METEOSAT THIRD GENERATION (MTG) GROUND SEGMENT AND TECHNICAL CHALLENGES TO INTEGRATE IT.

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ABSTRACT

The Meteosat Third Generation (MTG) geosynchronous satellite system consists of four Imaging Satellites and two Sounding Satellites. The first Imaging Satellite was launched in December 2022 and will be followed by the first Sounding Satellite with the launch currently planned for December 2024. During 2023, Eumetsat will be simultaneously preparing to launch a Sounder Satellite while the commissioning of the Imager is still on going. This complex level of internal and external coordination raises a number of complex technical and logistical challenges. This document explores the challenges related to the integration of the MTG Ground Segment, which will acquire payload data from all MTG satellites as well as generate, archive and distribute the data products. The Ground Segment will also provide satellite commanding and control capabilities. Unlike in other organizations, the Ground Segment is not split into Operational and Scientific Ground Segments. Instead, these functions will be combined, a goal that involves the integration of many different ground systems, environments and teams working on a wide range of testing, verification and validation activities, all progressing in parallel..

1. INTRODUCTION

The EUMETSAT Meteosat Third Generation (MTG) geosynchronous satellites, as successors of MSG (Meteosat Second Generation) satellites, host an imaging (I) and a sounding (S) mission, which will provide real time imagery in visible (VIS) and near-infrared (NIR) and infrared (IR) spectrum, lighting imagery and soundings in the ultraviolet (UV), VIS, NIR and IR spectrum. The first MTG-I, which was launched in December 2022, followed by the first MTG-S by 24 months. MTG will see the launch of six new geostationary (imaging and sounding) satellites from 2022 onwards. The satellite series will be based on 3-axis platforms and comprise:

- Four Imaging Satellites (MTG-I) (20 years of operational services expected)
- Two Sounding Satellites (MTG-S) (15.5 years of operational services expected)

The mission of the Meteosat Third Generation (MTG) System is to provide continuous high spatial, spectral and temporal resolution observations and geophysical parameters of the Earth Atmospheric System derived from direct measurements of its emitted and reflected radiation using satellite based sensors from the geostationary orbit. In order to achieve this, the MTG Space Segment in its fully deployed configuration consists of three in-orbit satellites – two MTG-Imager (MTG-I) and one MTG-Sounder (MTG-S). The Space Segment is supported by the Ground Segment (GS), the function of which is to acquire the data from the satellites as well as to generate, to archives and to distributes the data products.

2. MTG GROUND SEGMENT OVERVIEW

The Meteosat Third Generation Ground Segment will acquire data from all the MTG satellites, generate, archive and distribute the data products. It will also provide the capabilities to command and control the satellites and the ground segment itself. The Ground Segment consists of:

- The Telemetry, Tracking and Control (TTC) ground stations: the TTC interface between the Space Segment and the Mission Control Centre. The TTC ground stations are located in Italy (Fucino), Romania (Cheia).
- The Mission Data Acquisition (MDA) ground stations: the payload data interface between the Space Segment and the Mission Control Centre. The MDA ground stations are located in Italy (Lario) and Switzerland (Leuk).
- The Mission Operations Facility (MOF): provides functions for the preparation, planning and operation of the system, including satellite and mission operations and flight dynamics. The MOF and some supporting functions are also deployed in the MTG Backup Satellite Control Center in Italy (Fucino).
- The Instrument Level 1 Data Processing facilities (IDPF-I and IDPF-S): these extract the measurements from the sensors. They also perform a series of functions for the generation of level 1b data and level 1c data.
- Level 2 Processing Facility (L2PF): for the extraction of centrally generated L2 products. Multi Mission Elements, responsible for the Dissemination, Archiving and Monitoring of the Data.

- The Multi-Mission Elements: allowing, among others, the dissemination and archiving of the data.

The IDPF, L2PF and MMEs are located at EUMETSAT Headquarters.

Following graphic shows the Ground Segment context:

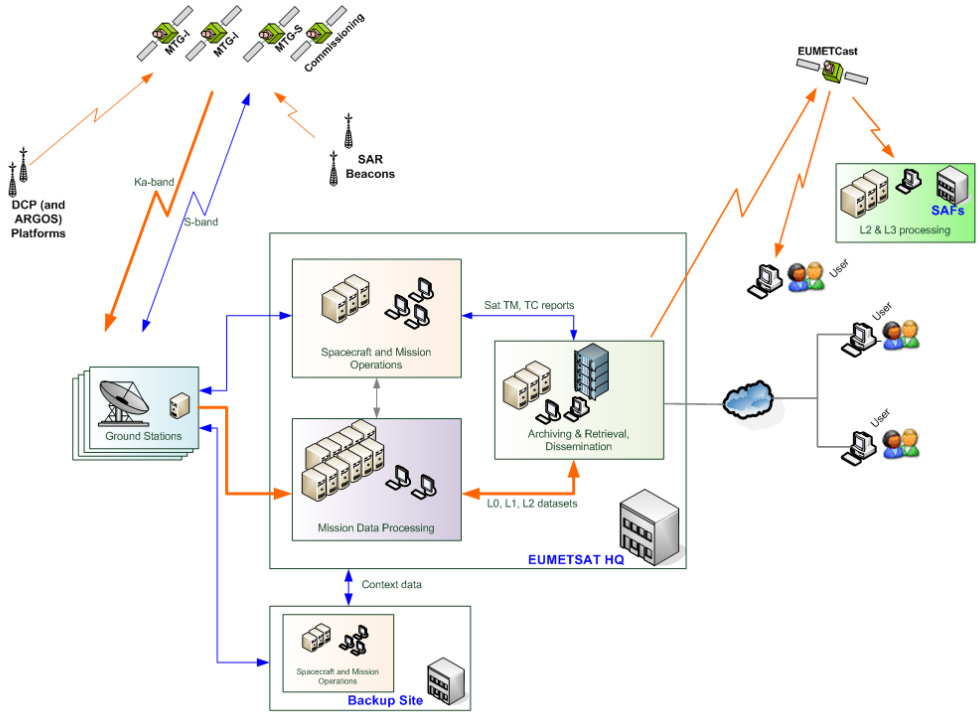

Figure 1: MTG Ground Segment Context

The Ground Segment provides all equipment needed to collect, process, disseminate and archive the instruments datasets from the MTG satellites and the related level-1 and level-2 products, with the required quality threshold, i.e. completeness, accuracy and timeliness. The system provides the reference archive for all science data and the services for the selection and retrieval of this data. It provides the capability to monitor and control the ground systems as well as the MTG satellites.

During operations preparation and routine operations Internal Users of the System (e.g. operations and maintenance engineering personnel, scientific and product experts) ensure that the Space and Ground Segment are operating effectively in order to provide the required science data to the End Users. The Internal Users are supported by Operations Partners, such as External Meteorological Products Experts and Scientists, the Satellite Manufacturer and the satellite Procurement Agency, ESA.

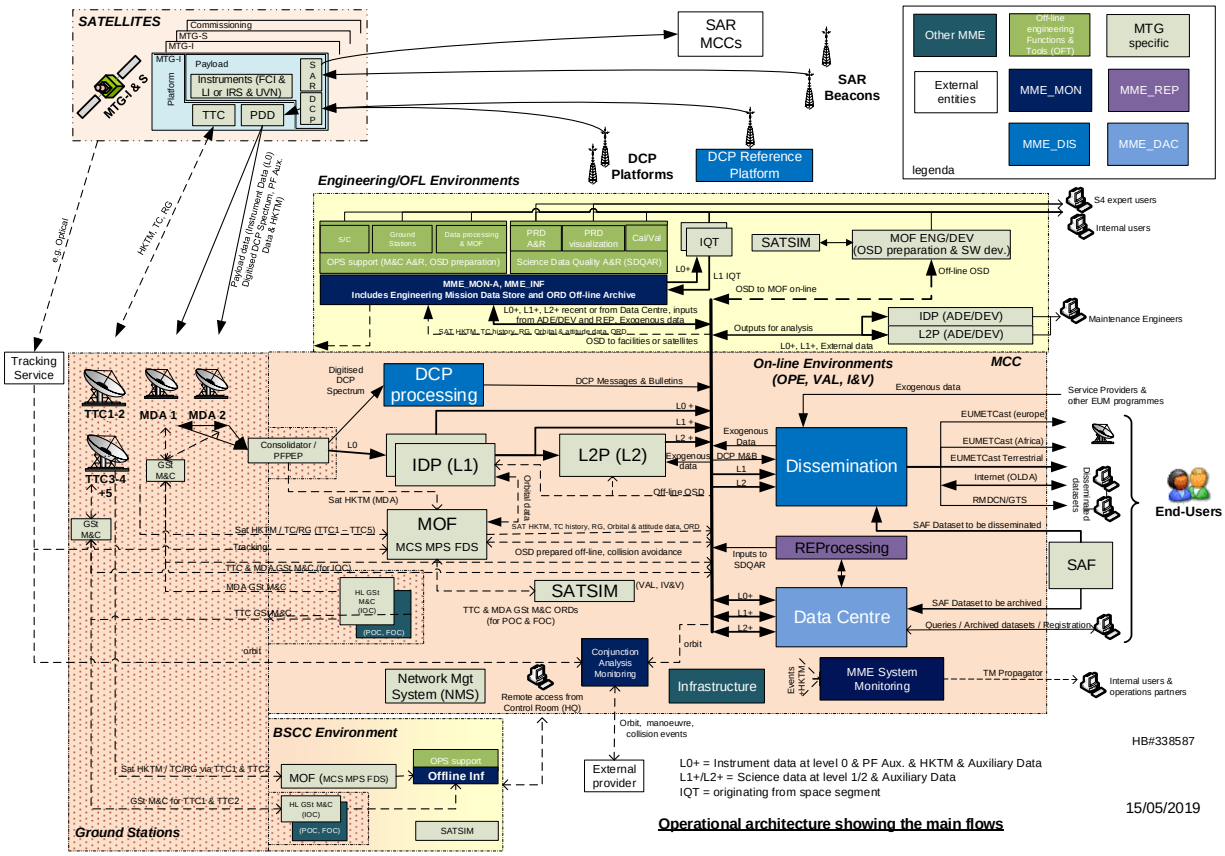

Figure 1: MTG System and GS Overview

The Space Segment and Ground Segment are configured operationally using operations static data which is defined and validated in advance of each satellite launch by operations engineering personnel. They are maintained throughout the lifetime of the Programme following upgrades of the system, operational experience or in response to system or operational anomalies.

The following graphic shows a hierarchical breakdown of the Ground Segment (out of the MTG System):

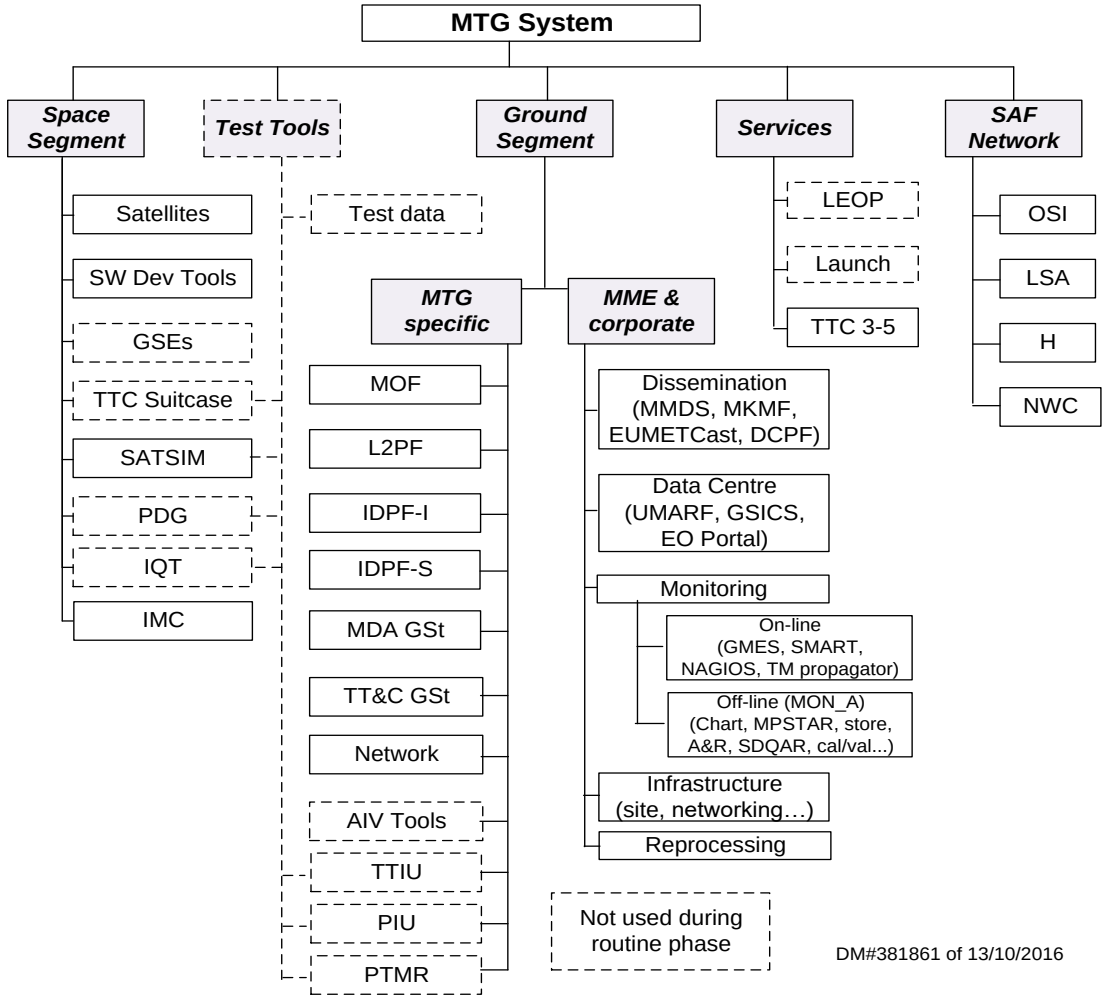

Figure 3: Hierarchical structure of the Ground Segment

The nominal configuration of the MTG Ground Segment will consist in hosting Ground Facilities and Infrastructure for up to three MTG Satellites at the same time in Operations plus one in Commissioning. The Launch dates for those three satellites are separated only by 18-24 months between them. This is the first time EUMETSAT will launch in so short time non-identical satellites. This means that when the first MTG-I1 Satellite is launched and in commissioning, at the same time an intense preparation for the second one (MTG-S1) is already on going, this includes, for instance, SVTs or other System Level Tests that need pre-defined HW and HR resources, environments and scheduling. The plit between the Operational Ground Segment and the Scientific Ground Segment does not exist for the MTG Programme; this is a specific EUMETSAT concept and requires a special coordination between both parts of one unique Ground Segment.

Therefore integration of MTG Ground Segment is a non-trivial process that requires a lot of coordination, scheduling and careful planning, given the number of facilities and environments to be integrated, and the number of in parallel ongoing activities.

The following sections will illustrate each technical challenge in detail.

3. TECHNICAL CHALLNGES TO INTERATE THE MTG GROUND SEGMENT

3.1 Integration approach in functional chains

The integration approach for the MTG Ground Segment has been set up in Functional Chains, due to the nature of different parts and functions of the Ground Segments.

These are the:

- Monitoring and Control Chain (M&C Chain) including Spacecraft Monitoring and Control functions, like:
    - TTCF (Telemetry, Tracking and Control Facility)
    - MOF (Mission Operations Facility)
    - SATSIM (Satellite Simulator)

- Data Processing Chain (DP Chain) including functions needed to process the Payload Data, like:
    - MDAF (Mission Data Acquisition Facility)
    - PDG (Payload Data Generator – Simulator)
    - IDPF (Instrument Data Processing Facility)
    - L2PF (Level 2 Processing Facility)

- Space-to-Ground Chain (S2G Chain) including functions needed to connect the Space Segment to the Ground Segment, like:
    - TTCF (Telemetry, Tracking and Control Facility)
    - MDAF (Mission Data Acquisition Facility)
    - DCP (Data Collection Platform)
    - STTs (System Test Tools)

A Full Chain set-up is still needed to ensure the integration of the three different chains back into Ground Segment and System:

- Full System Chain including all the connection parts and the external interfaces which have not been covered in another chains, like:
    - MME_DIS (Multi-Mission Elements Dissemination)
    - MME_DAC (Multi-Mission Elements Data Archiving)
    - MME_MON (Multi-Mission Elements Monitoring)
    - SAFs integration (Satellite Application Facilities)
    - Corresponds also to all the End-to-End Test Activities that have not been covered at other chains.

All the chains are dealing with System Level Testing and Integration. The following graphic shows the functional overlaps in the areas of each chain:

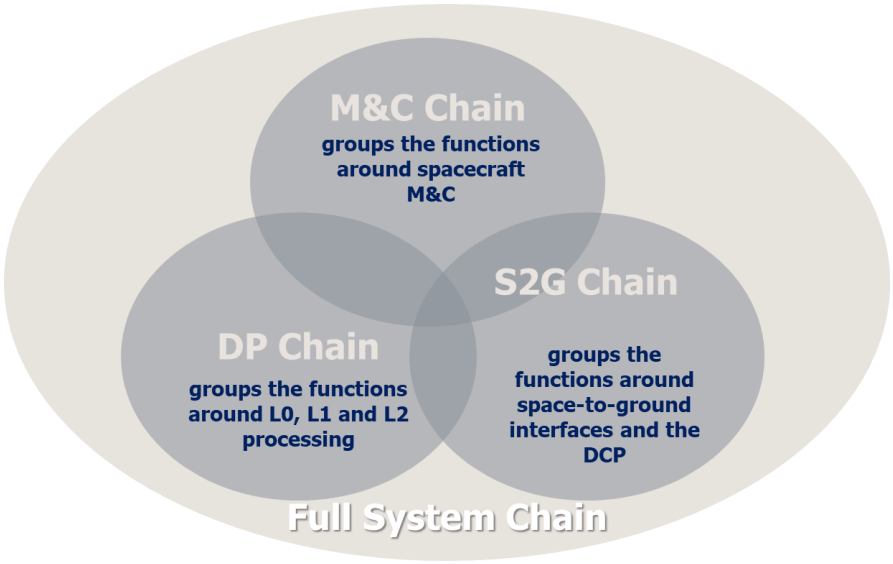

Figure 3: Integration using the Chains approach

The knowledge required in order to support the activities of each of the chains has a very distinct nature, for example the Data Processing Chain testing requires more scientific understanding of the Payload Instrument and the data generated by it, whereas the M&C Chain requires more knowledge of the Satellite itself and its commanding and control (AOCS, Flight Dynamics, etc), the Space to Ground Chain requires more detailed knowledge of the Ground Stations and Antennas and all the transmitter hardware.

In order to organize and keep track of the activities of each chain a daily “Stand-Up” meeting is held. The resources used by each chain (Hardware as well as Human Resources) for their activities have to be scheduled carefully, taking into accounts hard deadlines and priorities at each stage of the Programme. This task is not an easy task and requires a lot of coordination among the teams including other teams using the platforms, arisen due to the Matrix organization of EUMETSAT, see next Paragraph for more details.

3.2 Matrix organisation related approach

Combined teams, including members from the procurement team, the integration and verification team and the Operations Preparation team, perform integration and verification activities. Due to the structure of EUMETSAT organisation and heterogenic departments structure (Matrix organisation, described below) working on the same Programme, a significant coordination effort is needed among the teams, like IVV Team, Facility Procurement Teams, MME Teams, Operations Preparation Teams, to assure that those can share the resources and prioritize and schedule activities especially with respect to consecutive Satellites priorities.

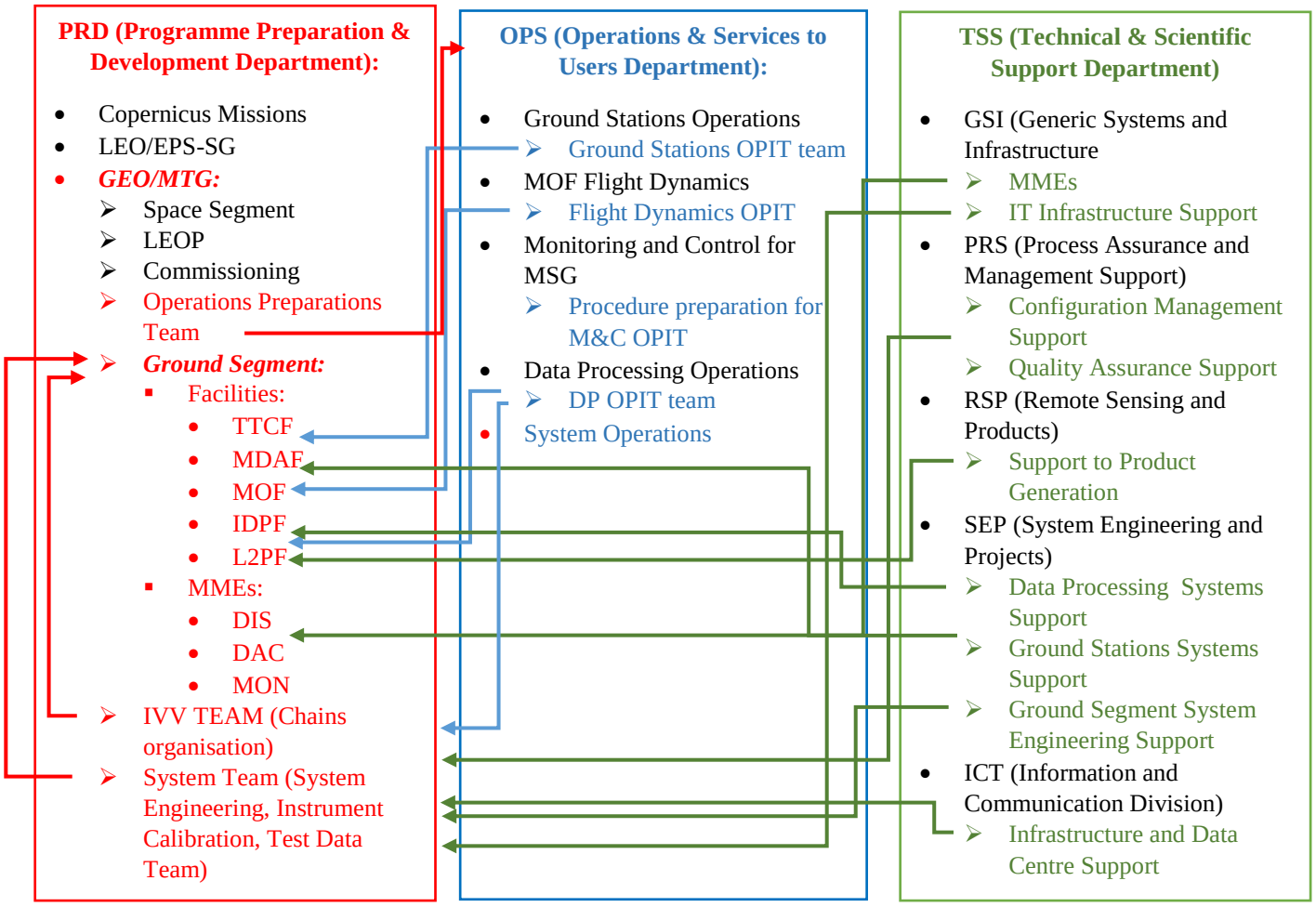

Figure 4: Matrix organisation of EUMETSAT

EUMETSAT is organised in three technical departments: the Programme Preparations and Development Department (PRD), the Operations and Service to Users Department (OPS) and the Technical and Scientific Support Department (TSS). However, in order to develop and integrate the MTG Ground Segment, which is under the responsibility of PRD, knowledge and resources from other Departments are required. This is what is called at EUMETSAT "Matrix organisation" (see Figure 4 above).

OPS department identifies subject matter experts from operations that support the programmes in development in specific aspects of operations preparation.

The TSS department gives support to all the programmes, independently of whether they are in Operations or in Development. As part of different Divisions, Competence Areas exist inside the TSS department, which have specific knowledge that can be shared among different programmes.

One of the challenges to work with the Matrix organization is the need on strong level of communication and coordination among the teams coming from different departments and in spite of different departmental objectives working on a common goal.

In order to ensure appropriate communication and coordination among the teams, the concept of OMIT was introduced.

The OMIT is managing for the system under its responsibility:

- the completion of the MTG-I1 and S1 development
- the transition from development into operations
- initial operations and maintenance activities, from hand-over of the satellite after LEOP and during the commissioning phase;

It is the responsibility of each OMIT Team Leader(s) to manage their functional areas, liaising as necessary with the other TLs to obtain any necessary cross-team support from staff allocated to that team, e.g. System IVV activities, System Services such as MMEs, System Engineering etc.;

The following graphic shows the OMIT and its structure within MTG:

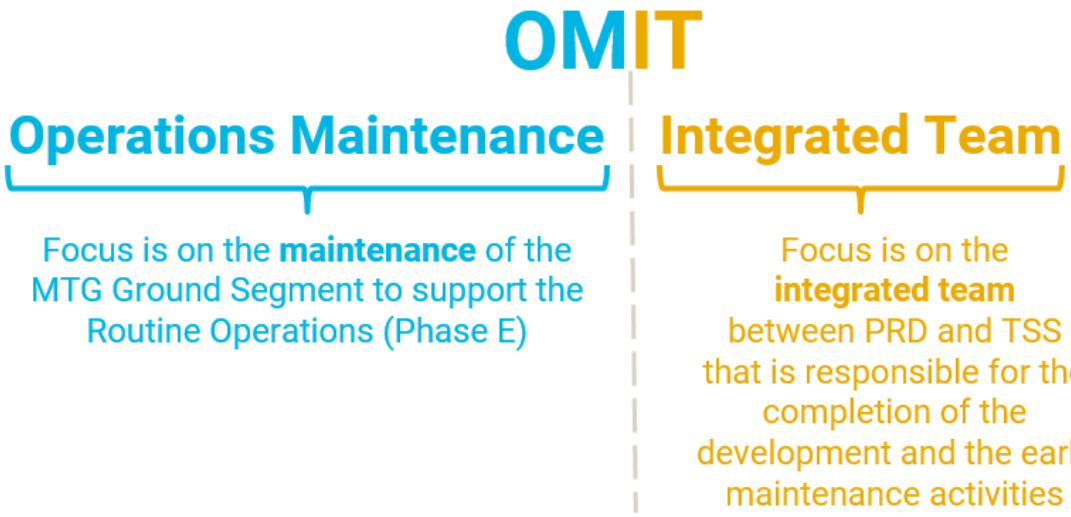

Figure 5: OMIT

The OMIT together with the OPIT – Operations Preparation Integrated Team operate within the larger context of the Operations Preparation organisation.

The OPIT is managing for the system under its responsibility:

- the readiness of the MTG-I1 system operations for Launch, Commissioning and Routine
- the transition from development into operations
- initial operations, from hand-over of the satellite after LEOP and during the commissioning phase

The following figure shows the OPIT organisation for MTG, whereby the matrix organisation is clearly visible through it.

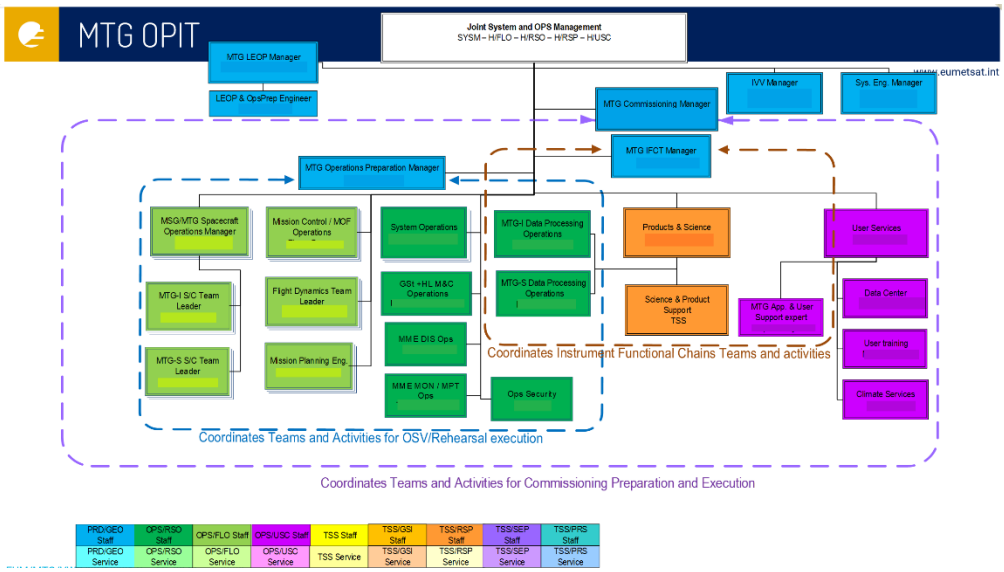

Figure 6: OPIT

The Operations Preparation Integrated Board – OPIB is the director's level board to which the OMIT and the OPIT teams report and depend.

There is one integrated team covering the entire MTG Programme: the OMIT and the OPIT. The MTG-I1 activities are already on-going and are the main focus of the integrated team. The activities on MTG-S1 are still focused on the ground segment procurements and the facility integration testing. However, the parallel nature of the activities means that decisions on priority and urgency have to consider potential impacts on both missions. The following figure shows the priorities organised in phases, being phase 1 before the Launch of MTG-I1 satellite and phase 4 being the start of routine operations of the S1 satellite.

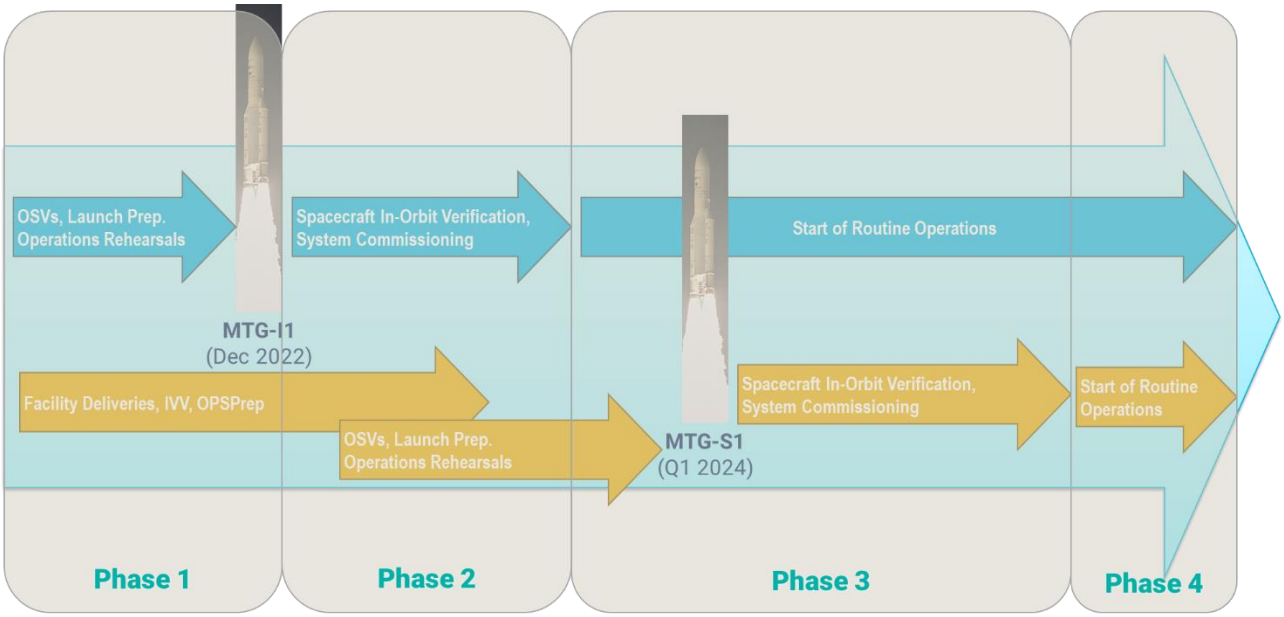

Figure 7: Priorities organized in 4 phases

A part of the OPIT and OMIT concepts, different measures taken to achieve this coordination are:

- Operations Preparation Manager in the MTG programme, managing Operations Preparation activities in coordination with the programme.
- Weekly Resources Scheduling Meetings (OPS for MTG-I1 and Programme level for MTG-S).
- Daily stand-up meetings (both OPS and Programme).
- Checkpoints after each System version.
- Release Control Board meetings.

3.3 Parallel activities of the MTG-I and MTG-S Satellites preparation

Due to the overlapping timelines of the MTG-I and MTG-S Satellites Launches and Commissioning, there is a strong need for concrete scheduling for the integration and testing activities. The organisation of the activities requires complex resources scheduling, on human and hardware level, for operational and non-operational environments, especially now, after the first Launch of the first MTG-I Satellite. Different environments (IVV, VAL and OPE) and their usage needs to be carefully planned, for verification and validation in parallel to routine operations, especially in the overlapping time between the launches of two consequent satellites.

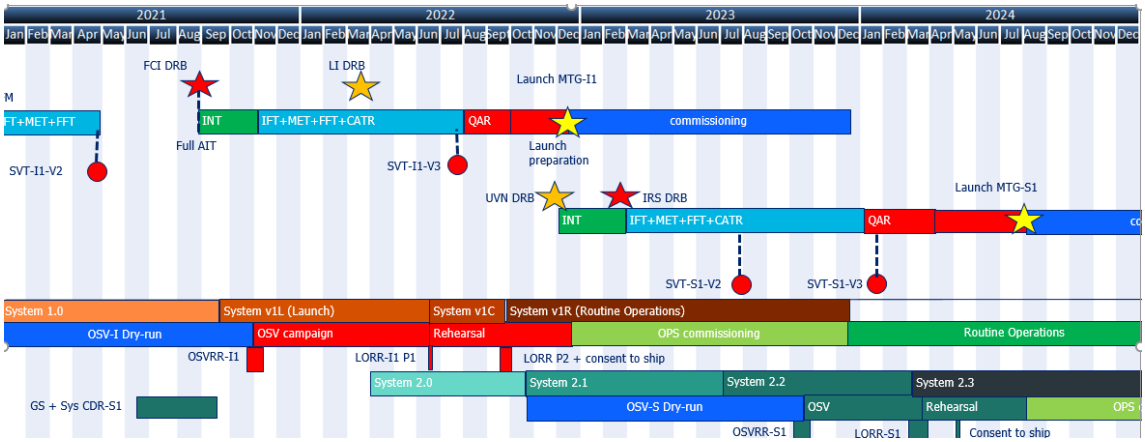

Figure 8: Timeline for MTG-I1 and S1 Satellites

As shown in the Figure 8, the timelines for the Launches of the MTG-I and MTG-S Satellites are overlapping. For example, after the first Launch of the first MTG-I Satellite and during Commissioning, which takes 1 year, other critical activities for preparation of the MTG-S Satellite Launch are taking place.

The following figure shows the environments at EUMETSAT used to perform the Integration, Verification and Validation activities, as well as the Operational Validation of new Releases and Patches and the Operations themselves:

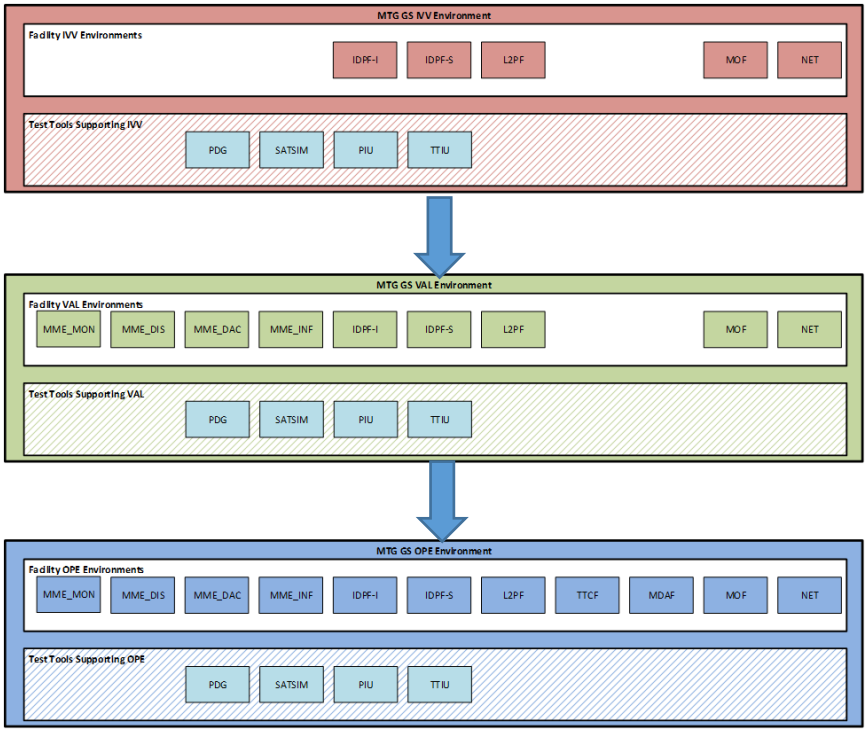

Figure 9: Environments

In order to assure parallel activities, like Operational Validation and Operations for MTG-I System and at the same time Integration, Verification and Validation for the MTG-S System, different environments have to be used. However, this is challenging task, since the use of the environments normally follows the following sequence: IVV->VAL->OPE.
This means that Integration and Verification activities are done first on the IVV environment, after the System has been integrated and verified, it is validated as a whole on the VAL environment, before it is rolled out on to the OPE environment for Operations. During the Commissioning phase, usually many integration and verification activities still have to be performed, and the Operational Validation of new Releases and Patches has to be done much more frequently than in the Routine Operations. At the same time, the IVV and VAL environments will have to be used for preparations of the MTG-S Satellite and execution of Integration, Verification and Validation activities.
This means that strong coordination and scheduling is needed in order to make it possible to use the same environments at the same time.

Following Figure 10 illustrates the evolution of the usage of different environments at the same time when the programme goes on:

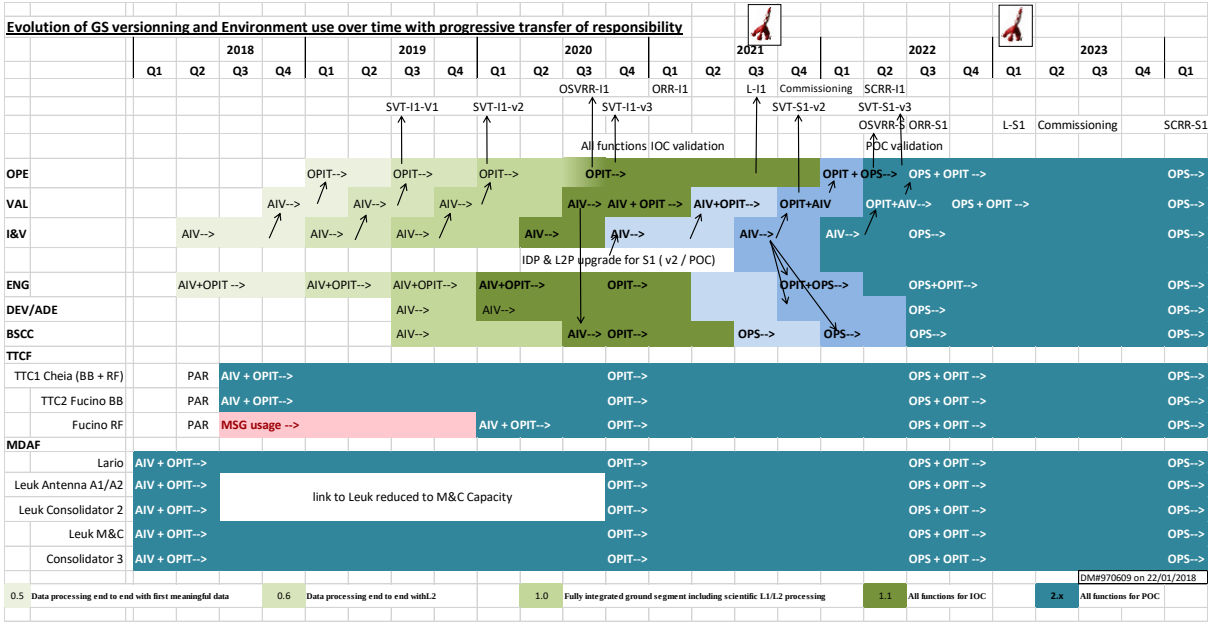

Figure 10: Evolution of GS environment use over time

Following measures are performed to make this possible:

- Long term schedule of all formal activities for OPS and Programme Resources.
- System versioning and careful planning of objectives of every system version.
- Weekly resources scheduling meeting with previous de-conflicting based on 2 month set priorities (for both OPS and Programme resources).
- Monthly Release Control Boards.
- Splitting the teams working on MTG-I and MTG-S Ground Segment.
- Splitting of the environments (except MOF and MME's).

3.4 Verification vs Validation

Internal EUMETSAT Organization is following the approach that Integration and Verification is done by the IVV Team, belonging to the Programme itself, whereby the Operations Preparation Team (introduced above) performs the Validation.

The transition between the Verification and Validation activities is ensured during the Operation Validation Dry-Runs, which are performed by the IVV Team, before handing over to OPIT for the formal Operational Validation. In preparation to the Launch and Commissioning, some activities are common between the two teams and need to be harmonised using synergy between teams to optimise the number of activities and the schedule. Also, the End-to-End Test could be interpreted as both Verification and Validation activities, however these can be done only once, due to the tight schedule and resources.

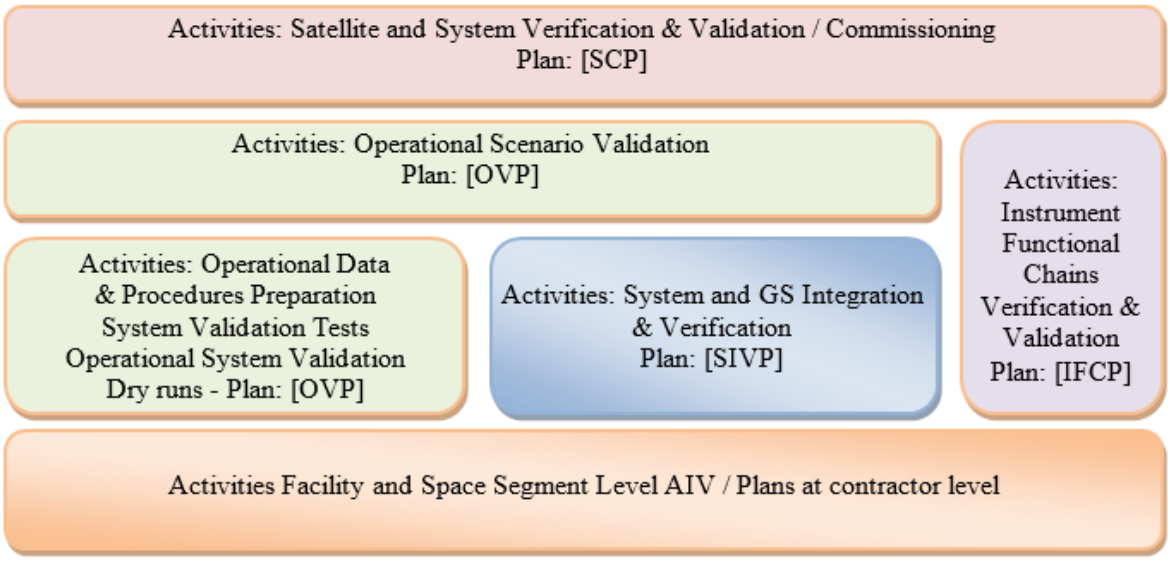

Figure 11: Verification vs. Validation

Figure 11 above shows the activities structure for the Verification and the Validation and from where these are derived. For example, the Validation Dry-Runs are going on in parallel with the Integration and Verification activities and both are pre-requisite to the Operational Scenario Validation, which is then a pre-requisite to the Satellite and System Verification and Validation during Commissioning of the Satellite. The same applies to the reception of new Facility version, first the IVV activities are done, and afterwards the Operational Validation. Any of those activities could be ongoing in parallel to the others.

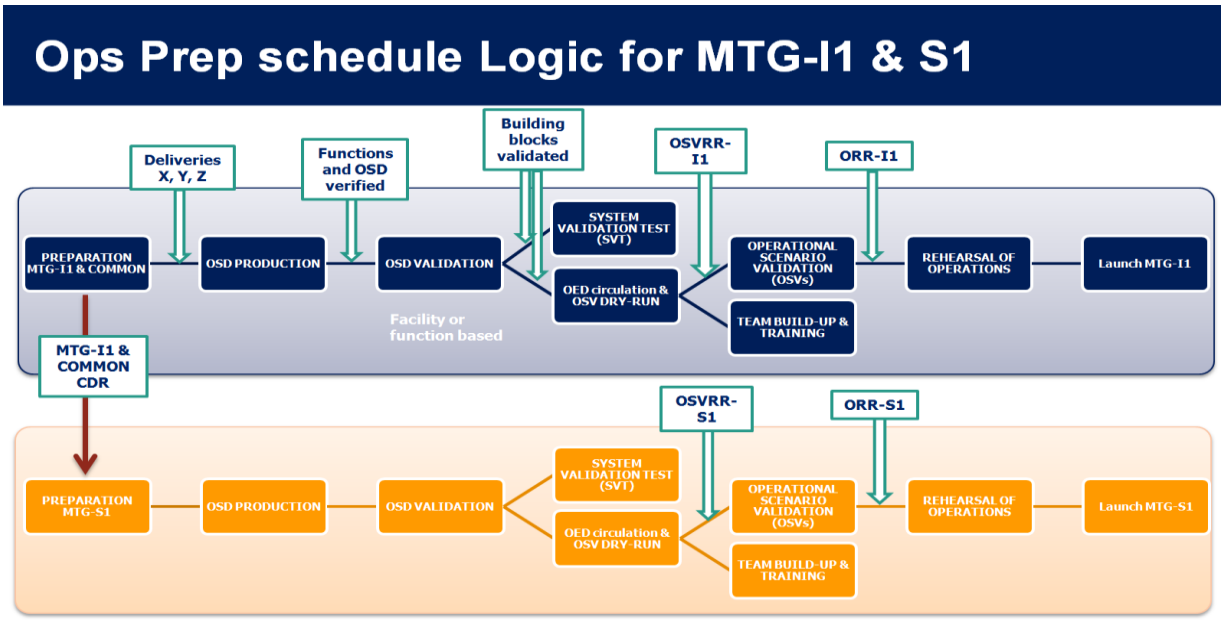

Figure 12: Validation logic for MTG-I1 and MTG-S1 Satellites

The above Figure 12 illustrates the Operational Validation progressive approach, showing the main activities run in the course of the Operational Validation. Some activities can be executed in parallel but this is not shown in the diagram.
The approach for MTG-S1 in terms of group of tasks and their sequencing is identical to the MTG-I1 operational validation campaign. This symmetry in the approach does take into account the differences in terms of (re-)validation or non-regression as needed for the system version considered.
The Ops Prep planning is decomposed in Ops Validation Stages and Validation Campaigns and Pre-requisites (Pre-condition to perform the validation intended for the operations targeted).
The Operational Validation, performed at facility level, is the initial Operational Validation activity and is ensuring the readiness of the Facilities (that have been verified beforehand) for the system operations and their usage in further End-to-End operational validation
For each Ops Validation campaigns, one of the drivers is to identify the test setup needs and boundaries expressed hereafter to relate to the resource scheduling:

- Facility level,
- Monitoring and Control Platform level,
- Data Processing Platform level,
- Ground Segment level (for instance for cross- chains interfaces testing between M&C and Data Processing chains)
- System Versions Levels.

3.5 Special measures before MTG-I1 Launch

A part of the challenges illustrated above and the measures and processes put in place in order to mitigate each of those challenges; the Programme had to put several measures and new processes in place, starting 9-6 months before Launch, and which are still on going.
The different measures will be illustrated below:

The figures 13 and 14 are showing the comparison of the scheduled both MTG-I1 and MTG-S1 activities on MOF and Data Processing environments over bigger time scale, including MTG-I1 Launch and Commissioning.
The comparison was done 9 months before Launch and has demonstrated that there was no blocking issue on the HW environments side.

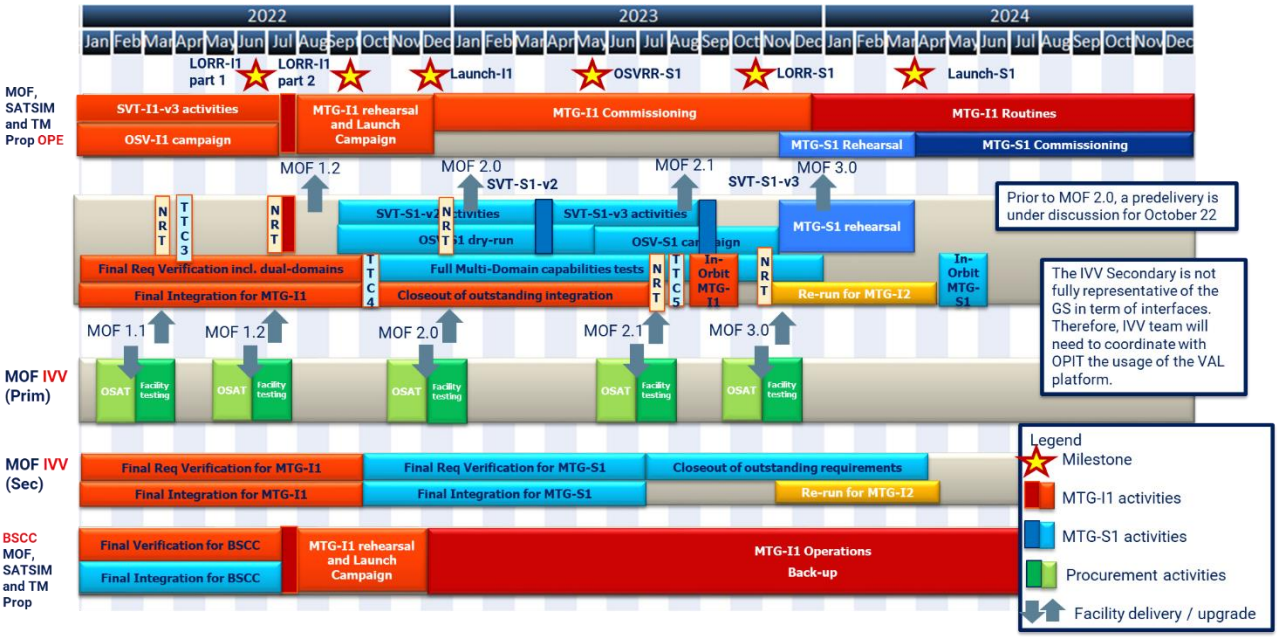

Figure 13: MTG-I1 and MTG-S1 activities on MOF environments

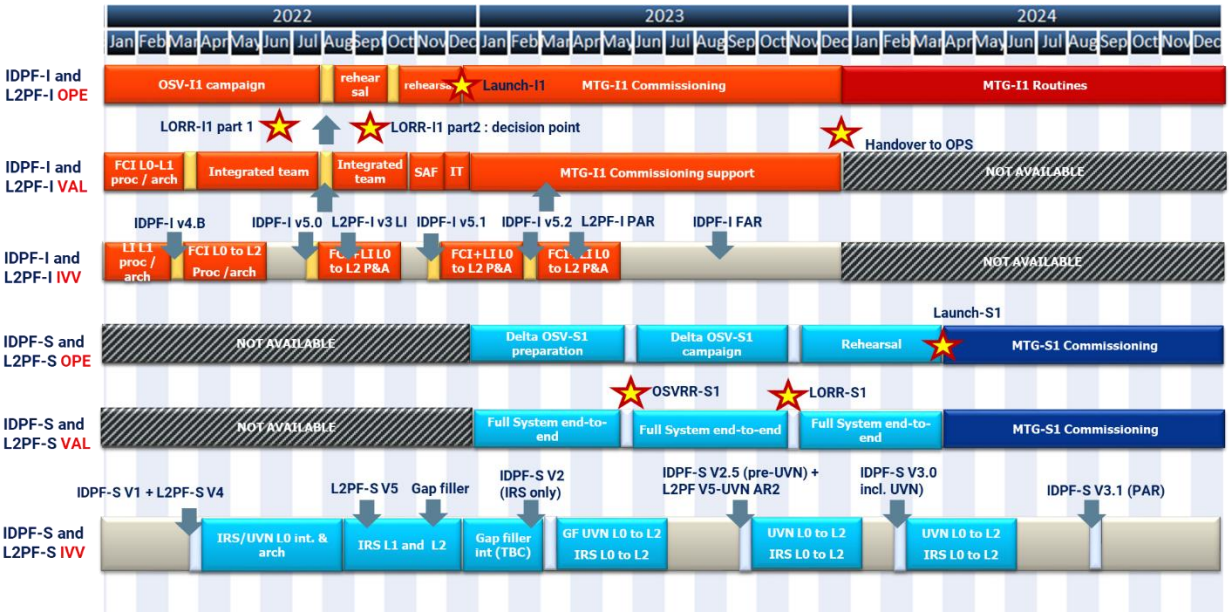

Figure 14: MTG-I1 and MTG-S1 activities on Data Processing environments

At the same time the updated Schedule of System versions was created, see the figure 15 below.

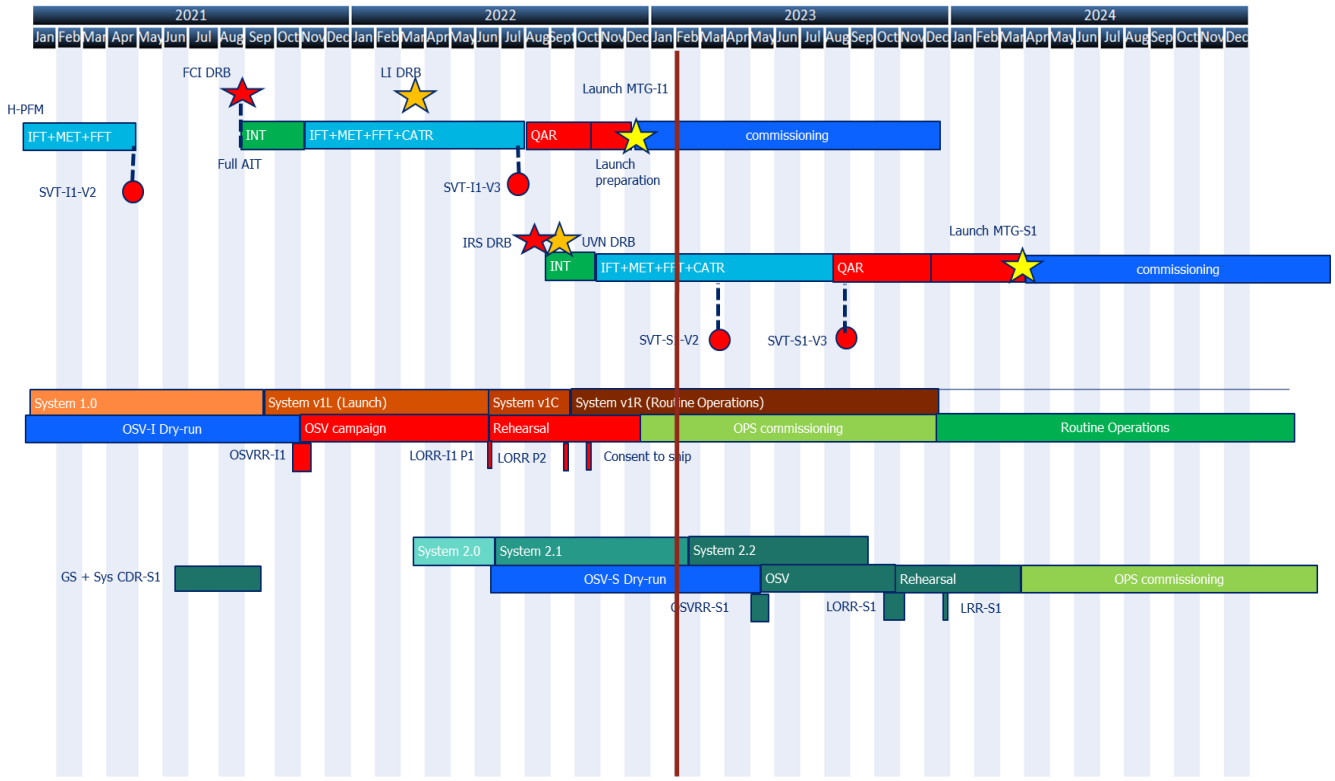

Figure 15: Updated Schedule of System versions

Approximately 6 months before MTG-I1 Launch another set of measures and processes was introduced, to facilitate the handover to Operations Division:

- Splitting of the resource scheduling process for OPS and Programme.
- Splitting of the daily stand-up meeting in two parts OPS and Programme.
- Assure teams availability in all different meetings.
- Splitting of the CCB process into OPS and Programme.
- Putting in place Freeze Board process authorizing any deployments on OPE or VAL environment.
- Additional introduction of the Fast Patching Release Control Board.
- Fast patching teams brought onsite for MOF and IDPF-I facilities to facilitate rapid resolution of bugs.

4. CONCLUSIONS

The Integration of the MTG Ground Segment is a complex task that requires careful planning and a significant coordination effort among heterogenic teams.

Following measures have been addressed for the resolution:

- Integration and Verification in Functional Chains
- Operations Preparation Manager in the MTG programme, managing Operations Preparation activities in coordination with the programme.
- OMIT and OPIT teams concepts.
- Daily stand-up meetings.
- Checkpoints after each System version.
- Long term schedule of all formal activities.
- System versioning and careful planning of objectives of every system version.
- Weekly resources scheduling meeting with previous de-conflicting based on 2 month set priorities.
- Monthly Release Control Boards.
- Splitting the teams working on MTG-I and MTG-S Ground Segment.
- Splitting of some environments (except MOF and MME's).
- Special measures before MTG-I1 Launch.

As the result of all of these measures taken over the last 3-4 years, we have seen a successful collaboration that lead to a successful integration of the MTG-I1 Ground Segment towards the Launch of the first MTG-I satellite, while at the same time working strongly on the first integration phases of the MTG-S1 Ground Segment. The next challenge will be to rollout a Multi-Satellite approach into Operations.

REFERENCES

[1] MTG System Development Plan
[2] MTG System Integration and Verification Plan
[3] MTG Operational Validation Plan