

MOSS-NG Applying Modern Ground Segment Engineering to ALTEC Mission in-Orbit Support Legacy System

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Abstract

ALTEC Mission Support Centre (MSC) and its Mission in-Orbit Support System (MOSS) has been supporting ASI since the beginning of the Agency's participation to the ISS project, initially with MPLM module (until July 2011) and, since march 2011, for PMM operations.

ALTEC MSC is equipped to support 24x7 operations and is connected, by exploiting ASI dedicated network asset, to NASA MCC-H at Houston.

In particular the ALTEC MSC is used for:

- daily Monitoring of PMM data for sustaining engineering through reception of real-time TM;
- reception of real-time Video from ISS;
- daily data assessment and trend analyses;
- real time support (upon NASA request) for PMM;
- general interaction with NASA and ISS International partner through a dedicated 48 channels voice-loop system;

In addition to that, since December 2021, ALTEC is also providing industrial support to ASI for the exploitation of the ISS resources (UTISS service). The ALTEC MSC is also used, in this context, to provide ASI P/L operations support capabilities, with proper interface with NASA MSFC in Huntsville, and dedicated environment deployed in a multi-mission architecture built over the year from the original MOSS system.

The ALTEC MOSS system and MSC environment had to face, over the years, the difficult challenge of continuous evolution, modernisation and improvement of the adopted technologies and engineering approaches in order to guarantee the highest standard and performances required for the major key aspects of the Ground System Engineering.

These aspects encompass automation mechanism, software and system maintainability, deployment technology and infrastructure and security.

The "initial" ALTEC MOSS had to undergo a major evolution over the years that has led to the definition of a new and modern "Next-Generation" Mission in-Orbit Support System (MOSS-NG), now fully operational.

This transition drastically changed and revolutionized the way ALTEC MSC ground systems are used, managed, monitored and deployed and significantly improved the automation in data management (retrieval, processing and archiving).

The set of evolution introduced includes:

- Major hardware upgrade of the underlying physical infrastructure hosting the MOSS virtualized services
- Full transition of underlying operating systems
- Deployment mechanism has transitioned from a "fully manual" system installation to an infrastructure as code approach. In this perspective a set of re-usable and easily customizable solutions, which can be used across different programs, project and environment has been developed.
- Dedicated CI/CD process has been put in place to allow easier ground segment system testing, configuration and control and final deployment in the operational environment.
- Usage of secure, rootless, container technologies deployment for specific application and data systems.
- Automation mechanism for data retrieval, processing and archiving has been improved over the years integrating ALTEC proprietary products, such as the ALTEC Space Data Processing (ASDP) framework.
- Security aspects has been revised and enforced thanks to infrastructure as a code approach, the creation and segregation of new perimeters and VLAN services, the general upgrade of the underlying OS systems and the introduction of additional security and monitoring services.

Keywords: mission control center, software engineering process, DevOps, network, security, virtual technologies.

Acronyms/Abbreviations

ALTEC	Aerospace Logistics Technology Engineering Company
EOL	End of Life
ISS	International Space Station
MOSS	MPLM On-Orbit Support Sub-System
MOSS-NG	MOSS Next Generation
MPLM	Multi-Purpose Logistics Module
PMM	Permanent Multipurpose Module
RHEL	Red Hat Enterprise Linux
VAMOS	Virtual ALTEC Mission Operation Service
VM	Virtual Machine

1. Introduction

The ALTEC MPLM On-Orbit Support Sub-System (MOSS) has been developed and activated since 2011 in order to support the Italian Space Agency since the beginning of the ASI participation to the ISS project (the MPLM module in until 2011 and PMM afterwards) [1].

At that time, the MOSS architecture was designed and based on a RHEL 4.X Operating System (at the time still supported) for technological constraints of the data systems and software installed.

Moreover, since December 2021, ALTEC is also providing industrial support to ASI for the exploitation of the ISS resources (UTISS service) and in this context, the need of supporting both PMM and UTISS activities, from the same mission control centre operational environment in a “multi-mission” context has become necessary.

MOSS was deployed on the existing Virtual ALTEC Mission Operation Service infrastructure (called VAMOS), the main infrastructure providing the hardware and essential virtualization capabilities serving the ALTEC Multi-Mission Control Centre room.

Although still functional, the need for proper upgrade had increased drastically over time, to face both the functional and technological evolution needs, as well as, threats and issues related to security aspects.

MOSS environment was designed and maintained using a traditional approach, with limited adoption of modern practices and tools capable of facilitate the integration of both development (Dev) and IT operations (Ops) teams by Ground Controllers and System Administrators.

Such modern practices have become, thanks to the technology evolutions over the years, essential to improve collaboration, automate processes, and accelerate software delivery and deployment

Moreover, the rejuvenation of the underlying ALTEC infrastructure (VAMOS), performed in 2023, has further facilitate and at the same time fed the need to drastically change the MOSS architecture toward a complete migration in both engineering approach adopted and a full technology upgrade, in order to continuously support PMM Sustaining Engineer activities during ISS lifespan over the future years.

All these consideration lead to the definition, implementation and realization of the new ALTEC Mission in-Orbit Support System “Next-Generation” solution (MOSS-NG).

However, the transition to the new System had to be performed without any outages on the existing operational environment, leading to an additional complexity in order to guarantee operational continuity but prepare (and test) the new environment and solution in parallel.

2. Design principles and constraints

MOSS-NG evolution in term of design and architecture definition has been based on a set of specific principles and constraints:

- ***New Underlying Infrastructure Environment:*** the MOSS-NG architecture and service organization has to be designed taking into account the underlying upgrade of ALTEC on-premises deployment infrastructure (VAMOS). Such infrastructure is characterized by:
 - From a physical perspective, 3 physically segregated clusters, each one of them reserved for a different functional perimeter.

- From a network perspective, two dedicated firewall clusters regulate all the traffics within the infrastructure with standardize policies to be complied with in order to ensure security requirements. In particular the VAMOS internal firewall manages the high security environment communication, while the VAMOS external firewall manages all the other connectivity towards environment considered less secure.
- From a virtualization perspective, the infrastructure provides a virtualization layer capable to deploy and manage the necessary VMs (as well as and Backup Policies) to ensure consistency and reliability of the general applications and environment.

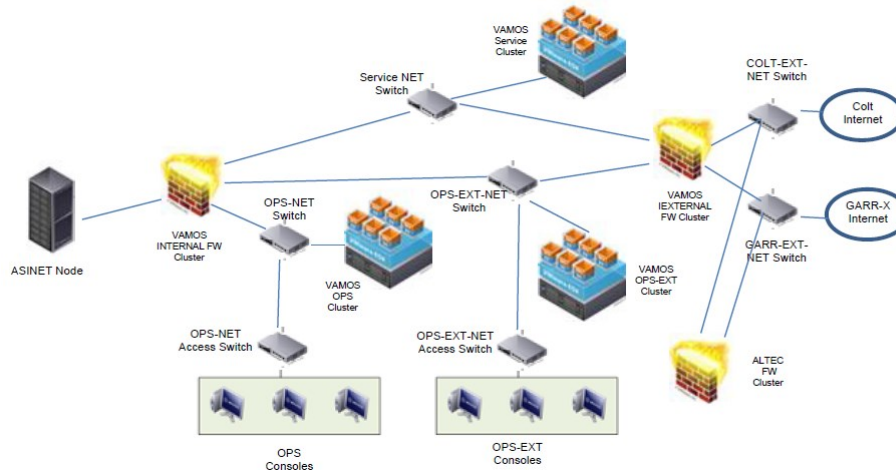
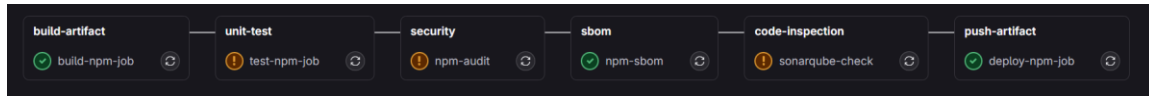


Fig. 1. ALTEC VAMOS Physical Infrastructure

According to the upgraded deployment infrastructure, new VLANs has to be defined allocating properly the services in the proper perimeter. This activities has also be useful and has been taken as the opportunity to thoroughly revise, clean-up and optimize all the internal traffic matrices and data flows, enabling a full refresh and improvement of all the traffic matrices and flows permitted in the new perimeter of the MOSS-NG.

- **Introduction of modern DevOps approaches and tools:** in order to improve and optimize data systems development and deployment process, automation level, control and to reduce maintainability complexity and effort, modern DevOps approaches has to be introduced and followed for MOSS-NG realization. This principle has been pursued through the following main activities:
 - **Software Version Control:** although some of the existing data system software in the legacy MOSS environment (in particular the most recent one) were already managed via software version control tools (i.e. git), this approach were not commonly adopted for every software in the old environment. For this reason, the full extension and utilization of a common and unique version control system was considered essential and one of the first activities to perform to improve the existing software management, organization and software development approach. All the data system software have been properly put under configuration and control in the ALTEC internal Gitlab instance. This step-up enables the possibility to properly keep track of both versioning and historical changes and evolution from a software perspective of all the ALTEC software deployed and developed for this specific environment and is a common practice that could not be avoided any longer in any development environment.
 - **Continuous Integration and Continuous Delivery tools:** as follow-up step, after proper versioning of the software, the extension and adoption of proper CI/CD pipelines has been also considered mandatory for all data system software in the revised software engineering activities. This allowed to introduce, for every data system, a continuous build, testing and automatic generation of newly created artifacts (if foreseen) for each commit in the related repository. The full adoption of this mechanism has the main objective to facilitate and grant a smoother, safe and controlled development process as well as improve the support for any rollbacks or takeover activities as needed.



• Fig. 2. Example of a MOSS-NG CICD Data System Pipelines

- *Introduction of IT Automation tools*: one of the major lacks in the legacy environment was related to the actual mechanism used to configure and maintain the different data system and services in the target environment. The application and data system configuration was generally performed manually by the authorized ground controllers, who however needed to have full and complete knowledge of applications characteristics (or should look for proper procedures and/or technical documentation associated to the specific software). This management strategy was time and effort consuming, not persistent, has a high dependency on the ground controller knowledge of the specific data systems and did not support any reproducibility in case of migration and/or redeployment of application in another environment (or target machine). All these consideration exposed the absolute need of identify and adopt a dedicated solution of DevOps automation tools (i.e. Ansible), capable to overcome, minimize (if not entirely remove) any manual operations needed in the environment to actually deploy and configure the data systems and software application according to the environment target baseline and version.



Dedicated ansible roles have been developed over time with general applicability across ALTEC different operational environments, as well as as specific roles for MOSS-NG Data System and specific context. Dedicated ansible playbooks have been developed for managing MOSS-NG client and servers configuration and set-up, according to the different functional scope and systems to be installed. Moreover, different inventories have been developed to facilitate and allow proper execution of such playbook in development (ensuring that playbook actually works) or production environment respectively.

- **Replacement/Rejuvenation of legacy/old technologies and tools**: this principle has been applied in the following major aspects:

- *Major Upgrade of Underlying Operating System*: one of the major and key aspects that primarily drove the need for a complete modernization of the MOSS legacy environment was related to the underlying Operating System. Several of the existing VMs and workstation were based on an ancient and no longer supported operating system (i.e. RHEL 4.X). Even the more recent ones, created over the years, were still based on OS that were reaching EOL (i.e. CentOS 7.x). For this reason a new target OS which would ensure the required lifespan and general support over the next years was necessary and mandatory. The final selection has been oriented towards a RHEL 9.X based open-source distribution (100% bug-for-bug compatible with Red Hat Enterprise Linux).



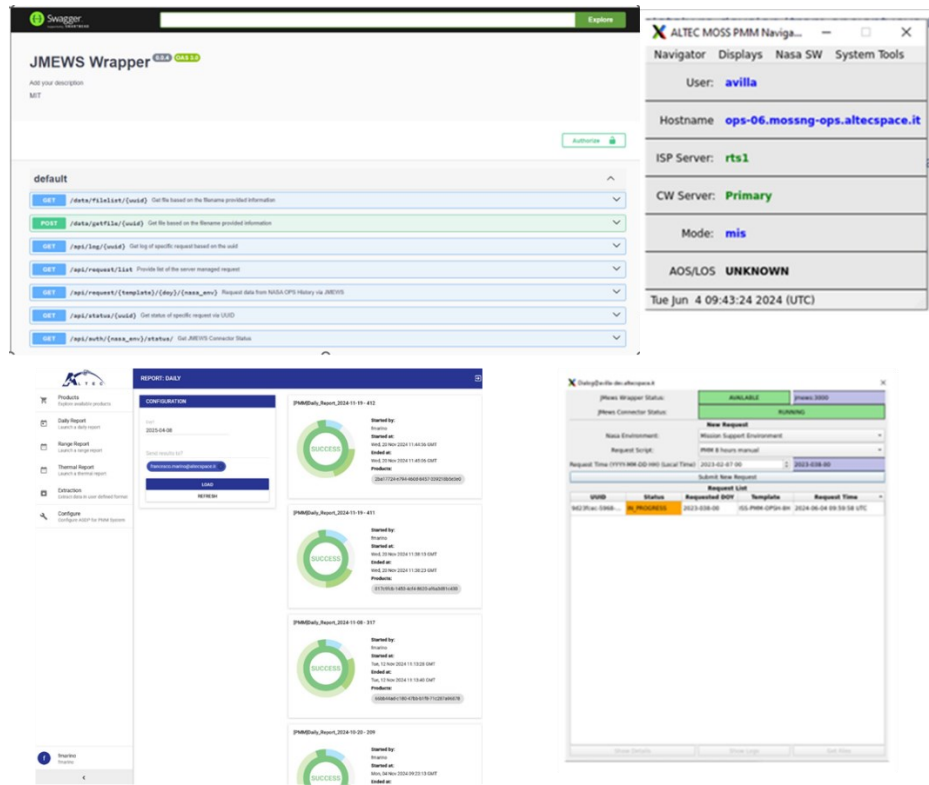
- *Adoption of container-based technologies*: the ancient MOSS environment, due to the underlying operating system limited capabilities and compatibility, did not use nor support any container-based service deployment. In order to improve and increase portability, scalability, and resource efficiency of the deployed data systems in



MOSS-NG evolution, container technologies have been enabled and encouraged in the new environment. The transformation and transition of deployed data system to container technologies has been partially performed, prioritizing the data systems that were natively developed to be deployed as containers, as well as new data system service stack introduced in the environment. Although not all the data system have been migrated to a container-based deployment, a first set of them has actually been set-up. This initial activities will allow to easily upgrade and perform rollout of new data system version, with minor impacts on the underlying OS, and can be considered as a first stepping stone to potentially evaluate further evolution in the future MOSSNG architecture (e.g. introduction of cloud-native orchestrator and cluster).

- *General upgrade of data system software (software dependencies or full SW renewal/development from scratch)*: in order to support the migration and upgrade of the underlying Operating System and/or Container technologies, several of the in-use software had to be either renewed in term of dependencies updates, rebuild activities and/or a full-fledge new implementation, where considered more efficient/useful had to take place. Considering the new resources and architecture of MOSS-NG environment, and based on the MOSS Operator collected

feedback, some features and data system capabilities have been added and extended according to their operational needs.

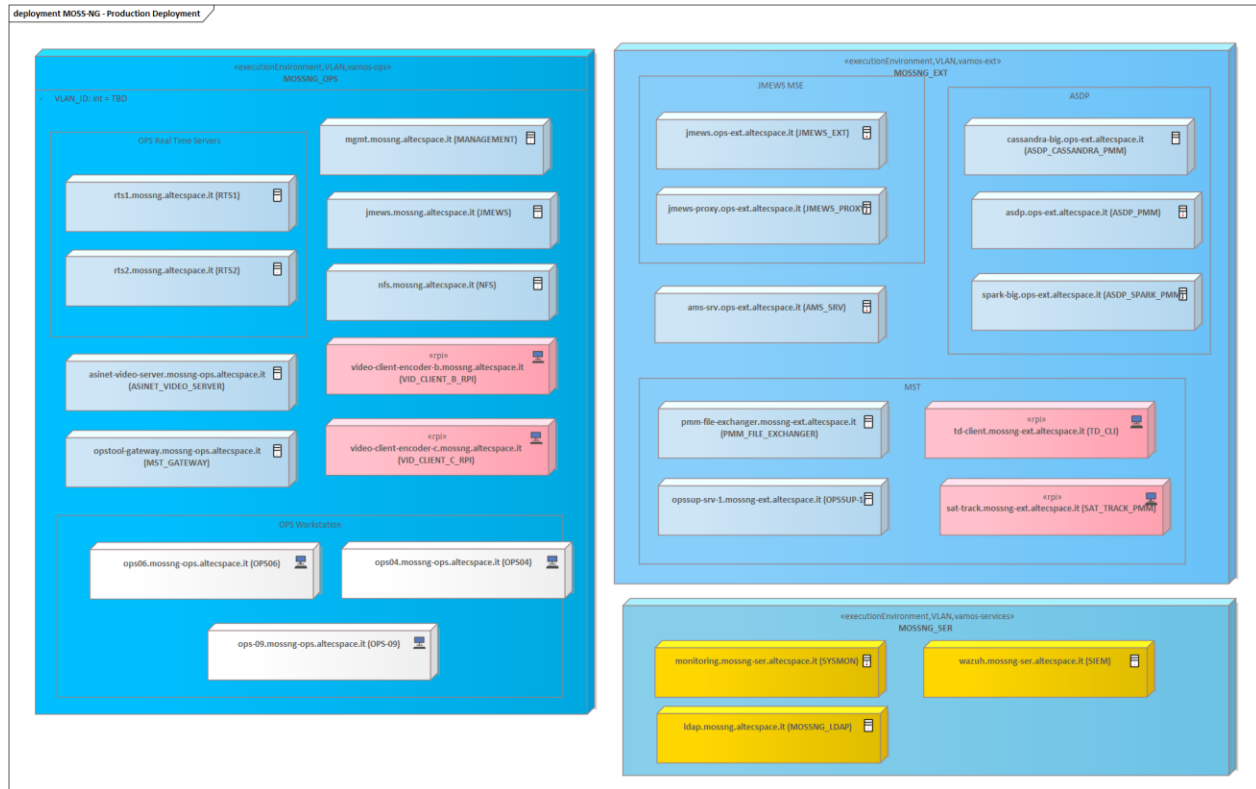


• Fig. 3. MOSS-NG ALTEC Data System Screenshots

- **Introduction of Data System Monitoring Solutions:** another key element was the introduction of proper technical solutions and tools for the environment continuous data system monitoring. In particular, with respect to the legacy MOSS environment, it has been necessary to introduce new mechanism and tools to enable general environment metrics monitoring (e.g. CPU, Memory, Disk utilization etc.) for all the environment virtual machines and physical workstations hosting MOSS-NG capabilities, as well as supporting data system log collection and monitoring in a centralized way.

3. MOSS-NG RoadMap Definition and Execution

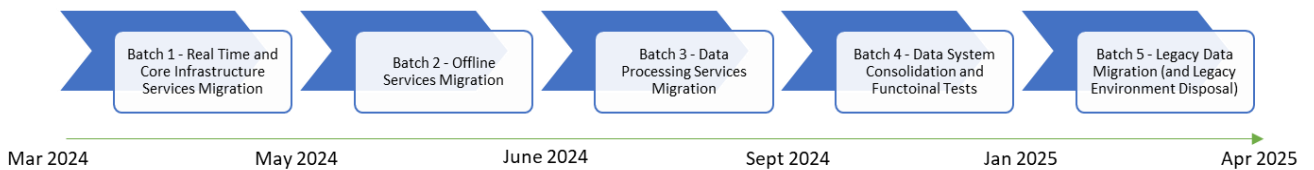
The MOSS-NG upgrade plan had to take into account that the MOSS environment was actively support operations during the transaction period. All the implementation steps to realize, deploy and test the MOSS-NG solution had to minimize, as far as feasible, any outage impacting ALTEC operations.



• Fig. 4. MOSS-NG Data System Architecture

After the initial design definition for the new architecture baseline, the MOSS-NG implementation roadmap was defined and executed through 5 main migrations batches, in a 12 month timeframe:

- Batch 1: Real Time and Core Infrastructure Services Migration
- Batch 2: Offline Services Migration
- Batch 3: Data Processing Services Migration
- Batch 4: Data System Consolidation and Functional Tests
- Batch 5: Legacy Data Migration (and Legacy Environment Disposal)



• Fig. 5. MOSS-NG Roadmap Execution Schedule

During most of the transition and upgrade phases (up to batch 4), both legacy and new environments have been kept operational in parallel (with few limitation), allowing to reduce the outages for the ALTEC operational team on one side, and granting the opportunity to double check and properly verify similar behaviour and expectation between the legacy and the new environment in parallel during the transition on the other.

4. Conclusion

All the activities performed for the creation and deployment of the MOSS-NG lays the foundation of a reference architecture that can be easily re-used in future and different mission context, either by re-using similar architecture

approach and service (but with dedicated instance deployment) or by providing general services that can be used as an infrastructure baseline for the future ALTEC missions that will be deployed on VAMOS infrastructure [2]. The technical complexity of upgrading ancient data system to modern OS, dependencies and technologies has been one of the major challenges faced to carry out this activity as well as the coordination between inter-discipline teams (operative Team, IT Team and Ground Segment Engineering Team), defining properly associated processes to handle the new environment. Moreover, the need to perform all the upgrade activities in parallel with the existing and operational legacy environment was an additional complexity that had to be managed properly to ensure business continuity as well as minimize the general outage introduced in an operational environment.

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