

An operations preparation ecosystem

Ground System Architectures Workshop 2021

F. Trifin, C. Lannes, T. Walsh – European Space Agency

Ground System Architectures Workshop - GSAW 2021

03/2021

EGOS-CC's OPEN preparation environment and the related applications for managing the tailoring data of the next generation of monitoring and control systems used at ESA

The current generation of heterogeneous control systems used at the European Space Operation Centre (ESOC) for Mission Operations and Ground Station Monitoring and Control are facing obsolescence

ESOC is implementing a project (**EGOS-CC**) with the aim of replacing the current ESA Ground Segment Monitoring and Control systems by a new Monitoring and control infrastructure

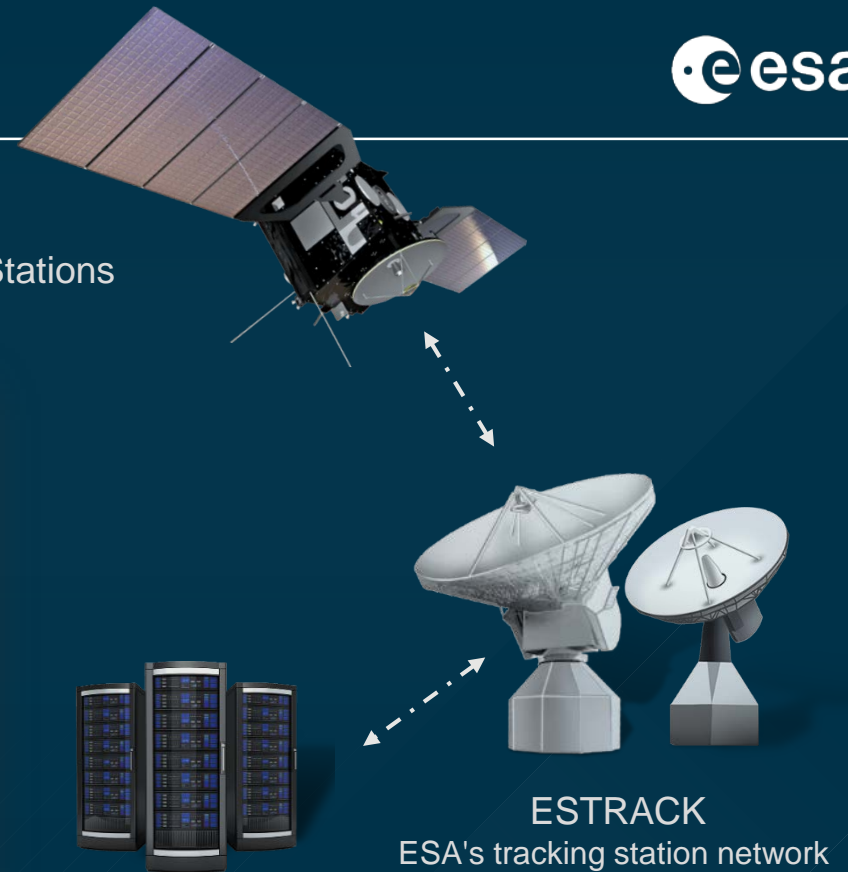
Approach

- Building upon the European Ground System - Common Core (**EGS-CC**), an ESA-led European initiative developing a common European Monitoring & Control infrastructure
- Ambitious objectives – aiming for a generic system, tailorable to support multiple use cases

High-level Introduction

European Space Operation Centre (ESOC)

- Monitoring and Control of Spacecraft and Ground Stations



High-level Introduction

European Space Operation Centre (ESOC)

- Monitoring and Control of Spacecraft and Ground Stations



High-level Introduction

European Space Operation Centre (ESOC)

- Monitoring and Control of Spacecraft and Ground Stations



High-level Introduction

European Space Operation Centre (ESOC)

- Monitoring and Control of Spacecraft and Ground Stations



High-level Introduction

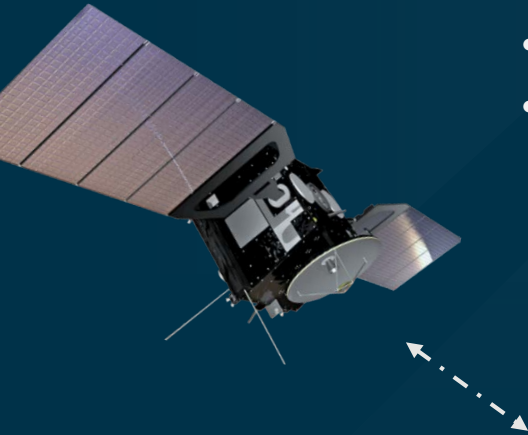
European Space Operation Centre (ESOC)

- Monitoring and Control of Spacecraft and Ground Stations



Monitoring and Control Systems

- Mission Control System (MCS)
- Ground Station Monitoring and Control (GSMC)

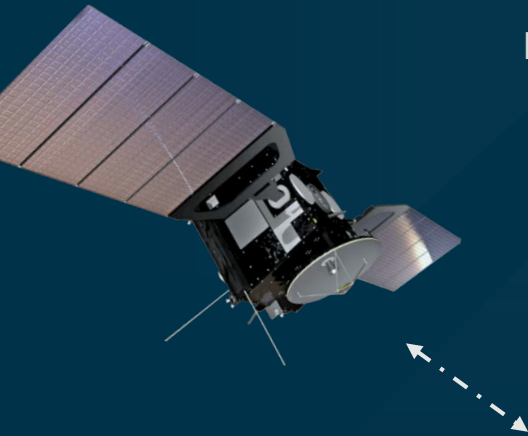


Mission Control System (MCS)



Ground Station Monitoring and Control (GSMC)

EGOS-CC – ESA/ESOC project for the adoption of EGS-CC
EGS-CC – European Ground System - Common Core

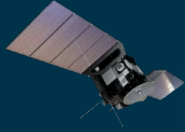


Mission Control System (MCS-CC)

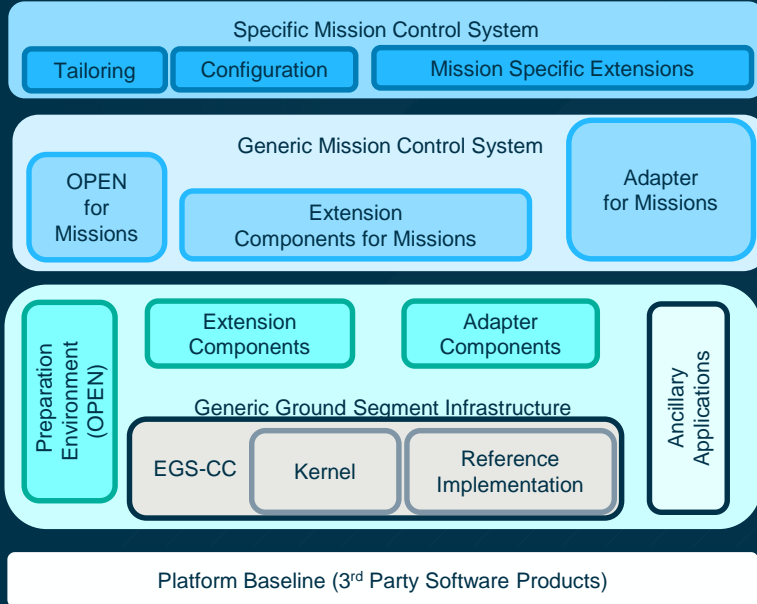


Ground Station Monitoring and Control (GSMC-CC)

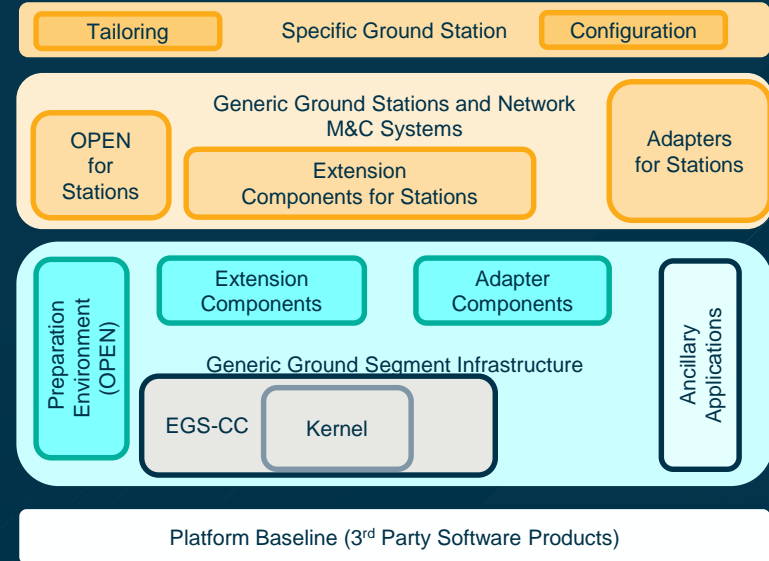


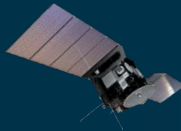


Mission Control System (MCS)

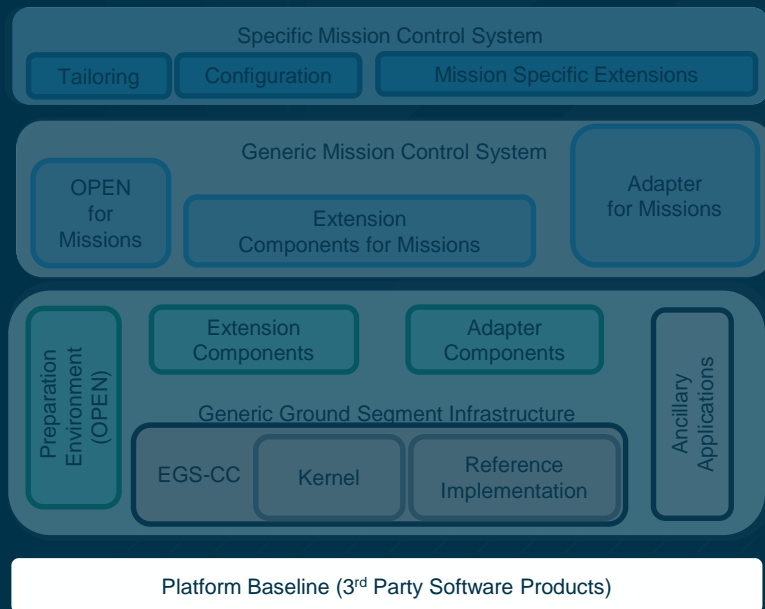


Ground Station Monitoring and Control (GSMC)

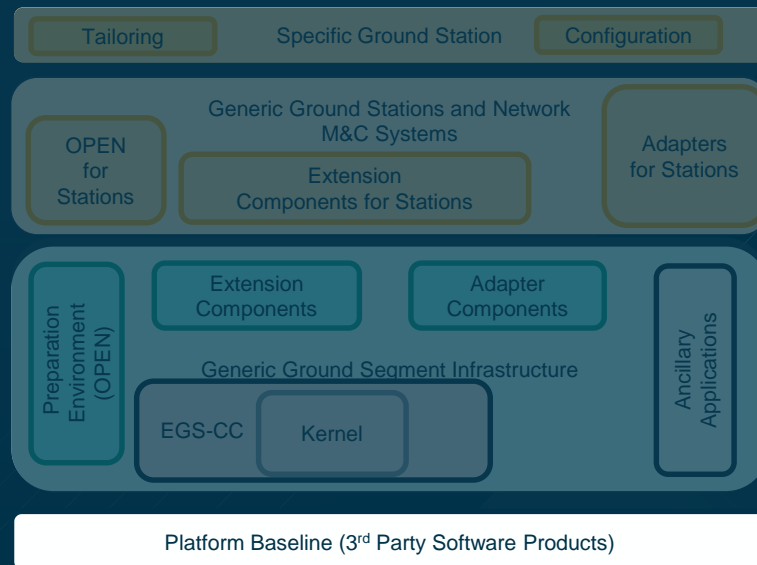


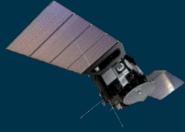


Mission Control System (MCS)

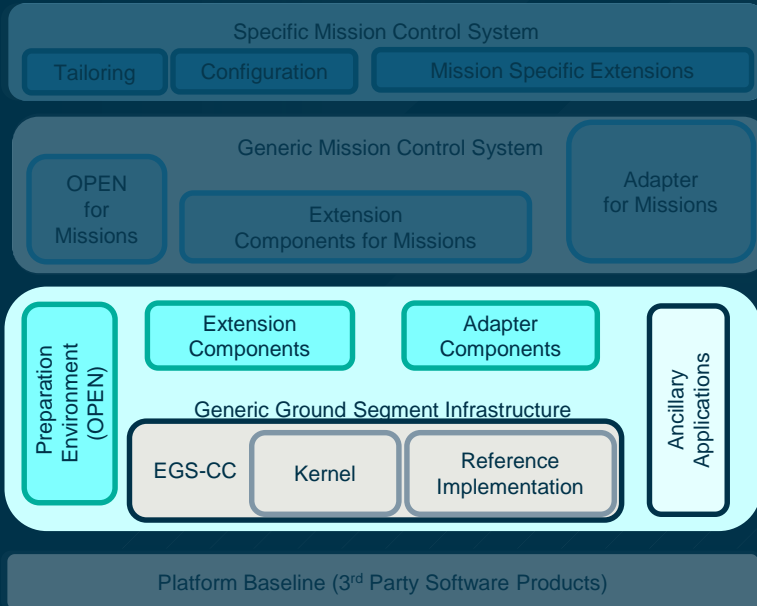


Ground Station Monitoring and Control (GSMC)

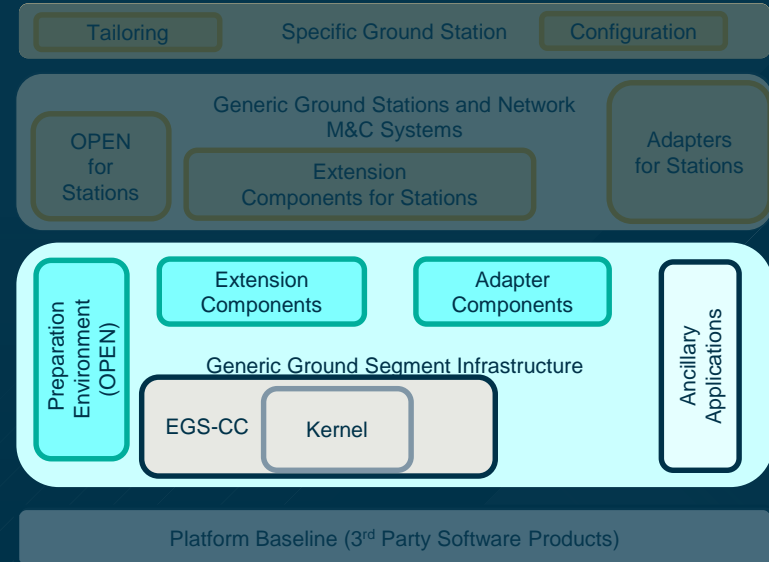




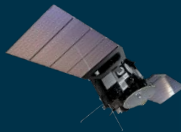
Mission Control System (MCS)



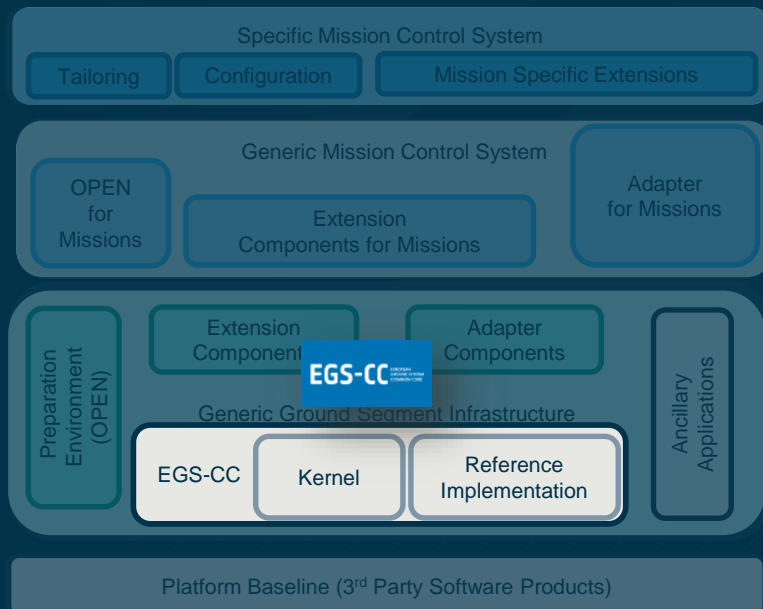
Ground Station Monitoring and Control (GSMC)



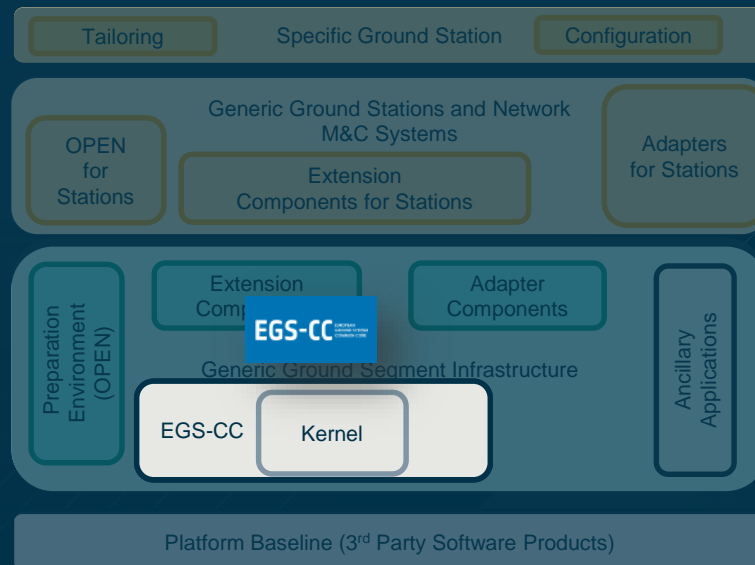
EGOS-CC High-level Architecture

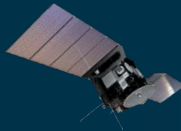


Mission Control System (MCS)

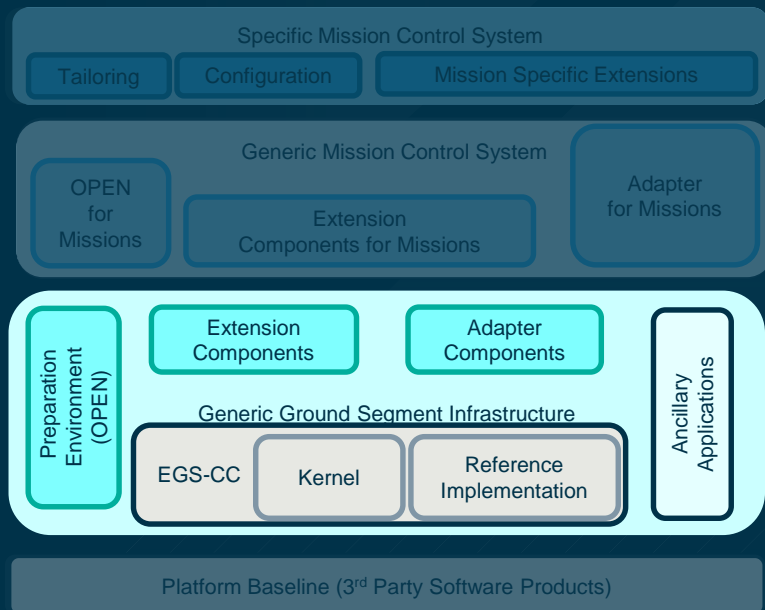


Ground Station Monitoring and Control (GSMC)

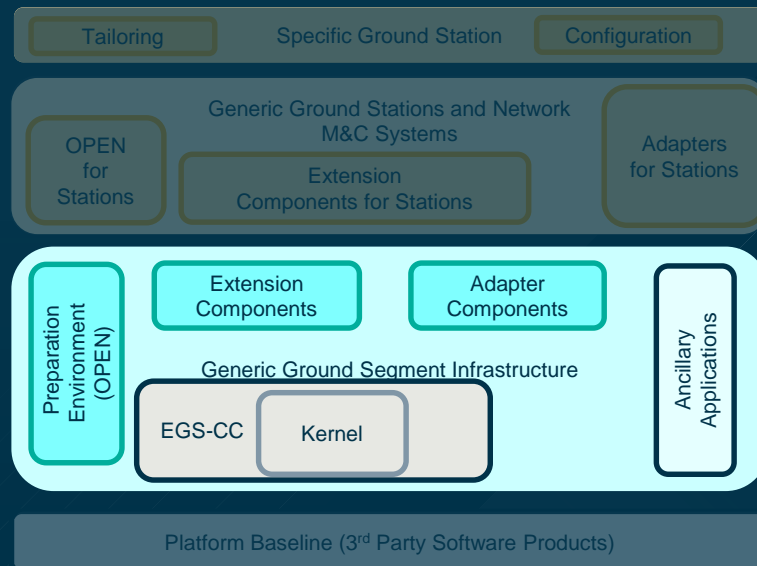


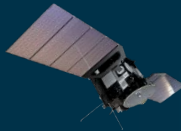


Mission Control System (MCS)

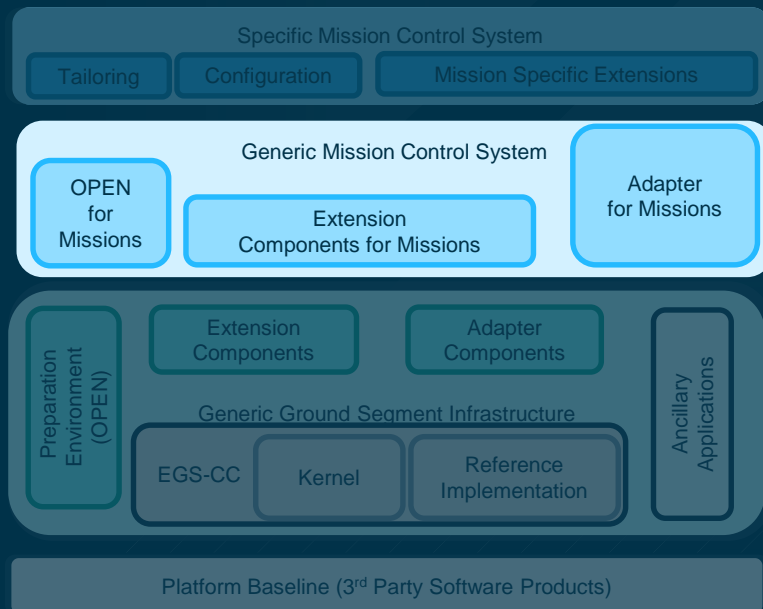


Ground Station Monitoring and Control (GSMC)

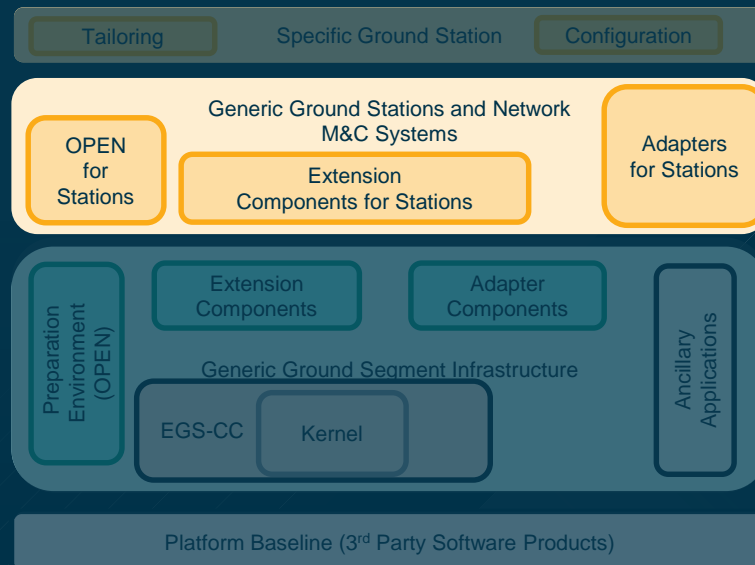


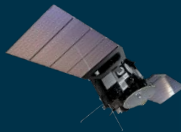


Mission Control System (MCS)



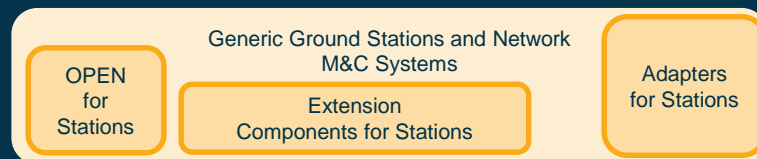
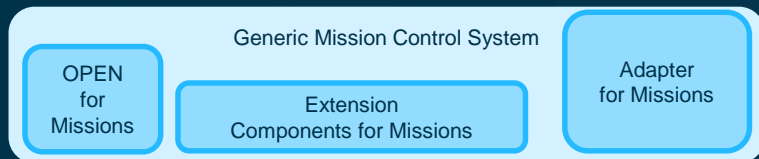
Ground Station Monitoring and Control (GSMC)





Mission Control System (MCS)

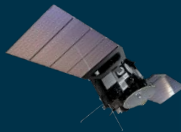
Ground Station Monitoring and Control (GSMC)



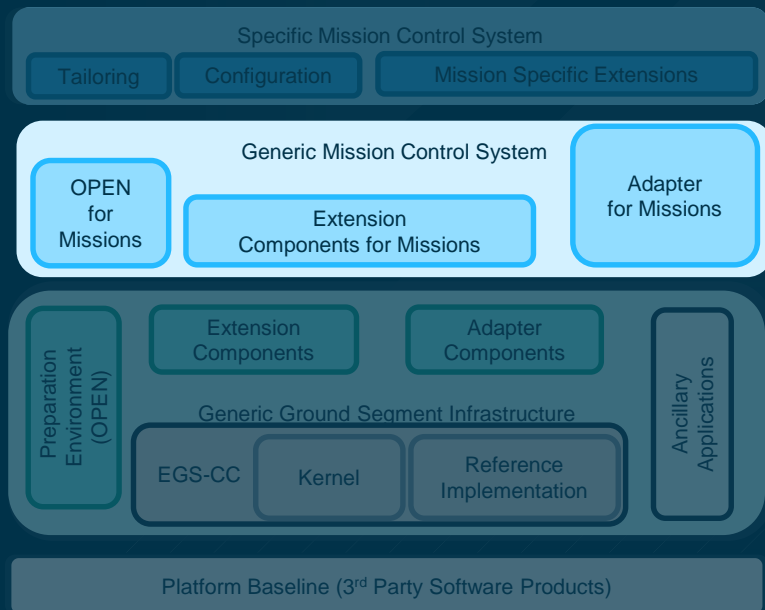
In this layer, e.g.

- User Interface Extensions (UIF)
- On-board Software Management (OBS)
- File based Operations (FBO)
- Telemetry File Ingestion (TFI)
- Ground Station M&C Adapter

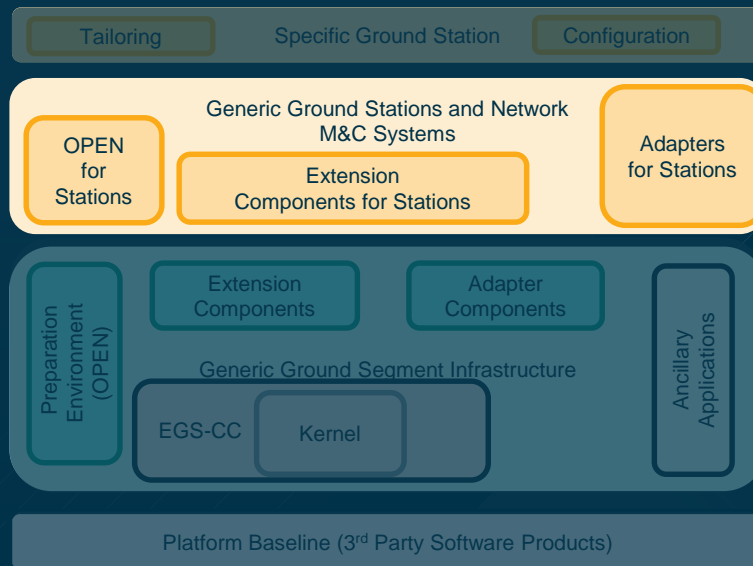
- Flight Dynamics Adapter
- Alert System REALS Adapter
- Command Request Management (CR)
- Long Term Archive Management (LTA)
- ..

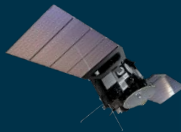


Mission Control System (MCS)

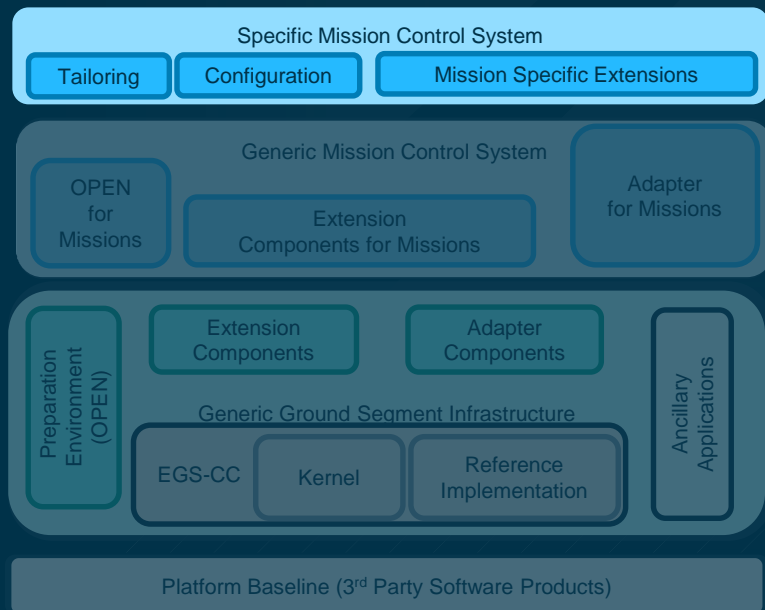


Ground Station Monitoring and Control (GSMC)

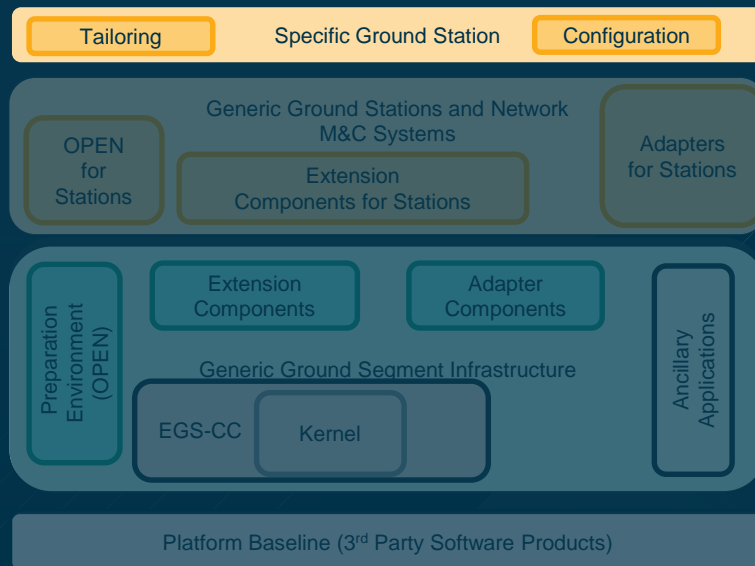


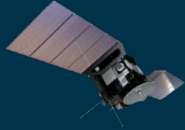


Mission Control System (MCS)



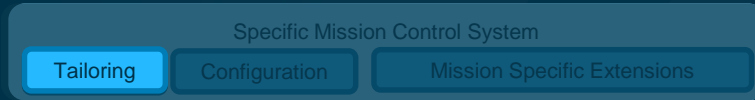
Ground Station Monitoring and Control (GSMC)





Mission Control System (MCS)

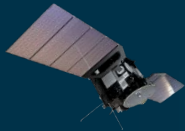
Ground Station Monitoring and Control (GSMC)



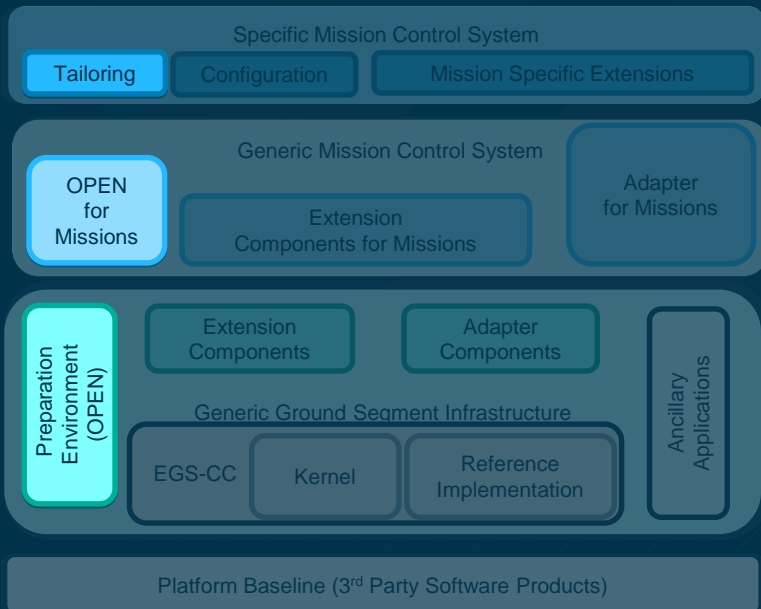
"Tailoring Data" covers all operator defined data consumed by the ground data M&C systems

such as

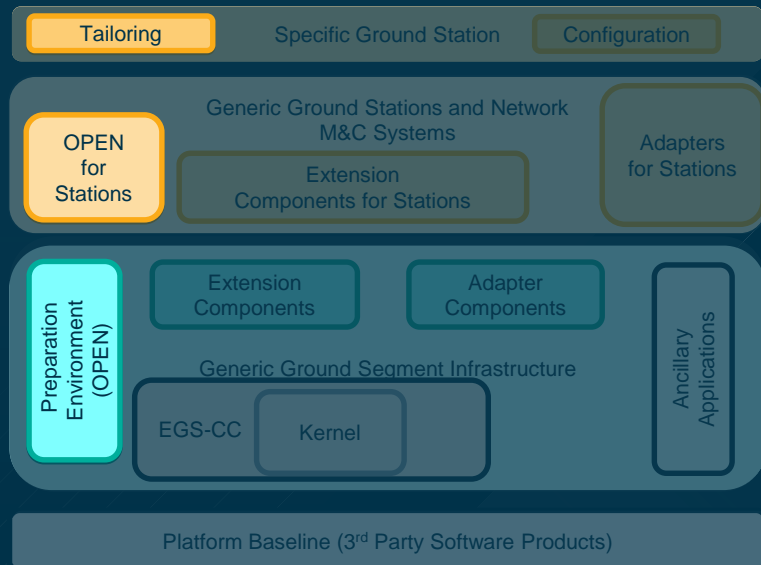
- Monitoring and Control models of the controlled system
 - Data structures exchanged with the controlled system (e.g. TM/TC packets)
- Operations Procedures (manual, automated, on-board)
- User Defined Displays (alphanumeric, scrolling, matrix, plots, mimics)
- Timelines, Schedule templates, Simulator scripts
- User configurations, ...

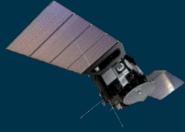


Mission Control System (MCS)



Ground Station Monitoring and Control (GSMC)





Mission Control System (MCS)

Tailoring

OPEN
for
Missions

Preparation
Environment
(OPEN)



Ground Station Monitoring and Control (GSMC)

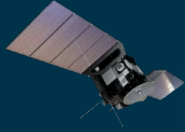
Tailoring

OPEN
for
Stations

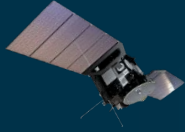
Preparation
Environment
(OPEN)

New components for the Management of the Tailoring Data

Tailoring Data Management for EGS-CC



New components for the Management of the Tailoring Data



Missions
Tailoring Data



OPEN-M
Preparation
Environment for
Missions

Ground Stations
Tailoring Data



OPEN-S
Preparation
Environment for
Ground Stations



Preparation
Environment
Framework

New components for the Management of the Tailoring Data

High-level Simplified Overview





Preparation Environments for
Management of EGS-CC Tailoring Data

EGS-CC Based Runtime
Monitoring and Control Systems

- Provision of streamlined, consistent, unified preparation environments to manage operations data required to tailor/operate the ground data systems
- Targeted towards EGS-CC systems, models and data
- Provides harmonised and coherent solution for the preparation of all monitoring and control tailoring data at ESOC

- **OPEN Framework is the foundation of software applications and services which are provided to end users, such as AIT engineers, operators and simulation teams.**

Main features

- Software framework (generic functionalities which can be selectively changed or expended)
- Model based (Automated generation of generic editors based on the model)
- Basic and generic user functions supporting the dedicated preparation environments
 - Version Control, Access control (Distributed using Simplified Tasks System)
 - Consistency checking (+ preparation/debugging of tailoring model checks)
 - Generic instance editors (User customizable “Form editors”) and multi instances editors (“Table editors”)
 - Import and Export in EGC-CC native data exchange format
 - Export to EGOS-CC M&C Systems (using EGS-CC data formats + additional OPEN metadata)
 - Scripting environment (Execution/Debugging of groovy scripts with API for framework services and CDM data modifications, Possibility for end-users to create additional UIs)
 - Data compare and Two or Three ways merging (CDM object model comparison - Custom EMF Compare UI)
 - Visualisation of Tailoring Model (navigate the EGS-CC CDM: object types, type hierarchies and properties)
 - Dedicated editors for Expressions, Groovy scripts, EAPL procedures, EUD User Defined Displays (Matrix, ANDs, etc..)
 - ..





OPEN-M
Preparation
Environment
for Missions

- **OPEN-M includes EGS-CC tailoring data editors and browsers to support the needs of the Mission Control Teams at ESOC**
- **Main Functionalities**
- All functionalities of the OPEN framework
 - +
- Dedicated configuration for Mission Control Teams
- Dedicated user documentation
- Import of SCOS-2000 MIB format (conversion from SCOS-2000 to EGS-CC Tailoring Model)
- Export to legacy systems in MIB format (sub-set only)
- ..



OPEN-S
Preparation
Environment for
Ground Stations

- **OPEN-S includes EGS-CC tailoring data editors and browsers to support the needs of the Ground Stations Tailoring Team at ESOC**
- **Main Functionalities**
- All functionalities of the OPEN framework
 - +
- Dedicated configuration for Ground Stations Teams
- Station Tailoring Language Procedure Editor
- Dedicated user documentation
- Import of Ground Stations MIB format (conversion to EGS-CC Tailoring Model and Ground Stations Extensions)
- ..

Specific Functionalities



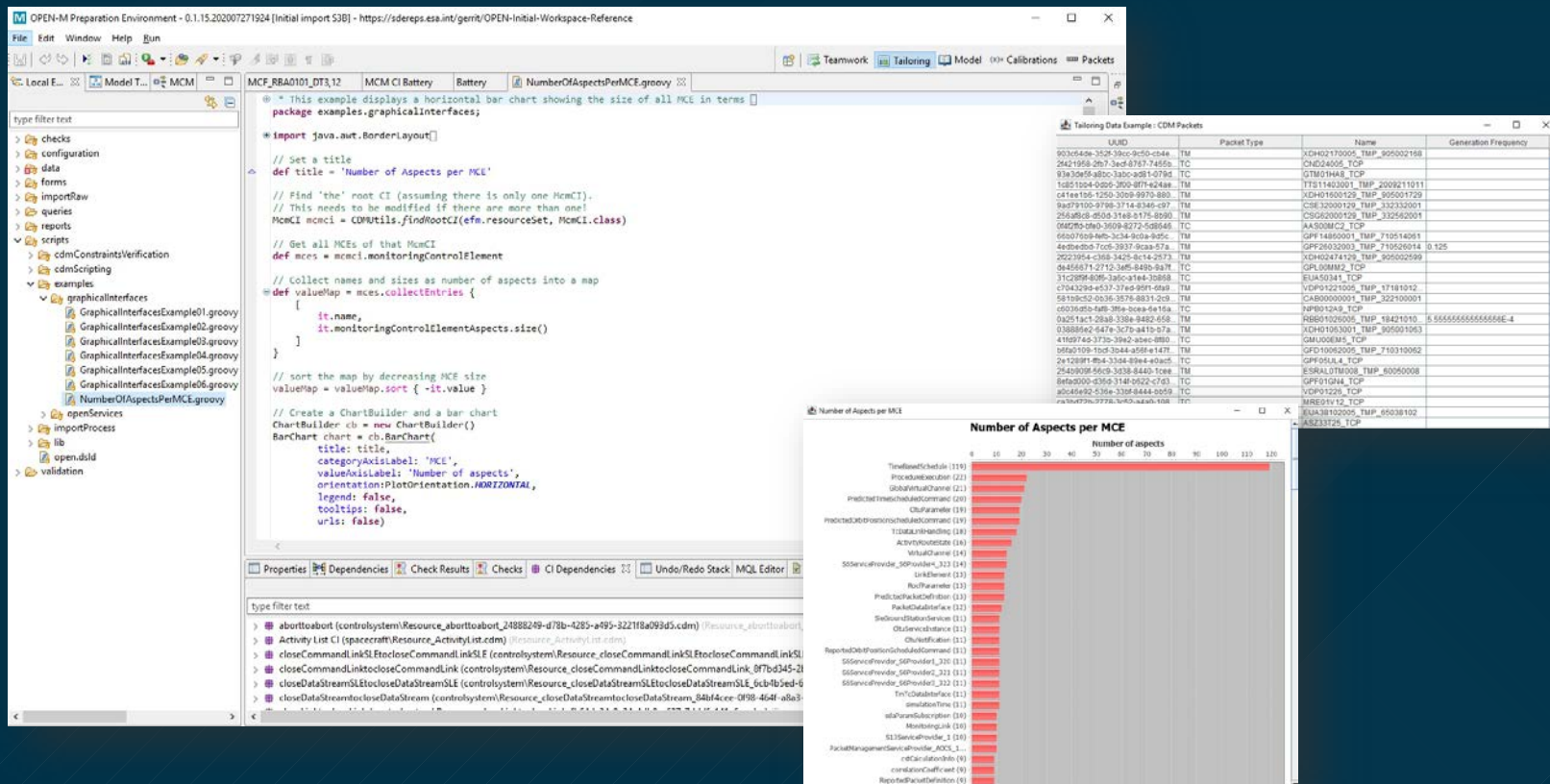
OPEN-M
Preparation
Environment
for Missions



OPEN-S
Preparation
Environment for
Ground Stations

The screenshot displays the OPEN Preparation Environment Framework interface, which includes several key components:

- My Tasks Panel:** A sidebar on the left showing a list of tasks. The 'Initial import S3B' task is highlighted and marked as 'COMMITTED'.
- Import Wizard:** A dialog box for selecting import data from EGS-CC Exchange Format files.
- Export Wizard:** A dialog box for selecting export data to a tailoring data container file.
- Properties Panel:** A panel on the right showing the status and details of the selected task.
- Check Results Panel:** A panel showing the results of various checks, including 'Check Modified', 'Check Results', and 'Check Results'.
- Calibration Base Panel:** A panel showing the calibration base, including 'Calibration Base', 'Low Tailoring Calibration', and 'Range Enumeration'.
- Algorithmic Panel:** A panel showing the algorithmic details, including 'Algorithmic', 'Interpolation', 'Logarithm', 'Polynomial', and 'Enumeration'.
- Conditional Calibration Panel:** A panel showing the conditional calibration details, including 'Conditional Calibration', 'Compound Calibration', and 'Default Calibration'.



The screenshot displays the OPEN-M Preparation Environment interface. The main window shows a Groovy script titled 'Number of Aspects per MCE' in the editor. The script defines a bar chart to visualize the size of all MCEs in terms of the number of aspects. The script includes comments and code for setting the title, finding the root CI, collecting MCEs, and generating the chart.

```

package examples.graphicalInterfaces;

import java.awt.BorderLayout;

// Set a title
def title = 'Number of Aspects per MCE'

// Find 'the' root CI (assuming there is only one MmcCI).
// This needs to be modified if there are more than one
MmcCI mmcCI = COMUtil.findRootCI(efm.resourceSet, MmcCI.class)

// Get all MCEs of that MmcCI
def mces = mmcCI.monitoringControlElement

// Collect names and sizes of number of aspects into a map
def valueMap = mces.collectEntries {
    [ it.name,
      it.monitoringControlElementAspects.size() ]
}

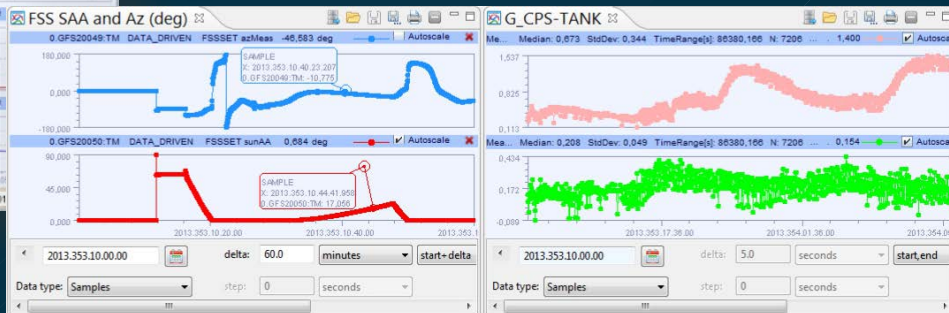
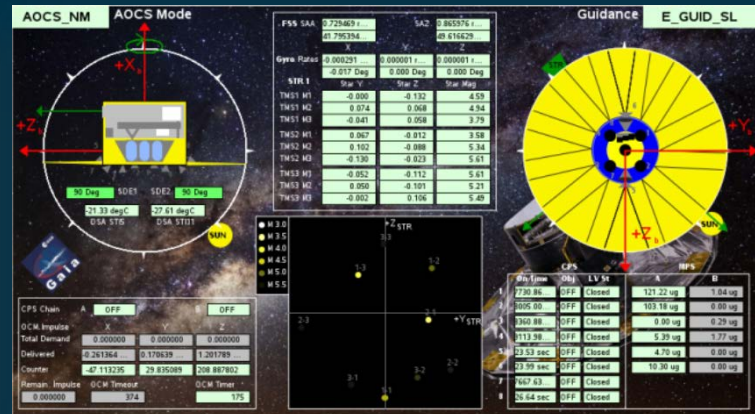
// sort the map by decreasing MCE size
valueMap = valueMap.sort { -it.value }

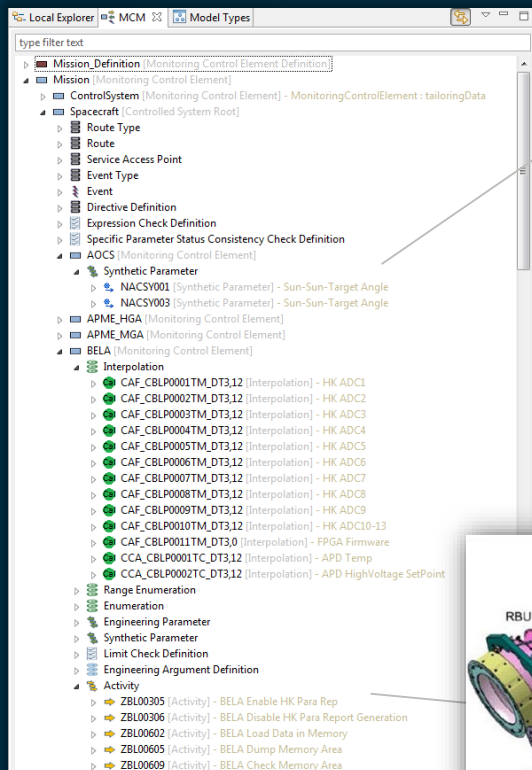
// Create a ChartBuilder and a bar chart
ChartBuilder cb = new ChartBuilder()
BarChart chart = cb.BarChart(
    title: title,
    categoryAxisLabel: 'MCE',
    valueAxisLabel: 'Number of aspects',
    orientation: PlotOrientation.HORIZONTAL,
    legend: false,
    tooltips: false,
    url: false)
  
```

The interface also shows a 'Tailoring Data Example: CDM Packets' table with columns for UUID, Packet Type, Name, and Generation Frequency. The table lists various packets and their associated frequencies.

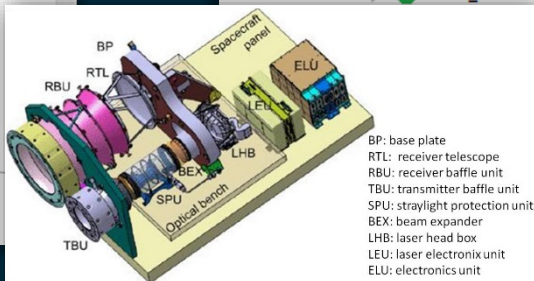
UUID	Packet Type	Name	Generation Frequency
903c440e-3528-33ac-9c50-c34e	TM	XCH02170005_TMP_805002168	
24d11958-2b07-3ed3-8317-7455b	TC	CHC04005_TCP	
939a3055-a83c-33dc-a811-0794c	TC	GT010148_TCP	
1d851104-0205-3050-8071-e248e	TM	ITS11420001_TMP_2009211011	
c47ee156-1250-3020-9975-880	TM	XCH047000129_TMP_305001729	
9a271100-9786-3714-8348-497	TM	CSE32000129_TMP_332320001	
254a8c08-8504-3148-5175-8990	TM	CSE02000129_TMP_332520001	
042f0c08-0963-3509-4272-50848	TC	AA5008C2_TCP	
66027108-8e5c-3c34-803a-905c	TM	GPF1480001_TMP_710514001	
4e8b4b07-c0c3-3937-6c3a-57a	TC	GPF26032003_TMP_710526014	0.125
20221954-c368-3425-8c14-2673	TM	VDP01221005_TMP_37181012	
6a464617-2715-34f5-8430-8a7c	TC	C48000000001_TMP_202100001	
31c289f408-3a5c-3a64-3088	TC	EUA50341_TCP	
c7043298-e537-3745-8911-49a9	TC	VDP01221005_TMP_37181012	
581b6520-0c36-3576-8811-3c0b	TM	C48000000001_TMP_202100001	
c0316d5b-4a5b-38fa-30ca-5a10a	TC	NP801248_TCP	
0a251ac1-28ab-338a-8462-458	TM	N860102005_TMP_18421010	5.6555555555555556e-4
03888a62-447e-3c79-ad19-57a	TM	XCH03063001_TMP_305001563	
41097453-3735-39a2-abac-880	TC	GAU000345_TCP	
569a0108-1b05-3044-a588-e147f	TM	GPD10062005_TMP_710310062	
2v12081f-8a4-3304-899a-e0a0d	TC	GPF0544_TCP	
254b0098-56cb-3a38-8440-1c0e	TM	ESRAL070008_TMP_60050008	
8e8a0000-4365-3148-0622-c763	TC	GPF01044_TCP	
20c45462-03a6-3388-8444-2a59c	TC	VDP01225_TCP	
2a3a5976-2775-7a43-a9ab-1038	TC	MRE0112_TCP	
		EUA38102005_TMP_65038102	
		AS333728_TCP	

Below the table, a bar chart titled 'Number of Aspects per MCE' is displayed. The x-axis represents the 'Number of aspects' (0 to 120), and the y-axis represents the 'Number of MCEs' (0 to 120). The chart shows a distribution of MCEs across different numbers of aspects, with a peak around 40 aspects.





- AOCS [Monitoring Control Element]
 - Synthetic Parameter
 - NACSY001 [Synthetic Parameter] - Sun-Sun-Target Angle
 - NACSY003 [Synthetic Parameter] - Sun-Sun-Target Angle
 - APME_HGA [Monitoring Control Element]
 - APME_MGA [Monitoring Control Element]
 - BELA [Monitoring Control Element]
 - Interpolation
 - CAF_CBLP0001TM_DT3,12 [Interpolation] - HK ADC1
 - CAF_CBLP0002TM_DT3,12 [Interpolation] - HK ADC2
 - CAF_CBLP0003TM_DT3,12 [Interpolation] - HK ADC3
 - CAF_CBLP0004TM_DT3,12 [Interpolation] - HK ADC4
 - CAF_CBLP0005TM_DT3,12 [Interpolation] - HK ADC5
 - CAF_CBLP0006TM_DT3,12 [Interpolation] - HK ADC6
 - CAF_CBLP0007TM_DT3,12 [Interpolation] - HK ADC7
 - CAF_CBLP0008TM_DT3,12 [Interpolation] - HK ADC8
 - CAF_CBLP0009TM_DT3,12 [Interpolation] - HK ADC9
 - CAF_CBLP0010TM_DT3,12 [Interpolation] - HK ADC10-13
 - CAF_CBLP0011TM_DT3,0 [Interpolation] - FPGA Firmware
 - CAF_CBLP0012TM_DT3,12 [Interpolation] - APD Temp
 - CAF_CBLP0013TM_DT3,12 [Interpolation] - APD HighVoltage SetPoint





Example Editor : Automation Procedure

The screenshot displays the OPEN-S Tailoring Application interface. On the left is a 'type filter test' tree showing a hierarchy of system root definitions and activities. The central pane shows the 'START_PASS.at' file with Groovy code for an automation procedure. The bottom pane shows the 'Properties' tab with a table of errors.

```
START_PASS.at

WINDOW MANDATORY;

INPUT

@ $scheme : @SCHED_SATCODE
Default /GSRA/03.VALUE
Prompt "Spacecraft name";

@ $typ_sup : @SCHED_SUPPORT_TYPE
Default select /GSRC/SUP/TYP.VALUE WHEN /GSRC/SUP/TYP.VALUE <> 'WSPAA';
NTTC_1 Otherwise
endselect
Prompt "Type of support";

@ $warm_up : @NO_YES
Default NOO
Prompt "Start Amplifier warm-up now";

DEFINE

@ $stat : @PSTATUS := NOX;
@ $msg : STRING;
@ $failed : BOOLEAN:=FALSE;

@ $start_time : TIME;
@ $proc_dur : DURATION;
@ $prise_amp : @GSRC_AMP_SEL;

== BEGIN -- Procedure Body ==

@ $msg := "35/START_PASS: ";

IF /STC/PRC/3T.VALUE = NON THEN LOG "Starting 35/START_PASS"; ENDF;
@ $start_time := NOW();

== IF /SYNTH/SyntheticParameters/SYNTH_Integer.VALUE = 3 THEN EXIT;
LOG "Spacecraft name : " + toString($scheme);
LOG "Support type : " + toString($typ_sup);
LOG "Start warm-up : " + toString($warm_up);

-- Prechecks that on-going schedule is not already using the station
-- If active for the same Spacecraft, support is stopped
-- If active for an other Spacecraft, job aborts.

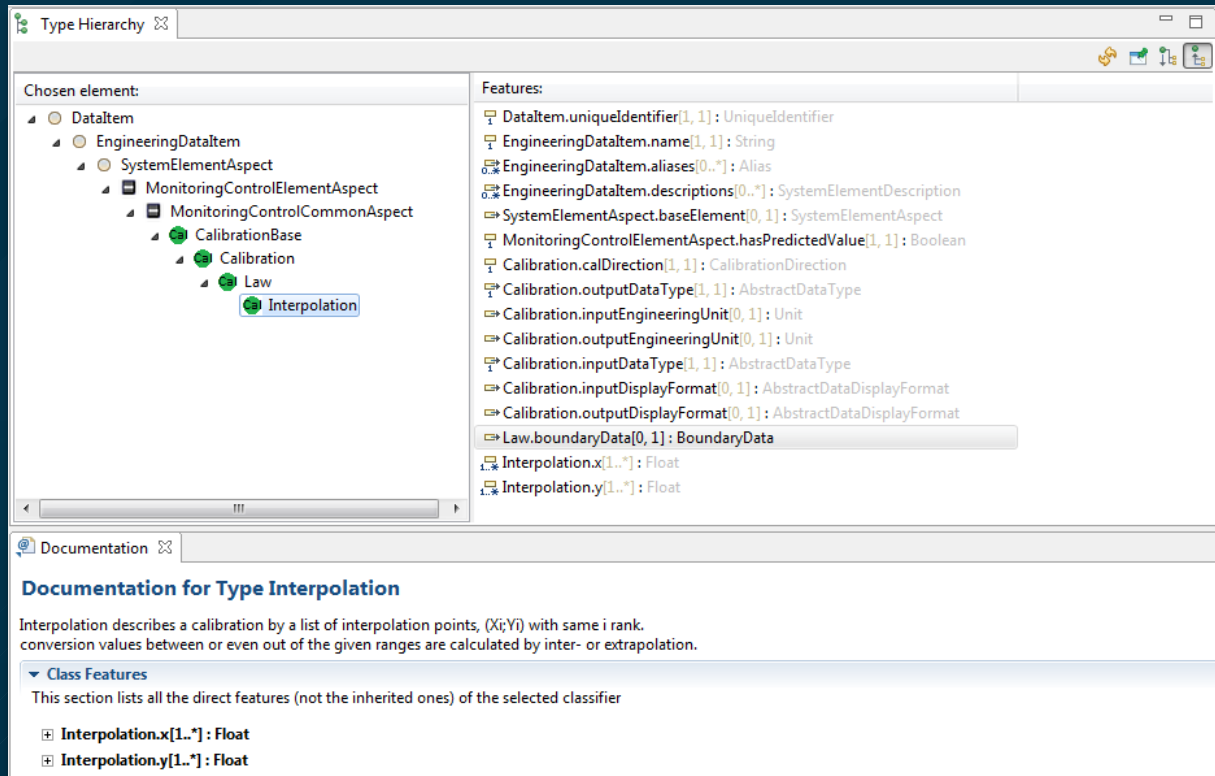
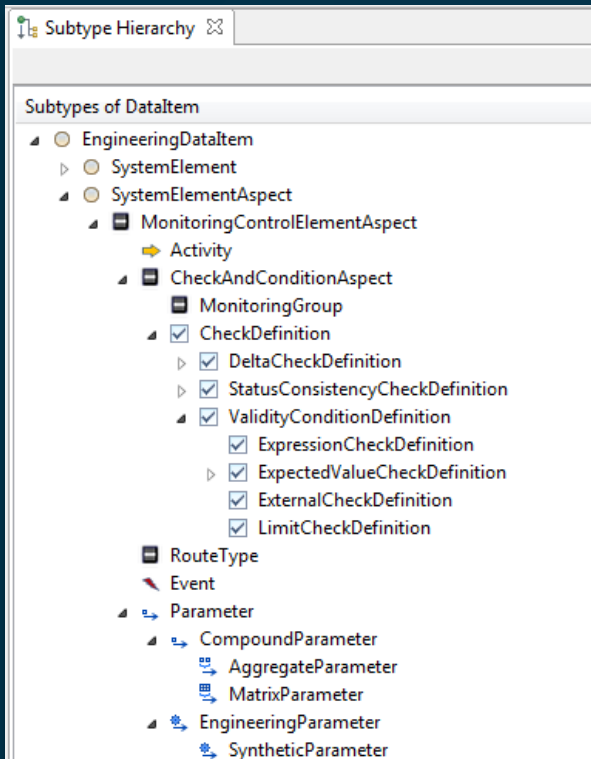
2 errors, 0 warnings, 0 others
```

Description	Element	Path	Location	Check	Groovy Rule Id	Type
Expected name S/TTCP_FRPL_SET	TTCP_FRPL_S...	/MissionProject/da...	line: 40 /Missi...			Stl Problem
mismatched input 'expecting TITLE'	TTCP_FRPL_S...	/MissionProject/da...	line: 40 /Missi...			Stl Problem



OPEN-S
Preparation
Environment for
Ground Stations

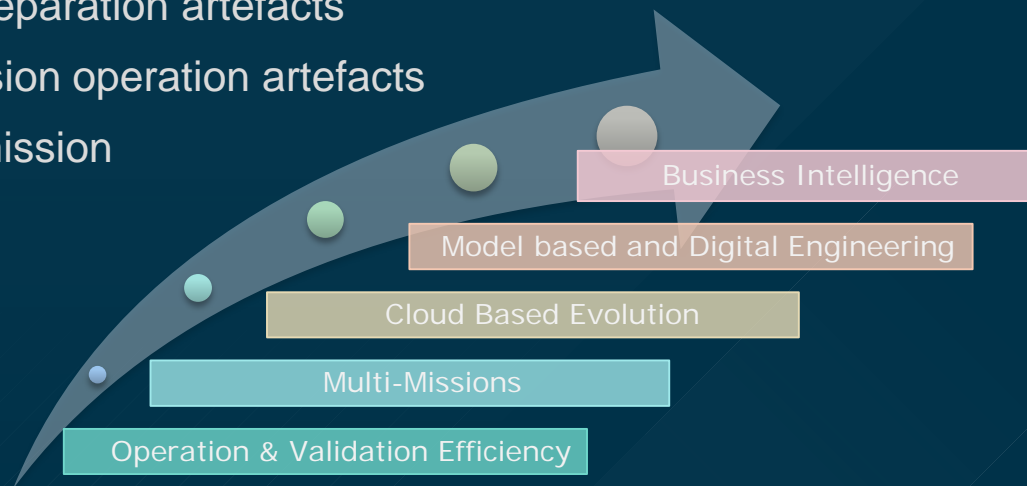
Example View : Model Visualisation



- The family is expanding further through new applications and extensions
- e.g. OPEN-D supports the management of the EGOS-CC system configuration files consistently with the tailoring model
- Foundation for an OPEN Multi-missions/Multi-systems Management
- OPEN-M Flight Control & Automation Procedures Management
- OPEN-M Timelines Management
- OPEN-M CCSDS MO services importer
- OPEN-M Extension for SIMULUS-NG



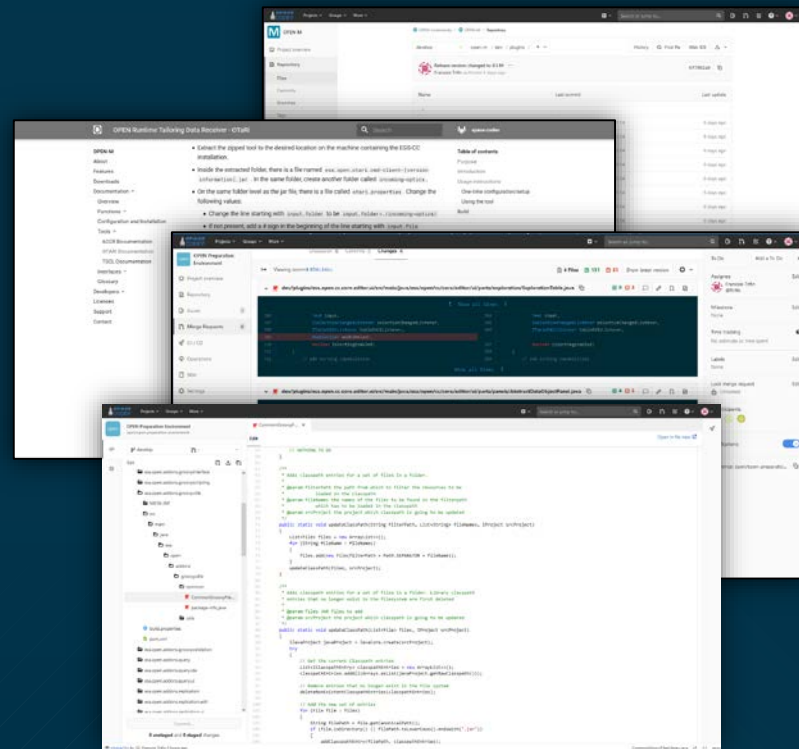
- Integration with Model Based Engineering Hub, Digital Ground Segment Engineering and Business Intelligence Platforms
- Improved operations efficiency of the ground segment (both missions and ground stations)
- Continuous Integration of operations preparation artefacts
- Support of automated validation of mission operation artefacts
- Enable coherent and innovative multi-mission integrated cloud based approach
- Integration with further operators tools and platforms



OPEN Environments

- OPEN is technologically designed to be an extensible platform federating various extensions which can originate from several sources in terms of funding and organisation
- The licensing scheme adopted for the OPEN framework and OPEN-M are designed for collaborative development under the ESA Community Software License
- Proprietary extensions are intended as part of the OPEN-based applications

- www.space-codev.org is a collaboration platform of the European Space community
 - Supported by the European Space Agency
 - Provides a collaborative software development environment
 - Projects available under the ESA Community Software License
- OPEN and OPEN-M Community Projects
 - Software Source code
 - Technical Documentation
 - Software Development Platform (Gitlab)



- The European Space Agency has developed an harmonised digital ecosystem of Ground and Space Monitoring and Control Preparation applications
 - ESA's tracking station network (ESTRACK) monitoring and control systems
 - ESA's mission control systems
 - Relevant for the Assembly, Integration and Test (AIT) and satellite simulator M&C areas
- The OPEN ecosystem is expanding with new extensions and applications
- The European Space Agency fosters an OPEN community of users and contributors sharing the benefits generated by the common software applications
- The OPEN preparation environments are intended to evolve towards multi-missions cloud based solutions and data hubs increasing cohesion to further areas such as MBSE and Business Intelligence

Thanks for your attention!

Software, documentation and tutorials available at <https://open.space-codev.org>

Related presentations at GSAW 2021:

- ♣ *A truly generic platform for control systems*
- ♣ *From Mission-Centric towards Infrastructure-Centric Processes and Services*

We would like to acknowledge the excellent work of all the OPEN project team members