The Next Generation Mission Operations Preparation Environment at ESOC

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INTRODUCTION

This paper introduces the Operations Preparation Environment (OPEN), its rationales and objectives, the related implementation concepts, the intended deployment strategy at ESOC and highlights possible extensions.

At the European Space Operations Centre (ESOC), the ground and space segment data systems used for mission operations require a considerable variety of tailoring data (e.g. spacecraft Monitoring & Control data definitions, procedures, user defined display definitions, etc.) that must be prepared by the Phase E operations teams. The processes required to generate and maintain a consistent set of products requires considerable effort. Equivalent or similar processes and products are required by the EGSE and AIT teams during mission's phase C/D to prepare environments for execution of simulation and testing campaigns.

Currently different data systems and missions have dedicated preparation environments. There is little overall coherent and no complete solution supporting the mission operators in their tasks related to operations preparation. There is also currently no synergy between the spacecraft and ground station operators communities.

In-order to rationalise the number of preparation environments for mission operations, ESOC 's strategy aims at a unified environment for the efficient and effective preparation of mission operations tailoring data. However, the range and scope of data to be prepared for mission operations is wide and varied and covers all tailoring data relevant to the controlled systems. Since every ESOC mission has unique requirements for data and features, it is not possible to offer a single application that is able to process all types of data. Additionally, some tools cannot be technically integrated and/or follow different governance cycles/principles (e.g. proprietary tools).

ESA is therefore creating a light framework supporting generic services and features which can be expanded via specific extensions to cover specific preparation application needs. The aim is to use the framework to develop applications covering the full scope of mission operations data preparation. The framework is meant to be light, data type agnostic and extendable by specific extensions covering specific data types or services.

The generic functions to be provided include common services for data management, such as access control, version control, reporting, data comparison and merging. It also provides via extensions standard views for common tasks such as editing and browsing of data related to monitoring and control models, flight operations, packets, displays, mission planning rules and procedures.

The objectives of the framework are to (a) streamline the mission operations tailoring activities and enable a reduction of the required efforts by operators; (b) provide a consistent environment where all applications related to operations preparation can be hosted and avoid proliferation of heterogeneous implementations;(c) harmonize the tools used by the spacecraft and ground stations operations teams; (d) extend the support of advanced features (e.g. configuration management) to all artefacts related to mission operations.

A secondary objective is to support the transition from the current generation Mission Control System Infrastructure (SCOS-2000) and the future generation of ground data system infrastructure based on the European Ground Systems Common Core (EGS-CC). The OPEN-CC framework is indeed intended to initially support the tailoring of mission operations data for EGS-CC based systems at ESOC.

Being 'open', extensions providing services, data type specific functionalities and the actual 'user front-end' functionality may originate from several sources in terms of funding and organisation. It is intended that proprietary extensions are developed and used as part of the OPEN-based applications at ESOC. At the same time, it is foreseen that the framework itself and some related extensions are made available under an ESA open source or community software license.

OPEN-CC BASED ENVIRONMENTS

Based on the foundation provided by OPEN, the OPEN framework is extended as OPEN-CC to specifically support the tailoring of EGS-CC-based data systems part of the European Ground Operation System (EGOS-CC) [1]. The OPEN is mostly agnostic to EGS-CC data types, while OPEN-CC is a framework based on OPEN but with framework extensions that are EGS-CC 'aware'. Extensions can be added to both the OPEN and OPEN-CC frameworks but EGS-CC specific extensions can only extend OPEN-CC.

The future generation of Monitoring and Control (M&C) ground data systems infrastructure preparation environments will be based on OPEN-CC. This will include the data system domains for (i) spacecraft operations; (ii) ground station operations; (iii) operational simulators preparation environments. Each domain will include extensions to data definitions, editors and browsers relevant to the end user needs.

i.   The preparation environment of MICONYS-CC, ESOC's Mission Control System software suite, will include EGS-CC based data definitions, editors and browsers to support the needs of the Flight Control Teams. It will extends OPEN-CC with a number of extensions specific to the Spacecraft Operations domain.

For example, functionality will be required for the production and maintenance of Flight Operation Procedures (FOP) by the Flight Control Team (FCT). The foreseen implementation of the FOP Editor is a re-engineering of the current FOP Editor, MOIS Writer, to make it compatible as an extension within OPEN-CC.

In addition to the EGC-CC native data exchange, the preparation environment will support the import of tailoring data from the legacy SCOS MIB format. This provides 1) support for the migration of missions from SCOS-2000 to EGS-CC and 2) enables an external organisation or a legacy implementation to deliver tailoring data to ESOC in SCOS-2000 MIB format but where M&C of the controlled system is based on MICONYS-CC.

ii. The Ground Station Monitoring and Control system (GSMC-CC) preparation environment will also extend OPEN-CC with a number of extensions specific to the Ground Station M&C domain. The primary extensions are additional data definitions and editors required for the tailoring of the GSMC-CC adaption layer which implements the interface between the GSMC-CC and the Ground Station Sub-Systems.

The GSMC-CC will be required to extend the Import function so that the Ground Station sub-system database can be imported into the preparation environment. Support shall also be added for the import of Ground Stations MIBs such that the corresponding EGS-CC Monitoring Control Model is correctly configured and user defined displays and low level automation control procedures automatically generated as necessary. Tailoring data is exported using the common OPEN-CC export functionality with extensions for additional data definitions for the tailoring of the GSMC-CC adaptation layer.

iii. Future operational and ground data system test simulators of EGS-CC based missions will require a set of applications extending OPEN-CC for the preparation of data.

DATA DEFINITIONS

A summary of the data definitions currently planned or envisaged to be supported through OPEN or OPEN-CC extensions is provided by Table 1. If the preparation of the data definition is not supported by common extensions (e.g. FCT documentation), the specific preparation environment must provide an extension.

OPEN-CC extensions to data definitions and associated editors and browsers will be provided for the MICONYS-CC and GSMC-CC preparation environments when not directly supported by the common OPEN-CC or OPEN extensions or the framework itself. Extensions to data management services will also be included as necessary.

Future extensions could also cover Mission specific On-Board Control Procedures, Flight Operation Plan requirements; Timelines, Diagnostic rules definitions, Tailoring data validation tracking, Verification and validation support data.

Table 1 Currently planned or envisaged Data Definitions

Data Definitions	Description	Data Definition support Required		
		MICONYS-CC	GSMC-CC	SIMULUS
Monitoring and Control Model	EGS-CC Monitoring & Control Model used to configure the EGS-CC Kernel	x	x	x
TM/TC packets	Definition of TM/TC packets used by the EGS-CC Packet Encoder / Decoder	x		x
ESA Ground Station M&C ICD required definitions	Variable lists of parameters, Transient Variables, Tasks and all other structures present in the interface		x	
On-board M&C Services (PUS)	PUS based monitoring and control services	x		x
User Defined Displays	Used defined displays running with the EGS-CC User Interface	x	x	x
Synthetic Parameters	Definition of Synthetic (Derived) Parameters	x	x	
Expressions	Expressions based on the EGS-CC script language	x	x	
Activity Lists	Lists of activities	x		
Ground Station Subsystem Interface Definitions	Definitions describing the interface to Ground Station Subsystems		x	
Flight Control Procedures	Manual Flight Control Procedures	x		
Scripts	Scripts written in the EGS-CC based script language	x	x	
Automation Procedures (Java)	Native EGS-CC Automation Procedures	x		
Automation Procedures (DSL)	DSL Automation Procedures	x	x	
Automation schedule templates	Automation schedules for execution	x	x	
Mission planning rules	Definition of Mission Planning Rules	x		

Data Definitions	Description	Data Definition support Required		
		MICONYS-CC	GSMC-CC	SIMULUS
FCT documentation	Generation of FCT documentation	x		
FCT Preparation Activity Planning	Reports of Activities in the MCM tree	x		
Ground Station Main Menu	The tailored main menu of the ground station M&C with associated actions		x	
Problem and requirements tracking	Requirements management with cross references to procedures and validation data.	x	x	
Simulator Preparation Data (e.g. simulators scripts);	Simulator preparation data			x

OPEN FUNCTIONALITY

OPEN functions are grouped into three main functional categories;

- Managed Data – the set of supported data definitions (e.g. procedures, packets, models, etc.) managed by the preparation environment;

- Data Management Services – set of data services for managing data, such as version control, access control, consistency checking, data merge and compare, reporting/publication, import/export, etc.

- Data Editors and Bowsers – the set of editors and browsers used to view and edit managed data. Dedicated editors and browsers are foreseen for all the supported OPEN-CC data definitions.

Within the OPEN-CC framework, the supported data models will be those covered by the EGS-CC Conceptual Data Model, (CDM) but additional data models specific to MICONYS-CC or GSMC-CC will be defined and supported.

The OPEN framework defines a set of common Data Management Services. For example, common services exist for consistency checking (e.g. checking of dependencies between data sets), the merging of data, comparison of data set versions, access control to different data sets, management of data sets baselines, generation of reports, change logs, delta and complete import/export, generation of baselines, etc. Some common services require specific extensions where data specific functionality is required. For example, import and export of data sets to a specific data formats (e.g. import of data from an S2K MIB) will be provided by dedicated extensions and which comply with the OPEN framework extension interfaces.

IMPLEMENTATION

The OPEN framework is built on the concept of software plugins which implement the core framework functions. This is extended by the OPEN(-CC) extensions with additional plugins to support the EGS-CC CDM data definitions and associated editors and browsers. For example, if editing of automation procedures is required, then an extension for procedure definitions managed data and editors are added into the framework to form the desired target application. All individual functions, composing the framework and extensions, are defined as distinct software plug-ins.

The framework is implemented using Java and relies on the Open Services Gateway initiative (OSGi) modular system and the Eclipse Rich Client Platform. OPEN extensions are naturally developed as set of Eclipse plug-ins.

The preparation environment's software applications using OPEN are to be delivered and deployed to end users as standard desktop applications. OPEN-CC is intended to run on multiple operating systems compatible with office applications, including Windows. It will support the editing of data in both an 'offline' mode (where the application runs locally on the user computer without any network connectivity) as well as 'online', when sporadically requiring TCP/IP connections to a centralised repository.

Finally, OPEN's managed data is internally handled as Eclipse Modelling Framework (EMF) models and stored and exchanged using a distributed version control system.

SUMMARY

The Operation Preparation Environment (OPEN) and related OPEN-CC are part of an ESA initiative to streamline and harmonise preliminary EGS-CC based preparation environments for spacecraft and ground stations operations teams at ESOC to manage operations data required to tailor and operate the ground data systems.

The extendable frameworks offers the possibility to combine and integrate in a consistent manner specialised tailoring tools from different organisations and develop an eco-system of applications around an open source framework system.

Beyond operation, OPEN can enable improved coordination and exchange between mission's phases C/D/E tools and organisations.

Along with the deployment of EGS-CC based M&C systems, OPEN is intended to ultimately become the preparation environment of all ESA missions operated at ESOC.

REFERENCES

[1]   M. Pecchioli, A. Walsh, "The EGS-CC based Mission Control Infrastructure at ESOC" SESP 2017, Noordwijk