAT LIDAR
C. GENERAL OBJECTIVES	
12. Data Collection Tracking from Earth's surface.	ARGOS

Table 3.2.2

INSTRUMENT REQUIREMENTS FOR OCEAN/SEA ICE

NAME OF INSTRUMENT	PREFERRED ORBIT M OR A	ORBIT REPEAT 3/14 DAYS	OPERATIONAL DEMONSTRATION OR EXPERIMENT (O, D OR E)	IOC OR LATER	RELATIVE PRIORITY	POSSIBLE PROVIDER (US/ESA NATIONAL/OTHER)	MASS kg	POWER W	DUTY CYCLE %
1. OCEAN/ICE PRIMARY INSTRUMENTS (IOC)									
ATSR	M + A	-	O	I	1	National	45	70	100
AOCM	M	-	E	I	1	ESA	100	156	70
RA	M + A	14 + 3	O	I	1	ESA/NASA	100	150	100
SAR + Wave Mode	M or A	3	E	I	1	ESA	300	1000	25
SSTIMR	M or A	-	O	I	2	NOAA	72	55	100
MFIMR	M or A	-	O	I	1	NOAA/ESA	120	70	100
WINDSCAT.	M + A	-	O	I	1	NOAA	300	275	70
PPS	M + A	-	O	I	1	National	42	22	100
2. OCEAN/ICE PRIMARY INSTRUMENTS (MOC/AOC)									
ARA	M or A	14	E	M	1	ESA/National	150	150	100
UVLIDAR	C	-	E	M/A	1	ESA	500	1000	10
PBIMR	C or M	-	E	M	1	ESA	500	70	100
WAVESPEC	M or A	-	E	M	1	ESA	100	150	70
DP DF SAR	C	3	E	A	1	ESA	600	10000	20
3. INSTRUMENTS FROM OTHER AREAS OF IMPORTANCE TO OCEAN/ICE									
AMSU	M + A	-	O	I	3	NOAA/UK	300	210	100
AVHRR-3	M + A	-	O	I	2	NOAA	30	33	100
LASER-ALT	M or A	-	E	M	1	ESA	120	300	10
RSR	C	-	E	M	2	ESA	100	120	100
4. GENERAL INSTRUMENTS									
ARGOS	M + A	-	O	I	1	National	100	110	100

Table 3.2.3

CONTRIBUTION OF INSTRUMENTS TO THE OCEAN/SEA ICE OBJECTIVES

INSTRUMENT \ OBJECTIVES	OCEAN SURFACE	LARGE SCALE CIRCULATION	MESOSCALE OCEAN FEATURES	SEA ICE CHARACTER-ISTICS	AIR-SEA-ICE INTER-ACTION	ICE SHEETS & SHELVES TOPOGRAPHY	OFF SHORES ACTIVITIES	SHIP ROUTING	FISHERIES	POLLUTION	COASTAL CALAMITIES
ATSR	X	X	X	X	X				X	X	
AOCM	X		X						X	X	X
RA	X	X	X	X	X	X	X	X			X
SAR			X	X	X					X	X
SSTIMR	X				X		X	X	X	X	
MFIMR	X			X	X	X	X	X		X	
WINDSCAT	X	X	X		X		X	X			X
PPS		X	X			X					
ARA	X	X	X	X	X	X	X	X		X	X
UV LIDAR	X								X	X	X
PBIMR	X	X									
WAVESPEC	X				X		X	X			
DP DF SAR			X	X	X					X	X
AMSU		X	X	X	X						
AVHRR-3	X	X	X	X	X				X	X	
LASER-ALT		X		X		X					
RSR					X						
ARGOS	X	X	X	X	X	X	X	X	X	X	X

3.3 Land Objectives

Continuous and long term observations of the land surface are essential for the monitoring of renewable and non-renewable resources and to satisfy the requirements of the very diverse user communities which benefit from land remote sensing techniques. User requirements fall into three main categories, namely:

- Research on land processes, hydrological cycle, etc.
- Demonstration of applications, primarily for renewable resources;
- Operational/commercial use mainly for non-renewable resources.

The table below provides examples of current remote sensing data utilization for each category :

Research	Demonstration of applications	Operational/ commercial use
Hydrological cycle	Agriculture : acreage/ crop yield forecasts	Geology/mineral resources
Biomass evaluation	Forestry : inventory/ monitoring/disease	Land use & planning
Soil survey	Land transformation processes: desertification/erosion	Cartography
Parameters affecting land transformation processes		
Soil moisture		

The objectives for future missions and instrumentation are :

- to maintain the capability for operational land remote sensing using the new generation of optical sensors (e.g. Landsat-TM, SPOT-HRV, Shuttle-MOMS);
- to further improve the capability of these optical sensors in terms of radiometric and spatial resolution, coverage, stereoscopic capability, etc.
- to improve the current experimental capabilities for all-weather remote sensing of land with microwave sensors, the ultimate goal being to provide an operational capability similar to the optical sensors;
- to optimise the integration of microwave and optical data;
- to set up demonstration programmes in the areas of renewable resources with the goal of reaching an operational status in the 1990's;
- to continue to promote fundamental research activities (spectral signature analysis, soil moisture, etc.).

Candidate instruments consist of :

- high and medium resolution advanced multichannel optical imaging sensors (and imaging spectrometers);
- advanced high resolution active microwave imaging sensors (SAR) and medium resolution passive microwave imaging radiometers;
- atmospheric sensors (for atmospheric corrections/calibration).

The instrument requirements together with related information are given in Table 3.3.

Table 3.3

INSTRUMENT REQUIREMENTS FOR LAND

NAME OF INSTRUMENT	PREFERRED ORBIT M OR A	ORBIT REPEAT 3/14 DAYS	OPERATIONAL DEMONSTRATION OR EXPERIMENT (O, D OR E)	IOC OR LATER "	RELATIVE PRIORITY	POSSIBLE PROVIDER (US/ESA NATIONAL/OTHER)	MASS kg	POWER W	DUTY CYCLE %
HROI	M	-	O	IOC	1	ESA/National	400-500	400	20-30
HRTIR	M or A	-	D (limited swath approx. 100 km) + E	IOC	2	ESA	200-250	300	20-30
TMD	M	-	O	IOC	1	USA	300-400	350	20-30
HRIS	M	-	D + E	IOC	2	USA	100	100	10
SAIS	M	-	D + E	MOC	3	National	500	500	5
1 Frequency SAR (C-Band)	M or A	-	O	IOC	1	ESA	350	1500	15
1 Frequency SAR (X-Band)	M or A	-	O / D	IOC	1	National	400	3000	15
2 Frequency SAR (L+C Band)	M or A	-	O / D / E	IOC	1	ESA	600	1500	15
LASTIR	M or A	-	E	MOC	1 / 2	ESA/National	500	600	5

3.4 Solid Earth Objectives

3.4.1 Objectives

The objectives for solid earth science and applications by space methods have been studied by the Solid Earth Working group, and its analysis and recommendations are given in a report entitled "Recommendations for a European Long-Term Space Programme in Solid Earth Science and Applications" (ESA/SEWG(85)1). A summarised version of its conclusions also appears in "Looking Down - Looking Forward" (ESA SP-1073, January 1985).

The scientific objectives comprise studies of:

- The dynamics of the lithosphere
- Physical processes in the mantle
- Core-mantle interaction.

The applications include:

- Mapping and charting control
- Precise positioning for offshore activities
- Mineral resources exploration (seismographic sounding)
- Deformation monitoring of hazardous structures
- Precise orbit determination of applications satellites
- Earthquake prediction research
- Real time monitoring of the sea surface topography (ship routing)
- Geophysical data collection.

The achievement of these objectives requires:

- Precise positioning capability
- Detailed knowledge of global gravity and magnetic fields
- Accurate determinations of the Earth rotation parameters (polar motion and length of day)
- Precise altimetry.

These also provide fundamental support to the study of global ocean dynamics.

The main parameters, together with the required observational accuracies and sampling rates, are given in table 3.4.1

Table 3.4.1

SOLID EARTH OBJECTIVES AND MEASUREMENT REQUIREMENTS

A) MOTION OF THE LITHOSPHERE		ACCURACY	SAMPLING INTERVALS
Global (5000 km)	horizontal	1-2 cm	1 year
	vertical	1 cm	1 year
Regional (500 km)	horizontal	1-2 cm	1 week
	vertical	$<$ 1 cm	1 week
Local (50 km)	horizontal	1-2 cm	1 day
	vertical	$<$ 1 cm	1 day

B) EARTH ROTATION AND POLAR MOTION	ACCURACY	SAMPLING INTERVALS
Conventional Celestial Reference System (CCRS)	0.0001"	few years
Procession-Nutation (P-N)	$<$ 0.0001"	
Earth Rotation Parameters	0.0001"	daily (0.5 day for diurnal nutation)
Convential Terrestrial Reference System (CTRS)	1 cm	1 year

C) GEOPOTENTIAL FIELDS (requirements for lithospheric studies at a resolution of 100 km	ACCURACY	SAMPLING INTERVALS
Gravity	$<$ 0.002 gal	years
Geoid	10 cm	years
Main magnetic field	3 nT	duration of measurements
Crustal magnetic field	3 nT	duration of measurement 1 year
Earth tides	from precise orbit analysis	

D) SEA SURFACE	ACCURACY	SAMPLING INTERVALS
Main circulation (currents)	1-2 cm	14 days
Mesoscale variability	1-2 cm	3 days
Tides	1-2 cm	Repeat tracks

3.4.2 Candidate techniques for solid earth missions from space

The instruments and systems that are, or soon will be, available to measure the required parameters are:

(a) **Microwave positioning systems** (e.g. DORIS/PRARE), for both precise terrestrial positioning and orbit determination. These require high orbits (7000 km) and medium inclinations (50°-60°).

(b) **Satellite and lunar laser ranging systems** for positioning, earth rotation and orbit determination.

(c) **Altimeters** for measurements over ocean and land (e.g. ERS-1). Currently altimetry provides the most precise and detailed ocean geoid and gravity anomalies. Advanced instruments are under development, including a laser altimeter.

(d) **Satellite to satellite tracking** for determining the gravity potential field. One or both satellites must be in a low polar orbit (160 km) in order to sense the short wavelengths of the gravity field.

(e) **Satellite-borne magnetometers.** These must be in low-orbit satellites, and could be associated with satellite to satellite tracking to form a geopotential research mission.

(f) **Satellite gravity gradiometry** for determining the gradients of the gravity field, using micro-accelerometers in low polar orbit.

(g) **Tethered satellite systems** for determining gravity gradients with micro-accelerometers flown in satellites attached by long (100 km) tethers to low-flying vehicles.

(h) **Satellite-borne lasers** ranging to passive ground targets for precise terrestrial baseline measurement.

(i) **Data collection system.** This can be a separate system (e.g. ARGOS) or an integral function of the microwave positioning system (e.g. PRARE).

3.4.3 Space Segment Requirements

Solid Earth Missions using space techniques for geodetic and geodynamic research and applications require, in general, as a pre-requisite, thedetermination of the spacecraft orbit and the positions of terrestrial tracking stations with the highest accuracy. This requirement distinguishes them from other Earth observation missions.

The three major forces that influence the orbit of a spacecraft are the gravitational force of the Earth (and of the sun, moon and planets), air drag due to the atmosphere, and solar radiation. Whereas the strength of the gravitational force depends only on the orbital altitude and not on the particular shape of the spacecraft, air drag and solar radiation (being surface forces) depend on both shape and altitude.

There are basically two different types of solid earth techniques: precise positioning and geopotential field missions. In both cases it is important to minimise the effect of non-gravitational forces. In low orbits this can be achieved either by measuring them (micro-accelerometer techniques) or by eliminating them (disturbance compensation systems). In high orbits a favourable (low) area/mass ratio is usually a sufficient measure (e.g. LAGEOS). For positioning, high-altitude orbits are an additional requirement in order to minimise the influence of the unknown part of the gravity field, whereas for gravity field measurements the signal is amplified by choosing a very low (200 km) orbital altitude.

3.4.4 Polar Platform Opportunities

From the previous section it can be concluded that a polar platform in a medium altitude orbit and with an unfavourable area/mass ratio does not provide a suitable vehicle for most of the techniques specified in Section 2. Therefore items (d), (e), (f) and (g) have to be eliminated. The opportunities that remain are therefore:

(a) Microwave positioning system for platform orbit determination and terrestrial relative positioning.

(b) Corner cube reflector in support of platform orbit determination.

(d) Altimeters.

Satellite-borne laser ranging (h) is not yet sufficiently developed to be considered more than a low-priority candidate technique, while geophysical data collection (i) can be more economically performed as an integral function of a precise positioning system.

Characteristics of the instruments required for (a), (b), (c), (h) and (i) above are given in table 3.4.2

Table 3.4.2

INSTRUMENT REQUIREMENTS FOR SOLID EARTH

NAME OF INSTRUMENT	PREFERRED ORBIT M OR A	ORBIT REPEAT 3/14 DAYS	OPERATIONAL DEMONSTRATION OR EXPERIMENT (O, D OR E)	IOC OR LATER	RELATIVE PRIORITY	POSSIBLE PROVIDER (US/ESA NATIONAL/OTHER)	MASS kg	POWER W	DUTY CYCLE %
PPS (PRARE, DORIS and geophysical data collection)	M or A	-	O, E	IOC	1	ESA/National	42	22	100
RA	M or A	-	(*)	IOC	1(*), 2	ESA	100	150	100
SPALT	A	-	E	MOC	2	ESA	150	300	10
CCR	M or A	-	O	IOC	1	National	5	0	-

(*) Strongly dependent on 1m radial orbit precision

4. TABLES OF INSTRUMENTS

The various instruments identified in Chapter 3 are included in the list of acronyms (Annex 2) and briefly described in Annex 4 and their key parameters summarised in Annex 5. Annex 3 provides a comparison of these acronyms with those used in other similar documents. The instruments can be classified into:

- Operational sensors, i.e. which are today (or likely to be in the near future) used for operational applications and which could be provided by operational entities (e.g. NOAA and Europe for some meteorological sensors) (see Table 4.1).

- Medium to large size sensors/multipurpose facilities which are candidates for being provided by ESA (see Table 4.2). They are described in the Annex 6.

  As well as addressing the different disciplines as shown in Table 4.2 they fundamentally depend on the development of:

  ° cryogenics
  ° large antennae
  ° lidar

  for use from space. (These techniques are described in Chapter 9.)

- Experimental sensors for research purposes, more likely to be nationally funded and selected as a result of Announcements of Opportunity.

Table 4.1

OPERATIONAL INSTRUMENTS

INSTRUMENT	ORBIT	MASS kg	
ATMOSPHERE			
AVHRR	M+A	60	
HIRS	M+A	80	
AMSU	M+A	300	
ARGOS	M+A	100	
GOMR	A	40	
ERBI	A	60	
			640
OCEAN/ICE			
AATSR	M+A	45	
RA	M+A	100	
PPS	M+A	42	
MFIMR	M/A	120	
WINDSCAT	M+A	300	
			607
LAND			
HROI	M	450	
SAR	M/A	600	
			1050
SOLID EARTH			
CCR	M+A	5	
(PPS)	M+A	(42)*	
(RA)	M+A	(100)*	
			5
			2302

* mass already included under ocean/ice

Table 4.2

POSSIBLE ESA PRODUCED INSTRUMENTS

INSTRUMENT	ORBIT	DATE	MASS kg	
ATMOSPHERE				
ATLID	A/M/C	IOC	100	
DIALID	A/M/C	MOC	150	
RSR	A/M/C	MOC	100	
CLSR	A/M/C	MOC	400	
WPLID	A/M/C	AOC	600	
				1350
OCEAN/ICE				
AOCM	M	IOC	100	
SAR + WM	M/A	IOC	300	
SSTIMR	M/A	IOC	72	
MFIMR	M/A	IOC	120	
UV LIDAR	C	MOC	500	
LASER ALT	M/A	MOC	120	
PBIMR	C/M	MOC	500	
ARA	M/A	MOC	150	
WAVESPEC	M/A	MOC	100	
DP DF SAR	C	AOC	600	
				2562
LAND				
HRTIR	M	IOC	250	
SAR	M/A	IOC	600	
LASER SENSOR	M/A	MOC	500	
				1350

5. POSSIBLE SCENARIOS FOR INSTRUMENT GROUPINGS

A number of scenarios are conceivable depending upon the following assumptions (in addition to those in section 2) :

a) Platform size : At present, in discussions with the USA, ESA is considering providing the morning platform. Taking into account the various constraints described in section 2 (financial, technical, launcher ...) the platform capability in terms of payload mass is likely to be of the order of **2000 kg** at IOC. This is equivalent to about 2.5 times the ERS-1 payload mass and is considered to be a maximum for the launch at IOC.

b) Platform evolution : It is considered that about 1000 kg of instruments could be added at the first servicing, say 2-3 years after IOC in addition to servicing the IOC payloads. The further evolution is under study, but it is assumed at present that an evolution to 4000 to 5000 kg of payload may well be feasible.

c) Platform number : It is assumed that only **one** platform in a morning orbit will be provided by **ESA** at IOC (1994/95). However, itis not excluded that additional platforms could also be provided at IOC or later (in a morning orbit) by other space agencies (Japan, Canada, etc.).

d) Payload groupings : Several ways of grouping have been presented in the previous sections, namely :

- by discipline (land-oriented, ocean-oriented, atmosphere-oriented, etc.)
- by objectives (research, demonstration, operational);
- by priority (high, medium, low);
- by preferred orbit (morning or afternoon);
- by source of procurement and funding (ESA, US, National);
- by date of availability (IOC, IOC + 3 years, + 10 years, etc.)

Several additional considerations may affect the possible payload groupings such as :

. **Technology trends:** For instance, it is clear that Europe has a definite intention to continue the development of more advanced SARs than that on ERS-1. This trend also applies to laser sensor development.

. **Commercial/operational payloads:** It is conceivable to embark commercial (Landsat-type, SPOT-type) payloads and/or operational sensors (meteorological packages) on the ESA morning platform. But this still has to be studied in detail in view of the implications, as mentioned in section 14. In this report commercial payloads are assumed not to be part of the payload at IOC.

6. IOC PAYLOADS FOR POLAR PLATFORMS

The initial consideration of payload groupings is based on the following assumptions :

i) At least a 2-polar platform system consisting of one morning (local time between 09.30 and 10.30 at descending node) platform, and one afternoon platform (local time between 13.00 and 14.30 at ascending node) at IOC (i.e. in 1994-95).

ii) Sun-synchronous orbits at an altitude between 700 km and 850 km, (the higher values to suit meteorological sensor requirements), with "multiple" cycles to give fast and slow repeat cycles (e.g. 1, 2-3 and 14 days). The morning and afternoon orbits would be synchronised and the platforms suitably phased so that the two platforms could provide improved coverage for those instruments common to both.

iii) Multi-disciplinary approach for payload groupings, i.e. combination of land, ocean, ice and atmosphere sensors.

iv) Multi-Agency funding for the various sensors : Europe (ESA and national), USA (NASA + NOAA) and others (Canada, Japan, etc.).

v) Lifetime of platforms = 15-20 years.

vi) Servicing capability on the basis of once every 2-3 years.

vii) The number of platforms may in the course of time after IOC increase for two reasons:

- to satisfy increasing requirements at medium and long term;
- to keep the size of platforms at a reasonable level in terms of power, mass and ease of sensor accommodation;
- to satisfy specific requirements of commercial users (e.g. land applications).

Taking account of the requirements and priorities in the different areas overall payload groupings for the two platforms might be expected to be similar to those shown in Table 6.1.

There is a balance among the different disciplines, as well as among operational, demonstration and experimental instrumentation.

However the total resulting payload mass for each platform is quite high, namely about 2800 kg for the morning platform and about 2200 kg for the afternoon platform.

Due to likely financial limitations in being able jointly to develop such a large amount of payloads in time for launch of the two platforms both around 1994, and due to the unlikelihood of being able to launch so much mass with a single Ariane-5 or shuttle in each case it is felt more appropriate to limit the payload mass to about 2000 kg at IOC for each platform and to add further payloads at each servicing.

There are a number of different ways to explore limiting the IOC payloads to 2000 kg, yet still fulfilling very attractive missions, by putting emphasis in different mission areas. The following three possibilities have been considered as examples:

Possibility 1: (See Table 6.2.1)

° The main emphasis is on atmosphere/ocean/ice mission objectives with a strong operational component including duplication of most of the operational sensor packages, and would consist of the following core payloads on the morning **and** afternoon platforms:

AVHRR	60 kg
HIRS	80 "
AMSU	300 "
ARGOS	100 "
WINDSCAT	300 "
Total	840 kg

° Capabilities for experimental/demonstration sensors on the morning platform for ocean research would consist of the following complementary payload:

AOCM	:	100 kg
ARA	:	150 kg
Total		250 kg

° Capabilities for atmospheric research on the morning platform include ATLID (100 kg) and possibly part or all of the AO instruments (163 kg). Better capabilities would exist on the afternoon platform, in particular within the AO instruments (700 kg).

° Land-oriented sensors include only a Synthetic Aperture Radar on the morning platform. It is assumed that operational/commercial optical payloads providing high resolution imagery of land surface are flying on separate (expendable and/or retrievable) platforms.

Possibility 2: (See Table 6.2.2)

° This places greater emphasis on land-oriented mission objectives at the expense of ocean mission objectives, whilst keeping the following full operational meteorological service capability on both the morning and afternoon platforms:

AVHRR	:	60 kg
HIRS	:	80 kg
AMSU	:	300 kg
Total		440 kg

- The land-oriented sensor complement includes both advanced optical and microwave sensors on the morning platform, namely :

HROI	:	500 kg
HRIS	:	100 kg
SAR	:	600 kg
Total		1200 kg

  and HRTIR (250 kg) on the afternoon platform.

- A reasonable AO instrument capability is maintained on the morning platform (360 kg) which could be used for oceanic/atmospheric research sensors.

Possibility 3: (See Table 6.2.3)

- This is a variation of Possibility 2 where the HROI package (currently assumed to be composed of two similar instruments in order to provide a 150-200 km swath) is reconsidered by limiting it to a single instrument (75-100 km swath) and thus recovering about 250 kg of payload capability on the morning orbit.

  By also limiting the AO capability to 110 kg (instead of 360 kg) this would allow about 500 kg to be allocated to oceanic/ atmospheric research and/or operational sensors (e.g. AR, AOCM, WINDSCAT, MFIMR, ATLID). Although the AO capability is somewhat reduced there is a large number and variety of experimental instruments addressing many disciplines. It is not excluded that some of these instruments might be provided instead as AO instruments.

- A reasonable AO instrument capability (450 kg) still exists on the afternoon platform.

- Commercial/operational optical high-resolution sensors are again assumed to fly on separate (expendable and/or retrievable) platforms.

- This possibility is considered fairly well balanced among the different disciplines, and among operational, demonstration and experimental instrumentation.

It should be noted that there is potentially a higher demand (in terms of sensor packages) for the morning platform. This is primarily due to the optical (visible and near infra-red) high resolution imaging sensors, which naturally want to take advantage of the clearer weather conditions in the morning before the afternoon build-up of cumulus clouds.

It is also due to the need to duplicate some operational sensor packages on both morning and afternoon platforms in order to provide a global earth coverage as well as a fast measurement repeat frequency. (This is the case for operational atmospheric and oceanic sensors, of which the data are used as inputs to numerical forecasting models).

A comparison of these three possibilities is shown in Table 6.3.

Table 6.1

IOC PAYLOAD GROUPING OVERALL REQUIREMENTS

INSTRUMENT	MASS kg		POSSIBLE PROVIDER
AM PLATFORM			
AVHRR	60		US
HIRS	80		US
AMSU	300		US + Nat.
ARGOS	100		Nat.
DF SAR	600		ESA
HROI	500		ESA
HRIS	100		US
AOCM	100		ESA
ARA	150		ESA
PPS	42		Nat.
WINDSCAT	300		US
CCR	5		ESA
ATLID	100		ESA
A.O. Instruments	400		Nat. + US
		2837	
PM PLATFORM			
AVHRR	60		US
HIRS	80		US
AMSU	300		US + Nat.
ARGOS	100		Nat.
ERBI	60		US
GOMR	40		US
AATSR	45		Nat.
RA	100		US or Nat.
PPS	42		Nat.
MFIMR	120		US + (ESA)
WINDSCAT	300		US
CCR	5		ESA
HRTIR	250		ESA
A.O. Instruments	700		Nat. + US
		2202	

Table 6.2.1

IOC PAYLOAD GROUPINGS - POSSIBILITY 1

INSTRUMENT	MASS kg		POSSIBLE PROVIDER
AM PLATFORM			
AVHRR	60		US
HIRS	80		US
AMSU	300		US + Nat.
ARGOS	100		Nat.
DF SAR	600		ESA
AOCM	100		ESA
ARA	150		ESA
PPS	42		Nat.
WINDSCAT	300		US
CCR	5		ESA
ATLID	100		ESA
A.O. Instruments	163		Nat. + US
		2000	
PM PLATFORM			
AVHRR	60		US
HIRS	80		US
AMSU	300		US + Nat.
ARGOS	100		Nat.
ERBI	60		US
GOMR	40		US
AATSR	45		Nat.
RA	100		US or Nat.
PPS	42		Nat.
MFIMR	120		US + (ESA)
WINDSCAT	300		US
CCR	5		ESA
A.O. Instruments	700		Nat. + US
		1952	

Table 6.2.2

IOC PAYLOAD GROUPINGS - POSSIBILITY 2

INSTRUMENT	MASS KG	POSSIBLE PROVIDER
AM PLATFORM		
HROI (x2)	500	ESA
DF SAR	600	ESA
HRIS	100	US
AVHRR	60	US
HIRS	80	NAT
AMSU	300	US + NAT
AO INSTRUMENTS	360	NAT
	2000	
PM PLATFORM		
AVHRR	60	US
HIRS	80	US
AMSU	300	US + NAT
ARGOS	100	NAT
ERBI	60	US
GOMR	40	US
AATSR	45	NAT
RA	100	US or NAT
PPS	42	NAT
MFIMR	120	USA + ESA
WINDSCAT	300	US
CCR	5	ESA
HRTIR	250	ESA
AO INSTRUMENTS	450	NAT + US
	1952	

Table 6.2.3

IOC PAYLOAD GROUPINGS - POSSIBILITY 3

INSTRUMENT	MASS KG	POSSIBLE PROVIDER
AM PLATFORM		
HROI (x1)	250	ESA
DF SAR	600	ESA
HRIS	100	US
AVHRR	60	US
HIRS	80	US
AMSU	300	US + NAT
ATLID	100	ESA
WINDSCAT	300	US
AOCM	100	ESA
AO INSTRUMENTS	110	NAT
	2000	
PM PLATFORM		
AVHRR	60	US
HIRS	80	US
AMSU	300	US + NAT
ARGOS	100	NAT
ERBI	60	US
GOMR	40	US
AATSR	45	NAT
RA	100	US or NAT
PPS	42	NAT
MFIMR	120	USA + ESA
WINDSCAT	300	US
CCR	5	ESA
HRTIR	250	ESA
AO INSTRUMENTS	450	NAT + US
	1952	

Table 6.3

Comparison of IOC Possibilities

POSSIBILITY 1		POSSIBILITY 2		POSSIBILITY 3	
AM PLATFORM	PM PLATFORM	AM PLATFORM	PM PLATFORM	AM PLATFORM	PM PLATFORM
. OPS METEO . OPS/DEMO OCEAN . EXP/DEMO LAND (MW only) . EXP ATMOS	. OPS METEO . OPS OCEAN	. OPS METEO . EXP/DEMO LAND	. OPS METEO . OPS OCEAN . EXP/DEMO LAND (IR only)	. OPS METEO . OPS OCEAN . EXP/DEMO OCEAN . EXP/DEMO LAND . EXP ATMOS	. OPS METEO . OPS OCEAN . EXP/DEMO LAND (IR only)
Small AO capability	Large AO capability	Reasonable AO capability	Reasonable AO capability	Small AO capability	Reasonable AO capability
Limited land capability	No land capability (poss. via AO)	No ocean capability (poss. via AO)	No atmos research (poss. via AO)	Meteorology, atmosphere, oceans and land all addressed	No atmos. research (poss.via AO)
955 kg of ESA-funded sensors	No ESA-funded sensors	1100 kg of ESA-funded sensors	255 kg of ESA-funded sensors	1050 kg of ESA-funded sensors	255 kg of ESA-funded sensors

7. GROWTH POTENTIAL AND EVOLUTION

At each servicing interval (approximately every 2 - 3 years) there is the opportunity for each Polar Platform:

- to exchange degraded or failed instruments
- to replace instruments with improved ones
- to add further instruments
- to increase, change and/or recover A.O. instruments.

It was indicated in Chapter 6 that the initial requirements may well exceed not only what the available funding may allow but also exceed the launch capability of a single Ariane-5 or shuttle. As a first step one can assume that whatever cannot be included at IOC is a first candidate for inclusion at the first servicing point (termed MOC). Beyond that, building up to a mature or advanced capability (termed AOC) it is more difficult if not impossible to be exact. However, based on the requirements so far identified it is not unreasonable to assume that payloads at IOC (of about 2000 kg) should be augmented at MOC by perhaps 1000 kg, and at AOC by a further 1000 kg, with corresponding and appropriate increases in power and data rates.

As regards the possible instrumentation candidates for MOC, this falls into 2 main categories:

(i) Instrumentation which were desired at IOC but could not be included because of platform resources limitations and/or financial limitations

(ii) Advanced instrumentation not ready or not mature enough at IOC (e.g. because of technology unavailability at IOC or concept not sufficiently "demonstrated").

For category (i) the list of candidate instrumentation can be derived by comparison of what is given in Table 6.1 with the payload composition given in Possibilities 1, 2, or 3.

For category (ii) the list of candidate instrumentation probably mainly includes instruments using advanced microwave and laser techniques, primarily for oceanic and atmospheric research.

Examples might be:

- rain scattering radiometer to delineate rain areas and estimate rain intensity especially over the oceans;

- low frequency push broom imaging microwave radiometer for soil moisture measurement, ocean salinity determination;
- cooled limb sounding radiometer for monitoring of atmospheric properties, composition and processes;
- wind profile lidar for atmospheric and measurement;
- differential absorption lidar for measurememt of atmospheric temperature profile, water vapour profile and surface pressure;
- laser altimeter for very high accurate distance measurements over ocean, ice and land;
- UV lidar to stimulate fluorescence for measurement of chlorophyll concentration in oceans/coastal waters, detection of surface oil pollution;
- laser imaging spectrometer operating in the thermal infrared for soil/vegetation discrimination, determination of atmospheric constituents.

Some features of these possible candidate instruments are given in the Table below:

Candidate instrumentation	Mass (kg)	Power (W)	Comments
RSR	100	120	large diameter antenna
PBIMR	500	70	very large antenna dimensions
CLSR	400	400	
WPLID	600	1,500	
DIALID	150	1,000	
LASER-ALT	120	300	
UV-LIDAR	500	1,000	
LASTIR	500	600	

The detail of what might be added at the second servicing point tends to be rather speculative. However given that a further augmentation of another 1000 kg should be in principle possible, those instruments in categories (i) and (ii) above which it has not been possible to include at MOC represent examples for AOC. However it should be noted that these would be further candidates which cannot be identified today but may well become apparent in a few years time.

8. A CO-ORBITING PLATFORM FOR EARTH OBSERVATION

Whilst the Polar Platform is seen as the major tool for future Earth observation systems, there is, nevertheless, considerable interest in considering a platform co-orbiting with the Space Station in a low altitude (say approximately 350 km) and low inclination (approximately 28°) orbit for mounting some of the new instruments currently in the conception stage which take advantage of recent technical or engineering developments and which promise to have a lot of potential for earth observation.

The advantages can be listed as follows:

- A low altitude orbit is of benefit to lidars and radars because it reduces the distance to the scene. Since for a radar, the signal is proportional to the fourth power of the range, for a given configuration about 20 times more signal is available at 350 km than at 750 km.
- A low altitude orbit enables higher horizontal resolution to be achieved for a given antenna or mirror size. For some measurements, e.g. of precipitation, resolution is of critical importance.
- Better coverage of the tropical regions will be achieved - an advantage for some oceanographic and atmospheric observations.
- The orbit is non sun-synchronous which for some observations, e.g. of precipitation, radiation budget, removes a critical problem of aliasing.
- Larger payloads can be accomodated - of particular advantage for large instruments such as lidars.
- Servicing from the Shuttle or the Space Station will be much more readily available.

Against these have to be put the disadvantages, compared with a higher altitude polar orbit, that some parts of the earth cannot be seen (only about half the Earth's surface can be viewed from a 28° orbit), and that at a low altitude sideways scanning cannot completely fill in the gaps between orbits at the equator, again giving some reduction of coverage.

However, for large, power-hungry instruments which need considerable instrumental and engineering development and for which there will also be a need to develop means to interpret and exploit the data, a low altitude, low inclination platform would be the appropriate vehicle at least for the period of the 1990s.

Suitable categories of instruments for the co-orbiting platform for which some or all of the advantages listed are substantial are the following:

- Lidars (refer to tables)
- The Rain Radar and Scattermometer
- Helium-cooled Spectrometers
  (frequent servicing/replenishment of cryogen, high mass)
- Solar or Stellar Occultation instruments (better coverage)
- Earth Radiation Budget Instruments (aliasing removal).

Strawman payloads for a co-orbiting platform have been chosen as follows:

- For IOC:
  - DIALID
  - SSLOR
- For IOC + 2 years:
  - WPLID
  - ATLID
  - PBIMR
  - RSR.

9. NEW TECHNOLOGIES

9.1 CRYOGENIC SYSTEMS FOR SPACE

Passive infra-red and microwave systems are widely used for observation of atmosphere, ocean, ice and land phenomena. Improvements to the sensitivity of such systems for future space missions are likely to come principally from the use of cooled detectors, either by increasing the sensitivity of current uncooled detectors through reducing their noise levels or by making possible the use in space of detectors which can only operate at very low temperatures (e.g. Superconductor Insulator Superconductor (SIS) type devices). Coolers using cryogenic fluids tend to be bulky and massive, and to require periodic topping-up at intervals considerably shorter than the expected servicing intervals of the Space Station Polar Platform.

An alternative approach is to use mechanical coolers such as those based on the Stirling cycle coolers being developed in Europe for instruments such as the ATSR for ERS-1 and the ISAMS for UARS. These coolers currently work down to about 80 K at 0.5 watts. Future systems will require both greater cooling capacity and lower temperatures (SIS devices operate at only a few degrees K).

The next advance is likely to come from developing multi-stage versions of the current single stage units, particularly for the focal plane assemblies. Improved single-stage coolers are also needed for cooling the optics/baffles.

ESA is already funding some development work in this area but increased effort will be needed to meet the instrument demands of the 1990's and beyond. This is an area where Europe already has a clear lead in technology.

9.2 LARGE ANTENNAE

In passive microwave radiometer systems the spatial resolution at the Earth's surface is a function of the size of the antenna aperture, measured in wavelengths, and the orbit height. In principle, the resolution is improved by increasing the antenna size but upto a limit. This limit is determined by the required radiometric resolution which depends upon the dwell time, i.e. the period in time in which a resolution cell is observed at satellite velocities.

Present microwave radiometer systems are scanning systems designed with antennae of very modest size so that a rather coarse spatial resolution is obtained, ranging from about 30 km to 150 km at frequencies between 37 GHz and 6.6 GHz. Data from these systems are useful for monitoring large-scale features, such as sea surface temperature in the open ocean and sea ice, as inputs to climate studies, for example. For other applications - snow mapping and soil moisture measurement, for instance - this resolution is too coarse. Applications such as sea ice monitoring also require fine resolution. The large antennae necessary may be able to be accommodated on the polar platform.

Development of large antenna structures are undertaken on both sides of the Atlantic. Thus, a 15m diameter paraboloid reflector antenna has been produced at NASA Langley Center. It is an unfurlable antenna with a wire-mesh reflecting surface for use at 1.4 GHz (± 20 cm wavelength) which may be carried by the space shuttle. A 122m antenna with the same characteristics has been designed so that it may also be carried by the space shuttle. In Europe, a 3.5m inflatable paraboloid reflector antenna is being developed for ESA at Contraves, Switzerland, with a thin-foil surface for use at frequencies upto 30 GHz. This is a demonstration model with a view to further development of larger antennae upto 15m diameter at frequencies upto 22 GHz. Unfurlable antennae are under development at SNIAS, France and MBB, Germany, with a concept similar to that employed in the US. Reflectors with a diameter of 8-15m are considered for frequencies upto 10 GHz. A solid-surface 2m antenna is under construction at CASA, Spain for frequencies upto 300 GHz whereas Dornier and MBB, Germany is developing a solid deployable antenna of about 5m diameter for frequencies upto 30 GHz.

Large antenna structures will have an appreciable mass and are therefore difficult to use in mechanically scanned systems where the moving antenna would have to be extremely well balanced. For this reason studies have been made of the so-called push-broom radiometer which has a fixed antenna and a great number of fixed beams, one for each resolution cell on the Earth's surface. Each beam is formed by a feed horn with associated microwave receiver using part of the antenna reflector, and since no movement is performed a long dwell time is obtained and thereby a very fine radiometric resolution. To ensure a high beam efficiency and good cross-polarization properties a torus-shaped antenna reflector is employed. Thus, a 1.4 GHz system has been proposed in an ESA study with an antenna reflector 30m by 60m and with 75 beams pointing along a conical surface.

In active systems, such as synthetic aperture radar, the antenna size is selected to fulfill the spatial resolution requirements and, especially, the range and azimuth ambiguities requirements. At present, the antennae are flat-plate slotted-array or printed circuit and are of relatively large dimensions when unfolded in space. Thus, the ERS-1 will have a slotted-array antenna of 1m by 10m while the Radarsat antenna will have the dimensions of 2m by 15m.

9.3 ADVANCED SARS

The trend for future satellite SAR systems is towards:

- wider swaths
- multiple frequencies
- variable incidence angle (or swath positioning)
- improved sensitivity

and possibly:

- polarisation diversity.

Already for ERS-1 it is a major step to provide an amplifier giving sufficient output power to meet the requirements.

For future SARs, where higher powers will be needed several options can be considered:

- parelleling of existing amplifiers
- higher power amplifiers
- solid state amplifiers distributed on the antenna (the so-called active phased array antenna).

The first two of the above options have their own particular problem, e.g. multipaction. The advantages of the third option is severalfold, e.g. graceful failure degradation, beam steering can be done in the feed network at low power.

Development of techniques to allow high powers and beam steering will lead to advanced SARs with the improved performance required to meet the different objectives.

9.4 LIDAR

Passive optical techniques in the visible are limited by the source strength(the sun) and the absorption characteritics of the region (for atmospheric measurements) or the reflectivity of the scene (for surface measurements). Similarly infra-red techniques are limited by the emission characteristics of the scene or region being observed.

Lidar techiques on the other hand:

- carry their own illumination source
- can use coherent techniques
- can be tuned to the spectal regions of most efficient interaction
- can utilise range gating to provide profiling directly
- can utilise the doppler effect for measuring winds and transport velocities.

The on-going development of space qualified lasers capable of operating for more than a year will open up a whole new area of parameters which can be monitored, either for the first time, or to much higher accuracy than before.

Such areas will include measurement of:

- wind velocities
- atmospheric composition
- cloud top altitudes
- water quality.

10. INTERNATIONAL COOPERATION

The monitoring of the Earth's environment is an extremely challenging objective which requires long term observations, high repetition rate over decades and also a multidisciplinary approach.

International cooperation is becoming an essential element for scientific research, in particular in the field of atmospheric and oceanic processes, where satellite systems will provide unique opportunities to measure quantities not otherwise practicable to observe coherently and repeatedly on a very large scale up to and including a global scale. As an example, a very important research programme can be mentioned entitled the World Climate Research Programme (WCRP), established jointly by the World Meteorological Organization (WMO) and the International Council of Scientific Unions (ICSU). The ultimate goal, as set by the WCRP, is to improve the understanding of the complex dynamics and thermodynamics of the climate system comprising the global atmosphere, the world ocean, the sea ice and the land surface with its vegetation cover. To this effect, major international experiments have been set up, in particular for oceanic processes, of which the following two are of great importance, namely :

- the World Ocean Circulation Experiment (WOCE)
- the Tropical Ocean and Global Atmosphere (TOGA) programme.

Both will make use of oceanic satellite data in a well-coordinated fashion. A list of approved or planned polar orbiting Earth observation satellite missions, together with their main features, is given in Table 10.1.

In view of the overall objectives for the Polar Platform element of Columbus and the financial requirements to fund the total payload, it is advisable to envisage an international cooperation at four levels :

1) **At the level of the platform** : to satisfy the requirements of flying simultaneously (at least) two platforms, one of which could be built by the USA and the other by Europe, with compatible and comparable resources and capabilities.

2) **At the level of the payload** : For the IOC, some of the payload elements will have already been developed for previous missions either in the USA or in Europe on a national basis or on a multilateral ESA basis. Consequently, instruments from the same source could fly on the two platforms, whatever the source. This could apply later to new instruments to be mounted onboard by a servicing in orbit. It is of paramount importance to standardize the electrical, mechanical and data handling interfaces between the different platforms and the payload elements.

3) **At the level of payload data management** : A major goal should be to make satellite data and products easily accessible for all users worldwide. In particular, the development of an international data format or family of formats should be considered to ease the utilisation of data from various satellite and non-satellite sources.

4) **at the level of institutions.**
At present, three groups are in charge of coordination of future remote sensing missions:

a) **the Economic Summit Panel of Experts on Remote Sensing from Space,** formed after the 1982 Economic Summit held in Versailles. The objectives of the panel are:

- to exchange information on remote sensing programmes and plans

- to coordinate remote sensing programmes and plans with a view to avoiding duplication of efforts

- to foster the compatibility of activities in order to enhance the value of these programmes in addressing global phenomena

- to promote more effective use of budget resources

b) **CEOS** (Committee for Earth Observation Satellites) which held its first meeting in Washington D.C. in September 1984: it is an informal grouping of countries or organisations which operate, or will operate, Earth observation satellite systems, excluding meteorological satellites.

c) **IPOMS** (International Polar Orbiting Meteorological Satellites) established by the 1984 Economic Summit held in London. This group is chartered "to discuss technical, financial, administrative and legal matters regarding future international contribution to the US polar orbiting environment satellites or an internationally developed system", in the specific field of meteorological missions.

From the present exercise, it appears that there will be no need in the future to make a distinction between meteorological missions and others. It could be appropriate to review the above three groups with the objective to create, at a later stage, a Committee for Earth Observation Space Systems.

TABLE 10.1

APPROVED AND PLANNED POLAR-ORBITING EARTH OBSERVATION SATELLITE MISSIONS AND THEIR MAJOR FEATURES

	Mission	Objectives	Main Sensors	Orbit Max. Altitude	Launch Date	Status of Approval
Brazil	Remote sensing satellite	Land applications	Multispectral pushbroom imager	650 km altitude Sun-synchronous	1990/1991	Phase B in progress
Canada	Radarsat	Ice and land monitoring	Synthetic Aperture Radar Wind Scatterometer Optical Sensor	1000 km altitude Sun-synchronous	1991	Phase B in progress
China	Earth resource satellite	Land applications	Multispectral pushbroom imager	400 km altitude Sun-synchronous	1988/1989	Phase B in progress
European Space Agency	ERS-1	Ocean-ice monitoring	Synthetic Aperture Radar Wind Scatterometer Radar Altimeter Along-track Scanning Radiometer Microwave Sounder Precise Positioning Package (PRARE)	780 km altitude Sun-synchronous	1989	Approved (Phase C/D started in January 1985)
France	SPOT-2	Land applications	2x High-Resolution Visible Imager (HRV)	832 km altitude Sun-synchronous	1987	Approved
	SPOT-3 & 4	Land applications	Improved HRV (near IR capability) Vegetation monitoring sensor (medium resolution)	832 km altitude Sun-synchronous	1990 & 1994	Approved
	Poseidon (on SPOT-3)	Ocean circulation	Radar Altimeter Microwave Sounder Precise Positioning System (DORIS)	832 km altitude Sun-synchronous	1990	Phase B in progess
India	IRS-1	Land applications	LISS I and II	904 km altitude Sun-synchronous	1987	Approved
Japan	MOS-1	Marine applications	Multispectral Electronic Self-Scanning Radiometer Visible and Thermal Infra-red Radiometer Microwave Scanning Radiometer	909 km altitude Sun-synchronous	1987	Approved
	JERS-1	Land applications	Synthetic Aperture Radar Visual and Near-Infrared Radiometer	570 km altitude Sun-synchronous	1990/1991	Approved
United States						
NASA	UARS	Upper atmospheric reseach	Wide Range of Atmospheric Sensors	600 km altitude 57° Inclination	1989/1990	Approved (Phase C/D in progress)
NASA + France	TOPEX/ Poseidon	Ocean circulation	2-Frequency Radar Altimeter Microwave Radiometer Precise Positioning Poseidon Instruments (see above)	1300 km altitude 63° Inclination	1990/1991	Phase B in progress
US Navy + NASA + NOAA	N-ROSS	Ocean applications	Radar Altimeter Wind Scatterometer Special Sensor Microwave Imager Low Frequency Microwave Radiometer	830 km altitude Sun-synchronous	1990/1991	Approved
NOAA	Advanced TIROS-N Series (NOAA-K, L,M)	Operational weather monitoring	Advanced Very-High Resolution Radiometer Advanced Microwave Sounding Unit High Resolution Infrared Radiation Sounder	approx. 850 km alt. Sun-synchronous	1989 onwards 3 launches	Approved Operational Series
NOAA + EOSAT	Landsat 6 & 7	Land applications	Thematic mapper Multilinear array	700 km altitude Sun-synchronous	1989 & 1991	Approved
US Navy	DMSP Series	Operational weather monitoring	Operational Linescan System Special Sensor Microwave Imager Infra-red and Microwave Sounders	833 km altitude Sun-synchronous	1986 onwards	Approved

Note: There are plans for follow-on missions to ESA ERS-1 (ERS-2), MOS-1 (MOS-2) and N-ROSS

11. OPERATIONAL REQUIREMENTS

The operational requirements are to a large extent influenced by the meteorology and ocean monitoring missions.

Meteorology

It is assumed that the polar platform(s) will continue to provide information for the three dimensional characterisation of the Earth's atmosphere presently carried out by NOAA polar-orbiting operational environmental satellites NOAA K through M to be flown until the mid 1990's. At that time, the meteorological community will rely more and more on space instruments : this means continuity and reliability of the operational instruments. The requirements imposed by that mission are the following:

- Two platforms should fly simultaneously, one named 'morning platform', the other 'afternoon platform'. This was confirmed by the International Polar Orbiting Meteorological Satellite "IPOMS" group at its first meeting in November 1984.

- The smooth transition from NOAA M to the polar platform implies that most of the equipment of the meteorological package will provide similar data. This does not impose, but suggests identical equipment for cost reasons.

Ocean monitoring

Ocean monitoring serves three purposes:

- real or near real time environmental observations

- input data for marine weather forecasting models

- research on ocean circulation, energy transport, biology etc.

Only the first two of the above three are discussed in this chapter. These operational objectives require accurate and quasi-continuous measurement of significant wave heights, currents, surface winds and waves and sea surface temperature.

Considering the rapid obsolescence of some of the above parameters, the repetition rate, the coverage and the data distribution requirements are similar for the meteorological and for the ocean monitoring missions.

Repetition rate

As indicated above, the evolution of the parameters is continuous and there is a strong interest in obtaining as many measurements as possible. It is recognised that the **same parameters obtained at least 4 times a day** are required for the feeding and updating of the forecast models. This confirms the need for a minimum of two platforms and imposes constraints on the choice of the orbit.

Coverage

Clearly, the operational requirements need a **full Earth coverage.**

Data requirements

The rapid changes in the observed phenomena require a very **fast distribution of the products to the final user,** as is the case for the NOAA Tiros-N satellites and for ERS-1. This places constraints on the availability and reliability of the transmission links: direct broadcast and via a Data Relay Satellite (DRS).

Orbit

The above objectives and requirements dictate the choice of the orbit. Many factors must be considered in selecting the "best" altitude for a mission and it is not obvious that the operational requirements lead to the same choice as for the research missions. The parameters to be taken into account are the

- repetition of the orbital track
- frequency of observations
- coverage
- orbit correction frequency
- measurement resolution
- atmospheric drag problem
- data transmission to ground stations (read-out time)
- payload lift capacity

In order to obtain a consistent geometric relationship between the orbit's track and the projection of the Sun onto the orbital plane, for constant illumination to suit optical instruments **the orbit must be Sun-synchronous.**

With the aim to obtain complete coverage twice a day, studies carried out either in India (for IRS-1), in Japan (for MOS-1) or in France (for SPOT), by ISPRS, lead to a choice of orbit altitude over 800 km. So as to ensure compatibility with the polar orbiting meteorological satellites, NOAA-K, L and M, an orbit of 850 km (± 25 km) is proposed. This choice is also close to ERS-1 (780 km), SPOT (832 km), MOS-1 (909 km), IRS-1 (904 km) and will not impose too many modifications on the design of the instruments which could be transferred from these satellites to the polar platform. Landsat 4-5 at 705 km (for reasons of geometrical resolution) are exceptions.

The exact altitude has to be chosen to obtain the desired repetition rate or revisit cycles. Given the requirements for:

- 4 times per day
- daily
- every 2-3 days
- 14 days

coverage it is necessary to select a "double" repeat cycle orbit for both platforms with e.g. a 14 day main cycle and a 2-3 day subcycle. Furthermore the two orbits should be exactly synchronised and the platforms correctly phased in them to suit those requirements whose coverage depends on identical instruments on both platforms.

Regarding the **equatorial crossing time,** there is a high number of factors associated with its choice, including conflicting requirements that need to be taken into consideration :

a) Compatibility between the two platforms suggests having an optimal 6 hour difference in local time.

b) Land observations in the visible spectrum require an adequate level of solar illumination prior to the daily cloud build up: This indicates a need for an equatorial crossing local time of between 09:00 and 11:00 with a descending node, to suit the Northern Hemisphere.

c) Requirements of operational meteorology, when considering the cut off times for entering observational data into forecasting runs, and recognising the importance of having as recent data as possible of the mid ocean to the west of the countries concerned, lead to a local time not later than about 9.45 for Europe, when utilising the descending node, and not later than about 15.45 for the US, when utilising the ascending node.

d) Ocean observations in the visible spectrum have a requirement for a high solar inclination, which has been suggested as placing the desired equatorial crossing around 11 a.m.-2 p.m. local time.

e) The satellite configuration is considered to be easiest around 6 a.m./6 p.m., or between about 09.30 and 14.30 to avoid complicating the solar array geometry and shadowing the instrument fields of view.

Altogether, it seems reasonable to choose an equatorial crossing time in the 09.30 - 10.30 local time period, utilising a descending node orbital configuration for the Platform and in the 13.00 - 14.30 local time period for the ascending node for the afternoon platform.

12. DATA SYSTEM

As indicated in Chapters 3 and 11, the distinction can be made between applications and scientific objectives. This distinction leads to different requirements on data acquisition, processing and distribution to the final users. Such tasks and the management of the myriad of data streams that will originate from the platform are very challenging.

Near real time applications

It is assumed that ocean applications will have many common requirements to those of current meteorological operations, and that both will require real time global data in the form of derived parameters such as atmospheric temperatures and near surface winds over the oceans, etc. In the period before IOC, it is confidently expected that present forecasting and assimilation models will both expand to include ocean parameters and develop to include near continuous data assimilation. The current emphasis on data at synoptic times, already declining, will become less important. Whilst it will remain desirable to have observation close in time to the synoptic times of 00, 06, 12, 18 GMT, it will nevertheless be possible to assimilate sensibly data from any time in the 24 hours.

The requirement will therefore be for **all available global data.**

Atmospheric and Ocean dynamics data are extremely perishable, and delayed data cannot be incorporated into the model cycles. The absent data then degrades the skill of the forecast. Therefore, the timeline for relaying satellite observations to the ground, data processing, and delivery of the resulting products to the forecast centres is critical.

This leads to the following requirements:

- Processed **global** data should be available within **three** hours of the observation time, no matter when in the 24 hours this occurs.

- Processed **regional** data covering areas of perhaps 1/3 of a hemisphere, should be available to the forecasting centres within **two** hours of the observation time.

- Processed **local** data covering an area of about 2000 x 2000 km should be available within about 15 minutes of the observation time.

The current NOAA system, based on a combination of local and direct read out plus central processing of tape recorded data (for data rates less than a few Mb/s) does not meet requirements at the present time.

For the future, high rate SAR data of ice infested waters will be required in near real time. Ground stations for direct read out may not exist in all areas, and the rates are probably too high to be recorded on-board.

A future system should consist of a combination of:

(a) On-board tape recording and/or EDRS/TDRSS based data relay satellites to one or more global processing centres which would make available products within 2-3 hours;

(b) Direct read-out equipment so that local centres could receive and process these data as required to meet the needs of local area models (c.f. X-band downlink on ERS-1 for all data and the APT and HRPT downlinks on TIROS-N for selected data).

Non real time applications

This applies in particular to land observation missions. The requirements as concerns the availability to users is less tight: order of days are acceptable. However, substantial data backlogs are not acceptable.

Scientific features

The distribution can also be performed according to the above non real time applications.

Data System concept

In order to be more effective, the data system must:

- be developed as an integral part of a highly complex user environment and not as an independent entity
- be compatible with the DRS capabilities
- permit the division into different transmission channels adapted to different customers as indicated above

The sum of the data streams generated by the various instruments onboard depends of course upon the instruments which fly. This sum could be between 5 Mb/s without high resolution optical and microwave instruments and 500 Mb/s with SAR and high resolution multi-channel optical instruments. The data stream must be flexible enough to accommodate such variations. There is also a real need to define a sampling strategy for observation in the case of high (or very high) data rate sensors such as SAR's and Optical Imaging Instruments.

The monitoring and control of the platform will be performed by a master station and an operation centre located in Europe. This operation centre will be linked to the Space Station control centre, in particular for in-orbit servicing.

13. RESULTING GENERIC REQUIREMENTS

13.1 Establishment of generic requirements

Chapters 6 and 7 have derived a candidate set of model payloads for IOC and a payload augmentation evolution though the first 2 servicings.

Although further refinements and changes to such candidate payload sets will occur it is felt that the resulting generic requirements will not be affected appreciably.

The different payload set possibilities derived in this report have been assembled as shown in Tables 13.1 to 13.6 for the morning and afternoon platforms at IOC and for the morning platform at MOC together with their key parameters (as currently estimated) and with tentative assumptions on time lining.

13.2 Resulting generic requirements

The resulting generic requirements have been calculated for eclipsed and non eclipsed parts of the orbits, to take account of possible reduced timelining for some instruments during eclipse, particularly in the IOC period, and are summarised in Table 13.7. It will be noted that the resulting generic requirements are to a large extent independant of the exact instruments of which each payload possiblity is composed. (For the afternoon MOC case and the morning and afternoon AOC cases the figures shown are estimated based on extrapolations from the other cases for a mass evolution from 2000 kg at IOC to 3000 kg at MOC and 4000 kg at AOC).

E A R T H   O B S E R V A T I O N   M O D E L   P A Y L O A D   (AS OF 29.04.86)

(DATA BASE / DAY POSSIBILITY 1)

INSTRUMENT	MASS (KG)	POWER (W)	STANDBY (W)	DEEP OCEAN (%)	CSTL OCEAN (%)	LAND (%)	ICE (%)	DATA RATE (KB/S)	AV.POW. (W)	AV.DATAR. (KB/S)	ORB.DATR. (GB)	MORNING IOC	MORNING MOC	MORNING ADC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON ADC
AATSR	45	70	70E	100	100	0	0	330	70	178	1.1				X		
AMSU*2	300	210	50	100	100	100	100	9	210	9	0.1	X	X		X		
AOCM	100	156	76	100	100	0	0	2100	119	1134	6.8	X	X				
ARA	150	150	150E	100	100	100	100	100	150	100	0.6	X	X				
ARGOS	100	110	110E	100	100	100	100	8	110	8	0.0	X	X		X		
AILID	100	500	100	30	30	30	30	100	220	30	0.2	X	X				
AVHRR*2	60	33	6	100	100	100	100	670	33	670	4.0	X	X		X		
CCR	5	0	0	100	100	100	100	0	0	0	0.0	X	X		X		
DESAB	400	1500	200	0	100	100	100	400000	837	124000	1176.0	X	X				
ERBI	60	45	45E	100	100	100	100	1	45	1	0.0				X		
GOMR	40	12	12E	100	100	100	100	1	12	1	0.0				X		
HIRS*2	80	33	6	100	100	100	100	10	33	10	0.1	X	X		X		
HRIS	100	100	100E	0	100	100	0	100	100	27	0.2		X				
HROI*2	500	400	150	0	100	100	100	70000	272	34300	205.9		X				
MEIMB	120	70	70E	100	100	100	100	50	70	50	0.3				X		
PPS	42	22	6	100	100	100	100	1	22	1	0.0	X	X		X		
RA	100	150	150E	100	100	100	100	20	150	20	0.1				X		
WINDSCAT	300	275	50	100	100	0	0	65	171	35	0.2	X	X		X		
ADV.INST.	250	1000	250E	100	100	100	100	100	1000	100	0.6		X				
AO(AM)IOC	163	300	100E	100	100	100	100	150	300	150	0.9	X					
AO(AM)MOC	313	900	300E	100	100	100	100	450	900	450	2.7		X				
AO(PM)IOC	700	1400	350E	100	100	100	100	700	1400	700	4.2				X		

AVERAGE PROPORTION OF EARTH SURFACE TYPE					MORNING IOC	MORNING MOC	MORNING ADC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON ADC
	DEEP OCEAN :	51.0	MASS (KG)	:	2000.	3000.	0.	1952.	0.	0.
	COASTAL OCEAN :	3.0	POWER (W)	:	3299.	5389.	0.	2430.	0.	0.
	LAND :	24.0	AV. POWER (W)	:	2206.	4178.	0.	2326.	0.	0.
	ICE :	22.0	DATA RATE (MB/S)	:	403.	474.	0.	2.	0.	0.
		----------	AV. DATA RATE (MB/S)	:	198.	233.	0.	2.	0.	0.
	TOTAL :	100.0 %	ORB. DATA RATE (GB)	:	1189.	1397.	0.	10.	0.	0.

Figure 13.1

E A R T H   O B S E R V A T I O N   M O D E L   P A Y L O A D   (AS OF 29.04.96)

(DATA BASE / NIGHT POSSIBILITY 1)

INSTRUMENT	MASS (KG)	POWER (W)	STANDBY (W)	DEEP OCEAN (%)	CSTL OCEAN (%)	LAND (%)	ICE (%)	DATA RATE (KB/S)	AV.POW. (W)	AV.DATAR. (KB/S)	ORB.DATR. (GB)	MORNING IOC	MORNING MOC	MORNING AOC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON AOC
AATSR	45	70	70E	100	100	0	0	330	70	178	1.1				X		
AMSU*2	300	210	50	100	100	100	100	9	210	9	0.1	X	X		X		
AOCM	100	156	76	100	100	0	0	2100	118	1134	6.8	X	X				
ARA	150	150	150E	100	100	100	100	100	150	100	0.6	X	X				
ARGOS	100	110	110E	100	100	100	100	8	110	8	0.0	X	X		X		
ATLID	100	500	100	30	30	30	30	100	220	30	0.2	X	X				
AVHRR*2	60	33	6	100	100	100	100	670	33	670	4.0	X	X		X		
CCR	5	0	0	100	100	100	100	0	0	0	0.0	X	X		X		
DESAG	600	1500	200	0	50	50	50	400000	518	98000	588.0	X	X				
ERBI	60	45	45E	100	100	100	100	1	45	1	0.0				X		
GOMR	40	12	12E	100	100	100	100	1	12	1	0.0				X		
HIRS*2	80	33	6	100	100	100	100	10	33	10	0.1	X	X		X		
HRIS	100	100	100E	0	0	0	0	100	100	0	0.0		X				
HROI*2	500	400	150	0	0	0	0	70000	150	0	0.0		X				
MEIMG	120	70	70E	100	100	100	100	50	70	50	0.3				X		
PFS	42	22	6	100	100	100	100	1	22	1	0.0	X	X		X		
RA	100	150	150E	100	100	100	100	20	150	20	0.1				X		
WINDSCAT	300	275	50	100	100	0	0	65	171	35	0.2	X	X		X		
ADV.INST.	250	1000	250E	50	50	50	50	100	625	50	0.3		X				
AO(AM)IOC	163	300	100E	50	50	50	50	150	200	75	0.4	X					
AO(AM)MOC	313	800	300E	50	50	50	50	450	600	225	1.3		X				
AO(PM)IOC	700	1400	350E	50	50	50	50	700	875	350	2.1				X		

AVERAGE PROPORTION OF EARTH SURFACE TYPE		
	DEEP OCEAN :	51.0
	COASTAL OCEAN :	3.0
	LAND :	24.0
	ICE :	22.0

	TOTAL :	100.0 %

	MORNING IOC	MORNING MOC	MORNING AOC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON AOC
MASS (KG) :	2000.	3000.	0.	1952.	0.	0.
POWER (W) :	3289.	5389.	0.	2430.	0.	0.
AV. POWER (W) :	1787.	3062.	0.	1801.	0.	0.
DATA RATE (MB/S) :	403.	474.	0.	2.	0.	0.
AV. DATA RATE (MB/S) :	100.	100.	0.	1.	0.	0.
ORB. DATA RATE (GB) :	600.	602.	0.	8.	0.	0.

Figure 13.2

E A R T H   O B S E R V A T I O N   M O D E L   P A Y L O A D   (AS OF 29.04.86)

(DATA BASE / DAY POSSIBILITY 2)

INSTRUMENT	MASS (KG)	POWER (W)	STANDBY (W)	DEEP OCEAN (%)	CSTL OCEAN (%)	LAND (%)	ICE (%)	DATA RATE (KB/S)	AV.POW. (W)	AV.DATAR. (KB/S)	ORB.DATR. (GB)	MORNING IOC	MORNING MOC	MORNING AOC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON AOC
AATSR	45	70	70E	100	100	0	0	330	70	178	1.1				X		
AMSU*2	300	210	50	100	100	100	100	9	210	9	0.1	X	X		X		
AOCM	100	156	76	100	100	0	0	2100	119	1134	6.8		X				
ARA	150	150	150E	100	100	100	100	100	150	100	0.6		X				
ARGOS	100	110	110E	100	100	100	100	8	110	8	0.0		X		X		
ATLID	100	500	100	30	30	30	30	100	220	30	0.2		X				
AVHRR*2	60	33	6	100	100	100	100	670	33	670	4.0	X	X		X		
CCR	5	0	0	100	100	100	100	0	0	0	0.0		X		X		
DESAR	600	1500	200	0	100	100	100	400000	837	196000	1176.0	X	X				
ERBI	60	45	45E	100	100	100	100	1	45	1	0.0				X		
GOMR	40	12	12E	100	100	100	100	1	12	1	0.0				X		
HIRS*2	80	33	6	100	100	100	100	10	33	10	0.1	X	X		X		
HRIS	100	100	100E	0	100	100	0	100	100	27	0.2	X	X				
HROI*2	500	400	150	0	100	100	100	70000	272	34300	205.8	X	X				
HRTIR	250	300	50	0	100	100	100	20000	172	9800	58.8				X		
MFIMR	120	70	70E	100	100	100	100	50	70	50	0.3				X		
PPS	42	22	6	100	100	100	100	1	22	1	0.0		X		X		
RA	100	150	150E	100	100	100	100	20	150	20	0.1				X		
WINDSCAT	300	275	50	100	100	0	0	65	171	35	0.2		X		X		
ADV.INST.	250	1000	250E	100	100	100	100	100	1000	100	0.6		X				
AO(AM)IOC	360	700	200E	100	100	100	100	350	700	350	2.1	X					
AO(AM)MOC	313	900	300E	100	100	100	100	450	900	450	2.7		X				
AO(PM)IOC	450	900	250E	100	100	100	100	450	900	450	2.7				X		

AVERAGE PROPORTION OF EARTH SURFACE TYPE		
	DEEP OCEAN :	51.0
	COASTAL OCEAN :	3.0
	LAND :	24.0
	ICE :	22.0
	TOTAL :	100.0 %

	MORNING IOC	MORNING MOC	MORNING AOC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON AOC
MASS (KG) :	2000.	3000.	0.	1952.	0.	0.
POWER (W) :	2976.	5389.	0.	2230.	0.	0.
AV. POWER (W) :	2185.	4178.	0.	1999.	0.	0.
DATA RATE (MB/S) :	471.	474.	0.	22.	0.	0.
AV. DATA RATE (MB/S) :	231.	233.	0.	11.	0.	0.
ORB. DATA RATE (GB) :	1388.	1397.	0.	67.	0.	0.

Figure 13.3

E A R T H   O B S E R V A T I O N   M O D E L   P A Y L O A D (AS OF 29.04.86)

(DATA BASE / NIGHT POSSIBILITY 2)

INSTRUMENT	MASS (KG)	POWER (W)	STANDBY (W)	DEEP OCEAN (%)	CSTL OCEAN (%)	LAND (%)	ICE (%)	DATA RATE (KB/S)	AV.POW. (W)	AV.DATAR. (KB/S)	ORB.DATR. (GB)	MORNING IOC	MORNING MOC	MORNING AOC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON AOC
AATSR	45	70	70E	100	100	0	0	330	70	178	1.1				X		
AMSU*2	300	210	50	100	100	100	100	9	210	9	0.1	X	X		X		
AOCM	100	156	76	100	100	0	0	2100	112	1134	6.8		X				
ARA	150	150	150E	100	100	100	100	100	150	100	0.6		X				
ARGOS	100	110	110E	100	100	100	100	8	110	8	0.0		X		X		
AILID	100	500	100	30	30	30	30	100	220	30	0.2		X				
AVHRR*2	60	33	6	100	100	100	100	670	33	670	4.0	X	X		X		
CCR	5	0	0	100	100	100	100	0	0	0	0.0		X		X		
DESAR	400	1500	200	0	50	50	50	400000	518	98000	588.0	X	X				
ERBI	60	45	45E	100	100	100	100	1	45	1	0.0				X		
GOMR	40	12	12E	100	100	100	100	1	12	1	0.0				X		
HIRS*2	80	33	6	100	100	100	100	10	33	10	0.1	X	X		X		
HRIS	100	100	100E	0	0	0	0	100	100	0	0.0	X	X				
HRDI*2	500	400	150	0	0	0	0	70000	150	0	0.0	X	X				
WEIIB	250	300	50	0	100	100	100	20000	172	9800	58.8				X		
MFIMR	120	70	70E	100	100	100	100	50	70	50	0.3				X		
PPS	42	22	6	100	100	100	100	1	22	1	0.0		X		X		
EQ	100	150	150E	100	100	100	100	20	150	20	0.1				X		
WINDSCAT	300	275	50	100	100	0	0	65	171	35	0.2		X		X		
ADV.INST.	250	1000	250E	50	50	50	50	100	625	50	0.3		X				
AD(AM)IOC	360	700	200E	50	50	50	50	350	450	175	1.0	X					
AD(AM)MOC	313	900	300E	50	50	50	50	450	600	225	1.3		X				
AO(PM)IOC	450	900	250E	50	50	50	50	450	575	225	1.3				X		

AVERAGE PROPORTION OF EARTH SURFACE TYPE		
	DEEP OCEAN :	51.0
	COASTAL OCEAN :	3.0
	LAND :	24.0
	ICE :	22.0

	TOTAL :	100.0 %

	MORNING IOC	MORNING MOC	MORNING AOC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON AOC
MASS (KG) :	2000.	3000.	0.	1952.	0.	0.
POWER (W) :	2976.	5389.	0.	2230.	0.	0.
AV. POWER (W) :	1494.	3062.	0.	1674.	0.	0.
DATA RATE (MB/S) :	471.	474.	0.	22.	0.	0.
AV. DATA RATE (MB/S) :	99.	100.	0.	11.	0.	0.
ORB. DATA RATE (GB) :	593.	602.	0.	66.	0.	0.

Figure 13.4

E A R T H   O B S E R V A T I O N   M O D E L   P A Y L O A D   (AS OF 29.04.86)

(DATA BASE / DAY POSSIBILITY 3)

INSTRUMENT	MASS	POWER	STANDBY	DEEP OCEAN	CSTL OCEAN	LAND	ICE	DATA RATE	AV.POW.	AV.DATAR.	ORB.DATR.	MORNING			AFTERNOON		
	(KG)	(W)	(W)	(%)	(%)	(%)	(%)	(KB/S)	(W)	(KB/S)	(GB)	IOC	MOC	AOC	IOC	MOC	AOC
AATSR	45	70	70E	100	100	0	0	330	70	178	1.1				X		
AMSU*2	300	210	50	100	100	100	100	9	210	9	0.1	X	X		X		
AOCM	100	156	76	100	100	0	0	2100	119	1134	6.8	X	X				
ARA	150	150	150E	100	100	100	100	100	150	100	0.6		X				
ARGOS	100	110	110E	100	100	100	100	8	110	8	0.0		X		X		
AILID	100	500	100	30	30	30	30	100	220	30	0.2	X	X				
AVHRR*2	60	33	6	100	100	100	100	670	33	670	4.0	X	X		X		
CCR	5	0	0	100	100	100	100	0	0	0	0.0		X		X		
DESAR	600	1500	200	0	100	100	100	400000	837	196000	1176.0	X	X				
ERBI	60	45	45E	100	100	100	100	1	45	1	0.0				X		
GOMR	40	12	12E	100	100	100	100	1	12	1	0.0				X		
UIRS*2	80	33	6	100	100	100	100	10	33	10	0.1	X	X		X		
HRIS	100	100	100E	0	100	100	0	100	100	27	0.2	X	X				
HRDI*2	500	400	150	0	100	100	100	70000	272	34300	205.8		X				
HRDI	250	200	75	0	100	100	100	35000	136	17150	102.9	X					
HRTIR	250	300	50	0	100	100	100	20000	172	9800	58.8				X		
MFIMR	120	70	70E	100	100	100	100	50	70	50	0.3				X		
EES	42	22	6	100	100	100	100	1	22	1	0.0		X		X		
RA	100	150	150E	100	100	100	100	20	150	20	0.1				X		
WINDSCAT	300	275	50	100	100	0	0	65	171	35	0.2	X	X		X		
ADV.INST.	250	1000	250E	100	100	100	100	100	1000	100	0.6		X				
AO(AM)IOC	110	200	50E	100	100	100	100	100	200	100	0.6	X					
AO(AM)MOC	313	900	300E	100	100	100	100	450	900	450	2.7		X				
AO(PM)IOC	450	900	250E	100	100	100	100	450	900	450	2.7				X		

AVERAGE PROPORTION OF EARTH SURFACE TYPE		
	DEEP OCEAN :	51.0
	COASTAL OCEAN :	3.0
	LAND :	24.0
	ICE :	22.0
	TOTAL :	100.0 %

	MORNING IOC	MORNING MOC	MORNING AOC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON AOC
MASS (KG) :	2000.	3000.	0.	1952.	0.	0.
POWER (W) :	3207.	5389.	0.	2230.	0.	0.
AV. POWER (W) :	2060.	4178.	0.	1999.	0.	0.
DATA RATE (MB/S) :	438.	474.	0.	22.	0.	0.
AV. DATA RATE (MB/S) :	215.	233.	0.	11.	0.	0.
ORB. DATA RATE (GB) :	1291.	1397.	0.	67.	0.	0.

Figure 13.5

E A R T H ' O B S E R V A T I O N   M O D E L   P A Y L O A D   (AS OF 29.04.86)

(DATA BASE / NIGHT POSSIBILITY 3)

INSTRUMENT	MASS (KG)	POWER (W)	STANDBY (W)	DEEP OCEAN (%)	CSTL OCEAN (%)	LAND (%)	ICE (%)	DATA RATE (KB/S)	AV.POW. (W)	AV.DATAR. (KB/S)	ORB.DATR. (GB)	MORNING IOC	MORNING MOC	MORNING AOC	AFTERNOON IOC	AFTERNOON MOC	AFTERNOON AOC
AATSR	45	70	70E	100	100	0	0	330	70	178	1.1				X		
AMSU*2	300	210	50	100	100	100	100	9	210	9	0.1	X	X		X		
AOCM	100	156	76	100	100	0	0	2100	119	1134	6.8	X	X				
ARA	150	150	150E	100	100	100	100	100	150	100	0.6		X				
ARGOS	100	110	110E	100	100	100	100	8	110	8	0.0		X		X		
AILID	100	500	100	30	30	30	30	100	220	30	0.2	X	X				
AVHRR*2	60	33	6	100	100	100	100	670	33	670	4.0	X	X		X		
CCR	5	0	0	100	100	100	100	0	0	0	0.0		X		X		
DESAR	400	1500	200	0	50	50	50	400000	510	98000	588.0	X	X				
ERBI	60	45	45E	100	100	100	100	1	45	1	0.0				X		
GOMR	40	12	12E	100	100	100	100	1	12	1	0.0				X		
HIRS*2	80	33	6	100	100	100	100	10	33	10	0.1	X	X		X		
HRIS	100	100	100E	0	0	0	0	100	100	0	0.0	X	X				
HRDI*2	500	400	150	0	0	0	0	70000	150	0	0.0		X				
HEQI	250	200	75	0	0	0	0	35000	75	0	0.0	X					
HRTIR	250	300	50	0	100	100	100	20000	172	9800	58.8				X		
MFIMR	120	70	70E	100	100	100	100	50	70	50	0.3				X		
EES	42	22	6	100	100	100	100	1	22	1	0.0		X		X		
RA	100	150	150E	100	100	100	100	20	150	20	0.1				X		
WINDSCAT	300	275	50	100	100	0	0	65	171	35	0.2	X	X		X		
ADV.INST.	250	1000	250E	50	50	50	50	100	625	50	0.3		X				
AO(AM)IOC	110	200	50E	50	50	50	50	100	125	50	0.3	X					
AO(AM)MOC	313	900	300E	50	50	50	50	450	600	225	1.3		X				
AO(PM)IOC	450	200	250E	50	50	50	50	450	575	225	1.3				X		

AVERAGE	DEEP OCEAN :	51.0	MASS (KG) :	2000.	3000.	0.	1952.	0.	0.
PROPORTION	COASTAL OCEAN :	3.0	POWER (W) :	3207.	5389.	0.	2230.	0.	0.
OF EARTH	LAND :	24.0	AV. POWER (W) :	1695.	3062.	0.	1674.	0.	0.
SURFACE	ICE :	22.0	DATA RATE (MB/S) :	438.	474.	0.	22.	0.	0.
TYPE		----------	AV. DATA RATE (MB/S) :	100.	100.	0.	11.	0.	0.
	TOTAL :	100.0 %	ORB. DATA RATE (GB) :	600.	602.	0.	66.	0.	0.

Figure 13.6

Table 13.7

DERIVED PAYLOAD GENERIC REQUIREMENTS

	MORNING PLATFORM			AFTERNOON PLATFORM		
	IOC	MOC	AOC	IOC	MOC	AOC
Mass (kg)						
° Possibility 1 ° Possibility 2 ° Possibility 3	2000	3000	4000	1952	3000	4000
Average Power Day (W)						
° Possibility 1	2206	4178	6000	2326	4000	6000
° Possibility 2	2185			1999		
° Possibility 3	2060			1999		
Average Power Night (W)						
° Possibility 1	1787	3062	5000	1801	3000	5000
° Possibility 2	1494			1674		
° Possibility 3	1605			1674		
Peak Data Rate (Mb/s)						
° Possibility 1	403	474	500	2	200	300
° Possibility 2	471			22		
° Possibility 3	438			22		

(i) Power and Data Rate figures for afternoon platform MOC and for morning and afternoon platforms at AOC are extrapolated estimates assuming the payload mass evolution shown.

(ii) Power and Data Rate figures for afternoon platform MOC and for morning and afternoon platforms at AOC are extrapolated estimates assuming the payload mass evolution shown.

14. COMMERCIALISATION ASPECTS

The Earth Observation requirements for the Polar Platform element have mainly addressed those from the scientific and operational users with the exception of commercial users interested, for instance, in land applications. There is currenly a trend to commercialise land remote sensing data from spaceborne optical sensors. This is the case for:

- SPOT in France with the setting up of SPOT IMAGE, and in Sweden with SAT-IMAGE;
- Landsat in the USA with the transfer of the Landsat system to the EOSAT consortium.

Requirements specific to commercial users include, amongst other:

- confidential nature of data (coding of data)
- stringent requirements for sensor operations (as an example, agriculture monitoring applications could be mentioned which would require acquisitions during the growing season at frequent intervals, say every 10 days) which would drive the mission operations plan in terms of repeat cycles, allocation of platform resources (e.g. power) etc.

Basically, two options are possible:

- commercially-oriented sensors cohabiting with research/pre-operational sensors on the same platform with, in this case, the mission planning driven by the commercial user requirements;
- the commercially-oriented sensors mounted on a separate polar platform in an orbit optimised in terms of altitude, repeat cycle, re-visit capability, transmission links, etc.

Further study of such options is still required. For the time being commercial instruments are assumed not to be a part of the morning platform payload at IOC.

15. OTHER PLATFORM REQUIREMENTS

Although the majority of requirements can be met by embarking the appropriate instruments on a pair of polar orbiting platforms (one in a "morning" orbit and the other in an "afternoon" orbit) there are some requirements which cannot be satisfactorily met by these orbits, nor by the co-orbiting plaftform discussed in Chapter 8.

These remaining requirements broadly fall in the two areas of **atmosphere** and **solid earth.**

Atmosphere: Most parameters can be satisfactorily investigated and monitored from coordinated sun-synchronous orbits. However those phenomena in which the exact diurnal variation is of prime importance (e.g. earth radiation budget) need access to a so-called "drifting" orbit which gradually precesses with respect to the Earth-sun line.

For those parameters best sensed by occultation techniques, studies have shown the benefit and improved observation time and latitude coverage obtained by a near dawn-dusk sun-synchronous orbit.

Solid Earth: Although a few requirements can be met from a polar platform orbit, the majority, as discussed in 3.4, require rather special orbits:

- much higher, to minimise the disturbances caused by the unknown part of the Earth's gravity field, for precise positioning

- much lower, to determine the higher order components of the Earth's gravity field.

16. CONCLUSIONS AND RECOMMENDATIONS

The resulting generic payload requirements have been estimated, and at first sight appear to be consistent with the assumptions being made in the Columbus Polar Platform Phase B1 study. This study at present shows that such assumptions are close to what can be realised with the use of a single Ariane-5 or shuttle for launching the inital configuration and a single shuttle for augmenting it at servicing intervals.

The candidate model payloads groupings represent a good basis for further international discussions in order to lead to a set of requirements agreed by space agencies who would participate in the provision or contribution of platforms and/or payloads to realise such a capability. A part of such discussions would be the standardisation of the interfaces needed between the instruments and the platforms, selection of orbits and the rationalisation of data acquisition through, e.g. on-board recording, direct downlinking and use of data relay satellites.

The detailed technical requirements to be derived by ESA from the above would be provided as requirements for the Columbus Polar Platform and be subject to configuration control.

ANNEX 1: Membership

WORKING GROUP ON EARTH OBSERVATION REQUIREMENTS FOR THE POLAR ORBITING PLATFORM ELEMENTS OF THE INTERNATIONAL SPACE STATION

Members:

J. Houghton (Chairman)
P. Gudmandsen
J. Bodechtel
R. Frassetto
P. Pacquet
M. Lefèbvre
M. Ackermann
J. Olliver
M. Wooding
Ch. Reigber
F. Barlier
R. Rummel
D. Hardy
D. Croom
D. Pick
D. Breton
P. Lemke
K. Bagot
J. Fellous
J. Morgan
A. Sieber
G. Megie
F. Schlude
E. Schrama

Executive:

P. Goldsmith
B. Pfeiffer
C. Honvault
G. Duchossois
S. Bruzzi
S. Hieber
P. Ingmann
N. de Villiers

ANNEX 2: ACRONYMS USED

AATSR	Advanced ATSR
ADCLS	Automated Data Collection and Location System
AELID	Aerosol Lidar
ALSAR	Advanced Level SAR
ALT	Radar Altimeter
AMPS	Active Microwave Pressure Sounder
AMR	Advanced Microwave Radiometer
AMSR	Advanced Mechanically Scanned Radiometer
AMSU	Advanced Microwave Sounding Unit
A.O.	Announcement of Opportunity
AOC	Advanced Orbit Configuration
AOCM	Advanced OCM
APT	Automatic Picture Transmission
ARA	Advanced Radar Altimeter
ARGOS	The name of the DCLS developed by France for TIROS-N
ATLID	Atmospheric Lidar
ATSR	Along Track Scanning Radiometer
AVHRR	Advanced Very High Resolution Radiometer
CCR	Corner Cube Reflector
CIMR	Cryospheric Imaging Microwave Radiometer
CLSR	Cooled Limb Sounding Radiometer
CSR	Conical Scan Radiometer
DCLS	Data Collection and Location System
DFDPSAR	Dual Frequency Dual Polarisation SAR
DF SAR	Dual Frequency SAR
DIALID	Differential Absorption Lidar
DMSP	Defence Meteorological Satellite Programme
DOPLID	Doppler Lidar
DORIS	Doppler Orbitography and Radiopositionning Integrated by Satellite
DP DF SAR	Dual Polarised Dual Frequency SAR
DRS	Data Relay Satellite
DWS	Doppler Wind Sounder
EDRS	European Data Relay Satellite
ERBI	Earth Radiation Budget Instrument
ERB-PACK	Earth Radiation Budget Package
ERS-1	ESA Remote Sensing Satellite -1
ESTAR	Electronically Steered Thinned Array Radiometer
F/P-INT	Fabry-Perot Interferometer
GLRS	Geodynamic Laser Ranging System
GOMR	Global Ozone Monitoring Radiometer

ANNEX 2: ACRONYMS USED, continued

HIRIS	High Resolution Imaging Spectrometer (US)
HIRS	High Resolution IR Sounder
HOX	Hydrogen Oxides
HOXM	HOX-Monitor
HRIS	High Resolution Imaging Spectrometer (ESA)
HROI	High Resolution Optical Imager
HRPT	High Resolution Picture Transmission
HRTI	High Resolution Thermal Imager
HRTIR	High Resolution Thermal IR Radiometer
HRV	High Resolution Visible Imager
HRV-2	Improved HRV
IOC	Initial Orbit Configuration
IR	Infrared
IR-RAD	IR Radiometer
IRS	Indian Remote Sensing Satellite
ISAMS	Improved Stratospheric and Mesospheric Sounder
JERS-1	Japanese Earth Resources Satellite -1
LASA	Lidar Atmospheric Sounder and Altimeter
LASA-A	First Phase of LASA (laser altimeter)
LASA-B	Second Phase of LASA (atmosphere lidar)
LASA-R	Retroranging Portion of LASA
LASER ALT	Laser Altimeter
LASTIR	Laser Sensor Thermal IR
LFMR	Low Frequency Microwave Radiometer
LIDAR	LIght Detection And Ranging
LIRS	Limb IR Sounder
LISS	Linear Imaging Self-scan Sensor
MFIMR	Multi-Frequency Imaging Microwave Radiometer
MLA	Multilinear Array
MLS	Microwave Limb Sounder
MOC	Medium term Orbit Configuration
MODIS	Moderate Resolution Imaging Spectrometer
MODIS-N	MODIS-Nadir (Nadir viewing)
MODIS-T	MODIS-Tilt (off Nadir viewing)
MOS-1	Marine Observation Satellite -1
MWS	Microwave Wind Scatterometer
N-ROSS	Navy Remote Ocean Sensing System
OCI	Ocean Colour Instrument
OCM	Ocean Colour Monitor
OILSAR	Ocean-Ice-Land SAR
OMV	Orbital Manoeuvering Vehicle

ANNEX 2: ACRONYMS USED, continued

OTLAMR	Ocean Temperature Large Antenna Microwave Radiometer
PBIMR	Push Broom Imaging Microwave Radiometer
PDWS	Passive Doppler Wind Sensor
PMR	Pressure Modulated Radiometer
PODS	Precise Orbit Determination System
PPS	Precise Positioning Systems (e.g. PRARE, DORIS)
PRARE	Precise Range And Range-rate Equipment
RA	Radar Altimeter
RSR	Rain Scattering Radiometer
SAIS	Staring Array Imaging Spectrometer
SAMS	Stratospheric And Mesospheric Sounder
SAR	Synthetic Aperture Radar
SBUV	Solar Backscatter Ultraviolet Instrument
SCAT	Scatterometer
SIR	Shuttle Imaging Radar
SIS	Superconductor Insulator Superconductor
SPALT	Spaceborne Laser Ranging to Ground
SPOT	Satellite Probatoire d'Observation de la Terre
SSLOR	Solar Stellar Limb Occultation Radiometer
SSM/I	Special Sensor Microwave Imager
SSP	Sub Satellite Point
SST	Sea Surface Temperature
SSTIMR	Sea Surface Temperature Imaging Microwave Radiometer
SSU	Stratospheric Sounding Unit
SUB-MM	Submillimetre Spectrometer
TDRSS	Tracking and Data Relay Satellite System
TIMS	Thermal IR Imaging Spectrometer
TMD	Thematic Mapper Derivative
TOPEX	Topography Experiment
TSS	Top Side Sounder
UARS	Upper Atmosphere Research Satellite
UV	Ultraviolet
UV LIDAR	UV Lidar
UV-VIS	UV Visible Spectrometer
VIS-UV	Visible-UV Spectrometer
WPLID	Wind Profile Lidar
WAVESPEC	Wave Spectrometer
WINDSCAT	Wind Scatterometer
WM	Wave Mode

ANNEX 3: ACRONYMS CONVERSION TABLE

POPE	F-UK-WG *	EOS **
AATSR	ATSR-2	ATSR or AATSR
AMPS	AMPS	-
AMSU	AMSU-A/B	AMSU-A/B or MODIS-T
AOCM	OCM	OCI
ARA	ARA	ALT
ARGOS	DCLS	ARGOS-ADCLS
ATLID	ATLID	LASA-B
AVHRR	AVHRR-3	AVHRR-3 or MODIS-N
CCR	CCR	-
CLSR	HOXM/CIS	-
DF SAR	ALSAR	SAR
DIALID	DIALID	-
DP DF SAR	DFDPSAR	SAR
ERBI	ERB-N	ERBI
ERB-PACK	CSR	-
GOMR	GOMR	GOMR/SBUV
HIRS	HIRS-3	HIRS-3
HRIS	HRIS	HIRIS
HROI	HRV-2	MLA
HRTIR	HRTI	TIMS
LASER ALT	LAR	LASA-A
LASTIR	-	-
LIRS	ISAMS	IR-RAD
MFIMR	MFMR	SSM/I or AMSR
MLS	MLS-2	MLS or SUB-MM
PBIMR	ESTAR	ESTAR
PDWS	DWS	F/P - INT
PMR	-	PMR
PPS	PPS	PODS
RA	RA	ALT

* F-UK-WG: Franco-British Columbus Utilisation Working Group Phase B1 Report

** EOS: Earth Observing System (NASA)

ANNEX 3: ACRONYMS CONVERSION TABLE, contd.

POPE	F-UK-WG *	EOS **
RSR	RSR	-
SAIS	-	-
SAR	OILSAR	SIR
SPALT	LAR	GLRS or LASA-R
SSLOR	-	-
SSTIMR	OTLAMR	AMR or LFMR
TMD	TMD	-
TSS	-	-
UV LIDAR	-	-
UV-VIS	-	VIS-UV
WPLID	WPLID	DOPLID
WAVESPEC	WAVESPEC	-
WINDSCAT	MWS	SCAT

* F-UK-WG: Franco-British Columbus Utilisation Working Group Phase B1 Report

** EOS: Earth Observing System (NASA)

ANNEX 4: SUMMARY OF CHARACTERISTICS OF INSTRUMENTS CONSIDERED

AATSR

The Advanced Along Track Scanning Radiometer would be an advanced version of the ATSR being developed for ERS-1. The passive instrument measures SST using four infrared channels between 1.6 and 12 micrometres with a spatial resolution of about 1 km. It is able to measure below and ahead and to scan with a swathwidth of about 500 km.

AMPS

The Active Microwave Pressure Sounder allows to derive the surface pressure of the atmosphere by transmitting and receiving six microwave frequencies between 25 and 73 GHz with a resolution of 100 x 10 km at SSP. It is able to scan having a swathwidth of approx. 400 km.

AMSU

The Advanced Microwave Sounding Unit is a passive instrument consisting of two parts (AMSU-A and -B) measuring in the microwave absorption lines of O_2 and H_2O.

AMSU-A will be used to derive the atmospheric temperature profile within the troposphere and stratosphere. It measures at 15 frequencies between 23 and 89 GHz with a SSP resolution of 50 km. AMSU-B will measure the atmospheric water vapour content at five frequencies between 89 and 183 GHz with a resolution of 15 km (SSP). Both instruments are able to scan and have a swath of 2250 km width.

AOCM

The Advanced Ocean Colour Monitor will be used to observe the optical parameters of the oceans. It will measure 8 channels in the visible and near infrared with a resolution of 250 m at SSP. Using a pushbroom technique it will have a swath of about 1140 km. For more details see Annex 5.

ARA

The Advanced Radar Altimeter will be an upgraded version of the RA. It will be an active instrument transmitting and receiving possibly near 13.8 GHz. For more details see Annex 5.

ARGOS

ARGOS is a data collection and location package. It is able to receive data from e.g. drifting buoys. It has, therefore, a 120 degrees IFOV around nadir and receives at about 401 MHz.

ATLID

The Atmospheric Lidar is an active instrument (laser) which will operate either at 1.06 or 1.53 micrometres to determine atmospheric parameters in the middle and lower atmosphere. The resolution should be in the range of 10 to 50 km in the horizontal and better than 0.5 km in the vertical. For more details see Annex 5.

AVHRR

The Advanced Very High Resolution Radiometer is an imaging multi-purpose instrument (e.g. for cloud mapping). It is able to scan crosstrack. The swath is about 2900 km wide. It has six channels in the visible and infrared betwen 0.63 and 12.0 micrometres with a resolution of 1.1 km (SSP).

CCR

The Corner Cube Reflector allows e.g. range determination and, therefore, orbit determination with a high accuracy through laser ranging from the ground.

CLSR

The Cooled Limb Sounding Radiometer will measure atmospheric emissions in the near to far infrared (5 to 20 micrometres) at the Earth's limb at altitudes from 10 to 200 km with a resolution of about 3 km in the vertical. In the horizontal a resolution of 40 km is achievable. To have a good performance it will have a cryogenic cooler. For more details see Annex 5.

DF SAR

The Dual Frequency SAR is an advanced active instrument for high resolution imaging of land, ice and parts of the ocean. It would problaly operate at 5.3 GHz (C-band) with a second frequency in L or X-band. It will have a swathwidth of about 200 km selectable over an incidence angle range of about 15 to 50 degrees. For more details see Annex 5.

DIALID

The Differential Absorption Lidar is an advanced active instrument probably operating in the 0.73 to 0.76 micrometre range. It will measure atmospheric parameters such as temperature profiles, humidity profiles and surface pressure to accuracies of about 0.5 K, 5% and 1 mb respectively. It may have a scanning capability. For more details see Annex 5.

DP DF SAR

The Dual Polarised Dual Frequency SAR is an advanced active instrument similar to the DF SAR, but with dual polarisation, for imaging land areas, ice and parts of the ocean.

ERBI

The Earth Radiation Budget Instrument will measure the Earth's incoming and outgoing radiance using 8 scanning and non-scanning channels. It will have 3 scanning channels from 0.2 to 5, 5 to 50 and 0.2 to 50 micrometres; non-scanning channels from e.g. 0.2 to 5 micrometres and 5 to 50 micrometres for both wide (limb to limb) and medium FOV measurements. The IFOV for the scanning channels is 3° x 4.5°, equivalent to about 70 km SSP).

ERB-PACK

The Earth Radiation Budget Package consists of three instruments, viz. the Conical Scan Radiometer, a Pyranometer and a Pyrradiometer. The Conical Scan Radiometer will measure the reflected and emitted Earth radiation in 10 channels between 0.2 and 50 micrometres. It scans the Earth with concentric conical scans about nadir with half angles of 0, 10, 20, 35 and 50 degrees with spatial resolution of about 50 km. The scan arrangement allows it to determine the variation of outgoing radiation with incidence angle. The Pyranometer is sensitive between 0.2 and 4 micrometres and the Pyrradiometer has essentially unlimited bandwidth. The whole package will be used to determine the Earth's radiation budget. The Pyranometer and Pyrradiometer each has a wide field of view to cover the whole Earth disc.

GOMR

The Global Ozone Monitoring Radiometer will measure the ozone content of the atmosphere. It will be an advanced version of the Solar Backscatter Ultraviolet Spectrometer used on the TIROS-N satellites. It would probably have 13 channels between 256 and 380 nanometres. The SSP resolution would be about 170 km with no scan capability.

HIRS

The High Resolution Infrared Radiation Sounder is a passive sounding instrument that allows to derive vertical temperature and humidity profiles of the lower atmosphere. For that reason CO_2 and H_2O infrared absorption bands are used. The HIRS-2 version measures radiation in 20 near and thermal infrared channels between 3.8 and 14.5 micrometres. The nadir spatial resolution is about 10 km and it has the capability to scan crosstrack having a swath 2300 km wide.

HRIS

The High Resolution Imaging Spectrometer is an optical instrument incorporating an interferometer and a CCD multilinear array for measuring/imaging detailed spectral characteristics of land surfaces. It will operate in the visible and near infrared with 10 channels between 0.4 and 1.0 micrometres. The SSP resolution could be around 20 m and the swath could be 60 km wide.

HROI

The High Resolution Optical Imager will be an imager for land applications. It will operate in 4 visible and near infrared channels between 0.45 and 0.90 micrometres and 2 middle infrared channels around 1.6 and 2.1 micrometres. Its swath width of 200 km may be achieved by using two instruments. The spatial resolution would be about 25 m.

HRTIR

The High Resolution Thermal infrared Imager Radiometer is a multi-spectral thermal imaging instrument for e.g. geological, agricultural and oceanographical applications. It will have one visible channel for reference and five in the infrared between 1.6 and 12.0 micrometres. The resolution at SSP would be 50 m while the swath would be around 100 km wide. For more details see Annex 5.

LASER-ALT

The Laser Altimeter would make high precision measurements of the distance between the satellite and the Earth's surface. It should complement the microwave altimeters (RA and ARA) under clear weather conditions, having the advantage of a very small ground footprint of special value in undulating terrain for making high precision topographic measurements over ocean, ice and land. For more details see Annex 5.

LASTIR

The Laser Sensor Thermal Infra-Red will be an active four channel laser spectrometer imaging in the thermal infrared of use for e.g. discrimination of soil and rock types or vegetation as well as being able to determine atmospheric attenuation. For more details see Annex 5.

LIRS

The Limb Infra-Red Sounder is a strawman instrument for monitoring emissions of stratospheric and mesospheric constituents. It will have TBD channels at TBD frequencies in the infrared to concentrate on certain species. It will scan the limb.

MFIMR

The Multi Frequency Imaging Microwave Radiometer will be an imaging instrument for monitoring ice conditions and for measuring ocean surface wind speed, soil moisture, precipitable water and cloud and liquid water content. It will have four channels between 19 and 85 GHz with both horizontal and vertical polarisation. The spatial resolution will be around 25 km and it will have a swath of 1400 km (similar to N-ROSS SSM/I).

MLS

The Microwave Limb Sounder is a microwave radiometer with at least five channels at frequencies between 63 and 300 GHz. The purpose is to measure microwave emissions of the atmosphere in a limb scanning mode at altitudes between 20 and 120 km.

PBIMR

The Push Broom Imaging Radiometer is a low frequency imaging microwave instrument. The scientific objectives are to measure ocean salinity and soil moisture over land. It will have one (or two) channel(s) between 0.5 and 3 GHz. The use of a large antenna with a push broom feed arrangement will allow a spatial resolution of around 10 km to be obained at such low frequencies. For more details see Annex 5.

PDWS

The Passive Doppler Wind Sensor will allow to derive winds in the atmosphere as well as the composition of the troposphere and stratosphere. It will operate in the visible between 0.59 and 0.76 micrometres. It has a complex viewing geometry, mainly looking to the limb at 45 and 135 degrees to the orbit velocity vector and 50 degrees off nadir in the orbit flight direction. The wind velocity is determined from measuring the doppler shift of solar lines scattered from the atmosphere.

PMR

The Pressure Modulated Radiometer is a gas filter radiometer for determining the temperature and composition of the atmosphere (e.g. PMR on Nimbus-6, SAMS on Nimbus-7 and SSU on Tiros-N). It has a resolution of about 5-10 km in the vertical sounding mode and about 2-3 km for limb sounding.

PPS

The Precise Positioning Systems will be used for orbit determination. It is essentially the ERS-1 PRARE and SPOT DORIS precise microwave ranging systems.

RA

The Radar Altimeter is an active microwave instrument based on the ERS-1 RA possibly operating at 13.8 GHz. The resolution will be about 20 km looking at nadir only. It allows to measure e.g. wave height, wind speed, sea surface topography and the shape of the geoid.

RSR

The Rain Scattering Radiometer is a combined passive and active microwave instrument. It may be used for detecting rain areas and allows estimates of the intensity to be made, especially, over the oceans. It would consist of an active part operating at 13.5 GHz and a passive part operating at 36.5 GHz. The SSP resolution would be about 20 km and it provides a limited swath through conical scanning. For more details see Annex 5.

SAIS

The Staring Array Imaging Spectrometer is an imaging instrument sampling 100 to 200 bands in the visible sequentially. It would be used for land applications. The resolution would be about 20 m and the swathwidth about 10 km.

SAR

The Synthetic Aperture Radar is an active instrument used for imaging land, coastalocean and ice. It may operate at C, L or X-band with horizontal or vertical polarisation. It will look to the side between 20 and 45 degrees crosstrack with a swath of upto 200 km width.

SAR + WM

The Synthetic Aperture Radar (and Wave Mode) is a SAR which can also be operated in a low power mode for measuring ocean wave directional spectra (e.g. as in ERS-1).

SPALT

The Spaceborne Laser Ranging to ground would be used for ultra precise monitoring of crustal movements. It would determine the distance between the spacecraft and ground points with an accurary of a few millimetres by using a spaceborne visible or infrared laser with an agile beam pointing system to range to corner reflectors at the ground points.

SSLOR

The Solar Stellar Limb Occultation Radiometer will measure in the near UV, visible and IR to derive atmospheric composition including aerosols through earth limb occultation.

SSTIMR

The Sea Surface Temperature Imaging Microwave Radiometer is an all weather instrument for observing the sea surface temperature. It will complement the infrared imagers (ATSR and AVHRR). Possibly it could be a similar instrument to LFMR to be flown on N-ROSS. A reasonable footprint size of about 25 km should be achieved. For more details see Annex 5.

TMD

The Thematic Mapper Derivative is a high resolution imager for land applications (crops, forests), derived from the Thematic Mapper on LANDSAT 4 and 5. It will operate at 7 channels in the visible and infrared between 0.45 and 12.5 micrometres. The SSP resolution will be 30 x 30 m (at 12.5 micrometres it will be 120 m). It will scan crosstrack with a swathwidth of about 200 km.

TSS

The Top Side Sounder is a high frequency receiver measuring the ionospheric breakthrough frequency. As noise from below the ionospheric F-2 layer can only be detected at frequencies above the F2 critical frequency the TSS sweeps through the low MHz range in order to determine the critical frequency.

UV-LIDAR

The Ultra Violet Lidar uses an active UV laser to stimulate fluorescence e.g. at the sea surface. It may measure, therefore, chlorophyll concentration or classify surface oil pollution. It needs a high power UV laser with a multispectral receiver. For more details see Annex 5.

UV-VIS

The Ultra Violet - Visible Spectrometer will provide high spatial resolution through limb viewing of emission spectra of the atmosphere from the far UV to the near IR leading to a thorough study of composition and processes of the atmosphere above the tropopause.

WAVESPEC

The Wave Spectrometer is an active instrument transmitting and receiving at 5.3 or 13.7 GHz, based on the equivalent ERS-1 instrument. The purpose is to measure the direction and intensity of ocean waves. It measures at a fixed angle of 10 degrees.

WINDSCAT

The Wind Scatterometer is an active instrument transmitting and receiving in the Ku-band (14 GHz) or C-band (5.3 GHz). It measures near surface wind speed and direction over the oceans. The swath width is about 1000 km and the resolution about 25 km.

WPLID

The Wind Profile Lidar is an active infrared lidar to determine the wind speed and direction of several levels in the atmosphere especially useful in the tropics. It might have one channel at 9.1 micrometres, might have a conical scan having a 52 degrees look angle around nadir, scanning at 3 rpm. For more details see Annex 5.

ANNEX 5: SUMMARY OF INSTRUMENT PARAMETERS

INSTRUMENT	MASS	POWER	STANDBY	DATA RATE
	(KG)	(W)	(W)	(KB/S)
AATSR	45	70	70E	330
AMPS	50	50	50E	1
AMSU*2	300	210	50	9
AOCM	100	156	76	2100
ARA	150	150	150E	100
ARGOS	100	110	110E	8
ATLID	100	500	100	100
AVHRR*2	60	33	6	670
CCR	5	0	0	0
CLSR	400	400	400E	100
DFSAR	600	1500	200	400000
DIALID	150	4500	100	200
DPDFSAR	600	10000	400E	400000
ERB-PACK	100	70	60	3
ERBI	60	45	45E	1
GOMR	40	12	12E	1
HIRS*2	80	33	6	10
HRIS	100	100	100E	100
HROI	250	200	75	35000
HRTIR	250	300	50	20000
LASERALT	120	300	100	100
LASTIR	500	600	150	1000
LIRS	100	100	100E	100
MFIMR	120	70	70E	50
MLS	250	500	100	5
PBIMR	500	70	70E	50
PDWS	40	20	20E	20
PMR	20	20	20E	10
PPS	42	22	6	1
RA	100	150	150E	20
RSR	100	120	120E	2
SAIS	500	500	500E	100
SAR-C	350	1500	100	200000
SAR-X	400	3000	100	200000
SARWM	300	1000	100	100000
SPALT	150	300	100	1000
SSLOR	150	100	100E	50
SSTIMR	72	55	55E	50
TMD	400	350	350E	100
TSS	10	30	30E	5
UV-VIS	100	100	100E	10
UVLIDAR	500	1000	500E	100
WAVESPEC	100	150	150E	20
WINDSCAT	300	275	50	65
WPLID	600	1500	550E	100

REMARKS :

THE '*2' AFTER THE INSTRUMENT NAME INDICATES
THAT THIS IS A FULLY REDUNDANT INSTRUMENT !

THE CHARACTER 'E' AFTER STANDBY POWER INDICATES
THAT THIS IS AN ESTIMATE !

ANNEX 6: POSSIBLE ADVANCED INSTRUMENTS

ATMOSPHERE LIDAR (ATLID)

DIFFERENTIAL ABSORPTION LIDAR (DIALID)

RAIN SCATTERING RADIOMETER (RSR)

COOLED LIMB SOUNDING RADIOMETER (CLSR)

WIND PROFILE LIDAR (WPLID)

ADVANCED OCEAN COLOUR MONITOR (AOCM)

SEA SURFACE TEMPERATURE IMAGING MICROWAVE RADIOMETER (SSTIMR)

UV LIDAR

LASER ALTIMETER (LASER-ALT)

PUSH BROOM IMAGING MICROWAVE RADIOMETER (PBIMR)

ADVANCED RADAR ALTIMETER (ARA)

HIGH RESOLUTION THERMAL INFRARED IMAGING RADIOMETER (HRTIR)

LASER SENSOR, THERMAL IR (LASTIR)

ATMOSPHERE LIDAR (ATLID)

Type of Instrument:

A first generation satellite lidar to measure atmospheric parameters and to provide proof of concept for a space qualified LIDAR capable of operating over several years.

Scientific Objectives:

- to determine global aerosol distribution in the troposhere and stratosphere,
- to determine atmospheric discontinuities such as the tropopause and boundary layer
- to measure cloud top heights
- to measure surface albedo.

These data will contribute to studies of atmospheric transport processes on scales ranging downwards from the global scale to sub-synoptic scales, as well as to more general studies associated with climate and earth radiation budget research.

Measurements:

The measurements are of aerosol, cloud and surface backscatter at either 1.06 micrometres or 0.53 micrometres. The horizontal resolution should be in the range of 10 - 50 km with vertical resolution of better than 0.5 km.

Instrument:

Solid state laser operating at either 1.06 or 0.53 micrometres, large diameter telescope (0.5 - 1 m diameter), preferably with a scanning capability to increase coverage and horizontal resolution.

DIFFERENTIAL ABSORPTION LIDAR (DIALID)

Type of Instrument:

An advanced differential solid state lidar for measuring atmospheric parameters such as temperature, humidity, and surface pressure, on a global basis.

Scientific Objectives:

- to measure atmospheric temperature profiles with a target accuracy of 0.5 K
- to measure water vapour profiles with a target accuracy of 5%
- to measure surface pressure with a target accuracy of 1 mb (2 mb would still be useful in some regions).

The instrument is expected to demonstrate improvements in accuracy and resolution compared with existing passive instrumentation and to explore the possibility of measuring surface pressure with useful accuracy. The improvements in accuracy and resolution are expected to be of immediate benefit to the operational meteorological community and will also aid atmospheric research.

Measurement Technique:

The measurements are by differential absorption lidar techniques in the 730 - 760 nm part of the spectrum.

Instrument:

Solid state laser, a scanning telescope of diameter 0.5 to 1 m with an overall weight estimated at 200 kg with 500 w power consumption.

RAIN SCATTERING RADIOMETER (RSR)

Type of Instrument:

Combined active and passive microwave radiometer.

Purpose:

The Rain Scattering Radiometer (RSR) is intended to delineate rain areas and estimate rain intensity, especially over the oceans.

Scientific Objectives:

To determine rain areas and rain rates.

This is particularly important in the tropical areas, and therefore this instrument is a possible candidate for a co-orbiting platform if the antenna size (6 m) or other factors initially preclude flights on a polar platform.

The data would be useful for research, particularly that concerned with details of the hydrological cycle, and has potential operational use once their qualities have been fully evaluated and calibrated.

Instrument:

A combined active/passive radiometer, probably using 13.5 GHz for active measurements, and 36 GHz for passive, with a 6 metre diameter conical scan antenna, a power requirement of TBD watts, and an estimated weight of about 100 kg.

COOLED LIMB SOUNDING RADIOMETER (CLSR)

Type of Instrument:

Cooled thermal infra-red limb sounding radiometer.

Purpose:

Observation of the infra-red emission of the earth limb at tangent altitudes from 10 to 200 km on a global basis for extended time periods.

Scientific Objectives:

Atmospheric infra-red radiance has various origins such as thermal emissions, resonant and fluorescent scattering of sunlight, chemiluminescence and high energy particle induced emissions. Observation data can be interpreted in terms of atmospheric composition and processes. They thus allow monitoring of atmopsheric properties related to sources and sinks of constituents, dynamics, radiation and climate. Short and long term observed changes allow the understanding of diurnal, seasonal and long term variations and trends. Observations over sufficiently long periods of time will allow the prediction of natural and anthropogenic changes in the earth climate induced upper atmospheric levels.

Technical Availability

Cooled instruments have been flown and can operate for about a one year lifetime.However technical development in cryogenics, infra-red sensors and optical design are required to enable such an instrument to operate from a polar platform visited only every few years.

Spectral Range required in Instrument:

From the near to the far infra-red with a spectral resolution of 1/100 as a minimum.

Angular Resolution:

To achieve an altitude resolution of 3 km, the angular resolution and pointing accuracy of the line of sight should be to a few arc minutes and one arc minute respectively. (Fine adjustment of the line of sight could be achieved internally.)

COOLED LIMB SOUNDING RADIOMETER (CLSR) - continued

Time lining:

Global coverage is required. A repeat cycle of once per week may be considered as a minimum, leading to a minimum of two days of operation every week.
In the case of special events, such as volcanic eruptions or high solar activity, a higher utilisation rate would be needed.

Disturbance aspects:

Normal susceptibility of IR sensors. Cooling would require special considerations for interfaces and refuelling.

Instrument Characteristics:

- Weight:
  - Approx. 400 kg.
- Power:
  - Approx. 50 watts
- Data Rate:
  - 50 Kb/s
- Spatial Scanning:
  - The vertical scan should be repeated every minute in order to achieve a horizontal resolution of about 40 Km.

WIND PROFILE LIDAR (WPLID)

Type of Instrument:

A doppler lidar system for measuring atmospheric winds.

Scientific Objectives:

Atmospheric wind measurements of many levels are of fundamental importance for atmospheric research and for operational meteorology. This is especially so in the tropics where atmospheric dynamics cannot be deduced from the horizontal distribution of atmospheric density. An instrument which can measure wind velocity with high accuracy and with good horizontal and vertical resolution would therefore be particularly valuable. WPLID appears to offer this promise if the technology aspects can be solved in a cost effective way.

Instrument:

High power CO_2 laser, conical scanning 1 m diameter telescope, weight about 600 kg with power requirements of about 2 KW.

ADVANCED OCEAN COLOUR MONITOR (AOCM)

Type of Instrument:

An 8 channel visible/near infra-red imaging spectrometer.

Science Objectives:

- To understand better the relationship between the optical properties of sea water and its bio-physical properties (pigment concentration, sediment load, yellow substance), particularly in coastal areas.
- To introduce bio-physical parameters and their time series in models for understanding and forescasting the dynamics of biological and physical processes (primary production, upwellings, coastal sediment transport).
- To monitor global radiation absorption by turbid water as heat storage and marine carbon fixation, for climate models.

Application Objectives:

- To map global and regional primary production and to determine its variation in time and space and its relationship to fisheries.
- To monitor extended pollution areas and coastal calamities such as eutrophication and coastal erosions.

Complementary Instrument Needs:

The AOCM should operate in conjunction with the AVHRR to obtain complementary thermal infra-red data.

Instrument Technique:

Pushbroom spectrometer imaging in 10 nm intervals over the range 400 - 1100 nm with a spatial resolution of about 250 m. Each of the 8 channels is a combination of an in-flight selectable number of 10 nm intervals.

DUAL FREQUENCY SAR (DF SAR)

Type of Instrument:

An advanced two frequency wide swath (imaging) synthetic aperture radar.

Objectives:

- Sea ice:

  - sea ice velocity
  - sea ice concentration and extent
  - sea ice type
  - sea ice floe size distribution
  - surface characteristics (roughness)
  - surface characteristics (water content)

- Coastal Zones:

  - interval waves
  - sea bottom topography, erosion
  - eddies, fronts
  - current shear zones
  - wave spectrum (wave mode)

- Land:

  - interactions between microwaves and land surface characteristics (e.g. vegetation, base soil)
  - soil moisture, humidity
  - penetration
  - crop monitoring

Instrument:

Antenna length about 20 m, high power pulsed transmitters at two frequencies in the L,C,X and Ku bands.

SEA SURFACE TEMPERATURE IMAGING MICROWAVE RADIOMETER (SSTIMR)

(OTLAMR in UK/French List or LFMR as on N-ROSS)

Type of Instruments:

Large antenna imaging microwave radiometer for all weather sea surface temperature measurement.

Scientific Objectives:

- To complement the use of instruments such as ATSR and AVHRR in the measurement of ocean surface temperatures, both for applications and climatology, by using a passive microwave system to make such SST measurements in the presence of extensive clouds.

Instrument Description:

This is essentially the two frequency microwave radiometer to be flown on the US N-ROSS satellite. In order to get a reasonable footprint size (25 km) at the lowest microwave frequency required (5 GHz) a 6 m scanning antenna is necessary.

Note: MFIMR is a multifrequency IMR at higher frequencies and with a smaller antenna. At this stage it is not obvious where the correct dividing line should be drawn between SSTIMR and MFIMR.

UV LIDAR

Type of Instrument:

Fluorosensor, using a UV laser to stimulate fluorescence.

Background:

Stimulation of the sea surface from aircraft by UV lasers has demonstrated lidarcapabilities to discriminate and determine with high precision the chlorophyll emission (at 685 nm) in coastal water where an Ocean Colour Monitor cannot make such a measurement accurately because of the presence of large amounts of yellow substance and sediments.

Such experiments have also demonstrated that the fluorescence emission of differentclasses of oil patches on the sea surface occurs at different wave length.

A well defined lidar with variable/selectable excitation and receiving wavelengths is the best tool to furnish qualitative information of surface pollution.

The wavelengths of peak response of different surface pollutants are under study and for most of them have already been established.

Objectives:

- to measure chlorophyll and yellow substance concentrations in turbid coastal waters
- to detect and classify surface oil pollution
- to investigate the potential of fluoresensing for other application areas.

Instrument:

High powered UV laser with large diameter telescope receiver.

LASER ALTIMETER

Type of Instrument:

An active visible/IR laser instrument to make high precision measurements of the distance between the satellite and the illuminated patch on the Earth's surface.

Scientific Objectives:

- To complement microwave altimeters by making higher (horizontal) spatial resolution high precision (few cm) topographic measurements over ocean, ice and land in cloud-free conditions, and for coastal dynamics measurements.

PUSH BROOM IMAGING MICROWAVE RADIOMETER (PBIMR)

(ESTAR in NOAA/NASA List)

Type of Instruments:

Low frequency pushbroom imaging microwave radiometer.

Scientific Objectives:

- To measure ocean salinity for oceanographic and climatological studies
- To measure soil moisture for climatological and agricultural studies.

Instrument Description:

In order to accomplish the above objectives, extremely low microwave frequencies (in the 0.5 - 3 GHz range) need to be used. This necessitates the use of a very large (15 - 30 m equivalent diameter) electronically scanned antenna to obtain adequate resolution (the footprint size for a 30 m antenna at 1 GHz is 11 km).

ADVANCED RADAR ALTIMETER (ARA)

Type of Instrument:

Cross-track scanning advanced radar altimeter with enhanced tracking capability.

Scientific and Applications Objectives:

- To extend the capabilities of altimeters such as those on ERS-1 and Topex/Poseidon by providing off-nadir and higher spatial resolution topographic data for ocean, ice and land applications.
- In the ocean area to provide increased topographic structural data on small scale features such as eddies and currents.
- In the sea-ice area to provide data on occurrence and extent, and possibly sea-ice type, as well as the interaction of ocean waves with sea ice.
- In the land-ice area to map the structure of the ice-sheets and ice-shelves in the cross-track as well as along-track directions.
- To measure rainfall rates on a cross-track scale comparable to the size of the rain-cells.
- In the land area to obtain data on lake levels, wetland levels, land slopes, land cover and general land morphology.
- In the solid earth area (through use of ground-based transponders) to aid geodetic and seismic studies by measuring both absolute positions and relative movements.

Instrument Description:

The altimeter would electronically be similar to the ERS-1 altimeter but with enhanced capability for tracking surfaces with rapidly changing mean levels (preliminary work is already being funded by ESA). The cross-track viewing would be obtained by using an interferometer antenna system comprising two 1 m antennas separated by about 11 m. In a diffraction limited system the corresponding footprint size for each interferometric beam would be about 2 km.

HIGH RESOLUTION THERMAL INFRARED IMAGING RADIOMETER (HRTIR)

Type of Instrument:

Two channel high resolution thermal infra-red pushbroom imager.

Application Objectives:

- observation of land features (e.g. surface type thermal inertia)
- surface moisture mapping
- volcanic terrain detection
- mineral resource exploration
- monitoring of vegetatian stress conditions
- special agricultural tasks
- monitoring of environmental conditions (thermal plumes, etc.)
- coastal zone and inland waterbody investigations.

Technology Areas:

- lens configuration.
- thermal CCDs and their cooling.

LASER SENSOR, THERMAL INFRA-RED (LASTIR)

Type of Instrument:

Four channel laser spectrometer imaging in the thermal infrared.

Application Objectives:

- detection of soil mineral content
- soil and rock type discrimination
- vegetatian discrimination
- measurement of moisture and water content.

Scientific Objectives:

- measurement of integrated atmosphere attenuation
- determination of atmospheric constituents.

Complementary Instrument Needs:

Requires to be flown in combination with a passive optical sensor.

Instrument:

Continuous wave or pulsed thermal infra-red CO_2 laser, 4 channel imaging spectrometer, heterodyne detection and surface acoustic wave analyser.