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Challenges and Lessons Learnt from the Migration of Multi Mission Platforms

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Abstract

EUMETSAT successfully operates and maintains a wide range of Multi-Mission Elements (MMEs) and Services, such as Data Dissemination, Archiving, System Level Monitoring or Service Indication and Reporting. MME platforms have demonstrated various benefits, although they introduce greater complexity when upgrading the underlying hardware or software, while still requiring supporting current and future missions. This paper reflects on the challenges and lessons learnt gathered throughout the migration of MME platforms, highlighting the technical difficulties, common mistakes and procedural intricacies in this complex transition.

This paper discusses key aspects during MME migrations, including strategies for onboarding current and future missions, overall system compatibility, transfer of extensive historical data and integration of new software alongside existing systems. Each of these points requires meticulous planning, robust testing and collaborative efforts across teams and departments to ensure a seamless transition while maintaining the operational integrity of ongoing satellite missions.

Real examples from the recent upgrade of EUMETSAT's Monitoring and Support Infrastructure Facility (MASIF) are also presented. Despite careful project planning, delays occurred due to unexpected software anomalies, resource unavailability from operations teams, parallel validation of both legacy and new software versions, and limited familiarity with the new data transfer technology. This paper focuses on how engaging relevant stakeholders from an early stage and maintaining open lines of communication fostered a collaborative environment, essential for addressing diverse requirements and perspectives. Additionally, an incremental implementation approach proved beneficial, allowing for continuous assessment and adjustment, while extensive testing at each phase improved system performance and reliability and prepared the team to manage the new system more effectively.

The paper outlines the major challenges and resulting lessons learnt from MME migration activities. The concluding sections reflect on the insights gained, which will serve as crucial inputs for future technological upgrades and migrations within large-scale operational frameworks.

Keywords: EUMETSAT, MME, Migration, Challenges, Lessons Learnt.

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Acronyms/Abbreviations

CFI	Customer Furnished Item
CO2M	Copernicus Anthropogenic Carbon Dioxide Monitoring
COTS	Commercial off-the-shelf
CRISTAL	Copernicus Polar Ice and Snow Topography Altimeter
DLR	Deutsche Zentrum für Luft- und Raumfahrt (German Space Agency)
EPS	EUMETSAT Polar System
EPS-SG	EUMETSAT Polar System – Second Generation
ESA	European Space Organisation
EUMETSAT	European Organisation for the Exploitation of Meteorological Satellites
IJPS	Initial Joint Polar System (between EUMETSAT and NOAA)
IT	Information Technology
IV&V / IVV	Integration, Verification and Validation
KB	Knowledge Base
KPI	Key Performance Indicator
M&C	Monitoring and Control
MCC	Mission Control Centre
MME	Multi Mission Element
MPT	Mission Performance Tool
MSG	Meteosat Second Generation
MTG	Meteosat Third Generation
NOAA	National Oceanic and Atmospheric Administration
OPE	Operational (Environment)
ORR	Operational Readiness Review
RoD	Review of Design
TRR	Test Readiness Review
TRB	Test Review Board
VAL	Validation (Environment)
VER	Verification (Environment)

1. Introduction

The intention of this paper is to present the challenges and lessons learnt associated to the migration and operational rollout of multi-mission systems, discussing critical aspects such as:

- System Complexity
- Planning and usage of environments
- Stakeholders' involvement
- Support to future programmes
- Testing and validation campaigns
- Migration strategies
- Data volume and continuity
- Resource constraints
- Training and knowledge transfer

The paper will explore the different challenges associated with each of these points, applied to an organisation such as EUMETSAT with a vast amount of current and future programmes and over a thousand employees (both staff and contractors).

2. Introduction to EUMETSAT

EUMETSAT is an intergovernmental organisation based in Darmstadt (Germany), responsible for the exploitation of Europe's meteorological satellites.

EUMETSAT operates a system of meteorological satellites that observe the atmosphere, ocean and land surfaces - 24 hours a day, 365 days a year. This data is then supplied to the National Meteorological Services of the organisation's Member and Cooperating States in Europe, as well as other users worldwide.

The satellites currently operated in the EUMETSAT HQ are:

- Geostationary satellites Meteosat -10, Meteosat-11 and Meteosat-12 over Europe and Africa, and Meteosat-9 over the Indian Ocean. Meteosat-9 -10 and -11 are part of the second generation (MSG), while Meteosat-12 is part of the third generation (MTG)
- Metop polar-orbiting satellites (Metop-B and Metop-C) as part of the Initial Joint Polar System (IJPS) shared with the US National Oceanic and Atmospheric Administration (NOAA).
- Jason-CS/Sentinel-6 satellite providing global sea surface height observations for climate monitoring and ocean and seasonal forecasts.
- Jason-3 as part of the Jason mission (an international partnership between EUMETSAT, CNES, NOAA, NASA and the European Union via the Copernicus programme), even though it is not operated by EUMETSAT.
- Sentinel-3 satellites (S3A and S3B) collecting observations of global ocean colour, sea surface temperature and sea surface height.

The future satellites and programmes which will be launched from 2025 - 2028, and operated at EUMETSAT, are:

- Two new satellites from the Meteosat programme, MTG-S1 and MTG-I2.
- A second satellite from the Sentinel-6 programme, Sentinel-6B.
- Three new satellites from the EUMETSAT Polar System programme, EPSSG-A1, EPSSG-B2 and EPS Sterna

- Two new satellites from the Sentinel-3 programme, S3C and S3D.
- Three new satellites from the new Copernicus Anthropogenic Carbon Dioxide Monitoring constellation, CO2M-A, CO2M-B and CO2M-C.
- The first satellite from the new Copernicus Polar Ice and Snow Topography Altimeter programme, CRISTAL-A.

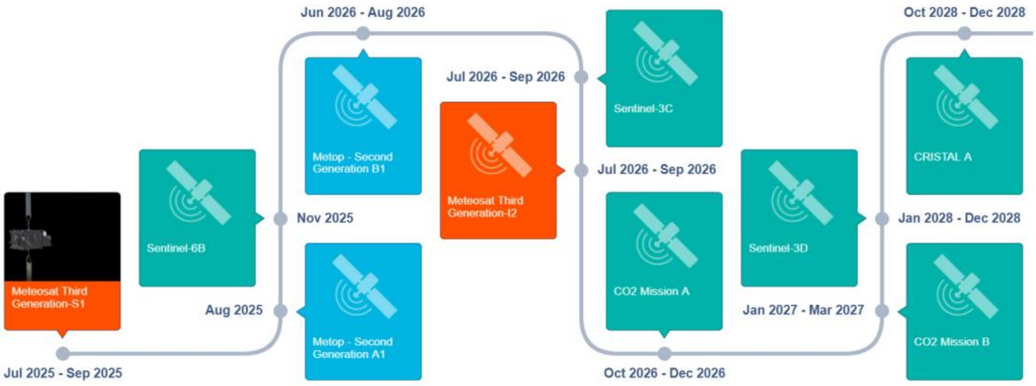


Figure 1: EUMETSAT upcoming launches and programmes (2025 – 2028)

On top of these upcoming launches, EUMETSAT's portfolio of missions and satellite launches is set to continue expanding significantly over the next two decades. This growth will lead to an increasing volume of data and systems that must be managed, placing considerable demands on the organisation's infrastructure. Accommodating new missions requires not only scaling existing systems but also redesigning those that become inefficient or incapable of handling the increased operational load.

3. EUMETSAT and Operations Multi-Mission Concepts

The concept of multi-mission systems and operations has been progressively developed at EUMETSAT in response to the growing complexity and scale of mission operations. Multi-Mission Elements (MMEs) can be implemented across various levels, including facilities, software, hardware, infrastructure and teams. Over time, the MME approach is evolving into the industry-standard model of "as a Service." A recent initiative aims to replace the aging hardware supporting many missions with a unified "Platform as a Service" (PaaS). This platform will provide all necessary hardware, infrastructure, storage, networking, orchestration, and high availability support, extending to the virtual server level where ground segment operations will be hosted.

EUMETSAT currently defines the following systems as multi-mission:

- **Data Access**: This includes archiving, discovery (also known as "pull data services"), and the reprocessing of legacy data with the latest algorithms.
- **Dissemination**: The real-time distribution of data to end users via DVB-S and the Internet.
- **Infrastructure**: Encompassing hardware, network, storage, and building facilities, including the operations control and support rooms.
- **Security Monitoring and Incident Response**: Ensuring the protection of systems and rapid response to incidents.
- **System Monitoring, Reporting, and Service Indication**: Provides event-based monitoring, data flow tracking, periodic checks, and telemetry propagation across the ground segment and spacecraft, with service status updates for end users.

- **Monitoring and Control Infrastructure**: Based on SCOS, this is tailored to the specific needs of various missions.
- **Offline Analysis Tools**: Used for spacecraft and ground segment data and product analysis.
- **Flight Dynamics**: This includes conjunction analysis to manage collision risks and optimise spacecraft trajectories.

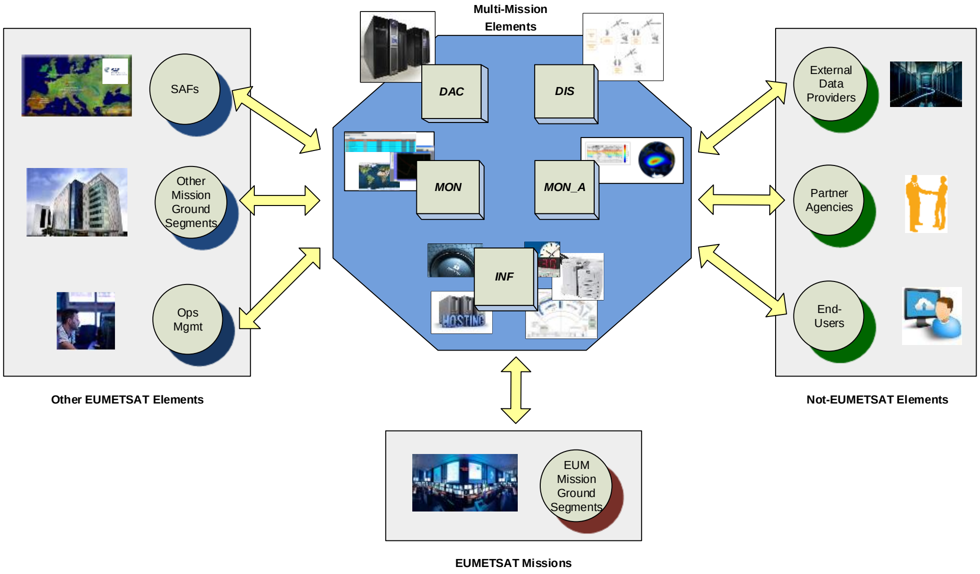


Figure 2: Multi-Mission System Examples

As highlighted above, the multi-mission concept is deeply embedded within EUMETSAT and is applied across nearly all aspects of ground segment and spacecraft operations. Given its widespread implementation, it is only logical to consider this approach early in the programme development process.

4. Reason for migrating MMEs - If they work, why do we upgrade them?

The Multi-Mission Elements (MME) approach has proven to be highly effective in consolidating operational functions across multiple missions [1]. However, even when a system is functioning well, there are several reasons why it might be subject to change or evolution:

Enhance scalability: On top of the mandatory programmes, one of the main objectives of EUMETSAT is also to create synergies with other operators of Earth observation satellites in Europe, China, India, Japan, South Korea and the United States, benefiting from the sharing of data from many other satellites. Initially designed MMEs, such as those for monitoring, data access, and infrastructure, may struggle to handle the increased workloads, requiring upgrades or redesigns to support higher data volumes.

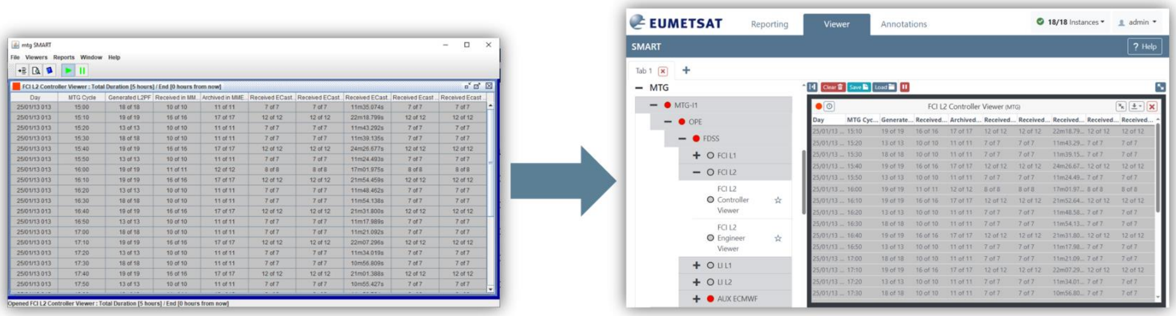
Integrate new technologies: As ground and space technologies rapidly evolve, continued reliance on legacy systems can be detrimental for operational efficiency. Modern solutions offer significant advantages, including fewer anomalies, faster resolution times, enhanced security, the removal of bottlenecks caused by outdated software or hardware, and increased automation. These improvements deliver greater value for money and contribute to the long-term sustainability of operations.

Add new requirements: While it is crucial to minimise the introduction of new requirements to MMEs to ensure their stability and prevent excessive growth in complexity, technological advancements occasionally necessitate their modernisation. For instance, methods of user communication have evolved, shifting from traditional approaches to more internet and phone-based solutions, as these technologies are now widely accessible, unlike ~40 years ago when EUMETSAT was established.

As previously noted, MME teams should avoid continuously evolving system requirements or introducing bespoke ground segment elements, as this approach is not cost-effective for operations and maintenance. Instead, EUMETSAT is moving towards defining a core set of MME functionalities, aiming to evolve them only when it brings clear, shared benefits across all missions.

Mitigate COTS and platform obsolescence: Outdated or unsupported software and hardware presents significant risks to system stability and security. Vendor-supported versions ensure that systems remain resilient by providing regular updates, security patches, and performance enhancements. Continuing to rely on unsupported systems can lead to compatibility issues, reduced performance, and increased risks, potentially affecting the reliability and success of missions.

Improve usability: Newer systems typically feature more intuitive interfaces, improved reporting tools, and enhanced usability, which can significantly boost the productivity and effectiveness of teams responsible for operating and maintaining mission-critical systems. Additionally, these advancements help lower training costs and reduce the likelihood of human errors during MME operations.



Version 3.5

Version 3.8

Figure 3: The Service Monitoring and Reporting tool (SMART) at EUMETSAT evolved from the outdated Java WebStart application to a more efficient, user-friendly web browser-based interface.

Increase reliability and redundancy: Modern MMEs are inherently designed with robust reliability and redundancy features, ensuring uninterrupted mission operations even in the event of system failures or anomalies. However, as MMEs continue to evolve, these features are further refined and enhanced, strengthening their ability to mitigate risks and maintain a continuous availability of critical services. This ongoing improvement reinforces the long-term stability and effectiveness of missions.

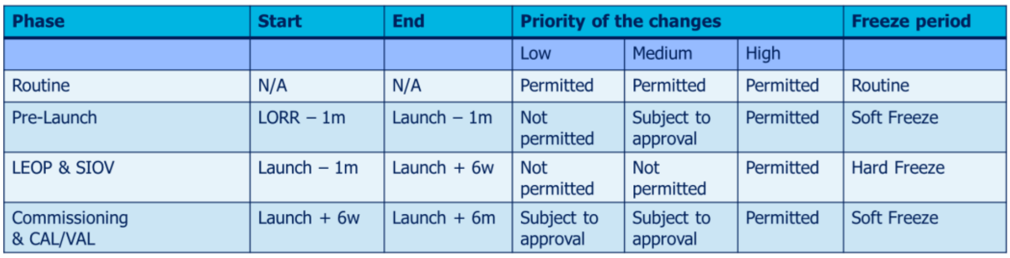
Reduce cost: Modernising MMEs can lead to significant cost savings by optimising resources such as power consumption, network usage, and hardware infrastructure. The automation of routine tasks and the reduction in manual intervention further streamline operations, resulting in operational cost reductions. These efficiencies directly contribute to better budget management and enable organisations to allocate resources more effectively, thereby enhancing the overall financial sustainability of mission operations.

5. Challenges of migrating MMEs – Why is it so complicated to upgrade them?

System complexity: Migrating MMEs is inherently complex due to the interdependence of software, hardware, and operational processes across multiple missions. At EUMETSAT, the integration of spacecraft, ground systems, and mission operations further amplifies this challenge, requiring meticulous coordination and system-wide adaptability. 24/7 operations cannot be interrupted, so any potential downtime has to be absolutely minimised.

In addition, the complexity of system integration increases with the interactions between different MMEs and between MMEs and broader programmes. For instance, each mission (current or future) has its own unique roadmap, encompassing its evolution, requirements, and operational activities (e.g., critical spacecraft manoeuvres). Combining the roadmaps of all missions to align with the migration of MMEs, which interfaces with all of them, presents a significant challenge. In these situations, a degree of flexibility is essential to accommodate MME upgrades. If every mission imposed strict constraints on avoiding any risk or impact, system evolution would become unmanageable.

System freezes: EUMETSAT implements system freezes, during which the configuration of certain ground segment facilities remains partially or totally unchanged before, during, and shortly after satellite launches. This measure ensures stability and minimises risks during critical phases such as Launch and Early Orbit Phase (LEOP) and commissioning. However, these freezes impose additional constraints on the evolution of MMEs which shall be carefully considered around these periods. This could lead to delays and added complexity in the planning and implementation of system improvements.



Phase	Start	End	Priority of the changes			Freeze period
			Low	Medium	High	
Routine	N/A	N/A	Permitted	Permitted	Permitted	Routine
Pre-Launch	LORR – 1m	Launch – 1m	Not permitted	Subject to approval	Permitted	Soft Freeze
LEOP & SIOV	Launch – 1m	Launch + 6w	Not permitted	Not permitted	Permitted	Hard Freeze
Commissioning & CAL/VAL	Launch + 6w	Launch + 6m	Subject to approval	Subject to approval	Permitted	Soft Freeze

Figure 4: Launch phases and corresponding system freeze periods for EUMETSAT programmes

As observed in Figure 4, while high-priority changes required for service continuity or covering major obsolescence issues are generally allowed, medium and low priority changes are subject to approval (or even not permitted in certain cases), potentially causing delays to planned MME activities.

Interdependencies with legacy systems: MMEs are often integrated with legacy systems and third-party applications, creating complex dependencies that can be challenging to manage. In some cases, certain components are too outdated to be feasibly upgraded, making it more practical to wait for their natural replacement rather than forcing an upgrade solely to align with MME migration. Attempting to modify these systems prematurely can introduce cascading effects, increasing the risk of failures and operational disruptions.

For instance, some EUMETSAT facilities supporting older missions still rely on Solaris OS, and migrating to Linux could pose significant risks to mission stability. Instead of a full OS upgrade, in some cases adapting MME interfaces would ensure compatibility while preserving operational reliability.

Complex validation campaigns: Testing and validation campaigns for MMEs, essential before deploying new systems into operations, demand meticulous planning and comprehensive documentation. Beyond verifying compliance with user requirements through a detailed Test Specification, MMEs also undergo Operational Scenario Validation (OSV) to assess their performance under conditions closely resembling real operations.

These OSV campaigns introduce additional test cases, often requiring extended-duration tests to confirm system stability, reliability, and responsiveness over time.

A key challenge for MMEs is aligning their evolution with the distinct needs and timelines of both current and future programmes. These programmes often have conflicting priorities, making it difficult to coordinate resources effectively. At EUMETSAT, sharing the MME validation (VAL) environment presents a particular challenge, as the validation of a future programme could be disrupted by ongoing testing of individual MME components. To address this, some MMEs have introduced a dedicated integration, verification, and validation (IVV) environment specifically designed to support future programme integration. However, this solution introduces new complexities, as multiple missions now rely on a single IVV environment, increasing competition for resources and necessitating careful scheduling to prevent conflicts.

Data continuity: Ensuring data continuity during MME upgrades is essential for multiple operational and analytical needs, including key performance indicator (KPI) reporting, historical anomaly investigations, and long-term data preservation. If an upgrade involves changes in data sources or processing pipelines, duplicating datasets may be necessary to prevent data loss and maintain consistency. This duplication of data impacts power consumption, infrastructure, and overall costs, which must be carefully considered during project planning.

Keeping historical data becomes particularly challenging when MMEs have been supporting missions running for over a decade, while requiring to be upgrade for future programmes. Migrating or adapting the MME without disrupting access to this data requires careful planning, as losing historical records could impact operational decision-making and scientific research. Balancing the integration of new capabilities with the preservation of legacy data demands robust migration strategies, structured archival solutions, and compatibility mechanisms to ensure seamless access across different mission phases.

Resource availability: Migrating MMEs often occurs within tight resource constraints, particularly in terms of budget, time, and personnel. MME teams' main responsibility is to support current operations, and therefore finding sufficient resources to also support the migration process is a delicate balance. In addition, these migration activities require personnel from other MME teams such as infrastructure, network, storage, etc. which have also their own priorities.

Managing MME team priorities is a complex task, particularly when urgent issues arise in an operational mission while a testing campaign is needed for an upcoming launch. Allocating resources effectively becomes challenging, as operational support typically takes precedence to ensure mission continuity but on the other side, future programmes are also critical to the organisation's long-term success. Matching the right balance requires proactive planning, flexible resource allocation, and clear prioritisation strategies to ensure that both current operations and future missions receive the necessary attention without compromising overall objectives.

Training and knowledge transfer: Initially, MMEs present a steep learning curve, making it difficult to understand and troubleshoot anomalies. As these systems evolve, continuous training and knowledge transfer become essential to ensure that teams are well-equipped to operate and maintain them effectively. Migrating MMEs requires a structured training approach, as operators and engineers must adapt to new tools, technologies, and procedures. This challenge is even more pronounced when transitioning from legacy systems to modern solutions, where differences in workflows and interfaces can lead to inefficiencies if not properly addressed through comprehensive training programs.

On the positive side, training programs for a new MME often serve as a "delta" or refresher course, focusing primarily on the differences and improvements compared to the previous version. This comparative approach simplifies the learning process for teams, allowing them to quickly adapt to the new system by building on their existing knowledge rather than starting from scratch.

6. Lessons learned and approach to MME upgrades – What did we learn from past migrations?

The initial approach to migrating MMEs closely aligns with standard system engineering methodologies (such as following the V-model), such as those outlined by INCOSE [2]. However, deploying MMEs within operational contexts is more complex and lacks clear-cut guidelines, as it depends on the specific nature of the MME and the characteristics of the missions involved, such as their phase, size, and other unique factors. Each deployment requires a tailored approach to address these variables effectively.

The following sections will outline the recommended approaches implemented at EUMETSAT, supported by a practical example: the upgrade of the Monitoring and Supporting Infrastructure Facility (MASIF). MASIF is itself considered an MME as it is not part of any one mission but centralised to them, and it was upgraded from second (2G) to third generation (3G) in December 2023. MASIF provides the hardware, COTS, network and storage for the applications that complete the Mission Performance Toolset.

The V-model: Our ally or adversary? At EUMETSAT, the usage of sequential methods for delivering systems is widely extended, with the V-Model being a preferred framework for system development and integration (see Figure 5). The strengths of these methods are predictability, stability, repeatability and high assurance [2], especially important for MMEs interfacing multiple systems. This structured approach ensures that each phase of the migration process is carefully planned and executed, with clear validation and verification steps at each stage as well as produced documentation.

However, this framework should not be treated as a rigid set of rules. In certain cases, incorporating iteration and recursion has proven beneficial. For this reason, the following aspects should also be considered:

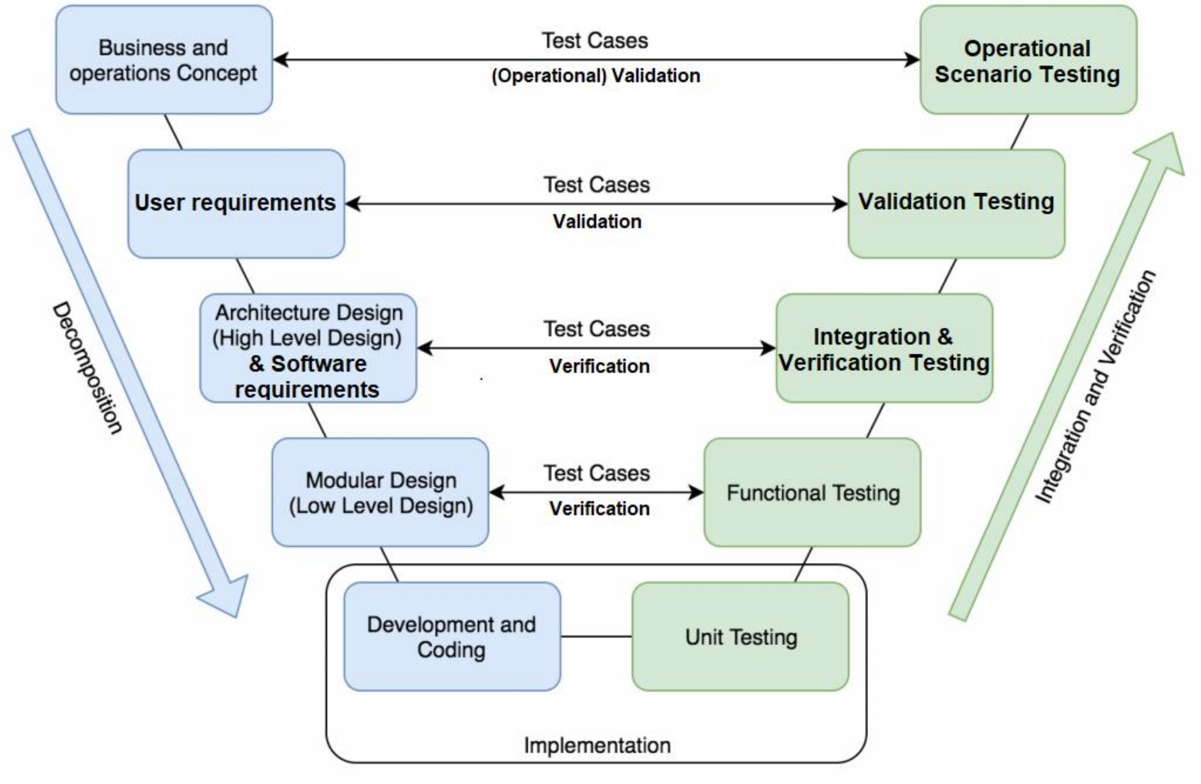


Figure 5: V-model representation, commonly followed at EUMETSAT during MME migrations

- **The V-Model is just a framework for structuring the required work.** It is intended to help guide people on what to do, how to divide and coordinate work and how to ensure effective communication. Adapting this to the nature of the MME is key for success.

- **Adding iteration and recursion to certain stages could be beneficial.** While this might seem incompatible with a sequential method, adding iterations by performing verification or validation campaigns incrementally (i.e. in “delta” phases) or combining verification and validation within the same campaign could be highly efficient. It could help distribute work and accommodate different deliveries of software or hardware, resources availabilities, etc.

  For the MASIF 3G migration, this iterative approach was followed, as shown in Figure 6. Since verification and validation were carried out by separate teams within the same organisation, phasing these activities provided greater flexibility. Additionally, adopting an incremental implementation strategy allowed the team to break the upgrade into smaller, manageable phases, continuously assess system performance, and make necessary adjustments throughout the process (first validation of GEMS, then SMART and finally together). This approach facilitated ongoing improvements and ensured that potential issues were identified and addressed early, contributing to the overall success of the migration.

- **Keep documentation to the necessary levels.** Both systems engineering [2] and project management frameworks such as PRINCE2 [5], recommend a long list of documentation to be generated after each milestone. Combining certain type of reports (e.g. Test, RoD and Analysis reports into a unique one) and evaluating which reports are strictly relevant to the project might liberate valuable resources.

- **Consider performing offline or light-version milestones**. EUMETSAT often implements lightweight or offline milestones (such as ORRs) when there are multiple planned, sequential, or incremental sub-releases following a full or light milestone. This streamlined approach could accelerate the release process while ensuring operational quality.

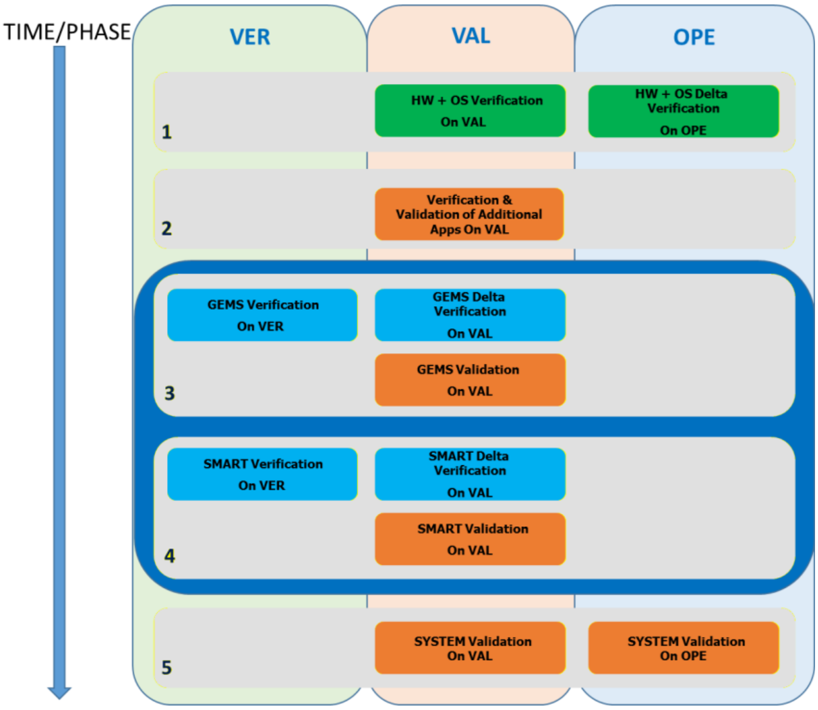


Figure 6: Phased Approach for MASIF 3G IVV

Usage of environments: Migrating MMEs involves transitioning between various environments, including development, verification, validation and operations. In a multi-mission context, these environments must accommodate the distinct needs of each mission while maintaining consistency across shared infrastructure and data management systems. Supporting future programmes during MME upgrades poses additional challenges, particularly when verification campaigns run concurrently. EUMETSAT mitigates this by structuring environments into Operational (OPE), Validation (VAL), Verification (VER) and Integration, Verification & Validation (IVV), being the latter dedicated to the integration of MMEs with future programmes and isolating it from current missions.

However, when a completely new MME is delivered, as a minimum a dedicated VAL and OPE is needed in parallel with the legacy environments. While this approach provides greater flexibility for upgrading each environment, it also introduces additional challenges, such as ensuring data continuity, increased maintenance efforts, and higher costs. The environments commonly used during MME migrations are:

- **Verification Environment (VER)**
    - Used to gain confidence that a software release runs correctly.
    - Executes a selected subset of verification tests, as it does not closely resemble the target environments.
- **Validation Environment (VAL)**
    - Primary environment for testing, closely resembling the operational (OPE) environment.
    - Supports full functionality and comprehensive testing to declare the system operational.
- **Operational Environment (OPE)**
    - The final environment where the system is deployed for real operations.
    - Hardware and OS are tested here as part of the preparation phase.
- **Integration, Verification & Validation Environment (IVV)**
    - Replication of OPE used for integration with future programmes
    - Decoupled from ongoing operations, it provides a stable space for testing and validation before deployment

For the upgrade of MASIF to its third generation, additional environments were required alongside the existing VAL-legacy and OPE-legacy environments, which continued to support ongoing missions. The new environments introduced were:

- **VER Environment** - Dedicated to the verification of MASIF third-generation tools.
- **VAL Environment** - Dedicated to the validation of MASIF third-generation tools.
- **OPE Environment** - Designed to replicate the OPE-legacy environment for comparison and transition purposes.
- **IVV Environment** - Established as an independent platform for future programs, ensuring separation from MME validation activities.

These new environments enabled a structured and phased approach to validation, minimising risks while ensuring compatibility with both existing and upcoming operational needs.

Prioritise data continuity: Ensuring data continuity is critical to maintaining mission operations, historical analysis, and KPI reporting. To achieve this, incoming data streams are typically duplicated, feeding both the legacy and new systems in parallel. This ensures that the new environment receives the same inputs as the operational one, allowing it to be fully realistic, support seamless historical reporting and prevent data loss.

Finally, it is also crucial for both systems (MME legacy and MME upgrade) to receive identical inputs to allow comparison of their outputs. This comparison serves as a validation check, ensuring the new system does not introduce regression issues. By aligning the data streams, discrepancies can be identified early, confirming the new system's accuracy and reliability.

Validation tests: Testing MMEs before their deployment into operations is essential to ensure their reliability, stability, and seamless integration. Comprehensive validation testing must cover the following areas to guarantee a successful rollout into operational environments:

- **Testing Documentation and Procedures**: Ensure all operational workflows are accurately captured and followed, validating the effectiveness of the documentation and procedures.
- **Component-Level Testing**: Validate the functionality of individual components (e.g. specific tools and scripts running as part of the MME) to ensure each part performs correctly in isolation.
- **System-Level Testing (end-to-end)**: Perform tests to validate the integration of components and ensure smooth overall system operations.
- **Operational Scenario Validation (OSV)**: Simulate real-world conditions to ensure the system's ability to perform under operational scenarios.
- **Long-Term Soak Tests**: Run the system for extended periods (e.g., one month) and under stressed conditions to analyse stability and performance over time.
- **Contingency Scenarios (such as Load Test)**: Test the system's response to unexpected failures or anomalies to ensure it can handle stress and unforeseen situations.

In many cases, teams focus their efforts solely on the component and system-level testing, neglecting to simulate operational scenarios. This approach can lead to undetected issues that may only surface later, potentially causing delays or disruptions when the system is deployed in a real-world environment.

Forecast and estimation of resources availability: Accurate forecasting of the resources required for the verification and validation process, as well as during the migration day, is essential to ensure timely completion of tasks. However, it is equally important to consider the operational workload of the teams involved, which often includes ongoing activities such as satellite launches, software upgrades, and routine operational tasks. Failure to account for these concurrent responsibilities can lead to resource conflicts, delays, and priority shifts that affect the overall migration schedule. In addition to resource constraints, the introduction of new technologies requires a considerable investment in training and familiarisation. This results in a temporary slowdown as teams had to learn and adapt to unfamiliar tools and processes.

For instance, during the MASIF 3G migration, the parallel validation of both legacy and new software versions put considerable strain on available resources, thereby increasing the risk of operational disruptions. Both software versions were not fully compatible, which led to branching and made comparison of results even more difficult. Additionally, the team had to integrate comprehensive training and allocate adequate time in the migration plan for knowledge transfer, ensuring all stakeholders were equipped to operate effectively.

Tracking of anomalies and changes: Tracking anomalies and system changes is essential, particularly in the final stages leading up to migration day. During this phase, it is crucial to assess and communicate current anomalies and system limitations to the operators before they receive the new MME, as well as to minimise changes to the system. On the other hand, anomalies found in legacy systems must also be addressed in the new system, leading to further branching and making the work more complex for both operators and maintenance teams.

A key component of this process is the use of a tool to track anomalies and system changes, followed by the maintenance of a comprehensive Verification Control Document (VCD). The VCD links all requirements to corresponding test cases, ensuring complete traceability and coverage. It serves as an invaluable tool for validating the system against predefined criteria, confirming that all requirements have been fully addressed.

For instance, during the MASIF 3G migration, the initial attempt was only partially successful and had to be split into two phases. The reason: a late change that was assumed to have no impact unexpectedly affected an external dataflow, requiring the second phase to resolve the issue.

Constant / Dynamic planning and coordination: Effective migration requires continuous, proactive coordination among all stakeholders, including mission planners, facility engineers, IT specialists, and end users. Common mistakes in migration planning include failing to involve other teams early in the process, leading to gaps in understanding and missed requirements. Additionally, neglecting to account for critical / freeze periods - when certain system components cannot be modified or tested - or other MME milestones can disrupt the migration timeline and create unnecessary conflicts.

For example, during the planning of the MASIF 3G migration, it was discovered that another major mission upgrade, which interfaced with MASIF and held significant priority within the organisation, was scheduled just two days after. After a thorough assessment, the decision was made to delay the MASIF 3G migration by an additional two weeks. This adjustment ensured the successful completion of the other upgrade first, minimising the risk of potential complications arising from simultaneous migrations.

Definition of a migration strategy: Developing an effective migration strategy is crucial to minimise risks and ensure the seamless integration of new technologies. The choice of migration approach, whether through multiple days, phases, or a big bang, depends on the system's complexity, number of interfaces, and operational requirements. A gradual, phased migration is often the most effective approach, as it allows system components to be migrated incrementally, maintaining operational integrity.

The creation of a document defining the migration plan, as well as the contingency plan to address potential issues during the migration process, is critical. This document shall also reflect lessons learned from previous projects to understand common challenges and avoid potential pitfalls and be reviewed by relevant teams.

As an example, the MASIF 3G migration was planned in four phases:

1. **Pre-Operational Handover:** Duplicate incoming traffic from legacy to new system.
2. **Operational Handover (migration day):** Synchronise databases and migrate all operational monitoring and external data flows from legacy to new system.
3. **Post-Operational Handover:** Migrate internal data flows from legacy to new system.
4. **Decommission legacy** hardware and software.

Each phase was designed with the objectives of validating the process using VAL environment and ensuring that no operational data outages occurred by utilising dual data flows to both legacy and new system.

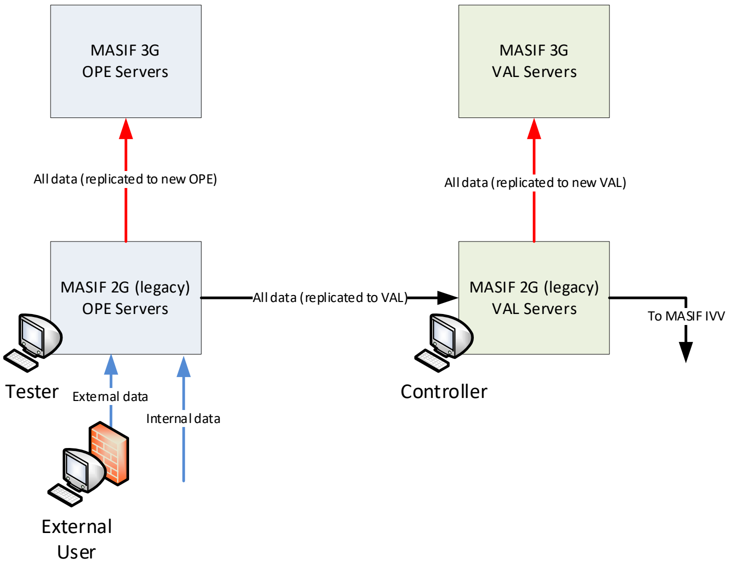


Figure 7: MASIF 3G before migration (simplified)

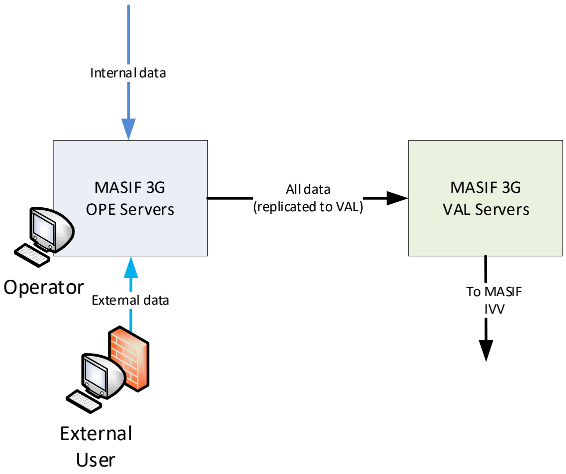


Figure 8: MASIF 3G after migration (simplified)

Definition of a rollback strategy: Creating a rollback plan is essential but challenging due to complex interdependencies between systems. A rollback may not always be feasible if other elements have already adapted to the changes, so the migration plan must clearly define either how to revert safely or how to mitigate issues if rollback is not possible. This could involve backup systems, temporary parallel operations, or other strategies. Ultimately, this plan is aimed at reducing risk, ensuring operational continuity, and building stakeholder confidence during the migration process.

Prerequisites for migration: The actual migration into operations should only commence when certain conditions are met, as agreed by the different teams. These conditions are normally:

1. **ORR Completion:** A successful ORR (or similar milestone, either Full, Light or off-line) has been completed, and the operational migration has been endorsed by the different teams (including upper management, when required).
2. **Post-ORR Actions:** Any actions identified in the ORR for completion before migration have been addressed.
3. **Pre-Migration Activities:** All activities identified in the operations schedule are completed, including:
    - Addition of migration steps to the schedule, agreed with the freeze board.
    - Synchronisation of legacy and new environments and sanity checks.
    - User awareness training provided.
4. **No Major Anomalies:** No major or blocking anomalies have occurred since the last milestone or test campaign, that could affect the system and remain unresolved.
5. **Operational Migration Planning:** The operational migration is planned and scheduled, with risks communicated to users.
6. **Security Compliance:** A thorough security audit or testing has been executed, ensuring it meets all security requirements and vulnerabilities are addressed.

7. Conclusions

Migrating and evolving MMEs is an inherently complex and dynamic process that requires careful planning, stakeholder collaboration, and continuous adaptation to new technologies and mission requirements. The use of MMEs at EUMETSAT has proven to be a robust approach, enabling the efficient consolidation of various mission components while maintaining flexibility and scalability across multiple operational domains. However, even systems that perform well must evolve to accommodate the increasing demands of both current and future missions.

The key challenges in migrating MME include managing system complexity, ensuring the continuity of data and operations, and planning obsolescence, resources and new requirement with sufficient time. These challenges require a balanced approach that considers technological advancements, future mission needs, and the evolving landscape of space operations. Moreover, the migration process must be underpinned by strong testing, validation, and training strategies to ensure that new systems can be effectively integrated without disrupting ongoing operations.

Ultimately, the goal of migration and system evolution is to future-proof MMEs by adopting new technologies, refining existing processes, and ensuring that operational systems are adaptable to meet the demands of both today and tomorrow’s space missions. To ensure long-term efficiency and sustainability, it is also essential to maintain a stable and well-defined set of MME functionalities. Going forward, EUMETSAT aims to evolve the ground segments towards a multi-mission approach, focusing on the development of a common MME core, in line with EUMETSAT’s strategy for harmonisation, maintainability, and operational efficiency.

By embracing a proactive approach to system migration and change, organisations like EUMETSAT can continue to deliver reliable, scalable, and efficient solutions that support the growing complexity of space operations and mission portfolios.

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