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Towards EGS-CC at ESOC

A New Era for Satellite Monitoring and Control

Vemund Reggestad[a]*, Klara Widegård[b]

[a] *European Space Operations Centre*, *European Space Agency, vemund.reggestad@esa.int*
[b] *European Space Operations Centre*, *European Space Agency*, *klara.widegard@esa.int*
* Corresponding Author

Abstract

For decades, Monitoring and Control of satellites at ESA/ESOC has been performed using SCOS-2000 and other complementary systems forming the MICONYS (MIssion CONtrol sYSstem) suite of generic products. These products have significantly evolved over time and provide now a mature baseline, which is able to very efficiently serve the needs of operating satellites at ESOC. However, the signs of obsolescence of SCOS-2000 based solutions can no longer be ignored. A replacement is needed.

To achieve the transition, a large project is ongoing, aiming at the preparation and integration of the European Ground Systems Common Core (EGS-CC) into the ESA ground segment as operated by ESOC. One major milestone has already taken place: In Apr-2024, ESOC re-confirmed that the next generation Mission Control System will be based on EGS-CC. This paper will outline the path taken to reach this important confirmation and some of the key issues encountered. This includes:

- Challenges related to setting up a new archive solution and concept based on EGS-CC and modern IT infrastructure
- An extensive test campaign of EGS-CC and the preliminary results
- Lessons learned from working in a large community of users and developers

Following the confirmation, the agreed way forward was to first focus on preparation of the system for the SWARM mission. The main history and process that lead to this decision will be outlined. The status of the preparation will as well be presented.

Finally, the paper will conclude with benefits that ESOC expect to achieve and how EGS-CC will enable ESOC to support our future missions. This includes among others:

- Synergies by having a single system supporting the various ESOC missions including the challenges of achieving this
- Achievements, benefits and experience of the automatic testing approach taken with EGS-CC
- Enabling of automation for operations
- Making ESOC ready to support almost twice as many missions in the future wrt. the past.

Keywords: EGS-CC, mission control system, Swarm

Acronyms/Abbreviations

Common Core (CC)
DAtaBase sYStem (DABYS)
European Ground Systems Common Core (EGS-CC)
European Space Operations Centre (ESOC)
Mission Automation System (MATIS)
Mission Control System (MCS)
Mission Control System based on EGS-CC (MCS-CC)
Mission Information Database (MIB)
MIssion COntrol SYStem (MICONYS)
Mission Operations Information System. (MOIS)
Next Generation (NG)
Operations Preparation ENvironment (OPEN)
Procedure Tool Suite (ProTos)
Satellite Control and Operation System (SCOS)

SCOS-2000 (S2K)
Space Link Extension (SLE)
Tailoring Data Model (TMD) (of EGS-CC)
Telemetry (TM)
Telecommand (TC)

1 Introduction

For decades, the Monitoring and Control of satellites at ESA/ESOC has been performed using SCOS-2000 and other complementary systems forming the MICONYS (MIssion CONtrol sYSstem) suite of generic products. These products have significantly evolved over time and now provide a mature baseline that very efficiently serves the needs of operating satellites at ESOC. However, the signs of obsolescence of SCOS-2000 based solutions can no longer be ignored. A replacement is needed.

1.1 *The Need for Transition*

To achieve the transition, a large project is ongoing, aiming at the preparation and integration of the European Ground Systems Common Core (EGS-CC) into the ESA ground segment as operated by ESA in ESOC. This initiative marks a significant shift in the approach to satellite monitoring and control, ensuring that the infrastructure remains robust and capable of meeting future demands. A transition of the core Monitoring and control system of a control centre is however no easy task. The current predictions at ESOC are that the process will take at least 7 years from EGS-CC first enters operations (in 2026) until the predicted end of life date of SCOS. This puts the end of life date as no earlier than 2033. One driver for the transition period duration is the large number of missions involved (above 40) at ESOC. Due to the length of the migration period, it is however even more urgent to make sure a suitable replacement is available in due time.

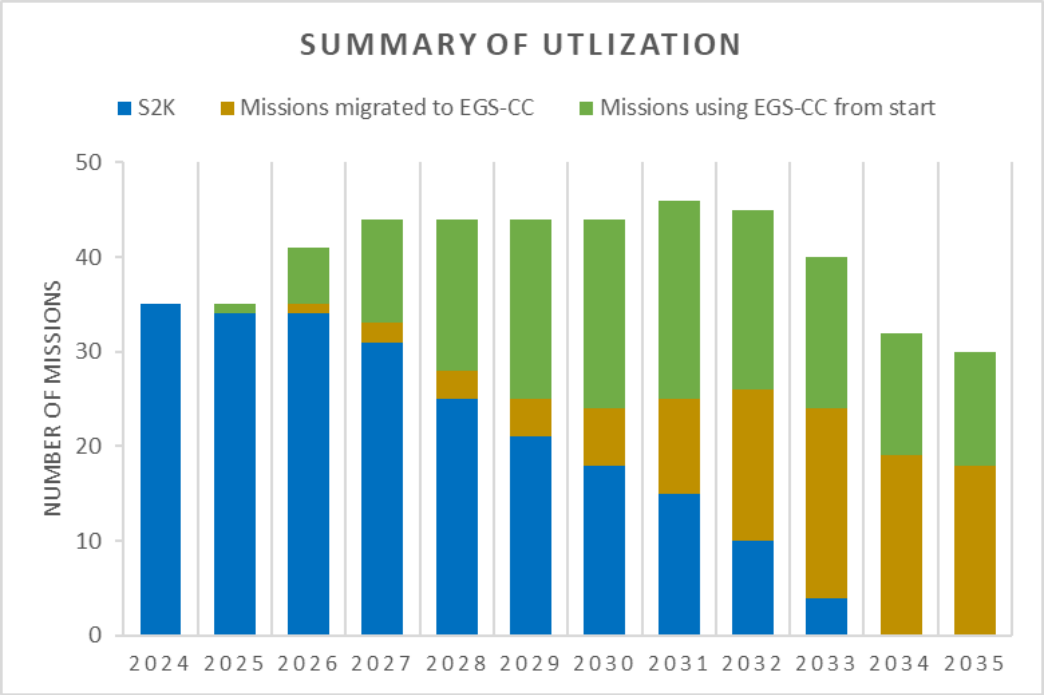

Figure 1: Simulation of transition scenario from SCOS to EGS-CC for ESOC

1.2 *Benefits of EGS-CC Integration*

The integration of EGS-CC into ESOC's operations is expected to bring numerous benefits.:

- The automatic testing approach taken with EGS-CC has also proven to be highly beneficial. It ensures that the system meets stringent quality standards and operates reliably under different conditions. This method of testing has led to several achievements, benefits, and valuable experiences that will be instrumental in supporting ESOC's future missions.
- Share the efforts/costs to modernise the pre- and post-launch control systems in Europe (EGSE and MCS)
- Define and adopt a common data model supporting the smooth definition, integration and validation of TM/TC related artefacts across pre- and post-launch mission phases
- Promote the cross-fertilisation and enable the exchange of ancillary applications (e.g. mission operations procedures definition and validation, scheduled operations automation, data analysis tools) across organizations and across missions
- Reduce the development, integration, validation and maintenance costs of pre- and post-launch control systems. One of the most significant advantages contributing to this is the synergy created by having a common code base supporting various ESOC missions (See Figure 2 below). This unified approach simplifies operations and enhances efficiency, making it easier to manage multiple missions simultaneously.
- Leveraging on the EGS-CC common functional layering to adopt a common solution for both Mission Control Systems and Ground Station M&C System.
- Smooth transition between manual and automated validation and execution of mission operations as EGS-CC has a native automation support
- Definition and adoption of common operations and associated tailoring data across missions
- 'Installation free' (Web-based) access from any authorized device
- Improved cross-fertilization across mission categories

In addition, EGS-CC is expected to:

- Promote the competitiveness of European industry in the international market
- Enable a common definition of ground systems infrastructure evolution for all European stakeholders

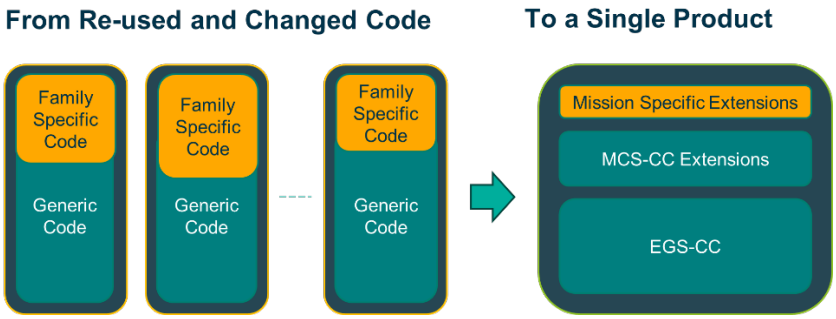

Figure 2:Common Code base

1.3 *Major Milestone: Confirmation of EGS-CC*

A major milestone in this transition has already taken place. In April 2024, ESOC reconfirmed that the next-generation Mission Control System would be based on EGS-CC. This confirmation is a testament to the rigorous efforts and planning that have gone into evaluating the new system's suitability. This paper will outline the path taken to reach this important confirmation, some of the key issues encountered and the activities undertaken since then, including:

- Challenges related to setting up a new archive solution and concept based on EGS-CC and modern IT infrastructure
- An extensive test campaign of EGS-CC and the preliminary results
- Lessons learned from working in a large community of users and developers

The paper will also provide an outlook on the path ahead, towards the operational acceptance

1.4 *Focus on SWARM Mission*

Following the confirmation of EGS-CC, the agreed way forward was to first focus on preparation of the system for the SWARM mission. SWARM, a constellation of three satellites launched by the European Space Agency (ESA) in 2013, is dedicated to studying Earth's magnetic field.

The selection of SWARM as the pilot mission was driven by several strategic considerations. First and foremost, SWARM's mission objectives, which involve detailed measurements of Earth's magnetic field, require a high level of precision and reliability from the control system. This makes SWARM an excellent candidate for testing the capabilities of EGS-CC. Additionally, the SWARM mission's scope and complexity provide a robust platform to evaluate the performance and scalability of the new system, ensuring it can meet the demands of future missions.

From the operational viewpoint SWARM allows the initial steps of the transition at no risk as SWARM is an operational mission, and the S2K system is available allowing a smooth transition in line with the increased confidence of EGS-CC. This risk free approach where essential to the user community to allow familization and reduce concerns.

2 Adoption at ESOC

The adoption of EGS-CC at ESOC follows several phases:

Design and Development: The initial stage involved designing the components extending the EGS-CC with additional features and developing the necessary IT infrastructure. This phase is largely completed.

Testing and Validation: During the current phase, comprehensive testing is conducted in the context of the selected pilot mission to ensure the reliability and performance of the system under various conditions. In this phase, there are three main activities:

1. **Migrating a Legacy Mission**

   The activity will concentrate on the adoption of EGS-CC for a flying mission, and for this purpose, SWARM was selected. This activity includes not only ensuring the maturity of the MCS-CC system but also all the auxiliary systems, procedures, and IT systems needed for running EGS-CC-based operations.

2. **Preparing for a Future Mission**

   The second step, after the successful migration of SWARM, will be to prepare a system for a mission to be launched on EGS-CC. The mission selected is Ariel due to its compatibility with the schedule for the preparation of EGS-CC:

   - First SVTs in 2027
   - Launch in 2029

   This schedule allows the mission to embark without unrealisable risk.

3. **Prepare a TDM native ground segment**

   This step comes with additional challenges since the mission will in this case no longer rely on the old MIB format of SCOS-2000 and the whole ground segment needs to support the use of the EGS-CC TDM. See chapter below for more details.

Operational roll-out: The final phase includes the operational roll-out of the MCS-CC system at ESOC and the transition of selected missions to the new platform. This phase is scheduled to start in parallel to the Testing and Validation phase, after the successful re-run of the SWARM operations scenarios. The roll-out needs to be carefully planned, taking mission constrains and mission critical phases into account. Bearing this in mind, the final phase is only expected to be completed in the early 2030s.

2.1 *Path towards an EGS-CC TDM based operations*

When considering migration to EGS-CC, the impact of moving to another data model for tailoring data must not be underestimated. ESOC plan to cover this migration in three steps where missions are classified into the following categories:

Figure 3: Data model categorisation

Each mission using MCS is, at a given time, within one of categories shown in Figure 2. . As the roll out progresses, missions will move into category 1 or into category 2 while new TDM native missions are directly classified category 3. The mission uses EGS-CC in all those categories.

Category 1: The mission natively uses a S2K MIB database, like SWARM. S2K generation tools such as MOIS, ProToS, MATIS, DABYS, FOPPER are used for the management of tailoring data (TM/TC database, procedures, etc..). OPEN-M is used as intermediate between those S2K MIB tools and MCS. The S2K MIB to EGS-CC TDM converter provides the means to import the tailoring data within the MCS. Flight control procedures are managed with MOIS or ProToS. OPEN-M can optionally be additionally used to manage those procedures and replace MOIS and ProToS, and optionally also MATIS and FOPPER but leaving the management of the S2K MIB as before. Category 1 missions do not have to technically move to category 2 and can remain in category 1 to use MCS, DABYS and other S2K generation tools and also optionally MOIS/ProToS and FOPPER.

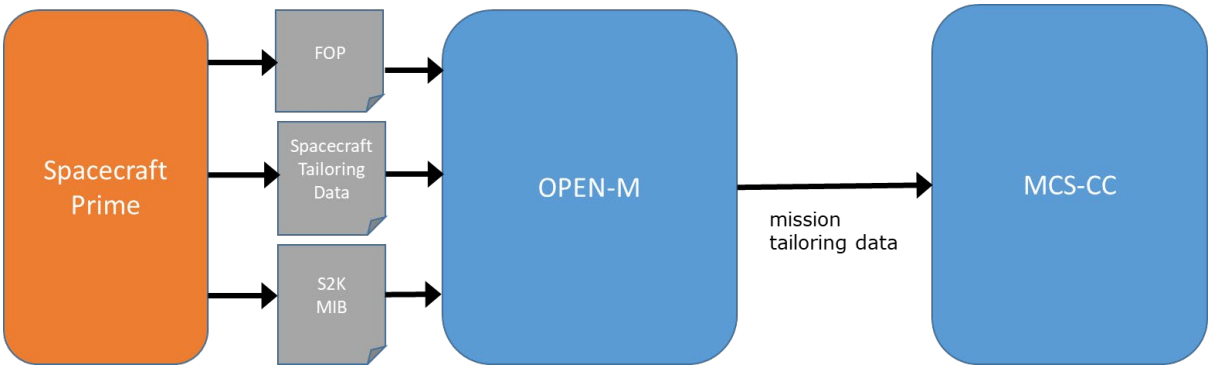

Figure 4: SWARM tailoring data process

Category 2: The mission originally used an S2K MIB database but fully migrated the tailoring data to the EGOS-CC formats and no longer uses S2K MIB based tools. Ariel is expected to follow this path; however this will need to be confirmed. All tailoring data has been migrated to OPEN-M using the converters (S2K MIB, MOIS and ProToS Procedures, FOPPER database). Those converters are already developed. OPEN-M replaces in this case the functions of MOIS, MATIS (Preparation) (automated execution is native in EGS-CC), ProToS, FOPPER, DABYS and other S2K MIB database management tools.

Category 3: The mission receives tailoring data directly in EGS-CC TDM format from industry and therefore does not require the S2K MIB to TDM converter. All tailoring data, including Flight Control Procedures, are managed within OPEN-M. This will normally be the case for missions using EGS-CC as well as AIV system.

The differences between category 2 and category 3 missions are within the use of converters which constrained the initial data population for an S2K-like use of the EGS-CC data formats.

User training will be provided once the Flight Control Team of the first relevant missions start to actively use the system.

2.2 *Challenges and Solutions*

Transitioning to EGS-CC involves overcoming several significant challenges, particularly in setting up a new archive solution that leverages modern IT infrastructure. The new system must be capable of handling vast amounts of data efficiently and securely. The concept behind EGS-CC is designed to address these needs, ensuring that the archive solution is both scalable and future-proof.

One of the primary challenges is balancing storage speed and volume with retrieval performance. The archive must support many different types of data, including telemetry frames, packets, parameters, events, log messages, alarm states and control activities. Additionally, the archive must accommodate performance peaks and support a large variety of filters and combinations thereof. Significant effort has been spent to optimize to reduce the total cost of ownership of data, and a roadmap for further improvements are planned.

Another crucial aspect of the transition is the extensive test campaign carried out to validate EGS-CC. Preliminary results from these tests have shown promising outcomes, highlighting the system's reliability and performance. Additionally, working within a large community of users and developers has provided valuable insights and lessons, on one side helping to refine the system further however as well as implies some overhead in processes compared to what the ESOC user community was used to with SCOS.

Of particular challenge it is worth to notice the user interface, as a significant part of issues with working in a community where concentrated around user interface issues. To levitate this a number of initiatives have been taken to allow more customization capabilities of the user interface allowing stakeholders more freedom and flexibility of extending the UI while still keeping parts common to maximise the benefit of the community approach. This effort must as well be continued in the future to improve the user experience of users with different expectations and needs.

2.3 *Recent activities*

To support the role out plans above, the current activities is focused on the needs of SWARM, allowing a set of key operational scenarios to be supported. These include:

- Various enhancements of the commanding chain, including support for pre-release checks.
- Improvements in the processing of playback telemetry.
- User interface for handling SLE links
- Performance improvements in user interface and backend
- Improvements in the ability of the system to retrieve and display historical data.
- A refurbishment of the Time correlation implementation
- Several improvements to the on-board queue modelling.
- Reduction in memory footprint of the application
- Several usability improvements to the user interface

These enhancements have been done as a mixture of enhancements to the EGS-CC itself, and as additional components for the MCS use case in a layer on top of EGS-CC, usually referred to as MCS-CC.

2.4 *Way Forward*

As the work of validating and testing the core of the system is in the process of completion, work will move on to the next set of features, including but not limited to:

- File Based Operations
- On-board Software Maintenance
- Security
- PUS-C for operational use cases including support for the Generic Operational Interface Requirements, that outline a set of common operational requirements to be supported by future missions operated at ESOC.

For most of the features listed above, advanced implementations already exist that will need to be enhanced and finally validated within a realistic mission scenario.

The validation of these features is expected to take most of 2026 leading up to a fully operational solution in 2027 for ESA missions, in line with the mission needs for Ariel to be launched in 2029.

3 Conclusion

The transition towards EGS-CC at ESOC marks a new era for satellite monitoring and control. Significant progress has been made to this goal in the last years powered by the steady improvements of the EGS-CC software. By adopting a modern and robust system, ESOC will be better equipped to meet the demands of future missions, ensuring that the infrastructure remains efficient, reliable, and capable of handling the complexities of space operations. The lessons learned and experiences gained during this transition will pave the way for continued success and innovation at ESOC.

Acknowledgements