

Towards Service based Operations

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Abstract

The Control Ground Segments at ESOC are designed using a common architecture and similar implementation across various systems. Standardized ground-to-space interfaces and mission operations services have enabled this harmonized design. However, adequate harmonization in system management processes and common operations, such as ‘pass operations,’ still needs to be achieved. The discrepancy is being addressed by the European Ground Operation Systems Multi-mission Generation (EGOS-MG) project which aims to improve the efficiency of Control Ground Segments through a service-based approach. This approach leverages the commonality of systems and economies of scale, moving away from a ‘mission-centric’ lifecycle to a ‘service-based’ method. The project aims to provide multi-mission services that offer end-to-end support, encompassing IT infrastructure, end-user applications, and the full functional scope of the Control Ground Segment.

The goal of the ‘Service-based Control Ground Segment’ is to separate as much as possible the processes governing common ground system elements with those related to the missions they support while also allowing integration with mission specific processes. Instead of dedicated ground segments for individual missions, an ‘enterprise-level’ process manages environments where missions are supported through shared products and services. This setup minimizes the effort required to establish and manage the Control Ground Segment for individual missions. Shared services managing ground systems enable further harmonization at the mission operations level. This involves abstracting typical operations-level interactions with the space segment and defining common operations services for all missions. A notable example is the support of a fully automated ‘file-based’ approach for generating, uploading, activating, and tracking on-board schedule increments produced by the mission planning service.

Overall, the EGOS-MG Project seeks to streamline the setup and management of Control Ground Segments, providing enhanced efficiency, harmonization, and common monitoring and control services for various missions.

Keywords: Mission data systems, multi-mission infrastructure, multi-mission services

Acronyms/Abbreviations

AIV	Assembly, Integration and Validation
DEV	Development
DevSecOps	Development, Security, and Operations
ESOC	European Space Operations Centre
EGOS	ESA Ground Operation System
EGOS-MG	EGOS Multi-mission Generation
ETE	End-To-End
IT	Information Technology
MCS	Mission Control System
OCC	Operations Control Centre
TCO	Total Cost of Ownership

1. Introduction

Ground data systems have been traditionally developed at ESOC based on an approach which maximises the re-use of common implementations across missions. Many of the ground data systems currently serving the various on-going missions are based on generic/tailorable applications which are referred to as ‘ground data systems infrastructure’. However, even fully generic applications are integrated in the mission ground segment following a completely independent lifecycle, which is thus repeated for every mission, and relying on a mission dedicated deployment (dedicated computing resources, dedicated deployments, dedicated validation and support teams). This approach does not enable a full exploitation of the potential benefits associated to the vast commonality achieved across missions’ control ground segments and operational concepts in the past decades.

On the technology side, cloud computing and the “Software as a Service” paradigm has gained popularity in recent years. Instead of dedicated deployments, software and computing resources are provided through centrally hosted services. Services can be purchased and licensed by customers with the minimum necessary hardware and software infrastructure, which is provided by the service providers. Also, on the side of automating the relevant processes (generally referred to as DevSecOps), significant progress has been made in recent years. The adoption of the Software as a Service paradigm will also involve the modernization and optimization of the complete engineering lifecycle, from applications development up to operational deployment.

The above is being addressed by the European Ground Operation Systems Multi-mission Generation (EGOS-MG) project which aims to improve the efficiency of Control Ground Segments through a service-based approach built around three main aspects; 1) shared environments and application products; 2) common processes and 3) organisational governance focused on service delivery. Operational users are systematically involved in the project through various forums to support the definition of the multi-mission environments, applications, governance and processes.

1.1 Objectives

The main targets of the EGOS-MG project include:

- Drastically reduce the time and effort involved in the ground segment engineering, integration and validation and enable to focus the available resources on the mission specific operations preparation and validation tasks;
- Promote a cultural change to move away from 'mission dedicated' thinking into scalable and expandable solutions, first proven end-to-end for a mission and then adopted by other missions ‘as deployed’ with minimal adaptation;
- Rationalise the various systems and system versions currently in use to enable a significant reduction of the operating and running costs related to ground data systems;
- Enable a further harmonisation of the ground systems operations executed in support to mission operations.

Following a system level analysis, the project targets listed above have been translated into and complemented by concrete technical, managerial and strategic objectives:

- Enable a reduction of the running and operating costs of mission ground segments by means of convergence and automation of the development, integration and validation environments and consolidation of the related activities;
- Reduce the efforts involved in maintaining expertise of strategic value by concentrating it in the provision of domain-specific multi-mission services and relevant teams;
- Enable the possibility to outsource the provision of the multi-mission Services, thus opening the door to direct service charge by industrial partners;
- Enable and promote the migration to the new infrastructure and adoption of multi-mission Services of flying missions/programs which are considered as 'long-lasting';
- Enable the rapid set-up of operations ready ground segments, thus potentially enabling support of customers imposing a very compressed preparation period, such as low-cost missions;

- Enable a simple, transparent and fair cost model towards the mission programs;
- Maximise the efficient adoption of computer resources modern capabilities, in particular by adopting consolidated solutions based on off-the-shelf proven architectures (e.g. cloud computing, storage clusters);
- Enable a drastic reduction in time and effort to develop and operationally deploy ancillary applications, complementing the core systems, based on newest technologies and supporting innovative concepts;
- Promote the capability to aggregate all operational data in consolidated repositories which are accessible for reporting, diagnosis and analysis purposes;
- Simplify the implementation of the applicable security rules and regulations, by ensuring that all operational systems adopt a consistent and timely synchronized approach;
- Increase the reliability of operational systems, by enabling a direct benefit of one mission's activities (e.g. validation) to the other missions;
- Enable more rigorous but less onerous management of architectural, technological and configuration baselines;
- Enable the definition and support of common 'operations services' complementing the monitoring and control services provided by PUS-based spacecraft in order to enable a fully harmonised approach to mission operations across all missions;
- Enable efficient and secure support of distributed operations.

2. The Target Multi-Mission Environment

2.1 Target scope

Figure 1 below shows the context and target scope of the multi-mission initiative described in this paper.

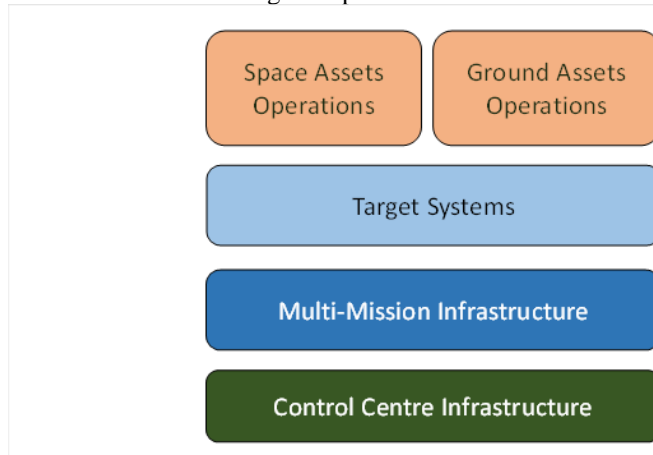


Figure 1. Target scope of the Multi-Mission Project

The elements highlighted in blue (i.e. Target Systems and multi-mission Infrastructure) are currently supported by means of mission dedicated solutions. The multi-mission program aims at setting-up, deploying and supporting solutions which maximise the shared elements across all missions operated at ESOC. The multi-mission infrastructure will include all elements commonly required by ground data systems to support their development, deployment and operational utilisation. It will initially consist of:

- Common environments: these represent 'logical grouping' of computing resources, tools, applications and associated processes supporting a coherent set of functions serving multiple target systems. Several distinct Common environments are expected to be set-up in order to support the various phases of the ground systems (e.g. development, preparation, validation, operation);
- Common processes and 'automated pipelines' (usually referred to as DevSecOps): these are a set of practices that cover all engineering and operations support tasks, ranging from specification and modelling up to systems deployment and run-time management. These practices are going to be automated as much as possible in order to shorten the systems development life cycle and provide continuous delivery with high software quality;

- Common stores: these are consolidated data storage solutions enabling the centralised provision at run-time of data management services to multiple instances of target systems. Ground systems supporting missions are data-centric, common stores thus provide the back-bone infrastructure to manage data at run-time;
- Common run-time services: these are functions and associated processes which are provided at run-time by a single software application to multiple target systems.

The various elements of the multi-mission infrastructure are deployed and supported in the various environments as necessary for the relevant stage of the Target systems lifecycle (namely, development, integration, validation and operations). Fundamentally two types of Target systems will be supported:

- Multi-mission applications: these are target systems which are customised, deployed and managed in the operational environment to support multiple missions;
- Mission systems: these are also target systems which are developed and deployed by configuration and if required extending generic applications and by making use of the multi-mission infrastructure. However, they are customised and managed to serve an individual mission.

2.2 Target services

Another important ambition of the multi-mission program is to redesign the landscape of the support services provided to the missions around ground data systems. The following Figure 2 provides an overview of the intended target service model. Services which are set-up and eventually provided by the multi-mission initiative are highlighted in blue, whereby the ones which are going to be consumed by the various elements constituting the ground systems supporting missions are highlighted in green.

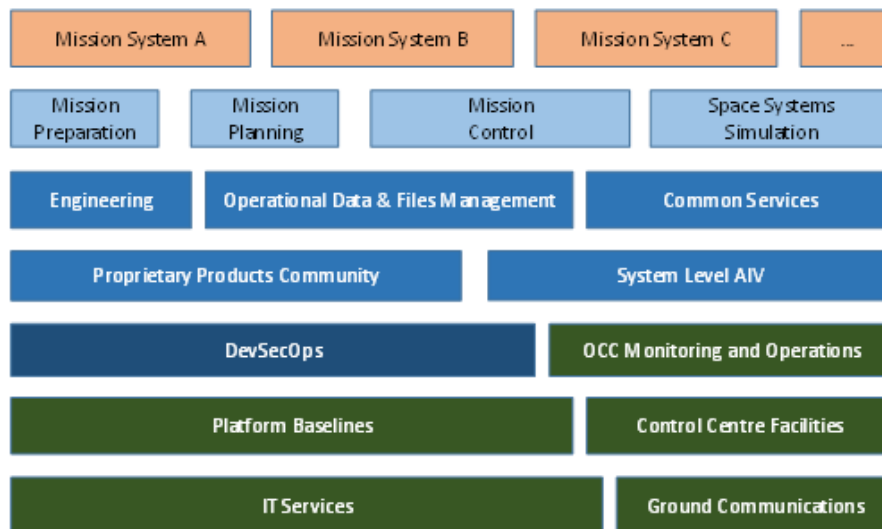


Figure 2. Overview of the Support Services related to the Multi-Mission program

The main driver in the definition of the Services landscape depicted above is the objective to cover all elements which are designed to support multiple targets (e.g. generic applications) by means of end-to-end services to be uniformly consumed within the applicability scope of the relevant functions. In this respect, it is worth noting that the services highlighted in blue in the figure are currently provided by mission dedicated teams, thus imposing an inefficient duplication of efforts and dissemination of highly-specific expertise. These Services are now being rationalised to be set-up and eventually provided according to the following main principles:

- Multi-target: the Services will be provided to all teams managing other services and/or target systems relying on relevant functions and processes. This will allow to maximise synergies across target applications (e.g. missions);

- Functional focus: the Services will cover a well-confined functional domain, thus allowing highly-specialised expertise to be maintained, developed and made;
- End-to-end (E2E): the Services will be responsible for the full scope of activities related to the functional domain which they cover, in particular they will manage any software application which supports the provision of the relevant functions as well as any associated process;
- Accountability: because of the End-to-end principle, a clear agreement between the service consumers and the service providers can be put in place, thus ensuring full accountability of the relevant responsibilities.

3. Evolution

As introduced in the previous sections, the multi-mission project has clear objectives which have been converted into an explicit definition of the target multi-mission environment, both in technical as well as in managerial and governance related aspects. This section addresses the issue of identifying a suitable path to achieve the defined target starting from the current approach to develop ground data systems at ESOC.

3.2 System Evolution

The current generation of ground data systems are deployed and managed using dedicated resources. This approach applies to all types of resources, even part of the computing resources are still procured and deployed to serve each individual target system. Clearly this approach does not enable any benefit of the modern technologies supporting the deployment over shared resources and in the long term leads to an undesirable accumulation of baselines to be supported. The system architectures are expected to progressively evolve such to enable the usage of truly shared resources, starting from the low level provision of computing resources up to the application level provision of the necessary functions to support the full lifecycle of mission operations, from preparation up to execution and evaluation. Figure 5 below provides an overview of this evolution direction.

The overall goal of EGOS-MG is to significantly lower the effort required to set up and operate a mission's ground segment and data systems. It covers a wide and complete functional scope of ground segment application services, including mission monitoring and control, planning, preparation, simulation and data analysis and dissemination, as well as the supporting shared Development, AIV and Operations Environments and common multi-mission and IT services. This scope is summarised in the following figure.

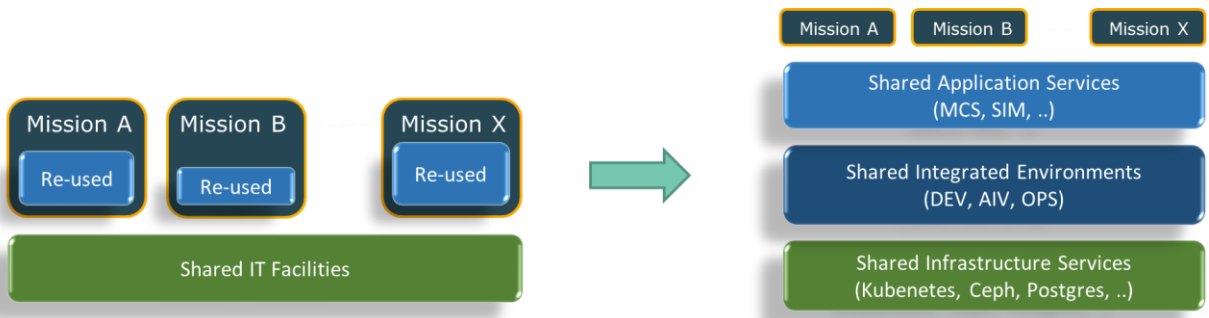


Figure 3. From Dedicated towards Shared Resources

The Common environments provided by the multi-mission program will be based on consolidated solutions providing the necessary computing resources (Infrastructure as a Service) and be complemented by common stores and software services (Platform as a Service) which enable an efficient development and deployment of potentially shared end-user applications (Software as a Service).

The shared IT Infrastructure is provided to the shared environments and includes IT services for container orchestration (i.e. Kubernetes), event streaming (i.e. Kafka), file, object and database storage services (i.e. Ceph, Postgres). These services are provided on premise at ESOC but are based on services commonly provided by public cloud providers. This will allow future utilisation of public cloud providers. The integrated environments support the full life cycle of an application, including;

- Development (DEV) environment, consisting of a coherent collection of tools collaborating together to support the software engineering processes for all EGOS-MG software and target systems;
- Assembly, Integration and Validation (AIV) environment, consisting of a fully representative assembly of ground data systems supporting integration and validation at various levels;
- Operations (OPS) environment, where EGOS-MG target systems are hosted to support the preparation, planning and execution of mission operations and the provision of data access and data analysis services to mission users.

Several legacy ground segment application services are being adapted and integrated with the environments. These include mission preparation, planning, control, simulation and data applications. These are full multi-mission application services or are extended based on a multi-mission core with mission specific extensions when required. The goal is to minimise the mission specific developments to an absolute minimum and ideally only require the configuration and tailoring of application services to adapt to mission needs.

3.2 Process Evolution

The current generation of ground data systems are developed based on generic implementations which are re-used wherever relevant. However, the lifecycle of the re-used code is entirely governed by means of processes entirely defined and managed in the context of the target application. More explicitly, any process and activity, which is necessary to bring the re-used code into a running application supporting the end users, is defined and implemented by dedicated teams and then repeated in the specific context of each mission. The multi-mission program enables and promote the definition and adoption of common DevSecOps processes to manage the re-used artefacts in the various target contexts. The driving principle is that re-used artefacts are to be managed in the same way and commonly, rather than individually. Figure 4 below provides an overview of this evolution direction.

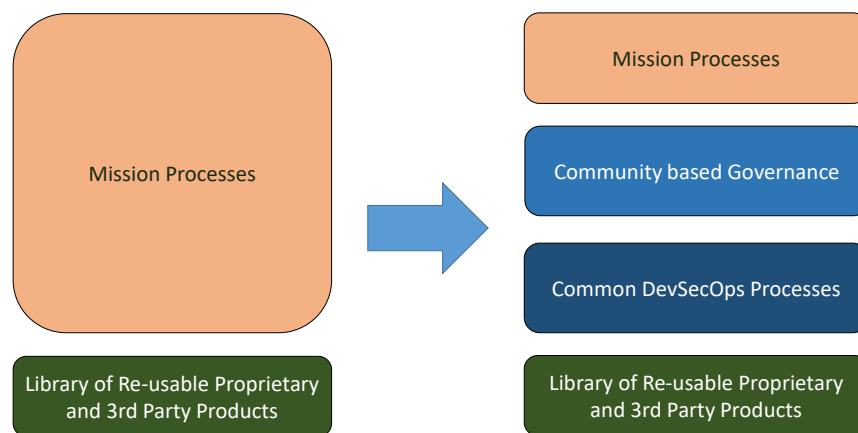


Figure 1. From Generic Software towards Common Processes

The multi-mission program will contribute to the required evolution of the ground data systems management approach by defining and supporting common processes covering all system management activities, from code development, verification and validation, up to operational deployment and support. Key DevSecOps principles include;

- Automation: Repetitive security checks are automated to ensure consistency and speed.
- Collaboration: Developers, security teams, and operations work together closely.
- Early Integration: Security is not an afterthought but part of every step.
- Continuous Monitoring: Systems are constantly observed for threats and compliance.

The various target applications will form a community following agreed governance rules and implementing DevSecOps processes aiming at ensuring cross-fertilisation and mutual benefit in the utilisation, maintenance and operations of the re-used generic products.

3.3 Organisational Evolution

As already introduced in the previous sections, an essential aspect of the required evolution towards multi-mission is the set-up and the provision to all relevant target applications of end-to-end services covering a given functional domain. It should be noted that the functional scope of end-user applications is not affected by this organisational evolution, only the managerial approach to manage the relevant software implementations. The following figure provides an overview of this evolution direction.

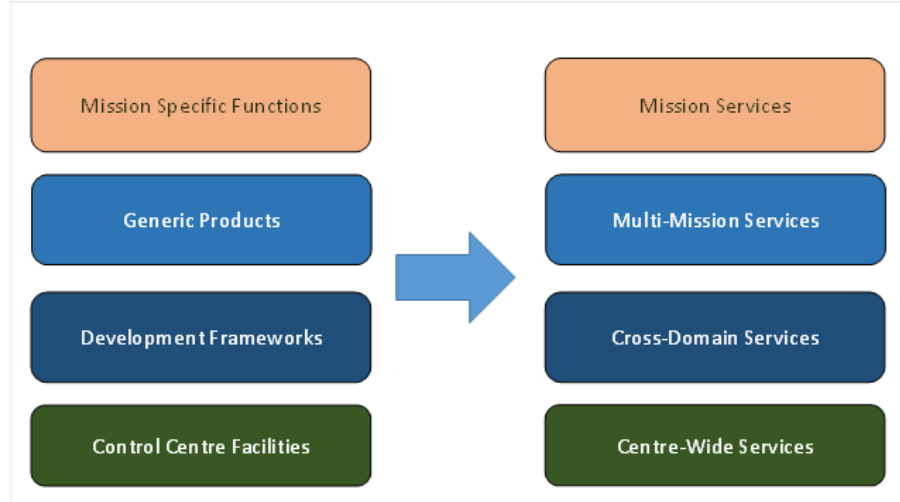


Figure 5. From Functions and Processes towards E2E Services

The multi-mission program will set-up the Support services highlighted in blue and promote a more consistent adoption of lower level services (e.g. IT Services) by the target missions. An important aspect characterising the end-to-end services depicted above is their scope. The various envisaged levels are briefly described next:

- Centre-wide: these are services which are consumed by all teams managing hardware and software based systems in the centre (e.g. IT services or Control Centre Facilities management);
- Cross-domain: these are services which are consumed by all teams managing software based data systems in the centre (e.g. Software Development or AIV services);
- Multi-mission: these are services which are consumed by all teams managing systems supporting missions (e.g. Mission Control or Mission Planning services);
- Target mission: these are services which are dedicated to the management of individual mission system (e.g. JUICE mission MCS service).

4. Programmatic Aspects

4.1 Cost model

One of the main targets of the multi-mission program is to enable and eventually achieve a significant reduction of the costs related to the set-up and operations of mission data systems. A qualitative cost model has been put in place to support the strategic decisions to be taken in this project.

The following Figure 6 below shows the estimated Total Cost of Ownership (TCO) to support an increasing number of missions according to various possible approaches, namely:

- Mission specific: each mission data system is developed on the basis of specific solutions, following a completely mission dedicated lifecycle and governance paradigm;
- Generic products: mission data systems are developed on the top of generic solutions but are managed according to mission specific processes and using mission dedicated resources (this is the current approach at ESOC);
- Multi-mission services: the needs of missions are satisfied by means of support services and resources which are shared across all relevant target applications (this is the target approach of the multi-mission program described in this paper).

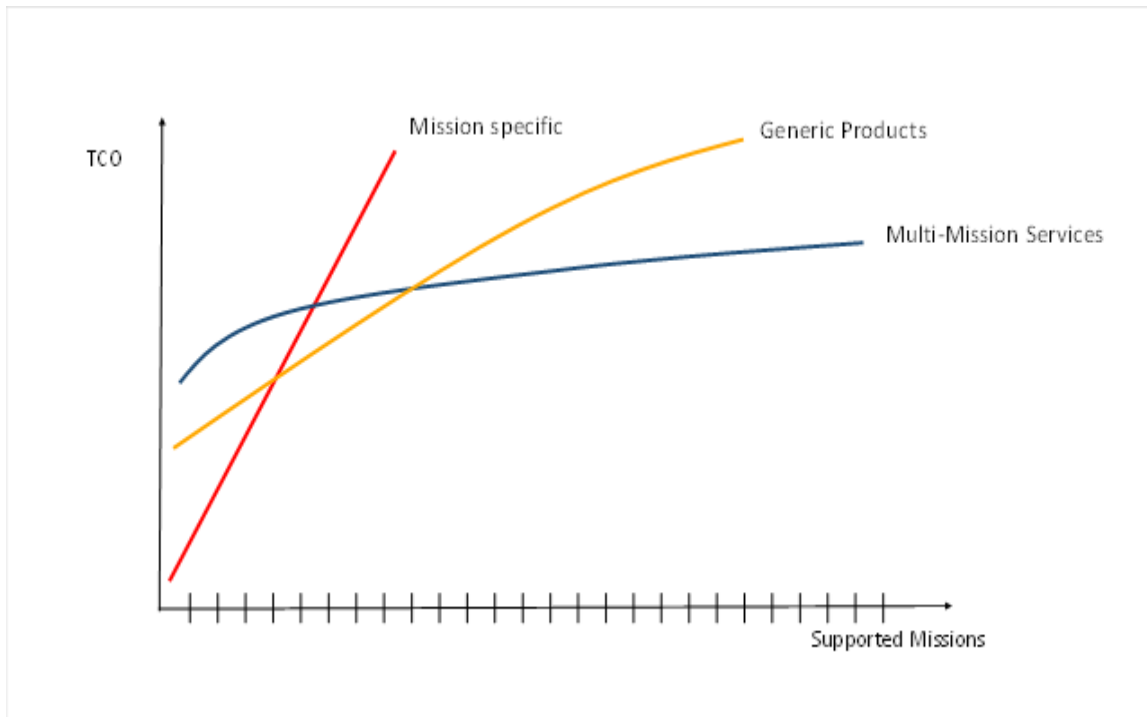


Figure 6. Total Cost of Ownership of Mission Systems

Entirely mission specific solutions lead to a linear TCO increase with the number of supported missions. The current approach requires a significant upfront investment and running costs (to develop and manage the generic products) but has the benefit of significantly reducing the development costs of mission data systems. However, the costs associated to other related processes (such as integration, validation and maintenance/support) can only really be reduced by further exploiting the potential synergies across missions in the system management activities. The multi-mission services based approach only starts to become cost-effective once a sufficient number of missions have adopted it. However, the multi-mission service model offers increasing economies of scale as the number of missions increase. An expected large increase in the number of missions to be supported at ESOC in the coming years is therefore a major driver in evolving to a multi-mission service model to minimise overall costs.

4.2 Mission Adoption

The biggest challenge to be addressed by the multi-mission program is its acceptance by the mission programs. A major cultural change is required to shift the focus of the individual programs from 'my mission' to 'our assets'. There has always been reluctance in accepting the delegation of any control of critical activities (such as systems integration and validation activities) to entities only indirectly responding to the individual programs. In order to attract the necessary trust of the target applications and also to ensure adequate quality of its deliverables, the principle of 'Pilot missions' is being systematically adopted in the multi-mission program as well as in the following provision of the multi-mission services. A Pilot mission is used as the reference target and takes the responsibility of ensuring adequacy of all multi-mission artefacts on behalf of the complete missions' community. This ensures that the relevant expertise of missions' experts is involved wherever necessary and avoids unnecessary duplication of efforts in repeating the

same tasks for each individual mission. Clearly, such an approach is only viable if the relevant engineering processes are designed and implemented in a way which is considered sufficiently representatives of all target mission categories, and which can be (automatically) repeated in the specific contexts of the individual missions.

The pilot missions selected for the multi-mission program are the Sentinel-5 Precursor (S5P) and SWARM missions. The work to integrate these missions into the multi-mission environment is currently in progress based on deployed DEV and OPS environments and the Mission Control and Simulation services. Qualification and security certification activities are underway in close cooperation with operational users and expected to be completed in 2025. The integration of the AIV environment and remaining application services with the pilot missions is expected to be completed by late 2026.

5. Conclusions

This paper has provided an overview of the main targets and evolution path of the multi-mission program at ESOC. This is an ambitious initiative aiming at shifting the focus of mission data systems management from the current 'mission-centric' approach towards an 'infrastructure-centric' approach [1]. From an end-user point of view the functional scope supported by the current generation of mission data systems will hardly be affected. However, a complete revolution of the way to implement the engineering activities leading to the development, integration, validation, deployment and support of operational applications will be put in place. The main evolutions directions of the existing approach to achieve the defined target have been defined and briefly described in this paper. End-to-end services holding the complete responsibility for a given functional domain will be set-up and eventually provided such to support multiple missions with shared resources. Significant benefits in terms of costs and time to deliver operational ground segments are expected to materialise once enough missions will have adopted the multi-mission infrastructure and associated services. These benefits justify the equally significant investments which are required to put in place the multi-mission infrastructure as well as to re-engineer the existing generic applications in order to be deployed and managed on the top of it. The initial deployments at ESOC of the DEV and OPS environments has been made and integration of two pilot missions with initial Mission Control and Simulation application services is in progress. Deployment of the pilot missions with the full scope of application services and multi-mission environments is expected by late 2026.

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