The EGS-CC based Mission Control Infrastructure at ESOC

Mauro Pecchioli[(1)], Anthony Walsh[(1)]

[(1)]European Space Agency, ESA/ESOC
Robert-Bosch-Str. 5, 64293 Darmstadt, Germany
Email: mauro.pecchioli@esa.int, anthony.walsh@esa.int

INTRODUCTION

Background

Many different systems are currently in use by European companies/agencies for monitoring and control of space systems. Different solutions are typically adopted to support the various mission phases, in particular for the Assembly Integration and Testing (AIT) and other pre-launch phases and post-launch mission operations. The lack of a common infrastructure leads to little synergy across missions and project phases.

Given the difficulties mentioned above, the ESA led European Ground System – Common Core initiative has been put in place (as described in [1]) and is now materialising. The EGS-CC products will provide the foundation to efficiently develop and deploy applications to monitor and control space systems. An appropriate functional scope and architectural layering has been devised in order to ensure all target applications and environments are adequately supported but without creating unnecessary complexity and dependencies. In particular, the EGS-CC kernel has been designed without making any implementation and interface assumption with the controlled system. This makes the EGS-CC an ideal platform to develop common solutions targeting completely heterogeneous monitoring and control applications e.g. to support space segment or ground segment operations.

At ESOC a common infrastructure relying on the SCOS-2000 product forms the basis since many years for the development of mission control systems supporting spacecraft operations and more recently also ground station network operations. However, the current generation is expected to face significant obsolescence problems in the next decade, with the maintenance and evolution costs which are expected to become excessive with time. The EGS-CC therefore represents an ideal opportunity to embark on the modernisation of the mission control infrastructure and associated processes at ESOC.

The Objectives of the EGS-CC Adoption at ESOC

The EGS-CC adoption at ESOC will enable the development of a new generation ground data systems infrastructure supporting all applications related to mission and network operations preparation and execution. The ambition is to deploy EGS-CC based solutions for all types of monitoring and control applications, for all categories of missions and mission phases and also for all types of controlled systems, including the space segment as well as the ground equipment, in particular the network of ground stations. As mentioned above, this is a step which is considered necessary to tackle obsolescence of the current infrastructure but it is also considered an ideal opportunity to re-think some of the current processes to pursue important strategic objectives, including:

- Leveraging on the EGS-CC as a European level initiative to minimise Cost of Ownership of the next generation M&C Ground Data Systems Infrastructure;
- Enabling long term reduction of development and maintenance costs of the ground data systems infrastructure and of the dedicated systems relying on it;
- Providing the users communities with an efficient environment to prepare and execute operations using modern technologies;
- Rationalising the organisation/architectures of the target systems to enable a clean split of responsibilities throughout the lifecycle;
- Promoting/enabling cross-fertilisation of concepts/solutions with other European EGS-CC stakeholders;

- Promoting/enabling cross-fertilisation of concepts/solutions between the Missions and G/S Network operations domains.

The objectives of the EGS-CC adoption are therefore very ambitious but at the same time also offer an adequate justification of the associated effort. The new generation of EGS-CC based infrastructure products is expected to provide the development and user communities with ancillary opportunities and benefits which go beyond the capabilities of the current implementations, namely:

- Support of heterogeneous controlled systems: the SCOS-2000 infrastructure has been designed assuming a given category of controlled systems, namely spacecraft exchanging TM/TC data with the monitoring and control systems on the basis of the ECSS Packet Utilisation Standard. The EGS-CC based infrastructure will provide an abstraction layer which will enable the design and execution of operations to act on any type of systems, including in particular the space and the ground segment systems involved in mission operations;
- Simplified integration of multiple controlled systems: this applies to the complete process to tailor, validate and deploy monitoring and control applications for ‘system of systems’, such as a space segment composite consisting of several units assembled together, a network of ground stations, a control centre consisting of mission dedicated or shared software applications, a family of missions managed by the same operations team, a constellation consisting of multiple spacecraft;
- Enable off-the-shelf re-use of ground data systems infrastructure products: the EGS-CC has been designed to respect a truly component and interface based approach, enabling the development and seamless integration of functional extensions. For the new generation infrastructure it is envisaged to adopt the same principles and architectural layering of the EGS-CC itself, so that a clear separation between the infrastructure and the application specific implementations is enforced. Full solutions can be designed, implemented and deployed without any detailed knowledge and, most important, need of modification of the underlying implementation (binary compatibility);
- Simplification of operations concepts: current implementations heavily rely on the definition and execution of operations at a very low level (e.g. individual telecommands, individual telemetry parameters). The EGS-CC provides an abstraction layer which enables a radical simplification of the interactions with the controlled system and also promote wherever possible the design of operations which can be relatively easily automated, thus leading to operations execution costs reductions;
- Cross-fertilisation across heterogeneous teams: currently largely different approaches are followed by the space segment and ground stations network operations teams, for example different tools are used in order to prepare and validate the necessary artefacts (e.g. M&C data, procedures, displays) but also substantially different lifecycles are followed to implement the operations planning and execution processes. The new generation EGS-CC based infrastructure will promote and somehow enforce the rationalisation and harmonisation of the associated processes e.g. through the adoption of a common data model to manage the applications tailoring for a given controlled system.

The Engineering Approach

The new generation EGS-CC based infrastructure shall be designed to achieve the objectives listed above and provide the users communities with the expected benefits. A fundamental prerequisite is that the new products will be at least equivalent to the current generation in all relevant aspects. This applies in particular to:

- Functional scope: the current systems provide the users with a rich set of functions resulting from many years of operational use and continuous evolution;
- Usability: an important aspect of operational systems is of course their ability to provide simple and predictable access to the available functions;
- Performance: this is a key aspect both in terms of responsiveness to user requests/actions as well as in terms of processing data rates;
- Expertise: the development and operational teams are very familiar with the current systems. This ensures that the whole engineering process, from specification up to validation, can be efficiently implemented with very competitive levels of costs and efforts;
- Operational maturity: thanks to the many years of operational use, the current generation infrastructure has gained a level of robustness and reliability which needs to be demonstrated for the new systems.

An engineering approach to specify and develop the new generation EGS-CC based infrastructure has been defined, aiming at meeting the expectations listed above. This is briefly described in the next paragraphs.

The current infrastructure generation provides a solid reference to determine the functional scope as well as the external interfaces to be supported. This is however very wide and a ‘flat specification’ of the full infrastructure would be of prohibitive complexity (e.g. the current specification contains thousands of user and software requirements). For this reason a top-down engineering approach has been adopted. The full scope of the ground data systems monitoring and control infrastructure has been captured in a formal specification defining the functions and interfaces by means of a hierarchical model. Each layer of the model provides a functional view which is appropriate for a given purpose e.g. to provide an overview of the new generation infrastructure as exposed to external systems, to identify the macro products to be developed, to assess the overlap of existing implementations with the EGS-CC, to identify the internal interfaces which will have to be supported in order to ensure backwards compatibility with legacy implementations, and so on.

The hierarchical functional model described above has been used to perform a ‘functional gap analysis’ of the EGS-CC: which of the required functions will be natively supported by the EGS-CC itself? Which of the required functions will have to be implemented as EGS-CC extensions? Which of the functions currently supported can be dropped as conflicting with the principles and concepts of the EGS-CC based applications? Following a traditional engineering process, all these questions would be answered by producing a full and detailed specification of the future generation infrastructure, from which a ‘delta specification’ focussing on the EGS-CC extensions would be derived. The approach which has been adopted also aims at producing the ‘delta specification’ but this is being done using a top-down approach which progressively goes to the level of detail which is most appropriate for the various engineering processes.

For each functional gap the key driving requirements and the most appropriate development approach have been identified. The key requirements have been specified starting from the end user perspective, focussing on the exact operations that this functional extension is expected to support (e.g. upload file from ground to on-board filestore). Design trade-offs have been performed to assess in particular whether the missing functions should be newly implemented as EGS-CC extensions or rather by re-using the relevant existing application. This latter option has only been selected in those cases where there was a clear evidence that it would minimise the total costs to operational deployment but without jeopardising the long term maintainability and the modernity of the future infrastructure. It is equally important to emphasize that the EGS-CC extensions will be developed following the same engineering processes, architectural concepts and quality requirements of the EGS-CC components proper. This will ensure implementation uniformity of all components running natively in the EGS-CC run-time environment, independently on their source, whether belonging to the EGS-CC as developed as an ESA specific extension.

A Disruptive Change

As described above, the adoption of the EGS-CC as the basis for operational systems at ESOC represents an excellent opportunity for modernising the relevant ground data systems infrastructure but at the same time it will introduce disruptive changes in many respects. The main ones are briefly addressed in the following paragraphs:

- Terminology: as part of the EGS-CC initiative a significant effort has been put in place in order to define and adopt a commonly agreed terminology. Due to the heterogeneous heritage of the various stakeholders involved, this was considered as an essential step to start the collaboration and share a product. Of course the consistent adoption of a newly defined set of terms implies a familiarisation and adaptation effort at all levels within the development and operational teams at ESOC;
- Engineering culture: the EGS-CC product will constitute a powerful basis for developing monitoring and control target applications. It is considered essential that the engineering process leading to complete applications customised for a given controlled system relies on ‘black box’ re-use of the EGS-CC product artefacts (‘EGS-CC as a third party product’). This implies a radical change compared to the current process which assumes the complete freedom of modifying the underlying infrastructure when designing and developing e.g. Mission Control Systems;
- Engineering support tools and associated processes: in order to enable the distributed and parallel development of its components as well as their progressive integration and verification, the engineering processes forming the basis for

the EGS-CC components development and validation have been accurately prescribed. Modern engineering paradigms have been adopted, such as model based engineering, component and interface based design, layered validation, end-to-end automation of Verification and Validation (V&V) processes. The EGS-CC product includes the development and integration environments (generically referred to as Software Development Environment, SDE), consisting of a rich collection of support tools collated together by means of well-defined artefacts and procedures. The intention is to adopt the same engineering processes and SDE for the required EGS-CC extensions;

- Technology: the current implementation of ground data systems largely relies on technologies which are superseded by the more modern ones selected to form the development stack of EGS-CC components (e.g. no C++, no CORBA, no SQL). This radical change in the technology stack will impact on the expertise profile required on the side of developers and technical managers;
- Data model: one of the key aspects of monitoring and control systems is their ability to be tailored for a given controlled system (e.g. a spacecraft, a ground station). The definition of tailoring data is under the responsibility of the user teams and require very precise knowledge of the data semantics and their actual use within the run-time environment. Currently all involved teams are very familiar with the so called ‘SCOS-2000 MIB ICD’ and all detailed aspects associated to the customisation of SCOS-2000 based systems. A significant effort shall be devoted to the task of acquiring an equivalent level of familiarity with the Conceptual Data Model (CDM) of the EGS-CC, which defines similar data types but on the basis of a largely different approach and data semantics. Also, the expected lifecycle of data definitions will be significantly impacted, in that a significant amount of them are expected to be defined in the early phases of the controlled system development and progressively integrated and validated throughout the preparation phase;
- External interfaces: the monitoring and control systems devoted to spacecraft as well as ground stations control require and provide many interfaces to other complex systems supporting complementary functions. Only a few of these interfaces are covered by international standards and thus can be assumed to be implemented in a similar fashion in the current and future generation systems. The EGS-CC will natively support many of the required and provided interfaces, however of course using an implementation which is different than the current one;
- Approach to operations: the EGS-CC architecture is based on a clear separation between core functions supporting monitoring and control operations for any type of controlled systems and an implementation layer providing the necessary adaptations to exchange data according to the specific protocols and interfaces supported by a given controlled system (e.g. a spacecraft). The core M&C functions rely on the concept of ‘model based operations’, whereby the controlled system is represented by a hierarchy of elements and associated M&C aspects (e.g. state parameters, events and control activities). This abstraction layer enables the design of control operations focussing on high-level operations objectives, which are achieved through one of many possible implementations e.g. by executing an automation procedure, by invoking a dedicated service or simply by encoding and transmitting a command to be routed to the controlled system. Operating through a model is today standard practice at ESA for ground station network operations but will introduce a very significant change in the way that spacecraft operations will be executed.

THE NEW GENERATION M&C INFRASTRUCTURE AT ESOC

High Level Decomposition

The adoption of the EGS-CC at ESOC will lead to the production of a new generation of infrastructure for monitoring and control systems. This will consist of elements which are briefly described in the following paragraphs. The following Figure 1 shows the high-level decomposition of the EGS-CC based M&C systems infrastructure at ESA.

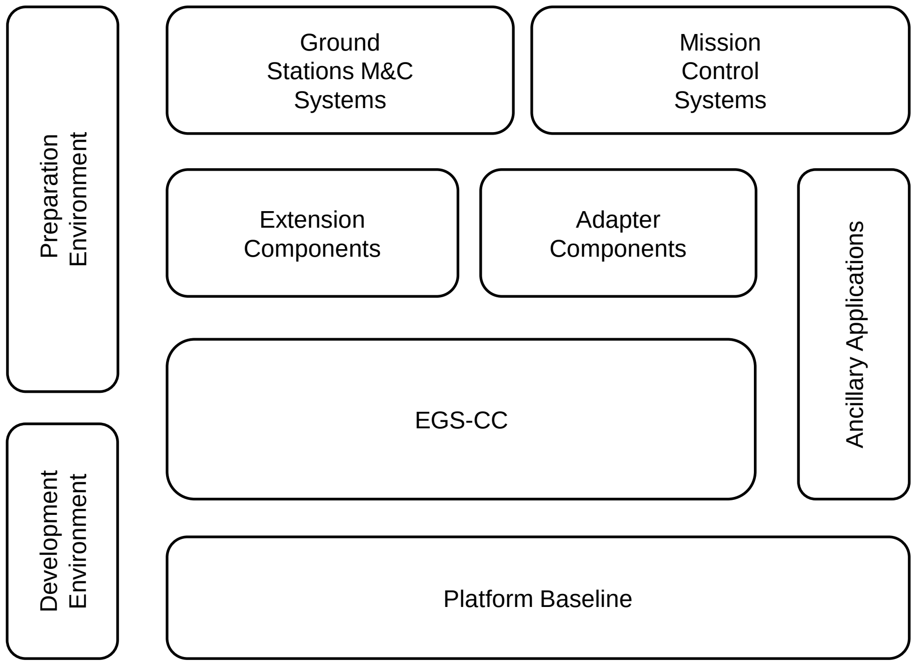

Figure 1. High-level Decomposition of the EGS-CC based Mission Control Infrastructure at ESOC

The elements shown in the Figure 1 above are briefly described in the next paragraphs:

- The Development Environment includes all tools supporting the development, integration and validation of EGS-CC components as well as EGS-CC based applications. It mainly consists of third party products and bespoke developments, customised and integrated to maximise the automation and repeatability of the various engineering workflows and processes. The development and integration environment also includes some proprietary applications e.g. to support the management of tests and the deployment of complete applications (including all necessary artefacts required to enable the composition of components in run-time applications);
- The Preparation Environment provides the user communities of EGS-CC based applications with the ability to define and manage the tailoring data. These include all artefacts (e.g. the definition of the monitoring and control model, TM/TC packets, automation procedures, user defined displays) which customise an EGS-CC based application for a given controlled system and associated operations. The Tailoring Environment at ESOC will consist of a framework supporting the common functions and services (e.g. import/compare/merge, consistency check, versions and baselines management, products generation and export) and a library of editors which are specific of a given data type (e.g. procedures, displays, M&C elements);
- The Platform Baseline consists of the operating system and the complete stack of third party products which constitute the run-time environment of the EGS-CC. Two distinct Linux based distributions are going to be

supported for the back-end (implementing the application business layer) and in addition also the Windows operating system will be supported for the front-end (hosting the user interface application);

- The EGS-CC provides the main functions of space system M&C applications and will constitute the core of the new generation infrastructure in this domain at ESOC. As already introduced above, one of the objectives of the on-going engineering activities is to enable the adoption of the EGS-CC without modifications. This is considered essential in order to minimise the efforts involved in integrating new EGS-CC releases as well as EGS-CC based components;
- The Extension Components complement the functional scope of the EGS-CC itself with additional features. They are being designed and will be developed using exactly the same approach and paradigm as for the EGS-CC components themselves, so that a homogeneous and consistent set of components is provided to the end users of ESA M&C applications. Two main categories of functional extensions have been identified, namely Operations Services (providing high level functions required to execute mission operations at a sufficiently high level of abstraction) and M&C Adaptation (providing the ability to interface with elements of the controlled system to receive monitoring data and deliver command execution requests). The main functional extensions which will be implemented through EGS-CC Extension Components are more extensively described in the relevant section below;
- The Adapter Components provide the necessary bridging between the EGS-CC supported interfaces and other ground systems contributing to the overall ground segment and with which information is exchanged (these include the Mission Planning System, the Flight Dynamics System and other external ancillary applications). A proprietary adaptation is needed in all cases where no international standard is adopted (or even available!) defining the interfaces and interactions between ground systems;
- The external Ancillary Applications play a complementary role to EGS-CC based applications e.g. to plan mission operations, to execute operations schedule and orchestrate the operations automation at ground segment level, to disseminate data across centres/organisations, to provide data post-processing capabilities (e.g. analysis and reporting), to notify on-call personnel of any relevant event generated by the M&C systems, to support the long-term storage of mission data, etc. Ancillary applications are largely based on legacy implementations and will thus not be based on the same engineering practices and technologies of the EGS-CC based application. As explained above, it is anticipated that the relevant interfaces will have to be adapted either on the applications side or on the EGS-CC side.

The top layer of Figure 1 shows the two main application domains which will be developed on the top of the EGS-CC based infrastructure at ESOC. These are briefly described in the next paragraphs, along with the main design drivers and challenges which they are characterised by:

The **Mission Control Systems** constitute the basis for mission operators to interact with the elements of the space segment while in flight. The main design drivers for this category of M&C systems are:

- Support of many dozens of users in parallel, in particular during critical mission phases such as the LEOP;
- Support of ‘off-line operations’, whereby the real-time interactions with the flying spacecraft may either be restricted to very short intervals (e.g. for LEO missions) or be affected by extremely long propagation delays (e.g. for deep space missions);
- Handling of real-time as well as deferred data to reconstruct the state of the controlled system. This poses severe requirements in terms of complexity and performance of the monitoring data processing;
- Ability to provide the operators with a comfortable and reliable environment supporting the execution and end-to-end verification of complex operations;
- Ability to automate the execution of routine operations which typically involve a large variety of systems, belonging to both the ground and the space segment;
- Management and ability to access/disseminate the full set of operational data accumulated during an entire mission.

The **Ground Station M&C System** provides local and remote network operators with the ability to configure and monitor the ground station equipment in order to e.g. support visibility passes for a given spacecraft. The key aspects of these systems are:

- Fully automated operations planning, scheduling and execution cycles. This includes among others the ability to react to unexpected conditions/events and selectively re-plan the operations for a given ground station or for a given spacecraft;

- Ability to share common definitions (tailoring data) across equivalent units deployed within the same or different ground stations. This is necessary to minimise the efforts involved in the definition, validation and maintenance of e.g. M&C model, procedures, displays for a significant number of similar equipment;
- Support of local (within the ground station site) as well as remote (from the control centre) M&C operations. The local operator may need access to the full monitoring and control capabilities e.g. to intervene in case of problems and/or validation activities. The network operator is responsible for the execution of routine operations and needs to be provided with an overview of the state and operations execution status for all ground stations. One specific design challenge is due to the very limited bandwidth to accommodate the delivery of the necessary M&C data.

The variety of EGS-CC based systems which will be needed and supported shows the versatility and wide applicability of the EGS-CC design but also provides an evidence of the complexity of the process to adopt them to produce the new generation of M&C systems at ESOC, considering in particular the level of reliability, performance and maturity required for operational applications interacting with complex and costly space systems.

EGOS-CC Products

The European Ground Operation System (EGOS) is the brand name for the ground data systems infrastructure applications managed at ESOC. For this reason the new generation of applications based on EGS-CC has been named "EGOS-CC". The main EGOS-CC Products and their constituent elements are shown in Figure 2 below.

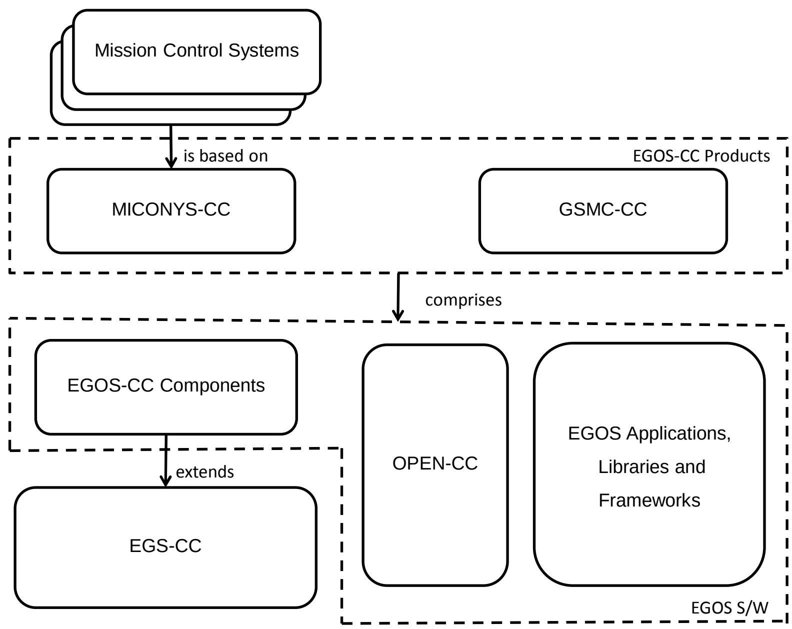

Figure 2. The main EGOS-CC Products and their constituent parts

The EGS-CC based Mission Control System infrastructure (MICONYS-CC) as well as the EGS-CC based Ground Station Monitoring and Control system (GSMC-CC) consist of:

- An off-line application (Operations Preparation Environment, OPEN) supporting all operations preparation activities under the responsibility of the target users, in particular the definition and monitoring of tailoring data artefacts such as the monitoring and control model, procedures, displays, etc.;
- A core (set of) application(s) supporting the execution of monitoring and control operations. This is based on the EGS-CC and includes additional 'EGS-CC like' components (referred to as "EGOS-CC Components") which extend and/or adapt its functionality;

- Several EGOS (legacy) applications providing ancillary functions such as data dissemination, analysis and reporting.

MICONYS-CC is used as the basis for developing and integrating full Mission Control Systems, which include a layer of mission specific extensions and functions.

EGS-CC Functional Extensions

In the following the main functional extensions which have been identified so far in order to serve the needs of the ESA target applications described above are briefly introduced. It should be noted that this section only describes real functional extensions of the EGS-CC, as opposed to other EGOS-CC components (referred to as “Ground System Adapters”) which will also need to be implemented but are only needed in order to enable the use of the EGS-CC functions/interfaces in conjunction with existing legacy implementations (e.g. adapters between an EGS-CC based Mission Control System and the legacy implementations of the Mission Planning System or of the Flight Dynamics Systems).

As briefly introduced above, two main categories of functional extensions have been identified, namely Operations Services (providing high level functions required to execute mission operations at a sufficiently high level of abstraction) and M&C Adaptation (providing the ability to interface with elements of the controlled system to receive monitoring data and deliver command execution requests). All extensions have been designed following the same conceptual layering and organisation of the EGS-CC Reference Implementations, as shown in Figure 3 below covering the extensions required by MICONYS-CC (these are the grey boxes and the additions of the white boxes).

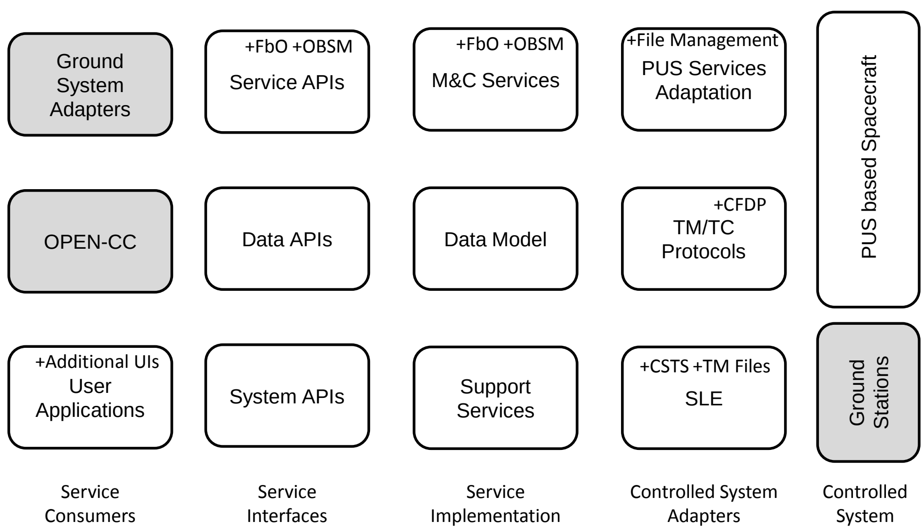

Figure 3. The main EGS-CC extensions required by Mission Control Systems

Operations Services

This layer provides the ability to interact with the controlled system, in particular with a spacecraft, on the basis of a high-level of abstractions of the user activities. This complements equivalent services provided by the EGS-CC reference implementation, in particular all the ones associated to the support of PUS based M&C services. The objectives of these extensions are to enable simplified operations and also to achieve a high-level of harmonisation across missions even in the presence of idiosyncrasies in the actual design and implementation of the space segment. The following EGS-CC extensions in this category have been identified:

- File based operations: several ESA spacecraft as well as the majority of future ones support the ability to operate at a high level of abstraction using files. The spacecraft provides file stores whose management is exposed to ground through services which mirror the capabilities of standard file systems (e.g. create file/folder, copy/move/rename file/folders, delete files/folders). In order to efficiently operate such a spacecraft the Mission Control System is expected to maintain an image of the on-board file store and provide high-level services, such as the ability to compare and synchronise the content of a selected on-board file folder against a specified directory of the ground file store. Services associated to specific type of files will also be supported, for example it will be possible to initiate the execution of previously loaded 'TC files' and expect that the Mission Control System will activate all necessary actions required e.g. to monitor and verify the execution of the commands contained within the activated TC file. Three levels of file based operations services are therefore anticipated to be supported, namely:
    - File transfer management services, enabling control of file transactions (e.g. initiate/suspend/resume file upload/download);
    - File store management services, supporting management of the content of a remote file store (e.g. create folder, delete files) as well as the maintenance of a ground image;
    - File utilisation services, supporting the implementation of high-level operations specific of a given type of files (e.g. TC files, spacecraft schedule increments);
- On-Board S/W Management services: the maintenance of the on-board S/W through patch operations initiated from ground is a critical task which normally entails complex operations. Specific services simplifying the task of uploading a patch and verifying its completeness and correctness prior to activation will be provided. The specific implementation will be based on the assumption that the on-board memories can be managed through PUS Service 6, however the memory images lifecycle and associated high-level operations has been designed without any specific assumption on the actual implementation details of a given spacecraft, so that it can be adapted where necessary on a mission specific basis;
- Automated schedule execution: the Mission Planning System generates several schedules covering a given planning increment for execution by the spacecraft (PUS Service 11) or by the Mission Control System. The EGS-CC only provides very basic capability to time-tag the invocation of control activities at a specified time. For the end-to-end automation of mission operations it is necessary to generate and execute more complex schedules which need to take into due account e.g. inter-dependencies between events and activities. An automated schedule execution service will therefore be needed, which should initiate control activities on the EGS-CC based systems at the same level of abstraction as the human operator would do.

M&C Adaptation

This layer provides the ability to exchange data with the controlled system by implementing the various protocols of the communication systems deployed in between in the various scenarios. As part of the EGS-CC Reference Implementations the necessary components to interface with a PUS based spacecraft via SLE as well as a limited number of adapters for SCOE are provided. The following extension components have been identified for specific development within ESA:

- File based reception of TM Frames: the missions supported by ESA which rely on very short passes and high downlink rates (in particular Earth Observation missions) receive telemetry data from the ground stations on the basis of files containing transfer frames. A similar mechanism is also used during pre-launch test activities e.g. to replay telemetry data recorded during AIT activities into the Mission Control System. The content of the TM files will be characterised by relevant metadata collected in a manifest file so that different formats as well as different types of telemetry data (e.g. real-time, deferred) can be automatically replayed and injected, without the need of configuring the relevant component accordingly. In the EGS-CC Reference Implementation architecture, the extension component supporting the injection of TM frames from files will play exactly the same functional role as the one implementing the SLE standard protocol i.e. no change of the interfaces/services supported by the other EGS-CC components belonging to the M&C adaptation layer will be needed;
- File exchange with the space segment: the support of files exchange with the ground segment is becoming common practice for ESA spacecraft. Several heterogeneous solutions are currently adopted but the commonly agreed

reference implementation for future missions will be based on the CCSDS File Delivery Protocol (CFDP). An EGS-CC extension component will be designed which will 'wrap' the generic ESA implementation of the CFDP by implementing the necessary interfaces (e.g. conversions of CFDP Protocol Data Units into TM/TC packets, storage/retrieval of files into/from the EGS-CC file store, enabling M&C of the CFDP engine through standard EGS-CC M&C capabilities);

- Cross-Support Transfer Services (CSTS): this family of CCSDS standards represents the new generation of the Space Link Extension (SLE) but in addition to the provision of TM/TC return/forward services, the CSTS will also provide the ability to receive monitoring data from the transfer services provider (i.e. the ground station equipment). An extension component will be implemented providing the ability to receive this monitoring data and forwarding them to the EGS-CC kernel components for processing;
- ESA Ground Stations M&C Interface: the equipment and systems belonging to the ESA network of ground stations are monitored and controlled through a common interface definition (this is referred to as the CORBA M&C ICD). An extension component will be implemented providing a user of an EGS-CC based system with the ability to execute M&C operations of the ground station equipment by forwarding the received monitoring data to the EGS-CC kernel components for processing and by invoking control directives through the relevant interfaces in order to implement the requested activities;
- Ground Systems M&C Adapters: similarly to the ground station equipment, also other ground systems located in the control centre need to be operated in the context of mission operations. It is intended to achieve this through M&C adapters which enable the inclusion of these ground systems as elements of the overall controlled system, thus ensuring that from a user perspective they can be operated using the standard M&C capabilities of the EGS-CC.

PROGRAMMATICS

The design and development of the EGS-CC based M&C infrastructure at ESA is being executed under the so called "EGOS-CC Project" using an incremental approach, including:

- System engineering
- Progressive development, integration and validation of EGS-CC based products
- Progressive deployment and infusion in real missions environment.

Phase B has been completed and delivered the high-level design and specification of the EGOS-CC Products, the required EGS-CC extensions and the preparation environment for the EGS-CC based applications. The actual development of the necessary EGS-CC extensions (EGOS-CC Components) is planned to start in the second quarter of 2017. The integration, verification, validation and deployment activities will be progressively implemented using an incremental approach similar to the one adopted for the EGS-CC product itself.

CONCLUSIONS

The EGS-CC initiative is starting to provide concrete deliverables which can be used as the basis for further development and deployment in the target environments. ESA is committed to implement the internal activities leading to a successful adoption of the EGS-CC for its future missions in the 2020 landscape. At ESOC an ambitious programme (the "EGOS-CC Project") has been put in place which aims at producing and deploying the new generation infrastructure for all future M&C systems related to mission and ground station operations systems.

The high-level specification for the main products which will constitute the new generation ground data systems infrastructure in this domain has been produced. A comprehensive functional model of the complete system has been defined containing a hierarchical decomposition, the necessary extensions and adaptations of the EGS-CC implementation, the definition of the target applications and their external interfaces. The trade-off between possible design and implementation approaches has been performed for all identified functional gaps, leading to a concrete definition of the necessary EGS-CC extensions as well as of the evolution path for the ancillary applications which complement its functional role.

An incremental approach for the development phase has been defined which is based on the progressive implementation, integration and validation of EGS-CC extensions on the top of the EGS-CC integration releases. This is planned to take place in parallel with the final phases of the EGS-CC development project, following the spirit of component and interface based design and aiming at an ‘off-the-shelf’ adoption of the EGS-CC deliverables.

SUMMARY

This paper has introduced the main technical and programmatic aspects of the EGOS-CC Project aiming at the development of the future generation EGS-CC based mission control infrastructure at ESOC. It has described the objectives but also the main challenges that this activity will face and the principles which are being adopted in order to mitigate the associated risks, with particular emphasis to the need of ensuring a smooth phase-over from the current to the next generation of the monitoring and control infrastructure.

ACKNOWLEDGMENTS

The authors of this paper would like to acknowledge the excellent contribution to the EGS-CC adoption given by the various stakeholders within ESOC, who are supporting this Project with technical competence, professionalism and sense of commitment.

ACRONYM LIST

AIT	Assembly Integration and Test
API	Application Programming Interface
CC	Common Core
CDM	Conceptual Data Model
CFDP	CCSDS File Delivery Protocol
CORBA	Common Object Request Broker Architecture
CSTS	Cross-Support Transfer Services
EGS-CC	European Ground Systems Common Core
EGOS	ESA Ground Operations System
EGOS-CC	EGS-CC based EGOS
ESA	European Space Agency
ESOC	European Space Operation Centre
FbO	File based Operations
GSMC	Ground Stations Monitoring and Control system
ICD	Interface Control Document
LEO	Low Earth Orbit
LEOP	Launch & Early Orbit Phase
M&C	Monitoring and Control
MCM	Monitoring and Control Model
MCS	Mission Control System
MIB	Mission Information Base
MICONYS	Mission Control System infrastructure
OBSM	On-Board S/W Maintenance
OPEN	Operations Preparation ENvironment
PUS	Packet Utilisation Standard
RTF	Reference Test Facility
SCOS	Spacecraft Control System
SLE	Space Link Extension
S/W	Software
TM	Telemetry
TC	Telecommand
UI	User Interface

REFERENCES

[1] M. Pecchioli, J. M. Carranza, A. Walsh, "The Highlights of the European Ground Systems - Common Core Initiative," SpaceOps 2014, Pasadena