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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

Common Ground Segment Monitoring and Control



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

<u>Approach</u>

- 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

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European Space Operation Centre (ESOC)

• Monitoring and Control of Spacecraft and Ground Stations





ESTRACK ESA's tracking station network



European Space Operation Centre (ESOC)

• Monitoring and Control of Spacecraft and Ground Stations













ESTRACK ESA's tracking station network

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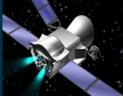
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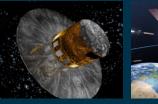








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ESTRACK ESA's tracking station network

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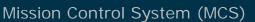
ESTRACK ESA's tracking station network



Monitoring and Control Systems

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





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Ground Station Monitoring and Control (GSMC)



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



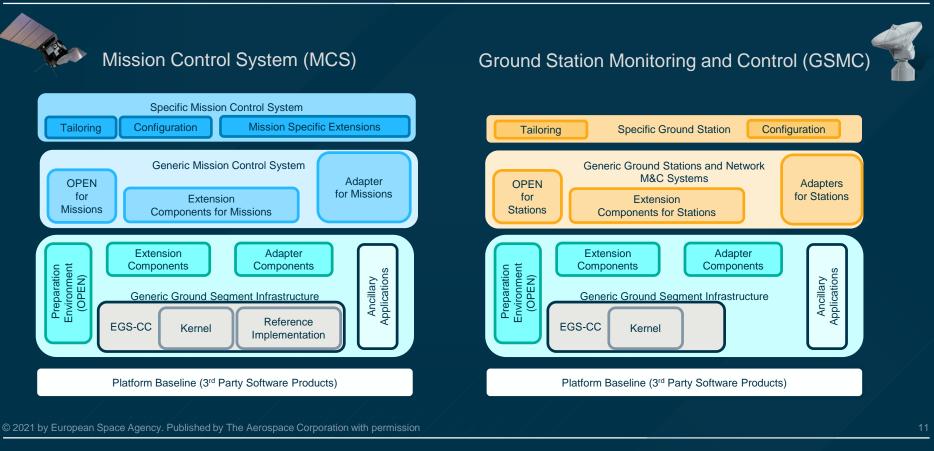
Mission Control System (MCS-CC)

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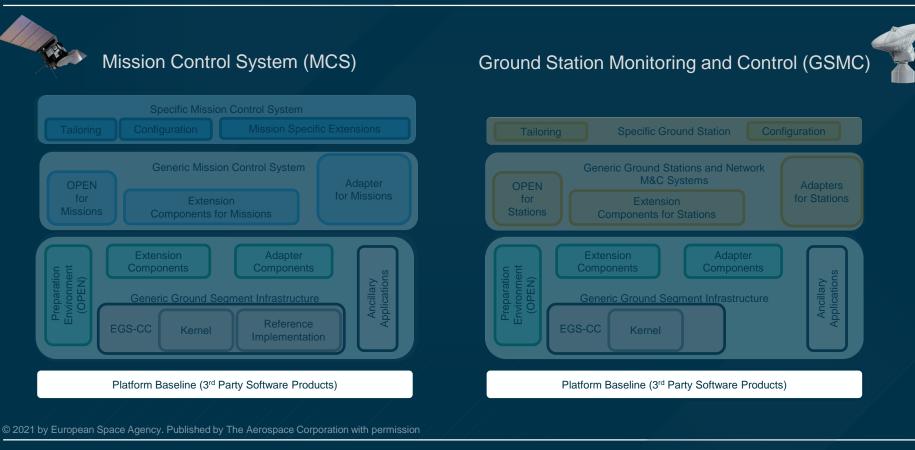
Ground Station Monitoring and Control (GSMC-CC)





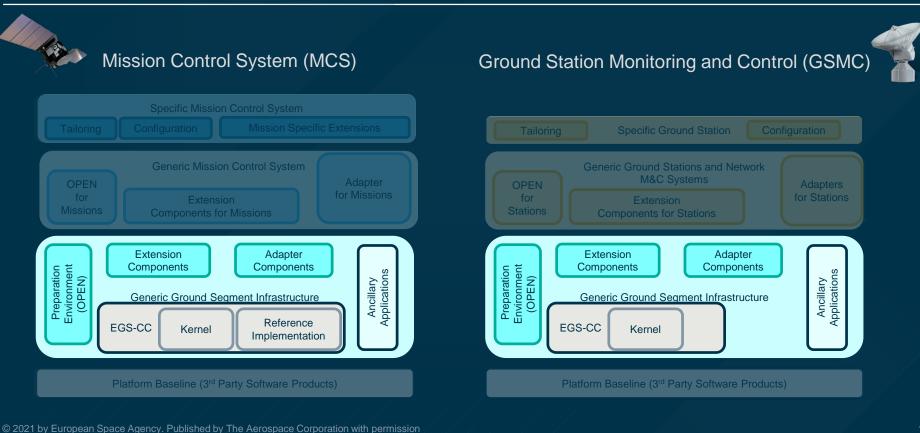
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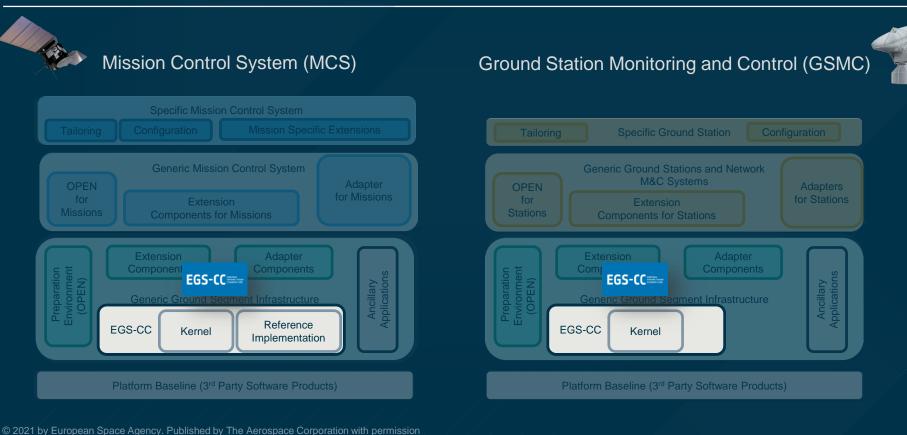


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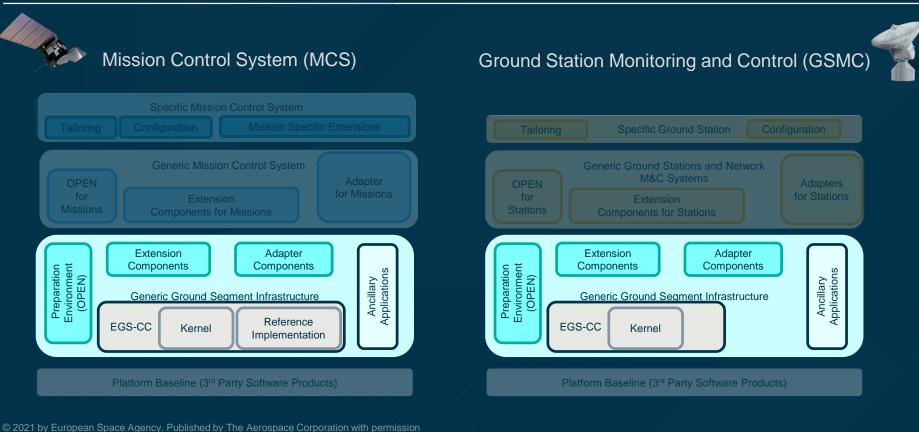




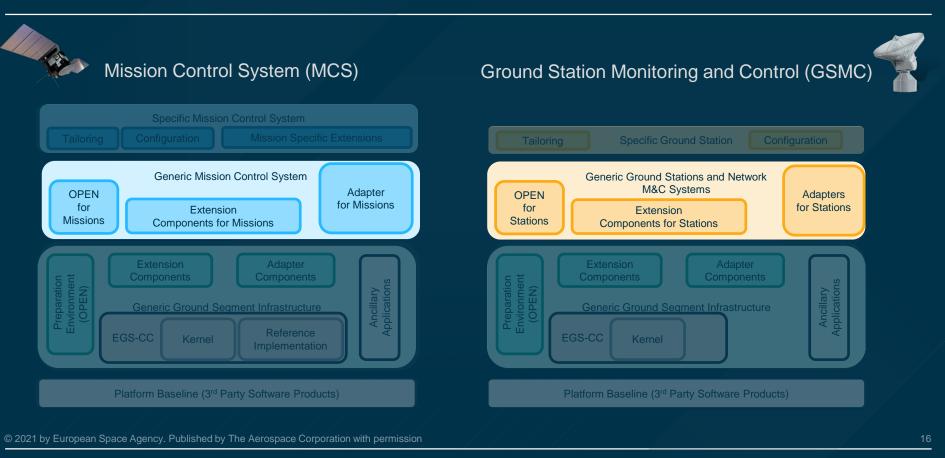


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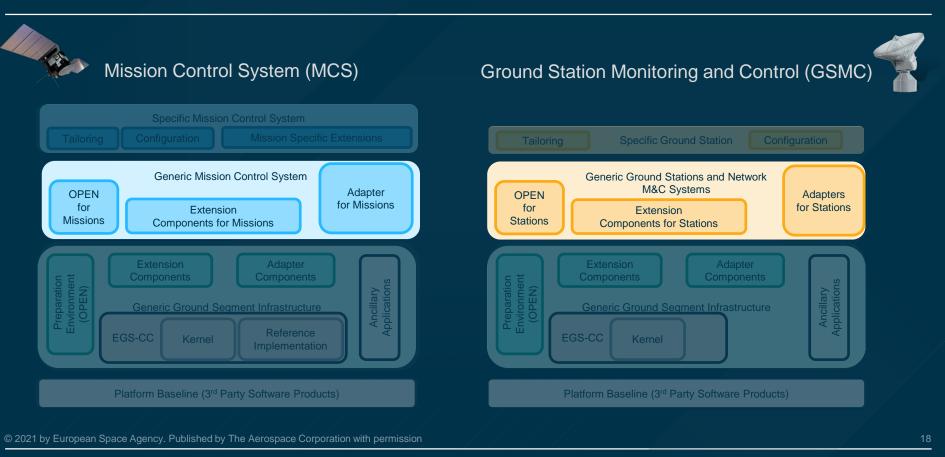




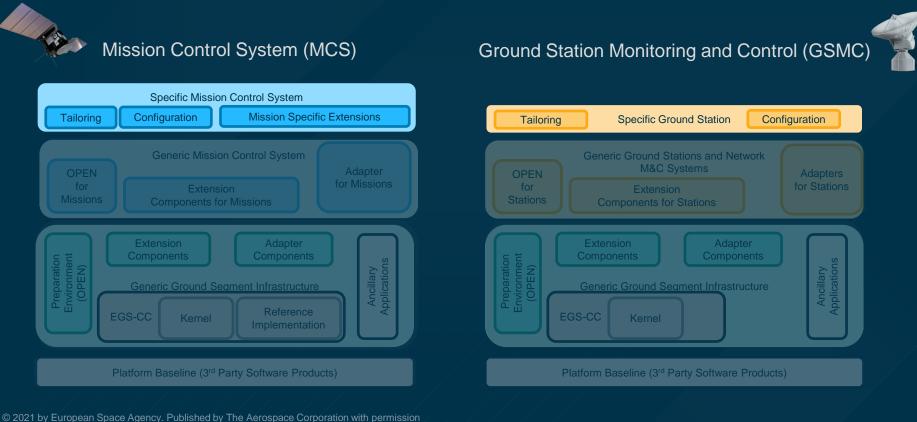
- User Interface Extensions (UIF)
- On-board Software Management (OBS)
- File based Operations (FBO)
- Telemetry File Ingestion (TFI)
- Ground Station M&C Adapter

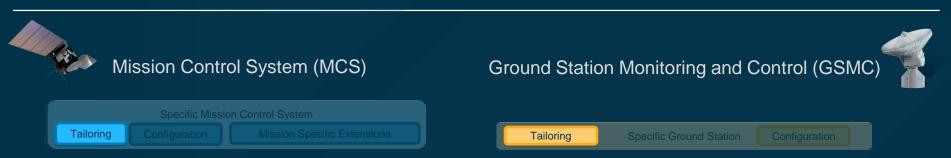
- Flight Dynamics Adapter
- Alert System REALS Adapter
- Command Request Management (CR)
- Long Term Archive Management (LTA)
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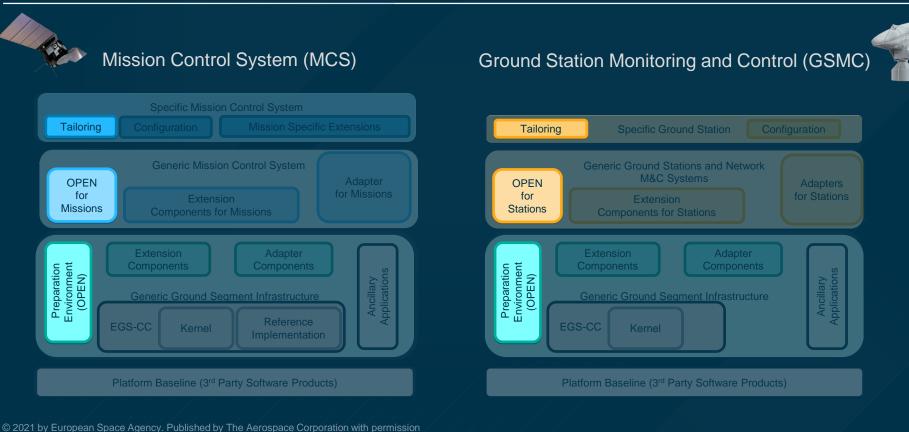
"Tailoring Data" covers all operator defined data consumed by the ground data M&C systems

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, ...







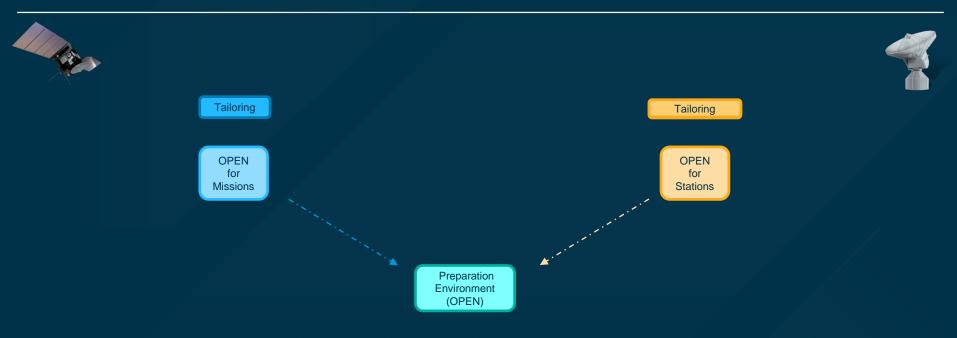
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New components for the Management of the Tailoring Data





New components for the Management of the Tailoring Data





New components for the Management of the Tailoring Data

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High-level Simplified Overview





Mission Control System (MCS-CC)

Ground Station Monitoring and Control (GSMC-CC)

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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

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OPEN Preparation Environment Framework

• 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..)

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Specific Functionalities





- OPEN-M includes EGS-CC tailoring data editors and browsers to support the needs of the Mission Control Teams at ESOC
- Main Functionalities
- <u>All functionalities of the OPEN framework</u>
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- 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

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- 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



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OPEN Preparation Environment Framework



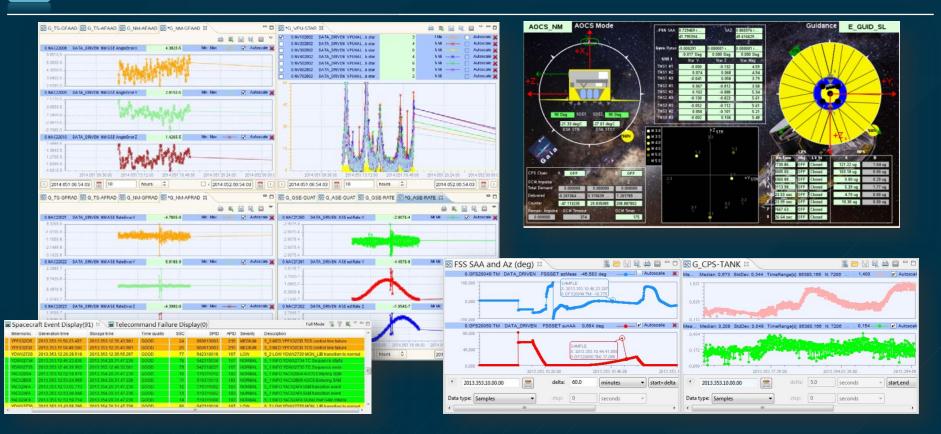
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Local E 🛛 🔝 Model T 🗨 MCM 🖱 🗖	MCF_RBA0101_DT3,12 MCM CI Battery Battery 🔝 NumberOfAspectsPerMCE.groovy 🖄						
95 😑	* This example displays a horizontal bar chart showing the size of all MCE in terms package examples.graphicalInterfaces;		<u>^</u> ====				
pe filter text	package examples graphicaline rates,		Tailoring Data Example : CDM Paci	ets		- 0	×
Checks	<pre>#import java.awt.BorderLayout[]</pre>		UUID	Packet Type	Name	Generation Frequency	
Ca configuration	(Lenger Lenger)		903c64de-3525-39cc-9c50-cb4e TM	- and the	XDH02170005_TMP_905002168	of the second second	1
the data	<pre>// Set a title def title = 'Number of Aspects per MKE'</pre>		21421958-2fb7-3ect-8767-7455b TC		CND24005_TCP		10
2h forms	der title = Number of Aspects per PAL		93e3de55-a8bc-3abc-ad81-079d TC 1c851bb4-0db5-3f00-8f77-e24ae TM		GTM01HA8_TCP TTS11403001_TMP_2009211011		-
a importRaw	// Find 'the' root CI (assuming there is only one McmCI).		c41ee1b5-1250-30b9-9970-880 TM		XDH01600129_TMP_905001729		-
	// This needs to be modified if there are more than one!		9ad79100-9798-3714-8346-c97 TM		CSE32000129_TMP_332332001		
🥭 queries	McmCI mcmci = CDMUtils.findKootCI(efm.resourceSet, McmCI.class)		256af8c8-d50d-31e8-b175-8b90. TM		CSG62000129_TMP_332562001		
City reports			014275-bte0-3509-8272-558545 TC 65b07659-M/5-3c34-9c0a-9d5c TM		AAS00MC2_TCP GPF14860001_TMP_710514061		-12
Ch scripts	// Get all MCEs of that McmCI		4edbedbd-7cc6-3937-9caa-57a TM		GPF26032003_TMP_710526014	0.125	- 7
> 🅞 cdmConstraintsVerification	<pre>def mces = mcmci.monitoringControlElement</pre>		2023954-c368-3425-0c14-2573 TM		XDH02474129_TMP_905002599		
> 🔄 cdmScripting			de456671-2712-3ef5-8495-9a7fTC 31c28f9f-80f5-3a5c-a1e4-3b868TC		GPL00MM2_TCP EUA50341_TCP		_
v 🗁 examples	<pre>// Collect names and sizes as number of aspects into a map</pre>		c704329d-e537-37ed-95f1-6fa9. TM		VDP01221005_TMP_17181012		-11
✓ Q _h graphicalInterfaces	<pre>@def valueMap = mces.collectEntries {</pre>		581b9c52-0b36-3576-8831-2c9 TM		CAB00000001_TMP_322100001		
GraphicalInterfacesExample01.groovy	it.name.		c6036d5b-fal8-3Me-bcea-6e16a TC		NPB012A9_TCP		
GraphicalInterfacesExample02.groovy	it.monitoringControlElementAspects.size()		0a251ac1-28a8-338e-9482-658TM 038886e2-647e-3c7b-a41b-07aTM		RBB01026005_TMP_18421010_ XDH01053001_TMP_905001053	5.5555555555555556E-4	-11
GraphicalInterfacesExample03.groovy			41fd974d-373b-39e2-abec-880 TC		GMU00EM5_TCP		-11
CaphicalInterfacesExample04.groovy	5		b6fa0109-1bdf-3b44-a56f-e147f. TM		GFD10062005_TMP_710310062		
GraphicalInterfacesExample05.groovy	•		2e120901-fb3-33d4-89e4-e0ac5 TC 25459091-56c9-3d38-8440-1cee TM		GPF05UL4_TCP ESRAL0TM008_TMP_60050008		-1
	// sort the map by decreasing MCE size		8efad000-d35d-314f-b522-c7d3TC		GPF01GN4_TCP		-
GraphicalInterfacesExample06.groovy	<pre>valueMap = valueMap.sort { -it.value }</pre>		a0c46e92-536e-330f-8444-0059 TC		VDP01226_TCP		
A NumberOfAspectsPerMCE.groovy		Aumber of Aspects per MCE	ra3h473h.2778.3c42.a4a0.108 TC		MRE01V12_TCP		
> Ch openServices	<pre>// Create a ChartBuilder and a bar chart ChartBuilder cb = new ChartBuilder()</pre>				EUA38102005_TMP_65038102 • ASZ33T25_TCP		
> Cay importProcess	BarChart chart = cb.BarChart(Number of Aspects per MCE	1			
> 😝 lib	title: title,		Number of aspects	12 13 137 28			
🙆 open.dsld	categoryAxisLabel: 'MCE',	0 TimeRasetSchedule (110)	10 20 30 40 50 66 70 89	90 100 110 120			
😂 validation	valueAxisLabel: 'Number of aspects',	ProcedureExecution (22)	The second s				
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consistionCoefficient (9)

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OPEN Framework User Defined Display Editors





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OPEN-M Preparation Environment for Missions

Example View : Monitoring Control Model

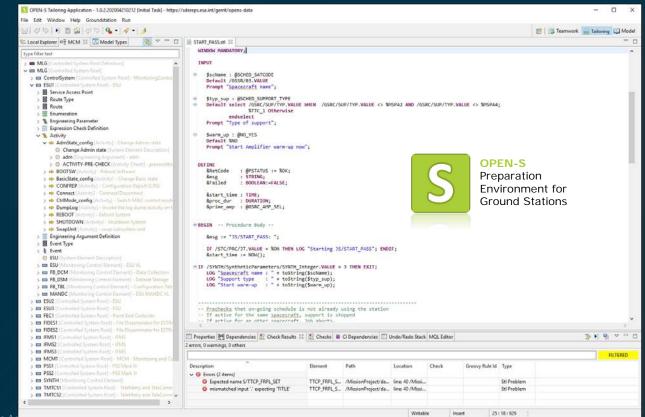


/pe filter text	
Mission_Definition [Monitoring Control Element Definition]	
a 🔲 Mission [Monitoring Control Element]	A CCS [Monitoring Control Element]
ControlSystem [Monitoring Control Element] - MonitoringControlElement : tailoringData	a 🛸 Synthetic Parameter
▲ ■ Spacecraft [Controlled System Root] ▶ ■ Route Type	a Synthetic Parameter
B Route lype B Route	NACSY001 [Synthetic Parameter] - Sun-Sun-Target Angle
Service Access Point	
Event Type	🔈 🐁 NACSY003 [Synthetic Parameter] - Sun-Sun-Target Angle
b & Event	ADAE LICA (Manitarian Control Flamont)
E Directive Definition	APME_HGA [Monitoring Control Element]
Expression Check Definition Specific Parameter Status Consistency Check Definition	APME_MGA [Monitoring Control Element]
Specific Parameter Status Consistency Check Dennition A AOCS [Monitoring Control Element]	
▲ Synthetic Parameter	a 📼 BELA [Monitoring Control Element]
NACSY001 [Synthetic Parameter] - Sun-Sun-Target Angle	Sector and the sec
NACSY003 [Synthetic Parameter] - Sun-Sun-Target Angle	Interpolation
APME_HGA [Monitoring Control Element]	CAF CBLP0001TM DT3,12 [Interpolation] - HK ADC1
APME_MGA [Monitoring Control Element] BELA [Monitoring Control Element]	
BELA [Monitoring control element] A A Interpolation	CAF_CBLP0002TM_DT3,12 [Interpolation] - HK ADC2
Gas CAF_CBLP0001TM_DT3,12 [Interpolation] - HK ADC1	
CAF_CBLP0002TM_DT3,12 [Interpolation] - HK ADC2	CAF_CBLP0003TM_DT3,12 [Interpolation] - HK ADC3
CAF_CBLP0003TM_DT3,12 [Interpolation] - HK ADC3	CAF_CBLP0004TM_DT3,12 [Interpolation] - HK ADC4
CAF_CBLP0004TM_DT3;12 [Interpolation] - HK ADC4	
	CAF_CBLP0005TM_DT3,12 [Interpolation] - HK ADC5
GAF_CBLP0007TM_DT3;12 [Interpolation] - HK ADC7	
CAF_CBLP0008TM_DT3,12 [Interpolation] - HK ADC8	CAF_CBLP0006TM_DT3,12 [Interpolation] - HK ADC6
GAF_CBLP0009TM_DT3,12 [Interpolation] - HK ADC9	CAL CRI D0007TM DT212 (Internal-tion) UK ADC7
CAF_CBLP0010TM_DT3,12 [Interpolation] - HK ADC10-13	CAF_CBLP0007TM_DT3,12 [Interpolation] - HK ADC7
@ CAF_CBLP0011TM_DT3,0 [Interpolation] - FPGA Firmware @ CCA_CBLP0001TC_DT3,12 [Interpolation] - APD Temp	08TM_DT3,12 [Interpolation] - HK ADC8
CCA_CBLP00011C_DT3,12 [Interpolation] - APD Temp CCA_CBLP0002TC_DT3,12 [Interpolation] - APD HighVoltage SetPoint BP	aco are
Range Enumeration	09TM_DT3,12 [Interpolation] - HK ADC9
B Enumeration	A LOOK DT212 (Let an a lateral All ADC10 12
KBU	10TM_DT3,12 [Interpolation] - HK ADC10-13
Synthetic Parameter El Limit Check Definition	11TM_DT3,0 [Interpolation] - FPGA Firmware
Engineering Argument Definition	
A S Activity	LHB RTL: receiver telescope 001TC_DT3,12 [Interpolation] - APD Temp
▷ ⇒ ZBL00305 [Activity] - BELA Enable HK Para Rep	
ZBL00306 [Activity] - BELA Disable HK Para Report Generation	RBU: receiver baffle unit TBU: transmitter baffle unit TBU: transmitter baffle unit
ZBL00602 [Activity] - BELA Load Data in Memory	SPU at the SPU: straylight protection unit
▷ ➡ ZBL00605 [Activity] - BELA Dump Memory Area ➡ ZBL00609 [Activity] - BELA Check Memory Area	offit BEX: beam expander
TBU	LHB: laser head box LEU: laser electronix unit

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Example Editor : Automation Procedure Environment for Ground Stations





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OPEN-S

Preparation

Example View : Model Visualisation



🚹 Subtype Hierarchy 🛛 🍃 Type Hierarchy 🛛 🔗 🛃 🖡 👫 Chosen element: Features: Subtypes of DataItem P DataItem.uniqueIdentifier[1, 1] : UniqueIdentifier ⊿ ○ DataItem EngineeringDataItem 4 🔘 a 🔘 EngineeringDataItem EngineeringDataItem.name[1, 1]: String SystemElement ⊿ ○ SystemElementAspect EngineeringDataItem.aliases[0..*] : Alias MonitoringControlElementAspect EngineeringDataItem.descriptions[0..*] : SystemElementDescription ▲ ○ SystemElementAspect MonitoringControlCommonAspect ➡ SystemElementAspect.baseElement[0, 1] : SystemElementAspect MonitoringControlElementAspect CalibrationBase T MonitoringControlElementAspect.hasPredictedValue[1, 1] : Boolean Activity Calibration Calibration.calDirection[1, 1]: CalibrationDirection CheckAndConditionAspect 🔺 🖬 Law Calibration.outputDataType[1, 1] : AbstractDataType MonitoringGroup Interpolation - Calibration.inputEngineeringUnit[0, 1] : Unit CheckDefinition Calibration.outputEngineeringUnit[0, 1] : Unit DeltaCheckDefinition Calibration.inputDataType[1, 1]: AbstractDataType StatusConsistencyCheckDefinition Calibration.inputDisplayFormat[0, 1]: AbstractDataDisplayFormat Calibration.outputDisplayFormat[0, 1]: AbstractDataDisplayFormat ValidityConditionDefinition □ Law.boundaryData[0, 1] : BoundaryData ExpressionCheckDefinition 1.* Interpolation.x[1..*] : Float ExpectedValueCheckDefinition Interpolation.y[1..*]: Float ExternalCheckDefinition LimitCheckDefinition 🔊 Documentation 🖾 RouteType Event **Documentation for Type Interpolation** Parameter Interpolation describes a calibration by a list of interpolation points, (Xi;Yi) with same i rank. CompoundParameter conversion values between or even out of the given ranges are calculated by inter- or extrapolation. 🖳 AggregateParameter Class Features 🖳 MatrixParameter This section lists all the direct features (not the inherited ones) of the selected classifier a 🐁 EngineeringParameter Interpolation.x[1..*] : Float SyntheticParameter Interpolation.y[1..*] : Float

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Expansion of the applications and further extensions

- 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







Perspectives of the OPEN environments

- 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

Business Intelligence

Model based and Digital Engineering

Cloud Based Evolution

/lulti-Missions

Operation & Validation Efficiency

OPEN Environments

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European Space Agency



OPEN to proprietary extensions

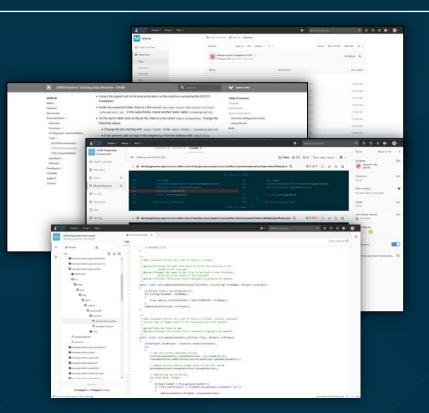


- OPEN is technologically designed to be an extensible platform federating various extensions which can originate from several sources in terms of funding and organisation
- The licensing scheme adopted for the OPEN framework and OPEN-M are designed for collaborative development under the ESA Community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

https://open.space-codev.org



- <u>www.space-codev.org</u> 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)



Take away



- 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

Ground System Architectures Workshop - GSAW 2021

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