

COSMO-SKYMED PROGRAM: UTILIZATION AND DESCRIPTION OF AN ADVANCED SPACE EO DUAL-USE ASSET

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ABSTRACT

This paper illustrates the mission goals and the main system elements, starting from an overview of the constellation to a brief sketch of the Space and Ground Segment elements. It also shows the main products and services offered to the final user. A strong emphasis is given to the dual-use (civil and military) nature of the system. The IEM (Interoperability, Expandability and Multi-sensoriality) concepts are also stressed, since these qualities bring COSMO-SkyMed to be a versatile system able to expand its architecture toward a set of “Partner-missions”. ASI announces the start of the COSMO-SkyMed Announcement of Opportunity allowing the scientific community to perform research activities exploiting the CSK advanced capabilities and products of the first two years of operations.

1. INTRODUCTION

The Italian 2006-2008 National Aero Space Plan (PASN), approved by the Ministry of University & Research (MUR), foresees the operational use of the COSMO-SkyMed (COntstellation of small Satellites for Mediterranean basin Observation) Project / Programme. COSMO-SkyMed (also called CSK) is the first European dual-use (civil and military) constellation of satellites for Earth Observation:

The COSMO-SkyMed Program System/Project is specified to be compatible for a multi-program/multi-function approach, so that the end-users of any partner can operate the system according to the agreed rules.

CSK is an end-to-end Earth Observation System dedicated to the remote sensing and data exploitation for dual (military and civil) use applications.

COSMO-SkyMed is the largest Italian investment in space systems for Earth Observation, conceived, funded and realized by Italian Space Agency (ASI) and the Italian Ministry of Defence (I-MoD) and developed by a team of Italian industries under ASI supervision in cooperation with I-MoD. The prime contractor is Alcatel Alenia Space Italia (AAS-I).

2. COSMO-SKYMED MISSION AND PERFORMANCES

2.1 Mission goal

World-wide civil protection, defence and resource managing users are today under an increasing pressure to take quick and appropriate decisions in fields like environmental management, monitoring and surveillance, risk and disaster management, hydrology, forestry, agriculture, urban and community planning.

In this frame Earth Observation (EO) market indicates a strong request for products and services which have to be reliable and frequently/regularly updated; for these reasons EO data users are demanding for higher resolution, better accuracy (geo-location, radiometry, etc.), better revisit & response time and quicker-and-easier ordering and delivery of data, products and services.

All these goals can be accomplished by increased density, frequency, duration or extent and bandwidth (resolution) of data acquisitions and new or improved measurement techniques such as a multi-sensor approach and a co-ordinated international co-operation for sharing experiences, technologies and resources.

With COSMO-SkyMed Italy offers today an efficient response to actual needs of environment management.

Main mission objective is the provision of data, products and services relevant to the:

- monitoring, surveillance and applications of MoD entities
- environmental monitoring, surveillance and risk management applications of institutional entities
- environmental resources management, maritime management, earth topographic mapping, law enforcement, informative / science applications of other institutional, scientific and commercial entities.

2.2 Mission characteristics

COSMO-SkyMed Mission has been conceived and developed on the basis of the following characteristics:

- full global coverage,
- all weather,
- day/night acquisition capability,
- large number of daily acquired images,
- higher resolution,
- higher accuracy (geo-location, radiometry, etc.),

- superior image quality,
- fast revisit/response time,
- interferometric/polarimetric capabilities,
- quicker-and-easier ordering and delivery of data, products and services.

These characteristics, in conjunction with the dual-use capabilities, makes today the COSMO-SkyMed System an advanced space EO dual use asset.

2.3 Mission elements

Cosmo-SkyMed is a constellation composed of four Low Earth Orbit (LEO) mid-sized satellites, each equipped with a multi-mode high-resolution Synthetic Aperture Radar (SAR) operating at X-band and fitted with particularly flexible and innovative data acquisition and transmission equipment to allow high-speed data transmission to ground stations.

The system is completed by dedicated full featured ground infrastructures for managing the constellation and granting ad-hoc services for collection, archiving and distribution to the users of acquired remote sensing data.

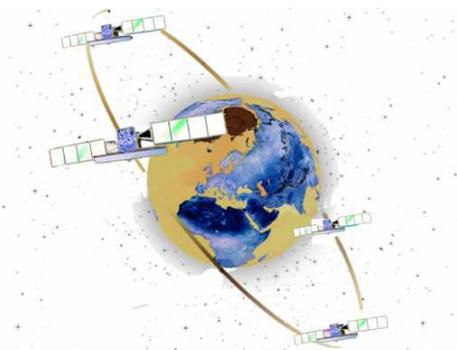


Figure 1. The COSMO-SkyMed Constellation

2.4 Images and Products Capacity

One of the main characteristics of COSMO-SkyMed is the capability to provide daily a large number of images and products.

The daily images and products capacity is the following: complete space segment is able to acquire up to 1800 images;

the on-line archive capacity is able to store up to 560 products

the processing is currently implemented to provide 200 civil products per day.

The archiving and processing architecture has been design to enlarge the capacity (see CSK IEM capability) when the user requests increase.

2.5 Operational Modalities & Time Performances

Three different System operational modes have been defined (routine, crisis and very urgent) allowing to respond to different needs in terms of required programming latency.

In routine mode the acquisition requests of the users are planned and sent to the constellation once a day.

In crisis mode this operation is done twice a day.

The very urgent mode is asynchronous, allowing the servicing of an image acquisition request with the minimum possible latency.

In routine mode the system is able to satisfy a user request (Response Time) within 72 hours for all the level 1 standard products; in crisis mode within 36 hours and in very urgent mode (acquisition plan uploaded asynchronously) within 18 hours.

The time performances of the constellation are defined on the basis of the following four definitions:

- reaction time: time span from the user request acceptance and deposit at the User Ground Segment (UGS) to the SAR image acquisition;
- information age: from the SAR image acquisition to the product availability at the UGS (data latency);
- response time: sum of the reaction time and the information age;
- revisit time: time span between two consecutive acquisitions over the same target.

The delivery time is not considered in the response time.

Following table reports the values to be considered for the above times:

	1 satellite	2 satellites	3 satellites	Full constellation
Information age	12 h	12 h	12 h	12 h
Response Time	110 h	90 h	85 h	72 h
Revisit time	65 h	40 h	40 h	12 h

Table 1. Time performances of the CSK constellation.

Please note that these values refer to routine (nominal) operational status and they are evaluated in the worst conditions. Actual values depend upon site coordinates, active ground segment, constellation configuration, operational mode etc., and they are supposed to reach better performances.

2.6 Interferometric Capability

The CSK constellation has been conceived to operate in interferometric configuration to acquire interferometric image couples with a time separation of few minutes (tandem mission in which two SAR satellites fly very closely).

The interferometric capability allows the generation of Digital Elevation Model (DEM) products with a absolute height accuracy of 8m in Spotlight mode, 17m in Stripmap mode and 58m in ScanSAR mode (horizontal accuracy varying from 18 m to 52 m) under specific conditions.

2.7 Polarimetric Acquisition Mode

The Stripmap PingPong mode implements a strip acquisition by alternating a pair of Tx/Rx polarizations across bursts (cross-polarization). This is obtained by means of a specific tuning of the antenna allowing acquisitions performed in strip mode alternating the

signal polarization between two of possible ones i.e. VV, HH, HV and VH.

In this polarimetric burst mode only a part of the synthetic antenna length is available in azimuth and consequently the azimuth resolution is reduced.

2.8 Mission Planning

In a dual-use environment, a particular emphasis has to be highlighted on dual-use mission planning functionality. It has been conceived in order to optimize system utilization and fulfilling at the same time different user classes needs, allowing the best exploitation of all the capabilities of the COSMO-SkyMed System.

This feature required a flexible architecture able to optimised the conflicts first in each single domain (civil and military) and then between them.

Furthermore the daily timetable has to guarantee the time performances (revisit time and response time); hence it has to be flexible to allow the users to perform the acquisition requests and solid to reach the fast time performances.

2.9 Resource Sharing

The system resources have to be considered as the envelop of all the elements defining the system functionality and its operational behaviour.

The COSMO-SkyMed System utilization shall be based on the evaluation of the system resources consumption. In the frame of specific agreement each authorized partner (civil or military) can use his own system resources usage quota to perform the necessary acquisition requests.

The challenge of this operations management is the optimal utilisation of system resources in coordinating simultaneously spacecraft and ground operations while serving and harmonising different and often conflicting acquisition requests of a heterogeneous user community.

2.10 Data Policy

Due to the intrinsic system “duality” nature and to the national and international co-operations access and use of COSMO-SkyMed system and data, a specific regulation for data distribution has been defined.

ASI has the main goal to ensure the data availability to national and international civil users.

3. COSMO-SKYMED SYSTEM

Peculiar characteristics of COSMO-SkyMed system is to be conceived, designed and developed from the very beginning as the first European Space Observation System devoted to both civil and defence applications, ensuring at the same time data confidentiality and integrity in any kind of operational situation.

This basic feature is clearly embedded in the COSMO-SkyMed architecture, as schematically illustrated in the Fig. 2, the design characteristics are deeply rooted into the “native” versatility of the architecture key elements.

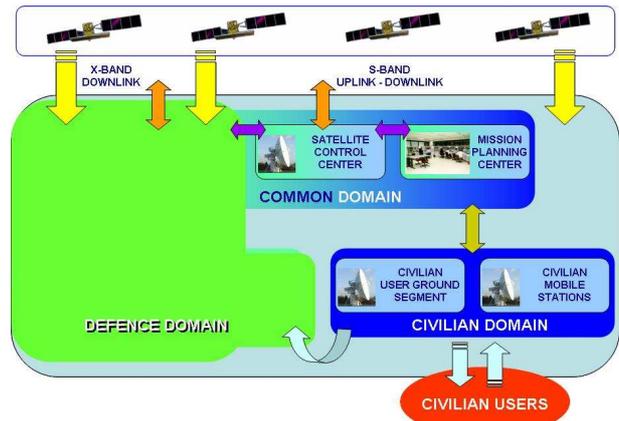


Figure 2. COSMO-SkyMed Architectural concept

A substantial architectural *symmetry*, aimed at implementing the Duality Principles, is implemented through:

- Duplication of Ground Segment (GS) elements which provide specific functionalities (e.g. sensing data acquisition, processing, archiving, and user services) to satisfy separately civilian and defence users needs. These GS elements include: User Ground Segment (UGS) centres, Receiving GS, and Mobile Stations;
- Dual centres where the information from civilian and defence domains, adequately protected in terms of security, are merged and treated together. The dual centres include: Mission Planning Centre (CPM) and Satellite Control Centre (CCS), in charge of mission planning, satellite tasking monitoring and control of COSMO-SkyMed spacecraft constellation.

COSMO-SkyMed provides security features, adequate to their “*sensitivity*” level, to both civilian and defence domains. Indeed, dual security pursues the twofold objectives of protecting *system assets* (e.g. satellites, GS infrastructures, networks) and *information* at defence standard level wherever necessary whilst, on the other side, ensures an indispensable flexibility in accessing information for granting system civilian utilization.

3.1 Space Segment

The CSK 4 satellites are, in the nominal configuration, equi-phased in the same orbital plane as depicted in Fig. 3 (also including the main orbital characteristics).

> NUMBER OF SAT.	4
> ORBIT TYPE	Down Dusk SSO
> INCLINATION	97.86°
> ECCENTRICITY	0.00118
> HEIGHT	619.6 Km
> LTAN	06:00 a.m.
> SATELLITE PHASING	90°
> ORBIT PERIOD	97.2 m
> ORBIT CYCLE	16 days
> REVOLUTIONS / DAY	14 + 13/16
> REP. CYCLE	237 orb. in 16 days
> ECLIPSES	Seasonal (max 21 m.)
> S/L PHASING	at 90° each other

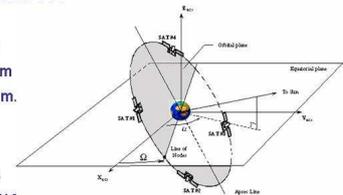


Figure 3. COSMO-SkyMed Orbitography

Fig. 4 provides a pictorial view of a COSMO-SkyMed satellite.

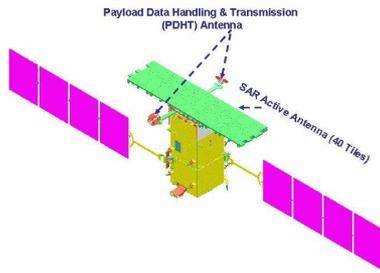


Figure 4. Satellite pictorial view

Satellite snapshots are listed in the following Tab.2:

Satellite Snapshots	
Satellite Mass	~1850 Kg
Attitude Stabilization	3 axes
Max Pointing error.	1 Km
Navig. And Time Refer.	GPS
Operational Lifetime	≥ 5 years
Operational Autonomy	≥ 24 h

Table 2. Satellite characteristics

Each satellite is equipped with a coherent, active phased array SAR instrument operating at X-Band.

The COSMO-SkyMed Payload is completed by a flexible and innovative Payload and Data Handling Transmission (PDHT) system providing all functions necessary for the real-time acquisition, storage and handling of data generated by the SAR payload and for their transmission to Ground.

The main features provided by CSK Payload:

SAR	
Frequency	9.6 GHz
Imaging Capability	Multimode
PDHT	
Storage Data Rate	Up to 450 Mbps
Downlink Data Rate	310 Mbps (2 Channels)
Storage Data Rate	Up to 450 Mbps (2 DL Ch.) Up to 600 Mbps (1 DL Ch.)
On-board Mass Memory	320 GB <i>End of Life</i>

Table 3. Payload characteristics

The SAR instrument can be operated in different beam modes to reach a multi-mode acquisition capability as describe in the following:

- SPOTLIGHT Mode (Spotlight 1 utilised for defence needs and Spotlight 2 also for civil one), allowing SAR images with spot extension.
- STRIPMAP Mode (HIMAGE and PingPong), achieving medium resolution and wide swath imaging.
- SCANSAR Mode (WIDE and HUGE REGION), achieving radar imaging with very large extension and a lower spatial resolution.

Fig 5 specifies the values of the COSMO-SkyMed multi-mode acquisition characteristics.



Figure 5. Multi-Mode Acquisition Capability

Right Looking Mode is the satellite nominal looking mode acquisition, in which the SAR instrument has an access capability, achieved by electronic beam steering, in the incidence angle range $25^\circ \leq \theta \leq 50^\circ$ (antenna boresight off-nadir angle $\sim 34^\circ$), yielding optimum radar imaging performance within an access area of ~ 630 Km.

The access area can be doubled with Left Looking Mode acquisitions obtained by commanding a slew manoeuvre to reach the same SAR antenna mechanical boresight on the left side and performing imaging within the same incidence angle range.

This range can be extended on both right and left side by platform roll agility, gaining access to $20^\circ \leq \theta \leq 25^\circ$ and $50^\circ \leq \theta \leq 59.5^\circ$ incidence angle ranges with slightly degraded performance (*Extended Mode*).

3.2 Ground Segment

The COSMO-SkyMed Ground Segment provides all the infrastructures needed to support the CSK mission in the dual use scenario. It is devoted to perform the main functions/operations at ground level needed to manage the COSMO-SkyMed System both in terms of control and global data management.

The COSMO-SkyMed Ground Segment main components located out to fulfil the high level requirements of the CSK mission are the following:

- Mission Planning and Control Centre (CPCM) which is in charge of co-ordinate on-board and ground activities, perform overall mission planning, allocate resources and solve acquisition requests conflicts,
- Core Ground Segment (CGS), which is composed by Satellites Control Centre (CCS) providing all the functions devoted to Monitor & Control the Satellite constellation, Flight Dynamics System (FDS), TT&C stations providing the primary link service between the COSMO-SkyMed satellites and the Ground Segment,
- User Ground Segment (UGS) devoted to manage user requests, to acquire, archive, process and deliver the

data received from the COSMO-SkyMed Satellites by means of co-located and/or remotely located X-band acquisition stations (including mobile terminals).

- Communication Network which is in charge to guarantee the connections between the different CSK centres/stations in a secure, reliable and efficient way,
- The GPS Fiducial Network is a service support element providing GPS ephemeris and data necessary to improve precision in CSK satellites orbit determination to improve precision in product geolocation.

The COSMO-SkyMed Ground Segment is geographically distributed over a wide territory including Italian sites and some extra-Italian sites. The facilities are both fixed centres and mobile terminals for civilian and defence utilization.

Finally, an Integrated Logistics and Operations Segment (ILS&OPS) collects all necessary operations & logistic resources and services required for operating the space segment throughout the whole system lifetime.



Figure 6. COSMO-SkyMed distributed Ground Centres

4. IEM CAPABILITY

One of the major problems the EO Users community has to face with is the high number of existing/planned spread EO facilities each providing different specific, regional or thematic functions (e.g. near real time data production and distribution, off-line archive, added value services, etc.).

Some international initiatives, such as GMES (Global Monitoring for Environment and Security), GEOSS (Global Earth Observation System of Systems), and, for Defence, MUSIS, aim at finding a viable way to provide cost-effective solutions for future EO systems, granting users with simple access to Multi-Mission/ Multi-Sensor (MM/MS) capabilities and streamlined operations.

The COSMO-SkyMed System architecture provides today a key mechanisms for implementing the future EO systems MM/MS capabilities by having been envisaged, from the elder design phases, as a versatile system able to easily and cost effectively expand its architecture toward a set of “partner-mission” (up to 5 civilian and up to 5 defence partners) so to cover a larger variety of utilization needs (e.g. optical, hyper spectral or other radar bands).

Such high versatility characteristics led ASI and I-MoD to further promote these characteristics and to develop an actual multi-mission architectural framework capable to be integrated and/or cooperate with other EO partner-systems, in order to:

- deposit and plan multi-mission requests among partner missions,
- receive sensing data from the partner satellite constellations,
- process, exploit, and deliver these multi-sensor data products.

In fulfilling this objective, highly innovative design solutions have been conceived for sustaining the whole MM/MS cycle, implementing the capabilities necessary to achieve the following “IEM” features:

- *Interoperability*, the capability of exchanging data and information with external heterogeneous systems according to pre-defined agreed modalities and standards, and irrespective of internal design of the cooperating parts.
- *Expandability*, the ability of COSMO-SkyMed architecture to either integrate mission-specific components “imported” from Partner EO System, or to “export” COSMO-SkyMed components to Partner EO Systems, including *Scalability*, the ability to easily increase its production capabilities.
- *Multi-Sensoriality*, that is the ability to request, process, and manage data related to different observation sensors. Such a feature finds its architectural and procedural basis on the Interoperability and Expandability.

COSMO-SkyMed is therefore a highly innovative system, presenting cutting-edge multi-mission and multi-sensor capabilities. The deriving benefits, in terms of both costs and user-friendliness, are witnessed by the actual cases ASI is currently carrying on through international cooperation programs such as ORFEO (Optical and Radar Federation for Earth Observation) with France and SIASGE (Italian-Argentinean Satellite System for Emergency Management) with Argentina.

5. PRODUCTS & SERVICES

SAR Products are composed by 5 “standard” products levels: RAW, SSC, DGM, GEC and GTC; and 6 types of “higher” levels product obtained by a post-processing of the standard products: Quicklook, Co-registered, Mosaiked, Speckle filtered, Interferometric and DEM. Products are characterised by a spatial resolution ranging from 1 m up to 100 m, a radiometric accuracy of 1 dB and a localization error on ground with as low as 15 m (GTC products).

A typical user request can be satisfied by accessing catalogue or by acquiring a new image. Some further ancillary services are allowable to the users, such as:

- Guide: general information about the system, the applications and offered services.

- Bulletin Board: information about major events impacting the operability of the system.
- Problem Solving: allowing the user to notify a problem / receive information about the solution.
- System documentation/information: controlled access to documentation/ information.

6. PLANNING

The launch of the first COSMO-SkyMed satellite is foreseen for June 2007. The successive launches will take place implementing the best efforts to reduce the time span in between and optimize the strategy of each satellite commissioning. Full constellation will be hence gradually deployed by the end of 2009 and will be fully operational by mid 2010.

The whole System Operational Lifetime will be at least 15 years.

7. CSK ANNOUNCEMENT OF OPPORTUNITY

ASI announces an opportunity to conduct scientific research and application development projects in Earth Observation using products from the COSMO-SkyMed dual mission. The opportunity is open “worldwide” for candidates submitting proposals which cover exploitation of COSMO-SkyMed products for:

- Scientific Research and Application Development
- COSMO-SkyMed Geophysical products (Level 2) algorithm development and validation
- Demonstration of COSMO-SkyMed capabilities in thematic domains of Global Monitoring for Environment and Security (GMES) service elements and Group on Earth Observation (GEO) Programme
- New Ideas for System Exploitation

Three out of four satellites will likely be available and operational during most of the time span of this Announcement of Opportunity (AO).

Selected project proposals from this AO will result in an allocation of products to the Principal Investigator (PI). No funds will be awarded. The advantages of being selected as Principal Investigator is the access to relevant COSMO-SkyMed products at no cost.

Project proposals must be submitted for evaluation via the dedicated website:

<http://www.cosmo-skymed-ao.asi.it>.

The submission deadline is 31/07/2007.

Project proposals will be evaluated under specific criteria identified by international experts coming from the main world space agencies.

The evaluation shall also take into account the relevant system resources consumption and security regulations. Following the ASI approval of the proposed projects, products necessary to execute the projects will be provided to the selected Principal Investigators free of charge within the limits of the system resources quota assigned by ASI to each proposal.

For projects with large difference between requested and assigned system resources quota, products provision

will be negotiated on a case-by-case basis prior to the acceptance of the proposal.

The CSK AO schedule is as follows:

Announcement and opening web for submission of proposals	T0 (May 2007)
Deadline for submissions	T0 + 3 months (July 31 st , 2007)
Deadline for evaluations	T0 + 9 months (January 2008)
AO projects start (products delivery)	T0 + 10 months (February 2008)
AO projects completion, final reports	T0 + 34 months (February 2010)

Dates are linked to the launch of the first satellite of the constellation.

8. CONCLUSIONS

The first satellite of the COSMO-SkyMed constellation is ready to be launched in June 2007 and it will be fully operational in the early 2008.

The first COSMO-SkyMed Announcement of Opportunity to conduct scientific research and application development projects in Earth Observation using products from the COSMO-SkyMed dual mission will start the first days of May 2007 accepting the submission of the project proposals.

The CSK AO projects will begin the first months of 2008, following the first operational phase of the CSK mission and it will last 2 years.

9. REFERENCES

[1], [2], [3] and [4] are available on the CSK AO website <http://www.cosmo-skymed-ao.asi.it>.

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