Streamlined Approach to the Operations of PRISMA

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PRISMA is an Earth Observation mission, precursor of an operative Hyperspectral one, funded by the Italian Space Agency (ASI) and developed by a consortium of Italian companies led by CGS. Telespazio is responsible for the Ground Segment design, development, testing and validation and the Satellite Operations preparation and execution in the Fucino Space Centre. The project is organized in a cost-effective and labor-saving way by means of the modularity of design, the intensive re-use of existing facilities, the use of low cost and open source available software solutions, the sharing of common resources and the maximum possible automation of the operational activities. This paper describes the approach followed in implementing the PRISMA ground segment in order to comply with mission requirements yet at the same time achieve effective reduction of the development and operational efforts. We will discuss the main systems that comprise the ground segment as well as the relevant operational concepts.

I. Introduction

The PRISMA mission is a “technology demonstrator, JHM precursor and pre-operative” mission where the primary beneficiaries of the mission are the end data users. The mission’s primary mode of operation is the collection of specific individual targets identified and requested by the end users. As a secondary mode of operation, the mission will have an established ongoing ‘background’ task that will acquire imagery such that the satellite and downlink resources are fully used. The PRISMA mission is aimed to make possible a widespread usage of the data for civilian and commercial applications, still guaranteeing the respect of any restriction would come from national security, European and Italian laws and from any established agreement supporting international cooperations.
The mission will acquire:

- Hyper-spectral images of the Earth simultaneously in a large number of narrow, contiguous spectral bands using an imaging spectrometer in a push-broom mode of operation;
- Panchromatic images of the Earth (simultaneous with the hyper-spectral images)

An analysis of the main PRISMA requirements and drivers has been performed in order to highlight the key points for development of operational and architectural design concepts.
The PRISMA Ground Segment System Architecture will be designed taking into account some general constraints, oriented to:

- minimise the design changes for new functionalities,
- use of existing network infrastructures and communication services,
- reuse general application services (e.g. data archiving, retrieval, configuration management),
- reuse existing software integration frameworks (e.g. middleware for process communication, test tools),

- install new GS elements into existing buildings and infrastructures.
- Low Cost Mission

As far as the GS is concerned, it is assumed that (where feasible), maximum use of existing maintenance, security, ground segment facilities and minimum modifications of these facilities, will be made, in order to reduce the effort of creating completely new operational documentation, approaches and procedures. This process will also reduce training activities on the new environment.

The described approach implies, as first design attempt, the co-location of new facilities and structures, in already existing sites in order to reduce the cost for a complete new installation, hosting the PRISMA GS core elements.

From a mission objective point of view, the operations organisation should refer to the following driving concepts:

- User segment hierarchy and permission;
- Re-configurability of the system on user demand;
- Area of Interest

From a system design point of view, the operations organisation should refer to the following driving concepts:

- Satellite autonomy;
- Ground Segment processes automation.

As for the remote facilities to be used during space/ground PRISMA operations, these are mainly represented by the:

- S/C Manufacturer Facilities;
- S/C Simulator.

During specific mission phases, additional external facilities will be used to properly execute particular tasks; among them the main ones are:

- External TT&C;
- EGSE;
- Launch Pad.

II. Background

PRISMA is in principle a technology demonstrator and it represents the first of a family of missions based on the same platform.

The experience gained in managing previous missions based on a precursor of the Prisma platform, namely MITA and AGILE, leads to identify a strong reuse of the knowledge acquired by the Operational Teams, the infrastructures and then an optimized approach to the Mission Operations Concepts development.

Considering the AGILE platform (still in orbit at the time of writing this paper) as the baseline, several enhancements have been envisaged both at Space and Ground segment level to introduce an augmentation, or optimization, of the system performances:

Space Segment :

- Implementation of a Propulsion System
- Design for a 3 Axis Stabilized Attitude
- The payload will be managed by adopting the same PDHT unit than the one used on the ASI Cosmo Sky-Med constellation.

Ground Segment :

The PRISMA G/S can be decomposed into the following main three Elements:

- MCC – Mission Control Center, including the Mission Planning System (MPS)
- SCC – Satellite Control Center, including:
  1. Satellite Control System (SCS)
  2. Flight Dynamics System (FDS)
  3. S-band TT&C Station (TT&C)
  4. G/S Network (Communication infrastructure connecting the PRISMA G/S centers and facilities)
- IDHS - Image Data Handling Segment/Center including the Centro Nazionale Multimissione (CNM) that provides all ground segment functions related to Customer Ordering, Data Acquisition, Archiving, Cataloguing, Standard Products Processing and Product Delivery.

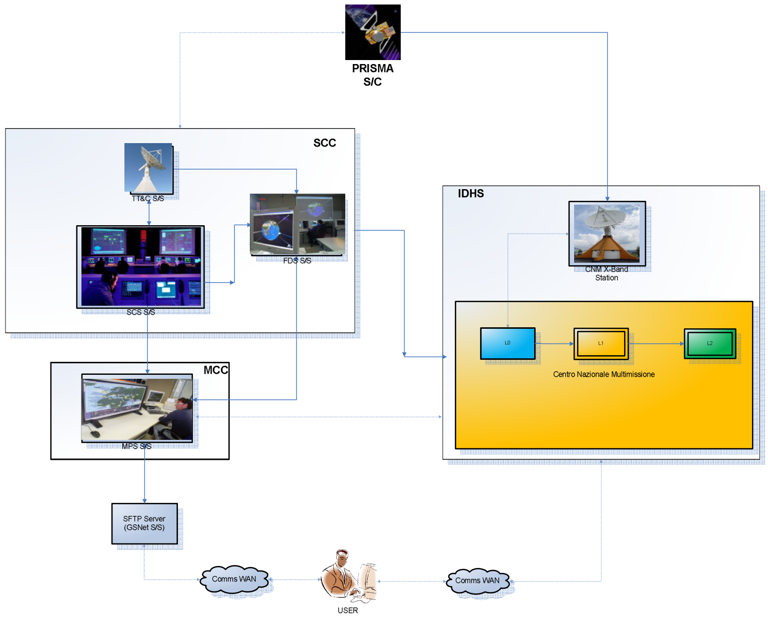

Figure 1: PRISMA Ground Segment

The PRISMA MCC (Mission Control Centre) and SCC (Satellite Control Centre) will exploit existing infrastructures, equipments, facilities and services available at the TELESPAZIO Fucino Space Centre in Avezzano "AQ" and already in place to support existing missions (e.g. AGILE)

For what concern the RAED services (Reception, Archiving, Elaboration, Dissemination), the use of the Matera CNM/IDHS, supporting several similar Missions, has been envisaged in the framework of the relationship with other Missions.

The PRISMA IDHS will exploit existing infrastructures and facilities of the National Multi-mission Centre (CNM) at the ASI's Geodesy Space Centre as well as the Xband multimission Cassegrain reflector antenna system in Matera.

The CNM is designed for a full exploitation of the capabilities offered by the existing and future Earth Observation satellites. At present, the CNM is technically able to exploit scientific data of the following active missions:

- Radarsat 1 (CSA)
- Oceansat-2 (ISRO)
- ALOS (only acqusition and archiving of raw data) (JAXA)
- Envisat (ASAR and MERIS) (ESA)
- SAC-D (CONAE)
- Meteosat Second Generation (ESA and EUMETSAT)

In order to provide integration and full compatibility between the CNM and the PRISMA mission, a CNM upgrading is scheduled. The upgrading, will interest the following CNM subsystems:

- The X band antenna system, that will be provided of a second down conversion "X to L band" and demodulation chain;
- The IDHS, that will be provided of a second data ingestion system to be able to decode and archive the data transmitted by both the PRISMA satellite X band downlinks.
- One set of L0, L1 and L2 processors and associated HW for the processing of the acquired images RAW data into products
- One PRISMA products archive, integrated in the CNM Archiving System.
- One dedicated Order/Help desk specific for the PRISMA mission.

III. Lesson Learned

Analysis of events occurred while managing the AGILE mission represent a major driver to enhance the space and ground segments design and implementation such as the operation execution approach.

This analysis will led to identify a streamlined but effective approach for the PRISMA mission.

The evaluation of the occurred events is mainly carried out by taking in the account the anomalies and NCR issued during the first five years of AGILE flight operations.

Observed NCRs are mainly referred to three categories:

- Anomaly Report generation by SCC;
- TM data analysis;
- Any other behaviour not expected in the frame of nominal operations execution;

Since the AGILE launch date (i.e. 23 of April 2007) to now, 30 NCRs have been opened, which 17 are classified as "major" and 13 as "minor". Of this amount, 8 NCRs are still open and under investigations because of the "non-repeatability" of the observed event.

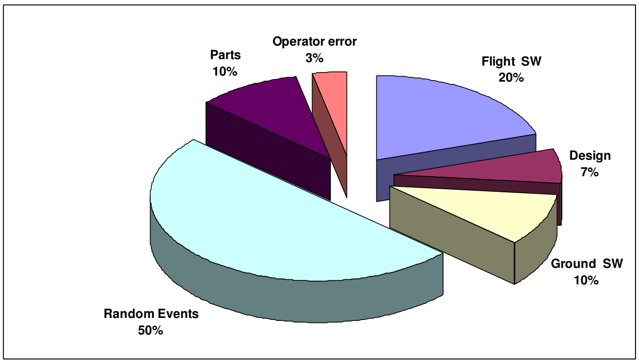

Figure 2: (AGILE) Generation Cause Statistical Data on NCRs

Considered the up to day issued NCRs it is worth to see the statistical data ranked per generation cause and kind of "corrective action".

In the Figure 2 the cause, which led to NCR generation is classified as:

1. Parts - No component failures are arisen so far, but temporary anomalous behaviour only.
2. Operator Error - A non correct command from ground only.
3. Flight S/W - Non conformance caused by on board S/W.
4. Design - The Reaction Wheel problem is ranked in this category.
5. Ground S/W - NCR caused by S/W problem on the ground segment.
6. Random Events - Events which are due to a very seldom combination of external factors - not to be attributed to a failure but a normal operations activity- leading to a temporary anomalous behaviour or events which are likely to be caused by a Single Event Effects such as SEU (single event up-set) or SEL (Single Event Latch-up).

The statistical overview of the NCRs issued so far with the associated corrective actions typology is shown in Figure 3. The highlighted percentage is referred to the number of NCRs which are resolved by the same kind of disposition.

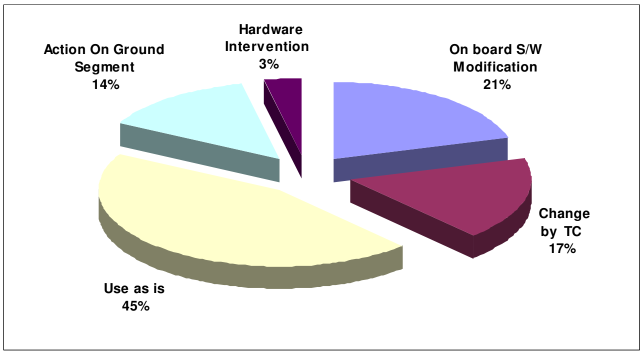

Figure 3: (AGILE) Corrective Action statistical data on NCRs

By the examination of data collected and represented in Figure 2 and Figure 3 it is basically confirmed that the approach followed during the AGILE GS design and implementations phases, the strategy adopted during the ground segment AIV and the implemented operational philosophy, represented a key factor in achieving the success of the mission. The most of the problem (50%) are ascribed to random events with negligible impact on the satellite dependability. Also the on-flight S/W modification (45% of the corrective actions) required a limited time to be implemented with low impact on the overall mission sustainability. These interventions on the space segment are justified by the impossibility to fully represent the space environment while executing the test on ground. The tests performed on ground with radioactive sources although allowed to test the satellite system with real gamma ray cannot be considered a 100% simulation of the space environment a uncertainty margin shall always taken into account. Nevertheless the possibility to increase the representativeness of the on-ground test to reduce the needs of on-flight corrective actions may be evaluated making a trade off between costs and benefits. At the end the NCR management process aimed to improve the satellite performances and this is demonstrated by the large amount of scientific data sent to ground which are under analysis of the worldwide scientist. The above described anomaly management system has guaranteed the satellite availability for almost of its overall mission time so far. The continuation of the satellite working life after 2 year of contractually foreseen mission and the winning of the 2012 "Bruno Rossi Prize" are the prove of the good success of the project and of the approach followed for this type of so called "small mission" financed by the Italian Space Agency. Now we have overcome five years of mission and the satellite will continue its observation of the deep space looking for cosmic events. The interoperability concepts, and the cost reduction achievement, foresee that a tracking station/network shall be used to support more than one mission. The above concepts require implementation, at the maximum extent, of automatic actions, mandatory to fulfil the time reduction in between two consecutive pass supports. This concept has been inherited from the Agile mission, where the antenna located in Malindi is shared between Agile itself and Swift and has been enhanced to cover the PRISMA mission needs as described in the following. The booking/scheduling and the conflicts resolution are items that foresee automatic offline activities, while the management of the facilities during the "Pre-pass", "Pass" and "Post-pass" phases, requires mandatory online activities. PRISMA mission will use as S-Band ground station the BTS-2 TPZ TT&C facilities located Fucino Space Centre in Italy, which is already committed in supporting other missions, some of them with orbit characteristics very similar to the PRISMA one. The facilities will be upgraded by Telespazio in order to comply with the multi-mission context and in addition, to the various BTS-2 equipped sub-system:

- The Scheduler subsystem; it is a tool that deals with the problem of allocating a given number of available antennas to follow satellite passes, over a ground station, in a multi-mission context. The scheduling process shares available ground station resources in such a way that all the mission-specific constraints are fulfilled.
- The Link Management Procedure, (LMP); the LMP tool manages the automatic execution of the operations (to be actuated by the Monitor & Control) required to establish the radio-link between the station and the satellite both in up and down directions at the beginning of the pass, to control the link maintenance during the pass and to close the link at the end of the pass, also initializing the off-line data transfer towards the final end.

The above-mentioned M&C subsystem is the component that performs the station equipment monitoring and control allowing the efficient configuration and the fault-management down to single unit level. The BTS-2 Scheduler receives Orbit files containing the orbit characteristics of the satellites to be tracked; by means of the scheduling process, it optimizes the allocation of the on-site tracking resources in order to maximize the support services that the ground station may offer to different space missions. The output product is the Integrated Master Schedule (IMS) that will be the chronological order of all the valid passes to be supported (the validity criteria are defined as boundary conditions for the processing and they may be specific for each supported mission). Any visibility overlapping conflict is solved by assigning the support of concurrent satellites passes to the available antennas taking into account their planned operational status and according to a predefined scale of priorities. From the IMS, the Link Management Procedure running within the M&C extracts the visibility start, and stop time, jointly with mission specific data. The responsibility of station configuration is demanded to the M&C according to pre-defined tables and macros, while the automatic execution of operations, in few words "when do the action", is the responsibility of the Link Management Procedure (LMP) that derive the time line from its on dedicated tables.
The previous evaluation findings and conclusions lead to the following lessons learned and recommendations used to approach the GS development and Operations preparation for PRISMA Mission.

IV. Description of Streamlined Approach for PRISMA Ground Segment Development and Operations

Following aspects are typical for a Space program and we will analyze the theoretical definition of those aspects and figures and the modifications/waivers applied to PRISMA. One common aspect is the Operation organization in TPZ where a Multi-Mission Team and Control Center is established, supporting several satellite Missions, LEO, MEO and GEO with multiple typology of Payloads spanning from navigation services to Gamma and X-Ray sky observations, passing through earth observation and telecommunications services. This result has been achieved by implementing a continuous training program involving the operational team and allowing to gain the requested skill to operate in an heterogeneous multimission control centre.

- **Configuration Management (CM)**

Configuration Management is the act of controlling all mission-impacting aspects of the satellite operator's environment. CM introduces organizational control into satellite operations. A properly controlled environment will produce predictable results, and allows the Program Manager to assume total ownership and responsibility for program success or failure. In some cases, this ownership may be held by the Operations Manger (OM).

In the approach followed for the AGILE mission and replicated to the PRISMA mission, everything has been covered under the CM plan. Neglecting seemingly un- important aspects will introduce ambiguity, invites "judgment calls" and creates headaches for everyone.

- **Operations Staffing**

In general, Operational staffing is dependent on several variables including the complexity of the operations; whether or not interactive payload operations are supported; the degree of automation that has evolved, how many spacecraft are supported by a single control center, whether or not the team also controls antenna, and whether all support functions are provided within the control center staff or there are external support organizations.

The followed approach in the PRISMA mission regarding the Operations Staffing, is substantially the same used for AGILE. It is derived from a trade-off analysis taking in account the respect of the required safety aspects of the Mission and the limited budget/effort available for the operations conductions.

As learned for AGILE, the solution is to build a Team where each component might perform more than one function. Secondary positions , such as Command Coordinator, Data Analyst, Orbit Analyst, Payload Analyst could be not included or will be covered ad interim by Primary positions. Ancillary positions, such as administrative assistants, trainers, etc., are not included in the Operations Staff.

In a so called “Small Team”, the operations positions are increasingly consolidated into a few people, while the functions continue to be performed, though usually in a less complex way and in a larger use of automations..

The minimum key figures individuated for all the Mission Phases of PRISMA are:

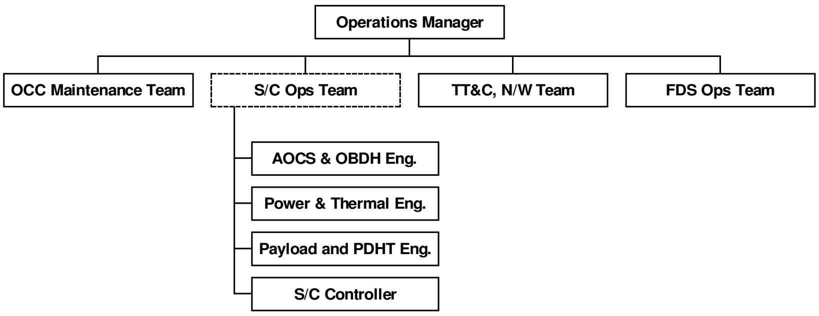

Figure 5: PRISMA Operations Staff

Operations Manager (OM):

The Operations Manager (OM) is responsible for all operational personnel and delegates authority through the operational supervisors (Deputies). This manager must be sufficiently familiar with all operations processes to provide direct supervision of all day-to-day activities, including real-time command and control, mission planning, data analysis, and flight dynamics. The normal function of the Operations Manager is to ensure the smooth running and performance of the flight operations teams. The OM interfaces with people outside operations, such as mission and science managers and Spacecraft Manufacturer. In the PRISMA framework the OM acts even as Flight Director, interfacing the Customer Mission Director for every aspect related to the Mission exploitation such as directly supervises all real-time operations and supporting analysis personnel that are directly concerned with the health and operation of the spacecraft and ground network. He will schedule shift operations, and will work closely with Spacecraft Engineering to improve the end-to-end operations processes. He is responsible for the training, certification, and re-certification of the operations personnel. The PRISMA OM acts also as Spacecraft Engineer (SCE) with the responsibility of the whole Space Segment and more in detail the OBDH (On Board Data Handling) Subsystem.

Spacecraft Engineer (SCE):

Each Spacecraft Engineer has general knowledge of the Space Segment and in particular he is skilled on one or more satellite subsystems. For these subsystems, he monitors and controls the functioning and health status, using nominal and contingency. The SCE is directly responsible of the flight procedures execution involving a certain Satellite Subsystem. The Spacecraft Engineer performs the real time and off-line data analysis and, in case of anomalies, executes the relevant trouble shootings and performances verification and then prepares the necessary correction activities. He reports to the OM.

Spacecraft Controller (Spacon):

Spacons will support all aspects of pass operations, and can also perform routine mission planning and scheduling, running the Planning Tool available at MCC, in order to accomplish all the activities requested for the image acquisitions and all the platform activities to maintain the nominal functionality of all the spacecraft subsystems.

They will also assist with data management and routine spacecraft trending and analysis. The Spacon will involve the satellite Engineers and OM at any problem or inconsistency or anomaly occurred or in case of any support is required.

FDS Team:

The Flight Dynamic System team is in charge of receiving the first message with the orbital data from the launcher company or making periodically orbit determination and to produce in the shortest time, on the basis of the acquired data, all the files to provide at Fucino TT&C station to automatically drive the Spacecraft acquisition of the next Spacecraft pass. FDS executes the orbital determination and propagation as soon as the AMD from TT&C Station (and/or GPS data from the Satellite) are available, and generates the files used by SCC and TT&C Station to acquire the satellite and to evaluate the necessary manouvres to reach the final orbit. In case of anomalous final orbit of the Spacecraft after separation, FDS co-operates with OM and to develop a real-time strategy for Spacecraft final orbit evaluation and, if necessary, for manoeuvres recovery implementation.

During the Routine Phase, the FDS Team is in charge to generate all the required products for the image acquisition and Platform managing planning (SOE, Contact Table, Ancillary files, etc.) FDS also carries out the Flight Dynamic Software maintenance.

HW/SW Maintenance Team:

The main activity of this team is to assure the HW and SW maintenance of GS sub-systems. The maintenance activity is composed of preventive and corrective maintenance. The first one is executed on the basis of a Maintenance plan and applying the dedicated procedures. The second one is performed against the anomalies or malfunctions on the GS. The maintenance team will operate autonomously according to the plan and in case of necessity will be coordinated by the OM.

- **Training and Certification**

A training program should have two purposes. One is to shape the culture, or behavior, of the Flight Operations Team (FOT) as it interacts with internal and external interfaces. The second is to teach the FOT how to operate the ground and flight systems. Training that encompasses both of these concepts will help ensure mission success.

The approach followed for the PRISMA Mission regarding the Training Aspects is substantially a “On the Job” training performed trough the Simulations Campaign where all the foreseen Nominal and Contingency Scenarios for the mission will be exercised. The Simulation campaign ,at the end of the pre-operation phase, has the target to assure that Operational Team has reached the necessary operative skill for assuming the Operations control during execution phase, either during nominal or contingency operations regarding both Space or Ground Segment.

A selected set of critical operative scenarios is identified and simulated. All the operative situations listed in the Simulation Plan will be simulated by the Ground Segment Operations Team working in “final configuration” and in the most possible realistic way. All the operative tasks, interfaces, message and data exchange through out, satellite and ground operations procedures will be exercised and tested by operative staff in the real operative scenario, applying the foreseen flight rules, operative staff in charge of their responsibilities. Each Simulation session will be organized and technically managed by the Operation Manager.

- **Process Improvement**

A major factor in the cost of spacecraft ground support is the effectiveness of the mission operations process. An ineffective, error-prone and labor intensive process will most likely result in increased cost, risk, and reduced customer satisfaction. In order to determine the effectiveness of how mission operations are performed and to determine areas of improvement, measures of effectiveness should be identified. The metrics obtained through these measures of effectiveness can then be empirically and subjectively analyzed to determine the areas of the operation that should be improved or automated to increase efficiency. For an Earth observation mission, effectiveness factors for the mission operations include:

- Percentage completion of science objectives (e.g., number of images successfully acquired, coverage obtained by imaging, quality of data, quality and quantity of calibration data obtained)
- Cost of operations (comparison of actual versus projected costs)

- Response time and flexibility of the mission planning an operations process (System response time and Latency Time)
- Efficiency (cost/data collected)

Some other metrics that can help to measure the effectiveness of this kind of mission operations include: error tracking, exceptions (complexity) factor, rush factor, effort factor, response factor, fatigue factor, and morale factor. In order to effectively generate, track, and use these metrics, they should be incorporated into the mission operation process. Due to the limited record keeping typical in many of today's faster, cheaper, and better missions, it is often difficult if not impossible to reconstruct these metrics accurately, either to generate historical test cases or to determine retroactively how the MoE factors have changed over the life cycle of a current operations process.
In the PRISMA contest, in order to collect these metrics, the following two steps have been implemented:
1) *Planning Follow-up:* Starting from the User Programming Request submission and to the Image available at CNM/IDHS for processing, at each step of the planning/uplink/downlink process a log recording the time that each event starts and stops in a sub-process will be generated and sent to the User. This automatic log should also record errors detected by the computer system, especially of errors that were detected in the input data, as well as any significant decisions or substeps.

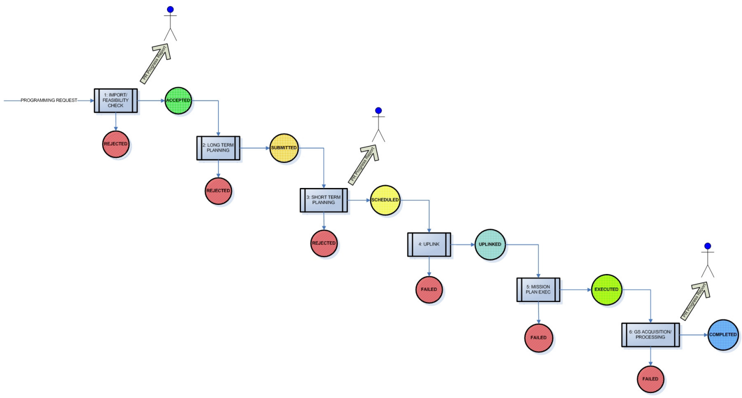

Figure 6: Process for new Image acquisition

2) *Trouble Ticket Tracking System MSCC-TTS*: This tool permits to record any errors/failure occurred in the Ground/Space segment, along with the recovery actions performed, the unavailability times (Outage) and several statistical reports. As soon a new Trouble Ticket is opened, the relevant informations are automatically sent to the OM/Service Team responsible and to the Team/person in charge for the anomaly trouble shooting. Informations contained are: Mission, System, Sub System, description of the anomaly, unavailability times both partial or total. A soon as the recovery is completed, even the recovery actions informations are added and the TT status will be changed from "Under Analysis" to "Closure Proposal". The OM/Service Team responsible evaluates the performed actions and change the status of TT to "Closed" if the recovery is satisfying the requirements or "Closure Rejected" if further recovery actions or trouble shooting are required.

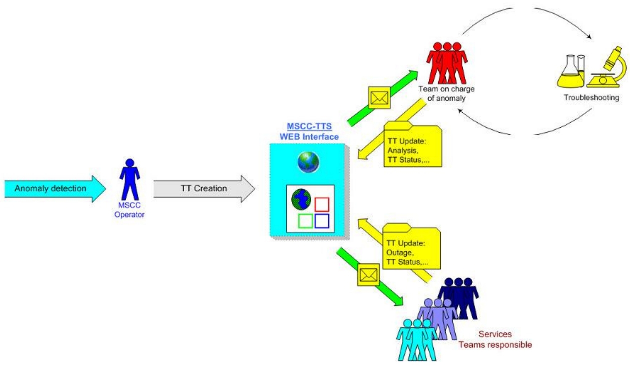

Figure 7: TT Life Cycle

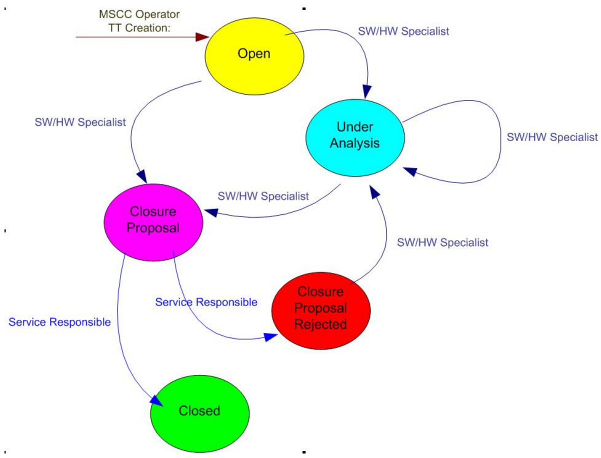

Figure 8: TT process flow

- **GS Development**

This section describes the approach followed for PRISMA Ground System development, including both the development process and ground system design. Main items involved in both process are reviews conducted during development, component selection, component delivery, testing, control, on- line access to mission , open and upgradeable systems and SW from previous Missions or Commercial Off-The-Shelf (COTS) solutions , common hardware platforms throughout as much as possible, user configurable capabilities, and providing automation for monitoring and non-mission-critical control capabilities.

Design Process:

Some key drivers have been evaluated during the PRISMA GS design process, to obtain a final product fully responding to the PRISMA mission needs but guaranteeing, at the same time, the flexibility and extensibility of the ground segment. In this process, different areas concurred to reach the proposed goal :

- Definition of the “user categories”;
- Clear definition of the system requirements ;
- System expandability;
- Modular approach in the software architecture definition;
- System interfaces standardization;
- System portability, to guarantee the compatibility with future system extensions and technology changes;
- Reuse (and adaptation) of already available software modules and libraries, from previous missions, allowing to avoids code duplication, simplifies maintenance and reduces development and testing time.

Development Process:

Operations staff/engineers was involved early in the ground system design. The ground system design team included a mixture of those experienced in space operations ground systems and those with recent information technology training. During the development process , spacecraft engineers, ground system developers, and maintenance personnel worked closely together in order to facilitate the development and maintenance process, minimize unnecessary delays, and ensure that the system meets user requirements and needs. The development Team is the same Team that will support the operations execution.

Automation:

Large use of completely/partially automated processes like LMP, FDS orbital and attitude products providing, Feasibility Analysis Tool, Station Scheduler, Mission Planning process for calibrations and background images, On Board SW Maintenance Tool (OBSM), Automatic Command Stacks, etc. leads to a reduction of the possibilities of human errors during the operations conduction and in a significant reduction of the effort needed for the operations with and increasing of the system response time in terms of optimization of the complete System resources.

Component selection:

Where possible, commercial hardware has been used. Obtained spare parts in advance to avoid work delays or system downtime during either development or operations. Arrangements done with vendors for quick supply of critical items, even for redundant systems. Investigated about the availability and where possible, implemented Commercial Off-The-Shelf (COTS) solutions. COTS applications are generally already operational, well documented, are easy to use. Where applicable open source software have been used. That SW either does what's needed or can be easily modified. For example, METEO data tool is an Open Source SW.

Component Delivery, Testing, and Control:

Maximized the use of Configuration Management (CM) and control mechanisms for source code, documentation, procedures, etc. All items will be under CM before testing begins. Establish a well-defined software release mechanism, which will instill organization, control, and tracking, albeit at the cost of a little extra (value added) bureaucratic overhead. Documentation will be produced in a standardized and portable format and will be easily maintainable. Highly representative Spacecraft Simulator, available in timeline is an important part of testing and training. Four sessions of System Validation Test (SVT) that allow the testing of the ground system with the spacecraft scheduled as early as is possible, with the last session (overall) few months before launch. During these tests the operators and engineers are running operational procedures in a mission like environment using the ground system in all mission phases. This includes launch and ascent, activation and checkout, and normal operations procedures. Scheduled continuous multi-day testing can expose unforeseen problems during the development process.

- **PRE-LAUNCH SPACECRAFT OPERATIONS DEVELOPMENT AND TEST**

The Mission Operation design and development approach used for PRISMA Mission foreseen an integrated team, the same for operations executions, providing early feedback to the project, spacecraft and instrument manufacturer, concerning the impact of the spacecraft hardware & software design on meeting requirements for both ground test and flight operations. The Operation Team is active part in the process to provide recommendations for changes to design and/or requirements to the manufacturers and to the customer. A review of the Operations Concept has been included as an integral part of all formal mission reviews beginning with the Systems Requirements Review, both at the system as well as the element level (e.g., spacecraft, instrument, ground). The PRISMA spacecraft / instrument design and the operations concept, evolved in parallel during the development phase. Contribution to the design reviews of the GS and working with the development team to prepare SW user manuals, technical notes, requirement documents for external developer, interfaces definitions (ICD), Ground Operation Procedures (GOP) and test procedures will raise relevant issues and concerns, from an operative point of view. Pre-launch meetings with spacecraft and instrument manufacturer, help to specifically define for the various mission phases, subsystem, instrument, and special event basis what parameters are the most important to be monitored in real-time and what one should be looking for in those parameters. Starting from the SVT, AIV, Ground Segment Operation Validation tests (GSOV) and Simulation Campaigns, all the procedures used are written keeping in mind the real mission operation both nominal and contingency. The Flight Operational Procedures (FOP) are engineered from the procedures used in the tests framework. This approach will permit to share the same FOP for the commissioning an routine phases, to reuse a FOP subset for the LEOP operations and will provide a general knowledge about the GS to all the Team and minimize the effort required for the training. Simulations will be focused and many times exercised with different scenarios both nominal and contingency, on the most critical phase of the mission, the LEOP (Launch & Early Orbit Phase). Cross training and multiple job responsibilities is essential to low-cost operations. Operations engineers , in PRISMA mission, will be data analysts, schedulers, planners, as well as ground systems , operating systems experts and Operation Manager deputy.

- **PRISMA Real Time control operations in Multi Mission Satellite Operations Center (MMSOC)**

PRISMA operations will be executed in the Multi Mission Satellite Control Center (MMSOC) in Fucino, where several satellite Missions, LEO, MEO and GEO with multiple typology of Payloads spanning from navigation services (GIOVE-B) to Gamma and X-Ray sky observations (AGILE), passing through earth observation and telecommunications services (ARTEMIS, AB-1). These operational differences are synthesized into a coherent operations concept to allow maximum efficiency of operations. The PRISMA S/C foreseen orbit will allow 4 useful pass per day on the TT&C Fucino GS. The first two pass are early in the morning and the last two pass are in the late evening. This allows to have a controller shift coverage only h12 per day 7/7, different from typical h24 7/7. MMSOC allows to use common processes and systems among varying satellites to save operations and engineering support costs relative to dedicated individual satellite control centers.

V. SUMMARY OF KEY ISSUES FOR A LOW COST DEVELOPENT AND OPERATIONS APPROACH

The low cost approach for the ground segment development has been implemented also from an operational point of view, by defining a support based on 12 'working hours' per day 7/7. This operational approach, different from the typical h24 7/7, has been selected in agreement with the satellite manufacturer and ASI. Budget constraints also limited the architectural choices for the ground segment main system and sub-systems. In particular, the maximum re-use of existing facilities has been envisaged from the preliminary phase of the program and the development of new systems has been carried out using low cost and open source available software solutions.
Key re-usability features of the resulting product are:

- The satellite control center, based on SCOS 2000 open source code from ESA and working in a LINUX PC based hardware environment;
- The flight dynamics center, developed in C++ , partly derived from existing Telespazio Flight Dynamics systems;
- The mission control center, developed starting from a SW COTS developed by TPZ-Germany and fully integrated with SCOS 2000 satellite control center environment and with flight dynamics center;
- The re-use of TPZ Fucino BTS-2 TT&C station and antennas, with specific PRISMA mission customization of the existing equipments;
- The re-use of ASI-net communication network to link the ground segment facilities located in Italy, at the Fucino Space Center, with the Matera CNM/IDHS X-Band Station;

Another important key issue for the PRISMA mission is the optimisation of in orbit operations: due to the satellite operation autonomy up to 72 hours in case of contingencies coupled with the automation mechanisms implemented in the ground segment the control centers and the ground station will be manned only during 12 'working hours', thus allowing a significant personnel reduction in comparison with 24/7' typical satellite operations.
Within Telespazio, the Prisma project has been approached in a structured way by involving different areas having specialized expertise allowing to cover the designing, development and testing of the Prisma ground segment and the relevant mission operations preparation and execution

VI. Conclusions

As described in the previous chapters, the G/S has been designed to cope with the mission requirements, with the customer constraint, with the S/C characteristics and the available budget.
Costs optimizations have been considered, evaluated in terms of costs/benefits trade off and, where feasible, implemented along the complete value chain of the product that is fully managed by Telespazio.
This aspect represent the real strength of the streamlined approach on the PRISMA mission, allowing Telespazio to participate the program since the phase A (Study phase) and to inherit and extend to the subsequent phases the gained expertise and knowledge. In fact, as per the Agile mission, the strict cooperation with the S/C manufacturer since the beginning of the project, has allowed to gain the knowledge on the satellite platform during the satellite design phase with a mutual benefits for both parties, which resulted, from the Telespazio point of view, in an accurate definition of the architectural and operations design choices.

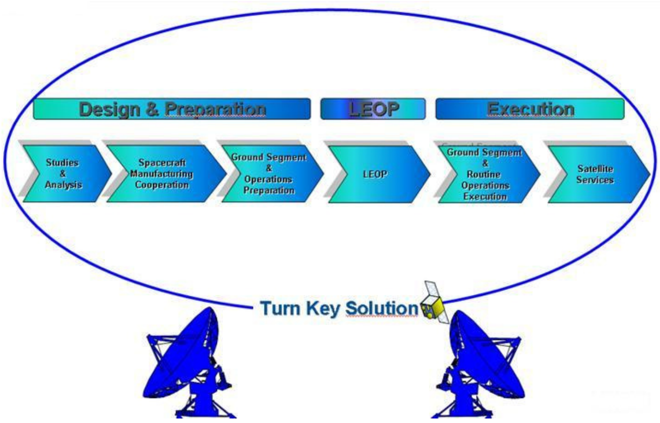

Figure 9: TPZ Positioning along the Value Chain

The PRISMA G/S design and operational approach choices have consequently been oriented to the maximum reuse of components already available from other programs to the adoption of COTS products, such as SCOS 2000 distributed by the European Space Agency, to the internal development of those components not directly available, such as the mission planning system, or too specific such as the flight dynamic software, to the information sharing within the operational, team implemented through a well organized training and simulation campaign.
After 5 years of successful in orbit operations for the Agile mission, the Customer and the Principal Investigator recognized that the Agile ground segment, including the ASI's Malindi ground station, for TT&C purposes, the Telespazio Fucino Space Center, for satellite in orbit operations management, the ASI's ASDC, for scientific data acquisition and processing, represents, up today, the most efficient ground segment in the world for scientific applications, representing an example from the efficiency/costs point of view.
Starting from this premise, the Agile's inherited concepts brought to the definition of a streamlined approach for the Prisma mission, driven the realization of a fully automated and low cost ground segment in the respect of the PRISMA mission requirements and representing the key factor for a further successful mission.