Towards 1 m Resolution from GEO

Executive Summary Report

Written by	***Responsibility*** + handwritten signature if no electronic workflow tool
E. Thomas	Study Manager
Verified by	
Approved by	
J-Y. Labandibar	Head of Optical Instruments Advanced Projects

Approval evidence is kept within the documentation management system.

CHANGE RECORDS

ISSUE	DATE	§ CHANGE RECORDS	AUTHOR
Draft	03/12/09	Initial version	E. THOMAS
1.0	17/03/2010	Approved version	E.THOMAS

TABLE OF CONTENTS

1. INTRODUCTION

This executive summary report gives an overview of the 9-month study led by Thales Alenia Space for ESA, in the frame of the General Studies Program (GSP).
The main objective of this study was the analyze and quantification of challenges necessary to allow improved spatial resolution from GEO.

1.1 Towards 1 m resolution from GEO

Today Earth observation is based on observations from Low Earth Orbit (LEO) which provides a wide range of resolutions but with a slow revisit and from the Geostationary orbit (GEO), providing fast revisit and Coarse resolution.
When considering applications related to security and environment monitoring, it appears a need to observe events or phenomena of small-scale and high dynamic. Taking into account the intrinsic time resolution advantage of the GEO orbit, improvement of the accessible resolution would authorize to cover such applications.

Following these observations, the study's objectives were:

- to review users needs identified during the study "Applications for Aperture Synthesis Techniques for imaging in Earth observation and Science",
- derive key mission requirements from the user needs,
- critically review and consolidate the mission concept,
- break down the key mission requirements to determine the mission driving requirements,
- analyze the critical components necessary to meet the requirements,
- analyze the key developments needed for the identified critical components.

2. STUDY ORGANISATION

2.1 Team structure

For this activity, Thales Alenia Space was supported in the frame of consultancies by:

- ONERA (France),
- Micromega Dynamics (Belgium),
- Selex Galileo (UK)
- CMOSIS (Belgium)

Responsibilities of each team member are given in the following table:

Table 2-1 Responsibilities were shared according to the expertise field of each team member

Team member	Main responsibilities
THALES ALENIA SPACE	Prime contractor, responsible for study management, mission, system requirements, critical technology identification and roadmap (with support of consultancies)
ONERA	Expertise on co-phasing and line of sight stabilisation solutions
Micromega Dynamics	Expertise on active control solutions for internal dynamics disturbances impact reduction
Selex Galileo	Expertise on the identification and expected performances of potential solutions for the architecture of IR focal planes
CMOSIS	Expertise on the identification and expected performances of potential solutions for the architecture of VIS CMOS focal planes

2.2 Study logic

The study was organized following 4 tasks (see Figure 3-1):

A first task dedicated to the overview of the applications and user requirements collected during the study “Applications for Aperture Synthesis Techniques for imaging in Earth observation and Science”.

Following task was dedicated to the consolidation of mission architecture and derivation of high-level requirements.

A third task dedicated to the analysis of critical components, identification of platform and payload concept designs that could meet the key requirements and analysis of mission design alternatives.

Last task was dedicated to the identification of technology roadmaps and pre-development approaches for the identified critical components.

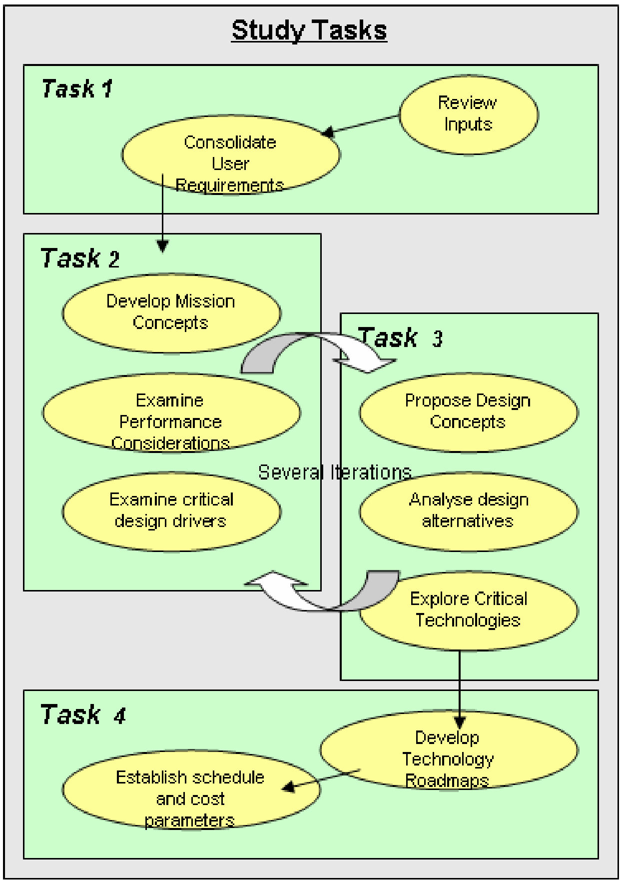

Figure 2-1 Study logic of Towards 1 m resolution from Geo study. Task 2 and 3 have been performed in parallel, several iterations being required

3. MAIN STUDY OUTPUTS

3.1 Review of user needs and key requirements

The review of user needs has covered the following application fields:

- environment monitoring,
- resource mapping,
- science of the Earth and atmosphere,
- land surveillance,
- meteorology,
- agriculture,
- disaster management (floods, forest fire, volcano eruptions,)
- security,
- defense.

Potential users of the system, corresponding to these applications, are listed hereafter:

- Scientists
- Meteo service providers
- Coastal authorities
- Emergency services
- Relief agencies
- Protection services
- Decision makers
- Military.

Selected applications have been classified in two distinct categories (see Figure 3-1) that are:

The key applications that justify the need of very High Resolution Observation System from Geo (as not feasible with other means) and define its characteristics (distinction is made between applications to save lives and those to reduce threats or improve human safety and/or health)

The promising applications that could greatly benefit from this kind of images without adding technical complexity at the space system level and allowing to feed observation plan of the system with predictable applications (these applications are classified in two categories, the former deals with pollution, security and sustainability, the later is related to resource and facilities management and to scientific applications).

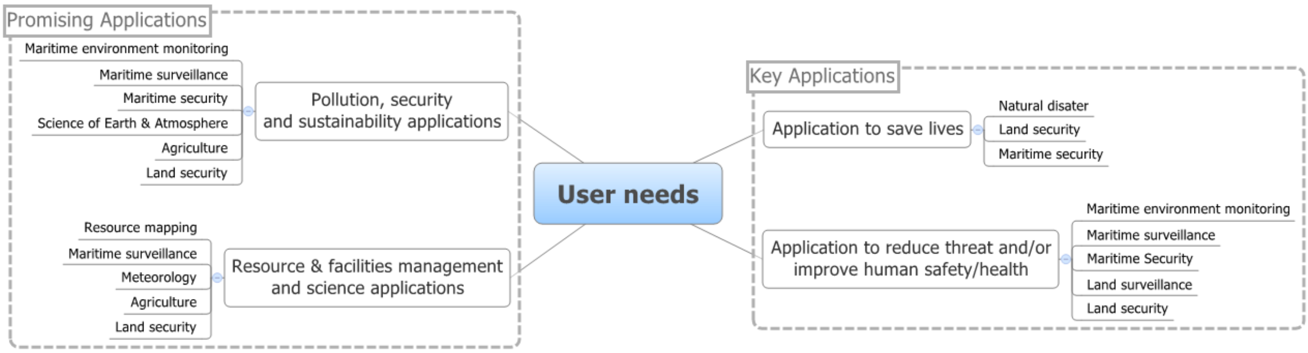

Figure 3-1 Identified user needs can be organized in four categories, covering security and resource mapping

Identified key applications justify the development of a very High Resolution Earth Observation satellite from GEO, mainly because of the following characteristics:

- they are not feasible by other means:
  - the need for temporal resolution (revisit time) is too high for Leo satellites,
  - the area to be covered does not allow to use airborne systems,
  - some applications linked to disaster monitoring result in requirements for on-demand imaging with near real time delivery

- they can answer to a crisis situation where fast damage assessment mapping is required
- they allow a monitoring capability.

As a complement to identification of needs, user review has shown that mission architecture should be compliant with the following main characteristics:

- The proposed system should be capable of **multi-mission handling:**
  - delivering routine pictures of a well defined zone with well defined temporal resolution (delivering pictures of Europe and Mediterranean regions with a resolution better than 10 m (over region of interest, i.e. 2 m at nadir) at a daily bases. This concerns missions in the category "Pollution, security and sustainability applications" and "Resource & facilities management and science applications",

  - handling urgent on demand observations of a specific zone. This concerns missions in the categories "Application to save lives" and "Applications to reduce threats and/or improve human safety/health.

- Provide risk management pictures products (MTF x SNR = 4).

- Provide VNIR + MIR + TIR pictures.

3.2 Consolidation of Mission Architecture and High Level Requirements

The review of applications has identified gaps that could be covered by a system in a geostationary orbit. The main identified gap is temporal and related to:

- Tasking
- Revisiting
- Access time

This high temporal requirement comes from the need to deliver products related to fast damage assessment or rapid mapping, monitoring and fast delivery of change detection.

The complete system should thus be optimized in order to reduce global system response time, this include all contributors in the chain: request processing, planning, satellite slew (to target) and stabilization duration, image acquisition and transmission duration, ground data processing and product delivery to user (through communication needs).

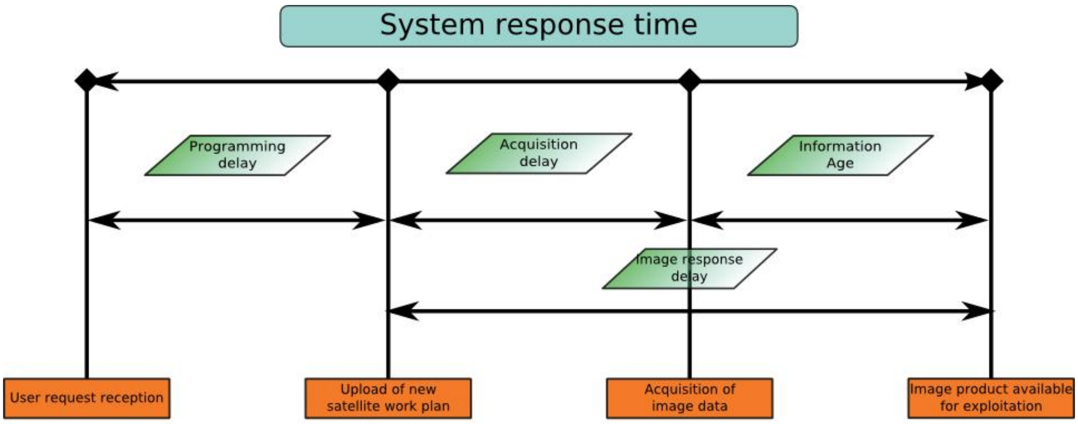

Figure 3-2 Each contributor to global system response time is to be optimize in answer to the near real time requirement for information age

Alert type missions drive the ground segment architecture. To complement the on-demand observation of specific zones, ground segment architecture should be such that data are accessible in specific locations (crisis theatres) to give support to the deployment on site of security means. To answer to this requirement, the ground segment could consist of centralized data processing and completed by distribution capacity to users located on specific crisis theatres, for security means deployment support.

3.3 Mission Design and analysis of critical components

The design activity has covered the major components of Tw1m system that are the space and ground segments.

Platform and payload concept designs have been proposed that can meet the key mission drivers in terms of temporal and resolution requirements, geographical coverage requirements and agility with the objective to maximize the number of images that can be acquired per day.

An equivalent pupil diameter of at least 7 m is required to obtain a 2 m Ground Sampling Distance from the GEO orbit. A monolithic telescope is not adapted to such a diameter and a deployable concept is mandatory for which Optical Aperture Synthesis is a candidate solution (Figure 3-3).

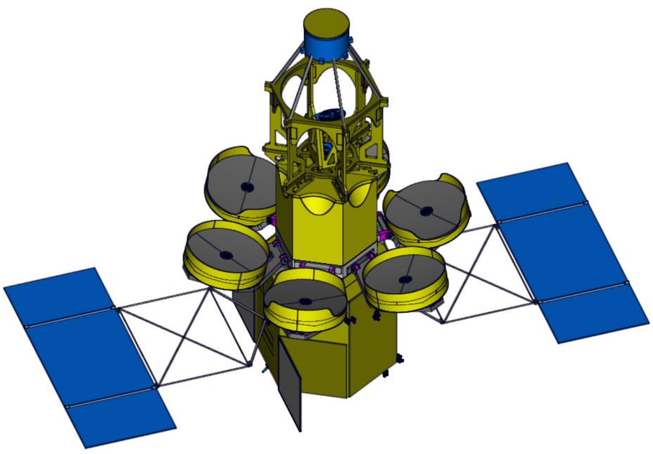

Figure 3-3 Proposed satellite concept for "Towards 1 m resolution from Geo". Deployable baffle is not shown

The use of a deployable concept implies a co-phasing approach, in order to ensure the required optical quality during image acquisition.

It is proposed to correct the optics misalignments after deployment using fine alignment mechanisms (3 to 5 ddl) of the segments themselves, and a fine control approach or co-phasing approach based on the use of:

- Internal sensors to monitor the geometry between M1 segments and M2 mirror
- An external sensor used to measure the wave front error at focal plane level by the analysis of the observed scene and based on the phase diversity technique. Performance of the phase diversity sensor made by ONERA in the frame of this study shows that expected performance (lambda/25) could be achieved.
- A deformable mirror is used as a fine correction stage to correct the misalignment residuals that can't be achieved corrected by the M1 segments and M2 mirror fine alignment mechanisms

The complete specification of the co-phasing approach requires the determination of short terms variations in terms of amplitude and frequency. This would require at least a thermal modelling of the sub-pupils and their support in the radiative thermal environment and a study of the impact of µ-vibrations.

Regarding the instrument thermal concept, the solar baffle is also identified as a critical point. A deployable baffle is proposed in the frame of this study based on two concepts:

- An inflatable baffle concept
- A rigid panels concept

These two concepts have advantages and drawbacks recalled in the following table. A trade-off between these two concepts would require complementary studies.

Solution	Advantage	Drawback
Inflatable solution	Low mass and stowed volume Compatible with SA and M1 segments in stowed configuration	Strong development
Rigid panels solution	High heritage solution (design based on solar array structure and mechanism experience)	Conflict with SA and M1 in stowed configuration

Stability of the line of sight during elementary integration time is an important contributor to the image quality performance. This performance will only be achieved through a global approach implying the use of Passive Filtering Device (PFD) to attenuate dynamics of disturbances induced by the AOCS actuators, completed by a Fine Control Stage implemented at instrument level to control the LOS drift and jitter.

For the Fine control stage, feasibility of performance achievement depends on the ability to estimate the drift. This drift is the residual S/C angular rate after a retargeting slew, combined with the gyro-stellar accuracy. It depends also on the ability to estimate the first harmonics of the jitter.

Solutions proposed are the use of Kalman Filter based-algorithms. Design and performance of such filters are still to be addressed in a more in depth study.

To relax the residual disturbances and thus the Fine Control stage constraints, solutions can be:

- to decrease as much as possible the PFD cut-off frequency. A compromise with AOCS has to be found,

- not to use the kinetic actuators at a rate lower than PFD cut-off frequency.

In complement, an estimation still to be done with magnetic bearing actuator-based.

To reduce the impact of tranquilization after a slew, it is proposed to use a steering mirror. With an angular stroke of less than ±1μm (in entry space) it allows to start image acquisition during the tranquilisation phase. For the survey mode (step and stare), this translates into a reduction close to a factor of 2 of the time required between two image acquisitions.
The use of this steering mirror will drive the number of images acquired per day;

For Survey mode: 25 s down to 13 s are required to slew and stabilize the instrument LOS prior starting an image acquisition sequence.

- In the case of 25 s slew duration: the number of images, limited by satellite agility performance, is ~ 1000 images per day in winter
- In the case of 13 s: the number of images, limited by viewing conditions is 1500 images per day

For Alert Mode: from 195 s down to 136 s are required for the largest depointing expected (6°). Given the revisit requirements:

  - industrial hazard: 5 mn
  - Fire: 15 min
  - Floods 30 mn

Thus in case of an industrial hazard type, from 1 to 2 alert could be handled depending on the agility performance. In case of a fire alert, from 4 to 6 alerts could be handled, implying the acquisition of 1 image every 2 minutes

The swift dissemination of pictures to crisis theatres is an obvious mission requirement. However, the use on theatre of a transportable X-Band station is not the most efficient solution.

- High cost of the station: 3 to 5 meters antenna, shelter with equipment, power generator.
- Not a fast deployment solution: time to transport the station (specific plane and specific truck) + time to install the antenna (need for secure and stable ground) + time to declare it operational.
- Need to have skilful operators with the station

The preferred architecture today is a unique centre for reception and processing of the data and dissemination via Internet and/or DVB-RCS-like satellite link.

Regarding data handling. The mission design activity has shown that taking into account the optimisation of the satellite agility and a possible on board data compression, the number of images accessible per day is compatible with actual or already in development technology.

3.4 Technology Roadmap Development and conclusion

To secure the development of such a mission, development activities should be started on the following technologies:

Deformable mirror, Primary mirror deployment mechanisms and fine alignment mechanisms. If these technologies have already reached a high TRL in the U.S in the frame of JWST and TPF development activities, no equivalent exist in Europe.
An effort should be dedicated also to the development of large visible focal plane assemblies based on CMOS APS.
Development activities oriented towards the manufacturing of large light-weighted mirrors have to be pursued but this is a need already pushed by all future high-resolution missions.

These development activities have to be complete by “proof-of-concepts” activities in the frame of breadboards.

Complementary studies are also necessary, which main output should be a thermal analysis of a complete instrument and a mechanical analysis. These analyses are essential to better define the instrument environment and thus the perturbations to be control by the co-phasing and LOS control sub-systems.

Other technologies are essential to the success of “Towards 1 m resolution” like on board command control, use of GPS but these technologies are not identified as critical since already in development, pushed by other projects.

Given these development activities, such a mission could be compatible with horizon 2023-2025.

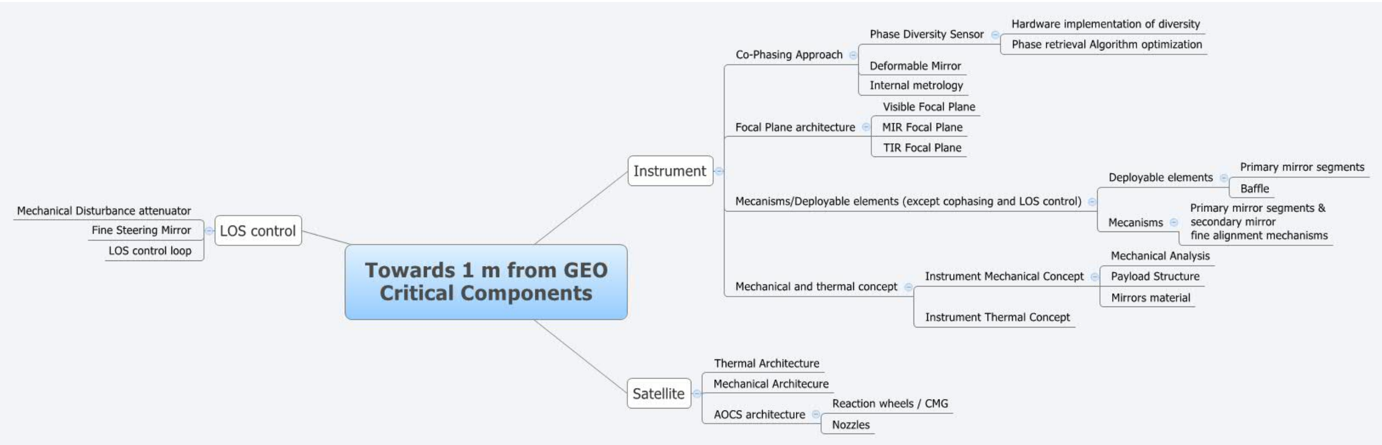

Figure 3-4 Identified Critical technologies. Main critical areas concern the deployment and control of the telescope and control of the Line of Sight

END OF DOCUMENT