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A Finmeccanica/Thales Company

Architecture and Development Process of Spacecraft Simulators for ESOC

Dr. Peter Fritzen

Telespazio VEGA Deutschland GmbH

27/05/2014

AGENDA

- Telespazio VEGA Deutschland GmbH (VEGA)
  - The Simulation, Navigation and Technology (SNT) Group
- Satellite Missions of the European Space Agency (ESA)
  - Mission Lifecycle and Phases
  - Some recent example missions
  - Role of the European Space Operations Centre (ESOC)
- Architecture of a Spacecraft, and a Reference Architecture for Simulators
  - High-Level Architecture of a Spacecraft
  - Approach for a Reference Architecture to facilitate Model Re-Use
  - Example of a specific instrument
- Development Process of Operational Spacecraft Simulators
  - Model Driven Architecture (MDA) for Design and Development
  - Application Lifecycle Management (ALM) and Automation

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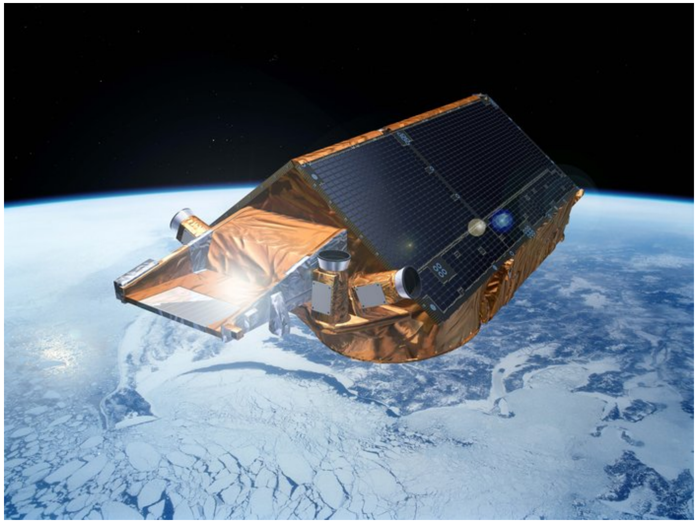
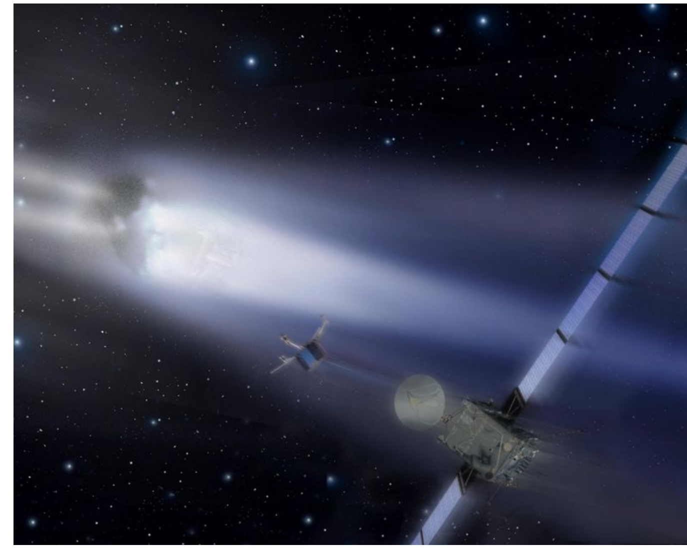
SOME EXAMPLE MISSIONS

- Earth Observation Missions
  - **CryoSat**: Are the Ice Caps shrinking?
    - Launched in April 2010
    - Still in Operations
    - Includes 3 Star Trackers
  - **Swarm**: Measure Earth Magnetic Field
    - Launched in November 2013
    - Just started Operations
    - Includes 2 Star Trackers
  - **EarthCare**: Clouds and Radiation
    - Launch scheduled for 2016

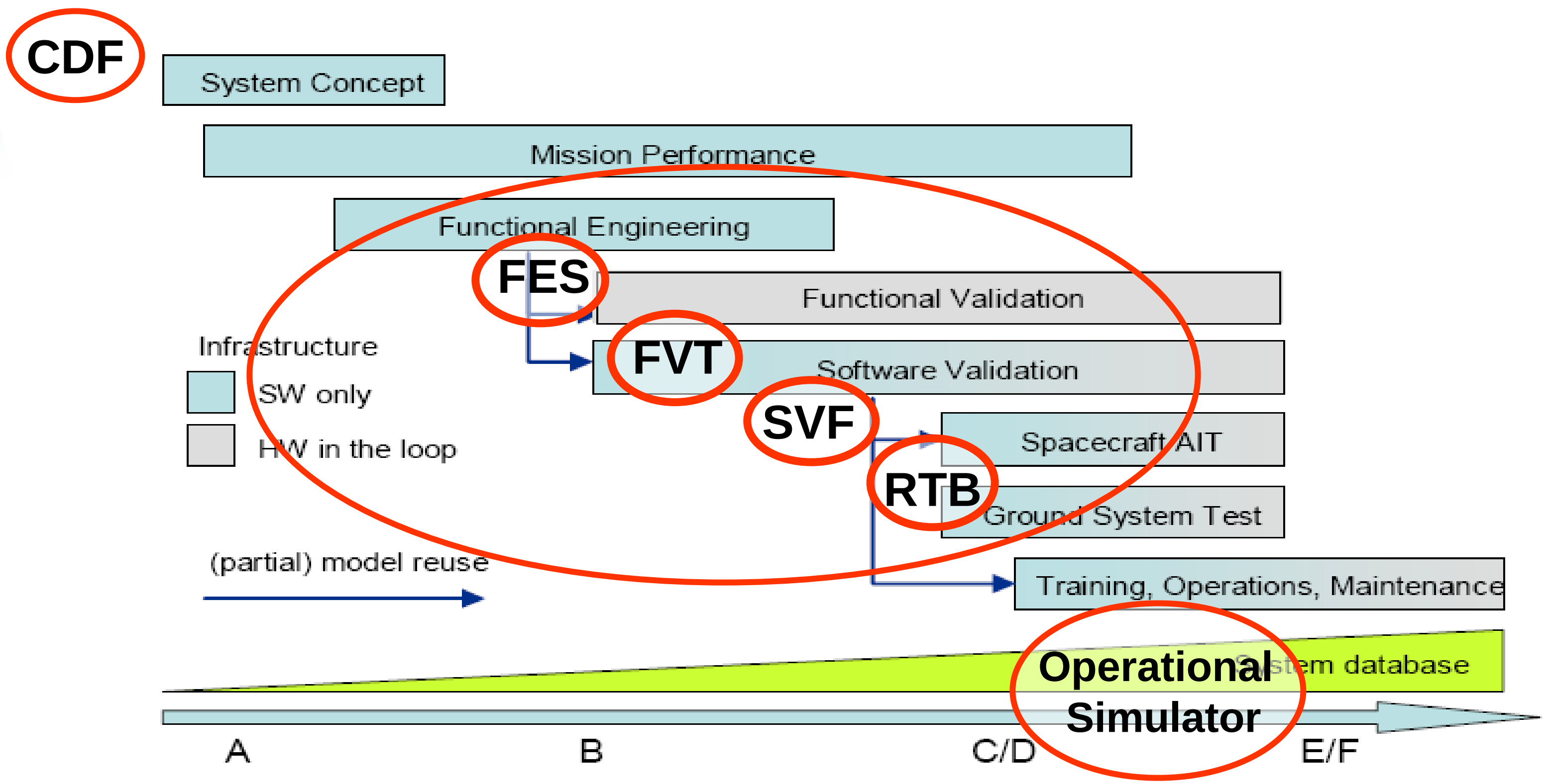


SOME EXAMPLE MISSIONS

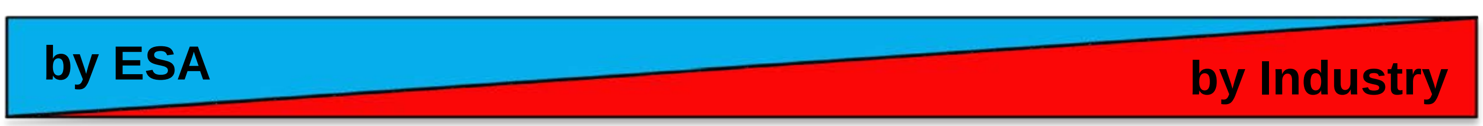
- Science Missions
  - **Rosetta**: The Comet Chaser
    - Launched in March 2004
    - Land on comet November 2014
    - Includes a Star Tracker
  - **Venus Express**: Explore Venus
    - Launched in November 2009
    - Science Operations just ended
    - Includes a Star Tracker
  - **Solar Orbiter**: Solar Physics
    - Launch scheduled for 2017



ECSS-E-TM-10-21A: MODELLING & SIMULATION ENG. PROCESS



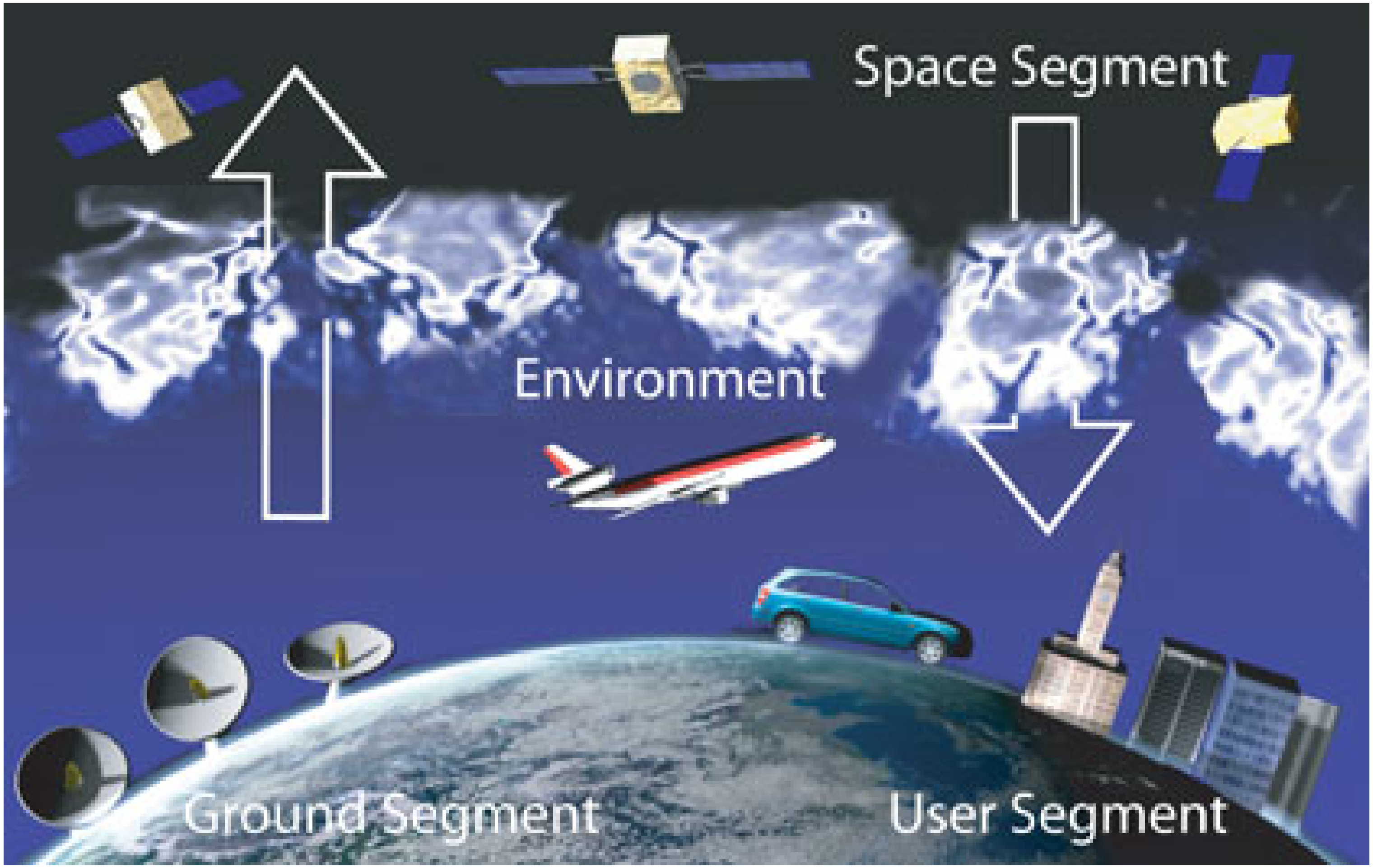
Model / Simulation Development



ROLE OF THE EUROPEAN SPACE OPERATIONS CENTRE (ESOC)

- "Seconds after separation from the launcher – […] – the spacecraft becomes the responsibility of the teams at ESOC."
  - Mission Planning
  - Mission Operations
  - Mission Disposal

ELEMENTS INVOLVED IN A SATELLITE MISSION



INTERFACE BETWEEN ESOC AND A SPACECRAFT

- ESOC Monitor a Spacecraft via **Telemetry**
  - Telemetry is generated by each subsystems of the Spacecraft
  - Telemetry is emitted by the Spacecraft to send data back to Earth
  - Telemetry is received by a Ground Station Receiver
  - Telemetry is visualised using the Satellite Control and Operation System (**SCOS**)
- ESOC Control a Spacecraft via **Telecommands**
  - Telecommands are assembled by a Spacecraft Controller via SCOS
  - Telecommands are transmitted by a Ground Station Transmitter
  - Telecommands are received by the Spacecraft
  - Telecommands are (typically) processed by the On-Board Computer

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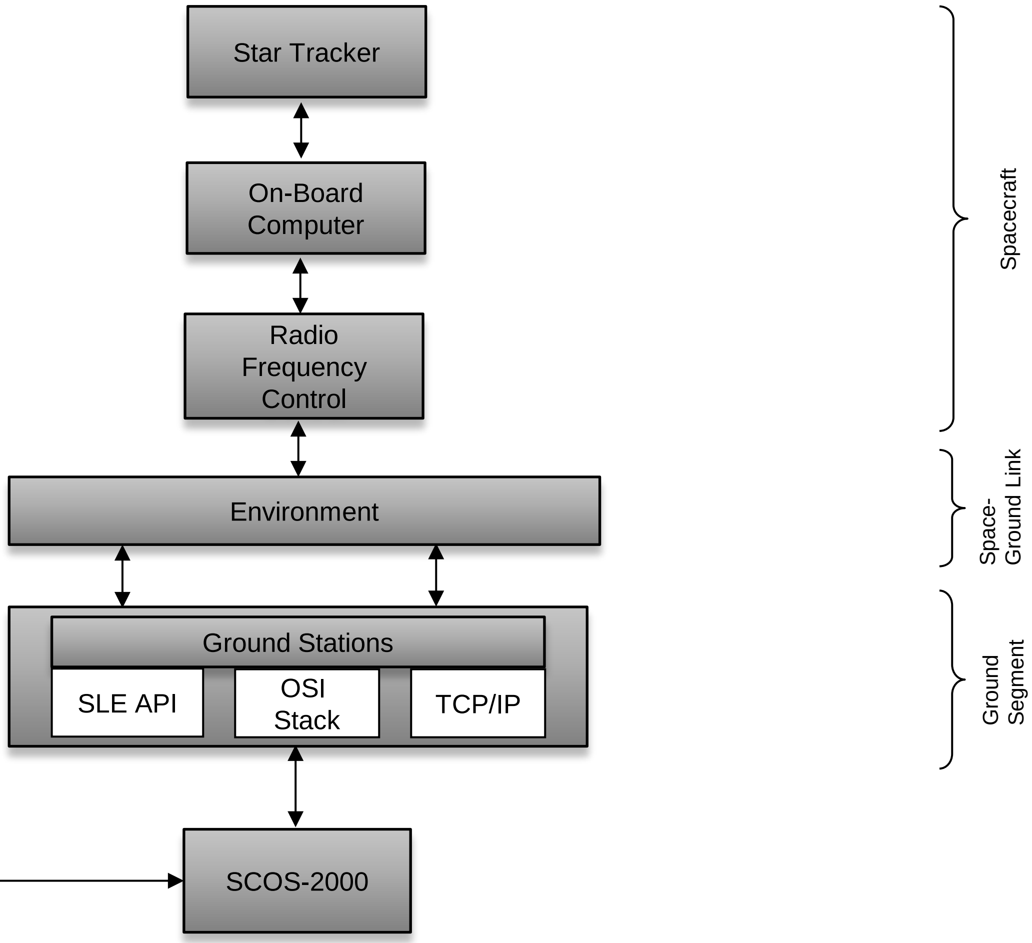
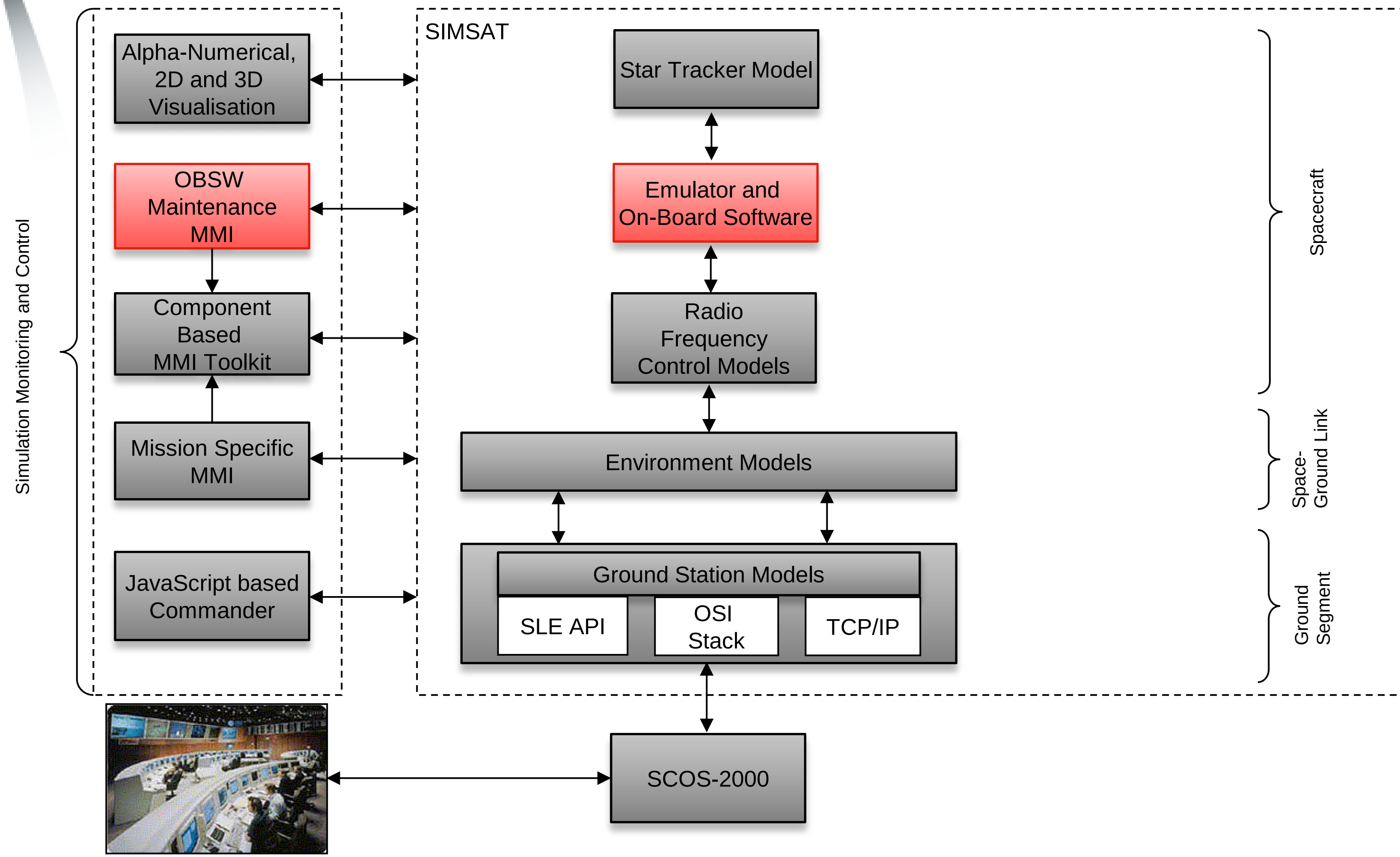
DATA FLOW BETWEEN ESOC AND A STAR TRACKER

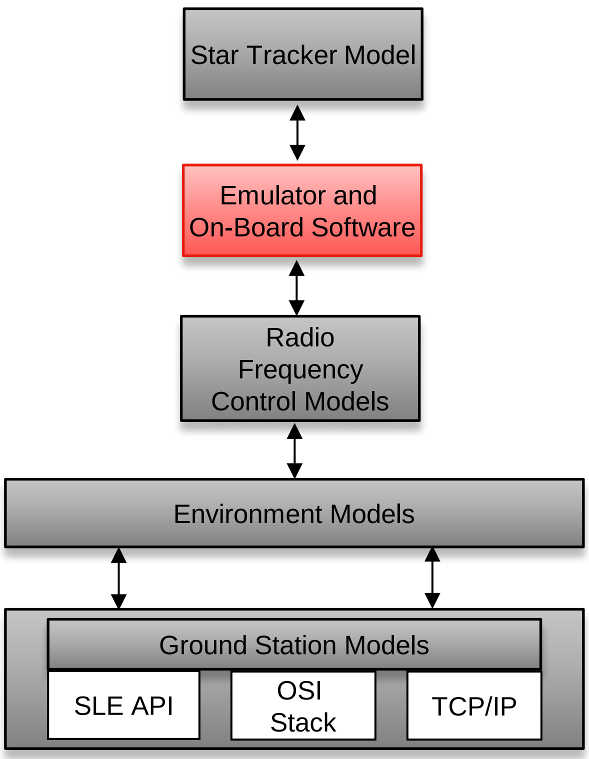


DATA FLOW BETWEEN ESOC AND A STAR TRACKER MODEL



APPROACH FOR SPACECRAFT SIMULATION

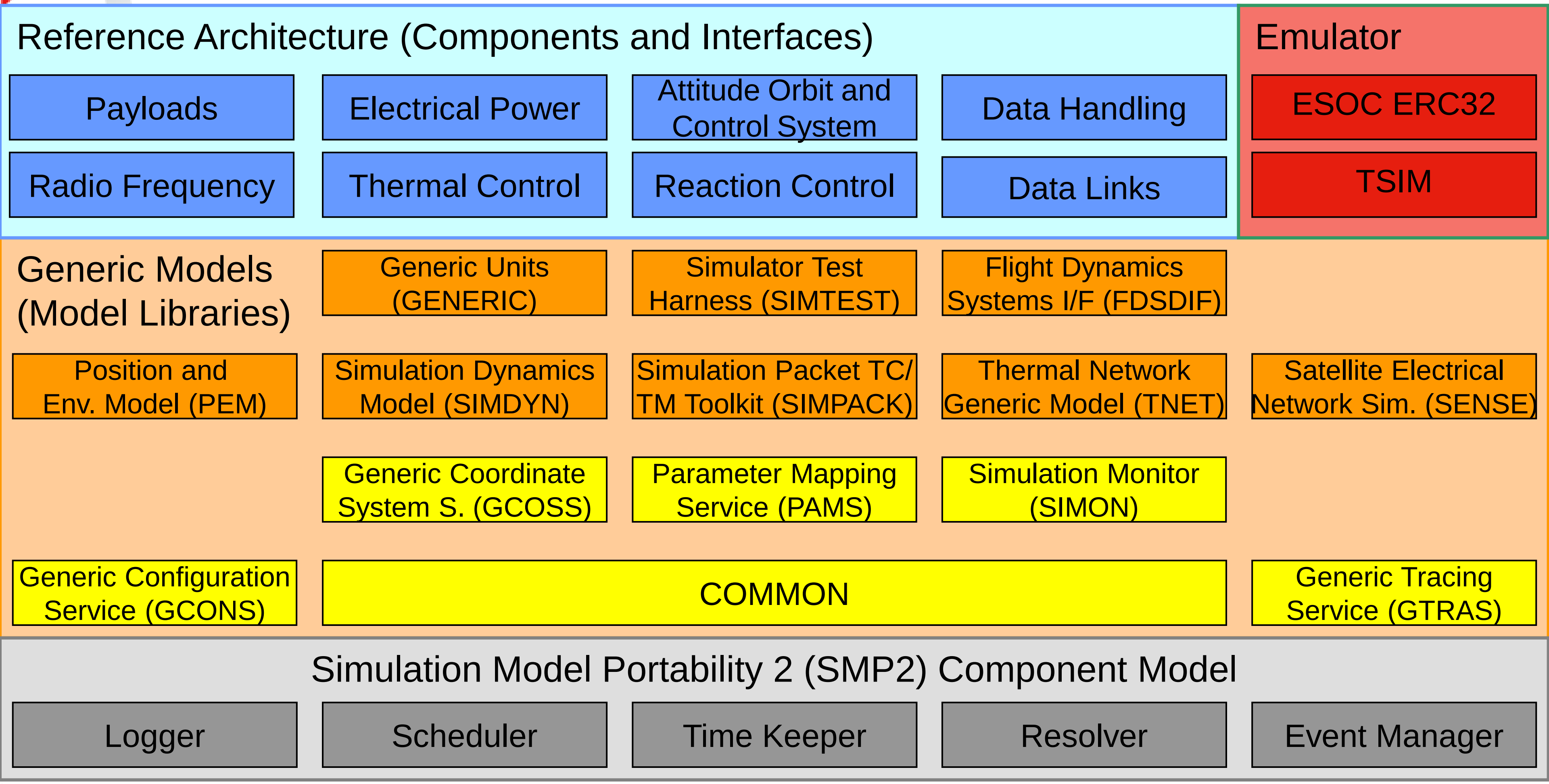
- For all Spacecraft Subsystems, a Reference Architecture (**REFA**) has been established
  - Architecture defines common components and interfaces between them
  - Architecture makes use of common libraries
- The On-Board Software is used from the Mission
- The Emulator is generic (per Processor) and can be re-used across missions
- The Environment Models are implemented as a Library which can be configured per Mission
- Ground Station Models are independent of a specific S/C and can be re-used across missions



THE SPACECRAFT SIMULATOR REFERENCE ARCHITECTURE

- Defines a reference architecture for operational simulators for ESOC.
- Defines standard interfaces between common satellite subsystems' models
- Used within ESOC's UML modelling framework (UMF)
- Strongly based on ESOC's Generic Models (GENM) Libraries
- Promotes consistency in design across the different mission simulators
  → facilitates re-use of design and models.
- No model implementation provided – design only.
- Can be extended to meet a particular mission simulator needs.
- Mission changes may feed back into the maintained REFA.

REFERENCE ARCHITECTURE (REFA) AND GENERIC MODELS

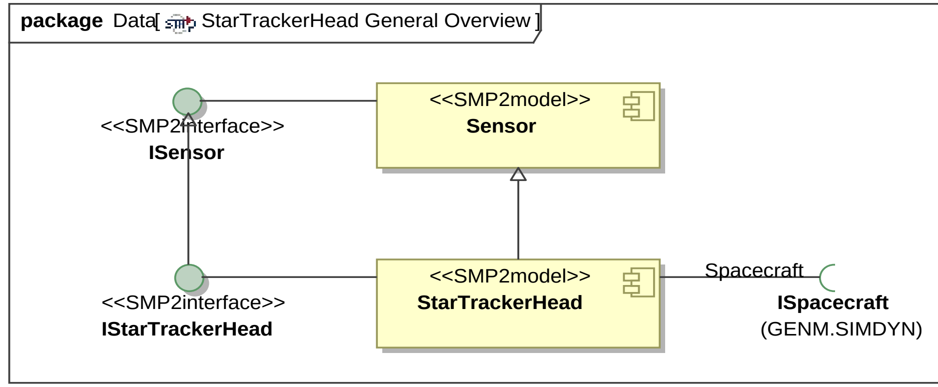


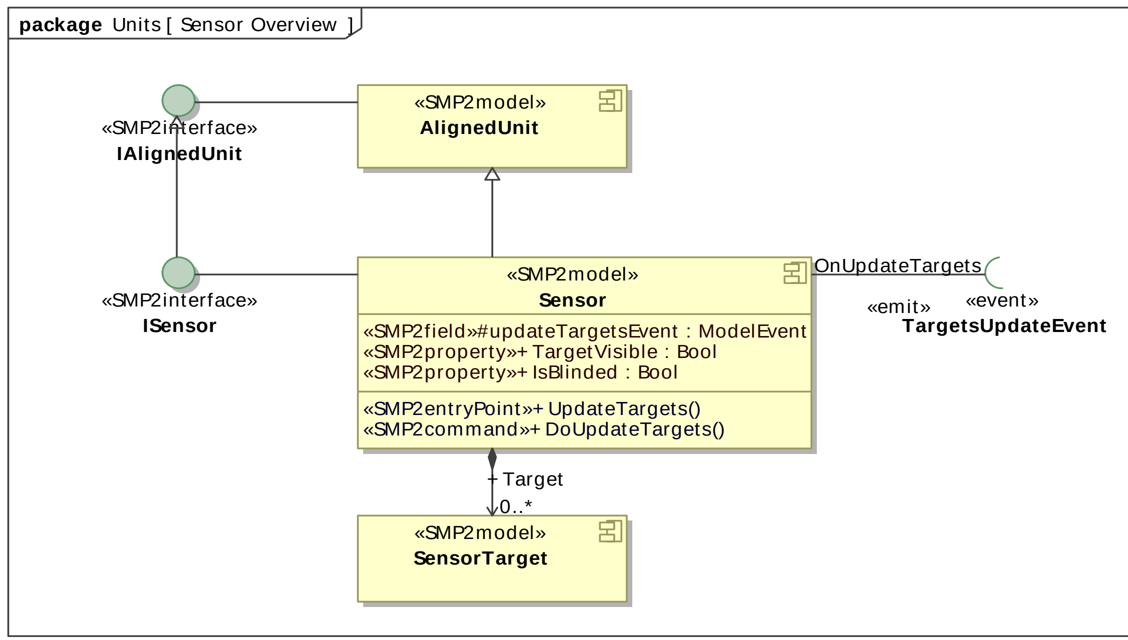
REFA SUBSYSTEMS

- The Reference Architecture covers the following subsystems
  - AOCS Attitude and Orbit Control System
  - DHS Data Handling System
  - DL Data Links
  - EPS Electrical Power System
  - RCS Reaction Control System
  - RFCS Radio Frequency Control System
  - TCS Thermal Control System
  - PL Payloads (only generic architecture)

REFA EXAMPLE – THE STAR TRACKER HEAD ARCHITECTURE

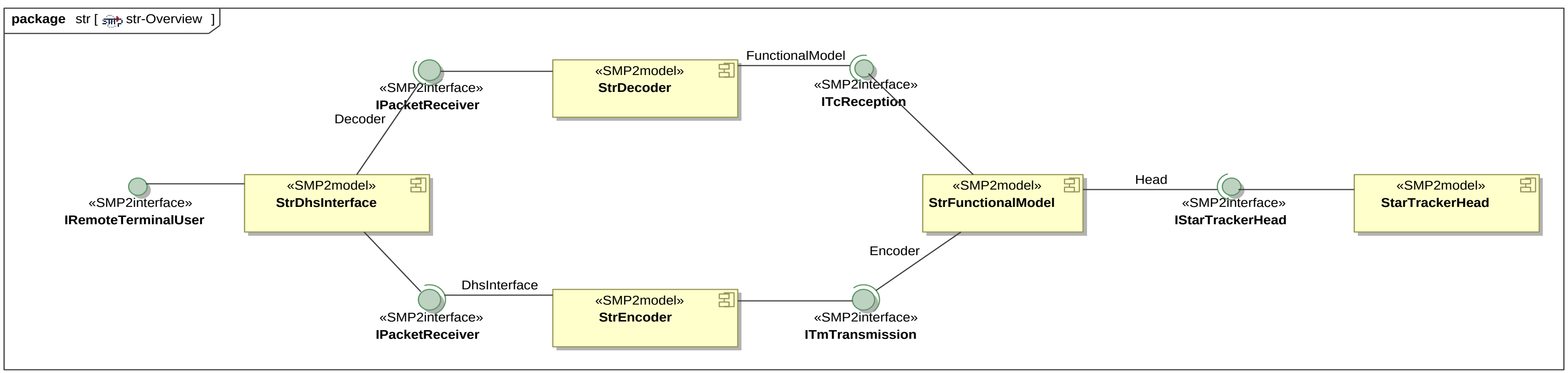
- REFA defines interfaces and "abstract" models for design
  - These models make use of GENM interfaces and model libraries
- GENM libraries provide fully tested code for common cases
- Missions need to "complete" their implementation by deriving from REFA





REFA EXAMPLE – THE COMPLETE STAR TRACKER

- Complete Star Tracker (**STR**) design includes various other elements
  - The STR communicates with the On-Board Computer via a Bus
  - The STR decodes **Telecommands** and encodes **Telemetry**
  - The STR implements a Functional Model (complex state machine)
  - The STR receives Measurements from the Star Tracker Head



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TECHNICAL CHALLENGES

- Accurate Modelling of highly complex System
  - High focus on formal testing and validation
- Demanding Requirements on Documentation
  - European Commission for Space Standardisation (**ECSS**)
- Long-Term Maintenance until End of Mission
  - Typically requires migration to new platform/operating system
- Distributed Development Team
  - Fully integrated development environment across countries

RECENT TECHNOLOGIES

- Full Automation of Testing
  - Unit and Integration Testing is done via CppUnit / JUnit
  - System Testing is done via JavaScript procedures (Scripting Language)
  - All Tests are executed every night ("nightly build and test approach")
- Apply Model Driven Architecture (**MDA**) based development approach
  - Complete system is modelled in Universal Modelling Language (**UML**)
  - Source code is generated from UML Design
  - Documentation is generated from UML Design
- Strict Adherence to Open Standards
  - Avoid dependency on a specific Platform, Operation System or Tool
  - Use Static Code Analysis to detect platform specific code
  - Build and Test on various Operating Systems (LINUX, Windows)

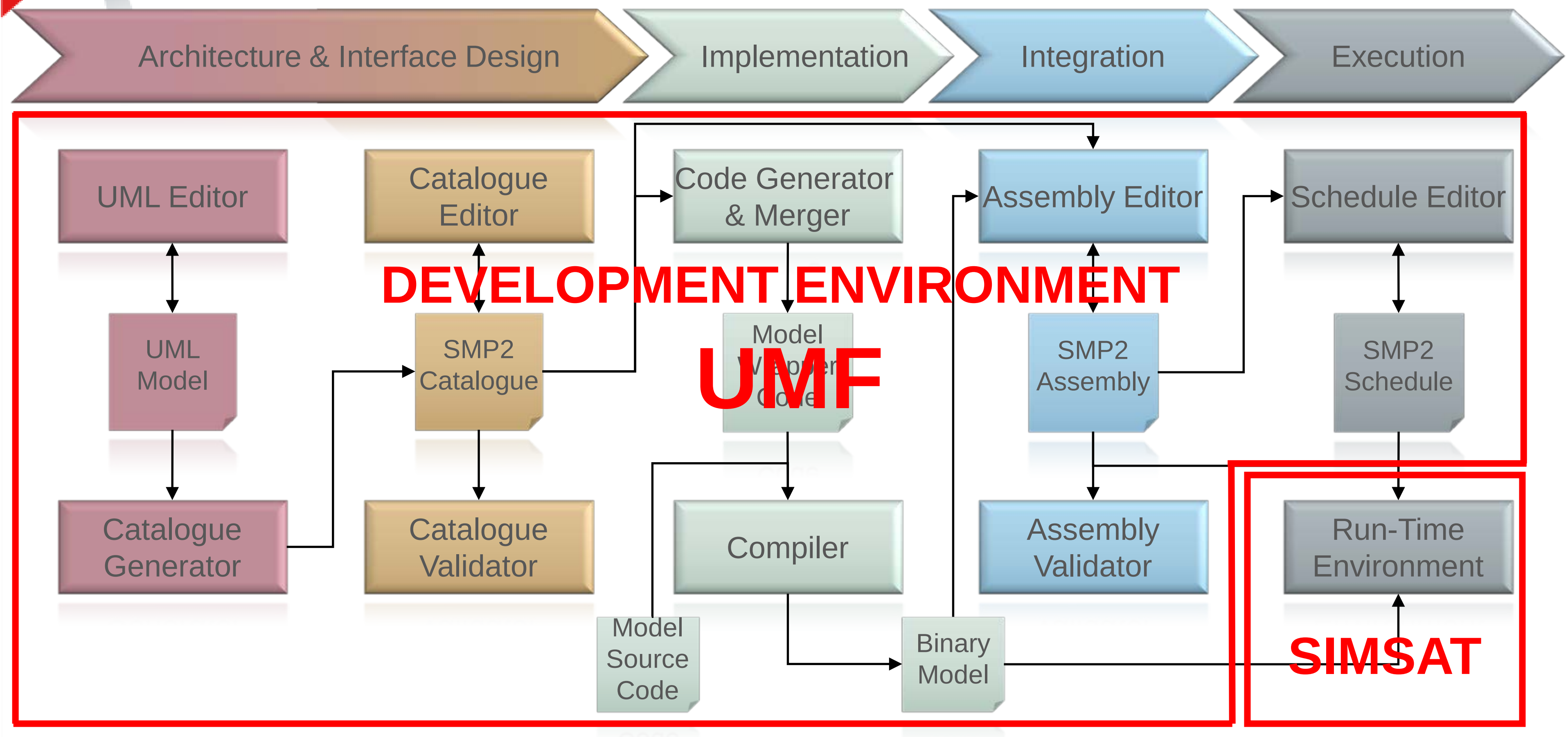
MODEL DRIVEN ARCHITECTURE APPROACH FOR SIMULATORS

- As a common simulation platform, a simulation standard has been defined
  - **SMP2** is the Simulation Model Portability Standard by ESA
  - **SMP** is the Simulation Modelling Platform Standard by ECSS

- To support MDA, a Domain Specific Language (**DSL**) has been defined
  - The Simulation Model Definition Language (**SMDL**) is part of SMP2
  - An Implementation of SMDL in a commercial UML tool is available
  - Tools to generate Documentation from SMDL have been developed
  - Tools to generate C++ Source Code from SMDL have been developed

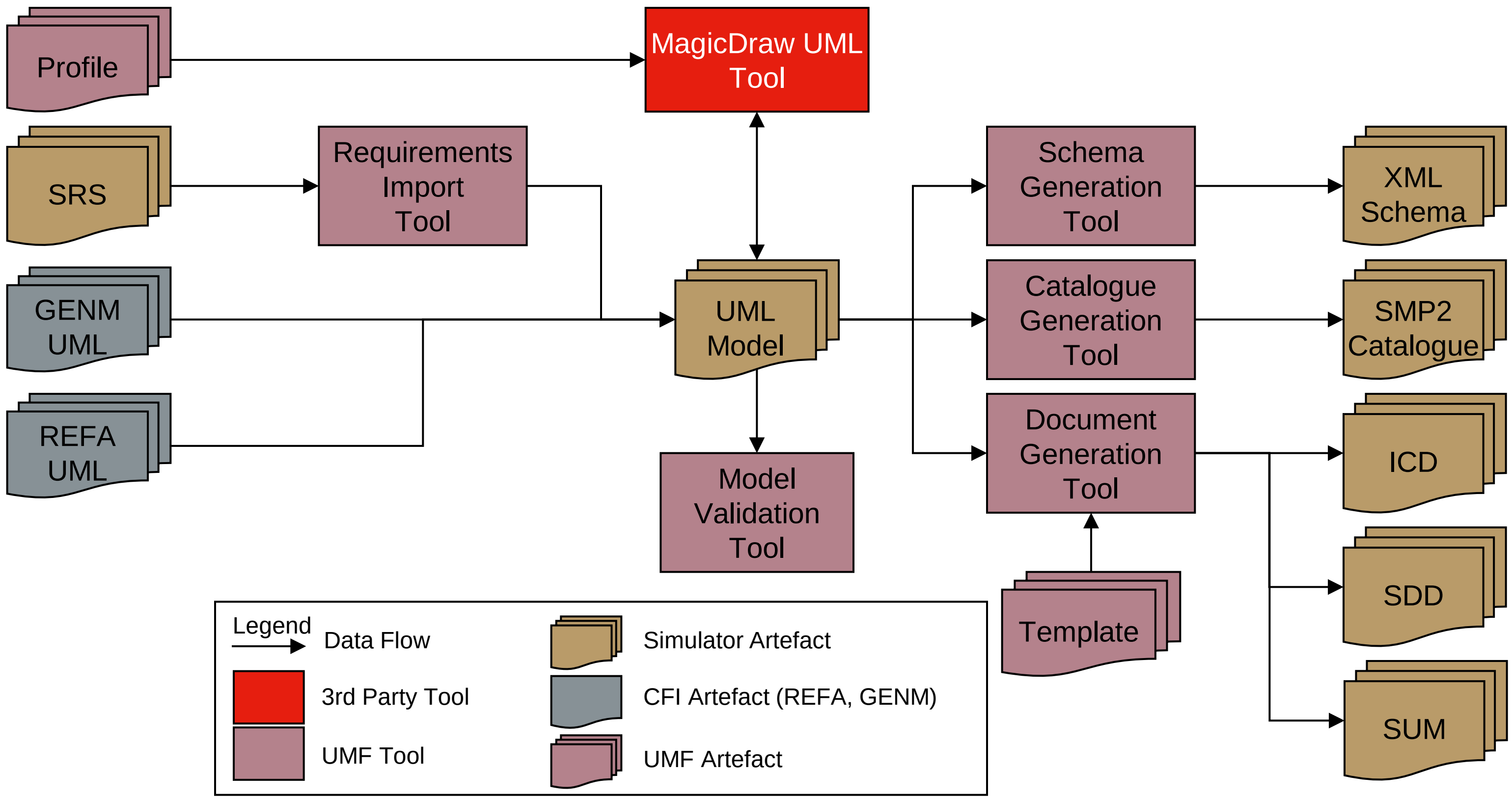
- All Generic Models (GENM) have been migrated to SMDL and SMP2
- The Reference Architecture (REFA) has been defined using SMDL

SMDL SIMULATION DEVELOPMENT LIFE-CYCLE AND TOOLS



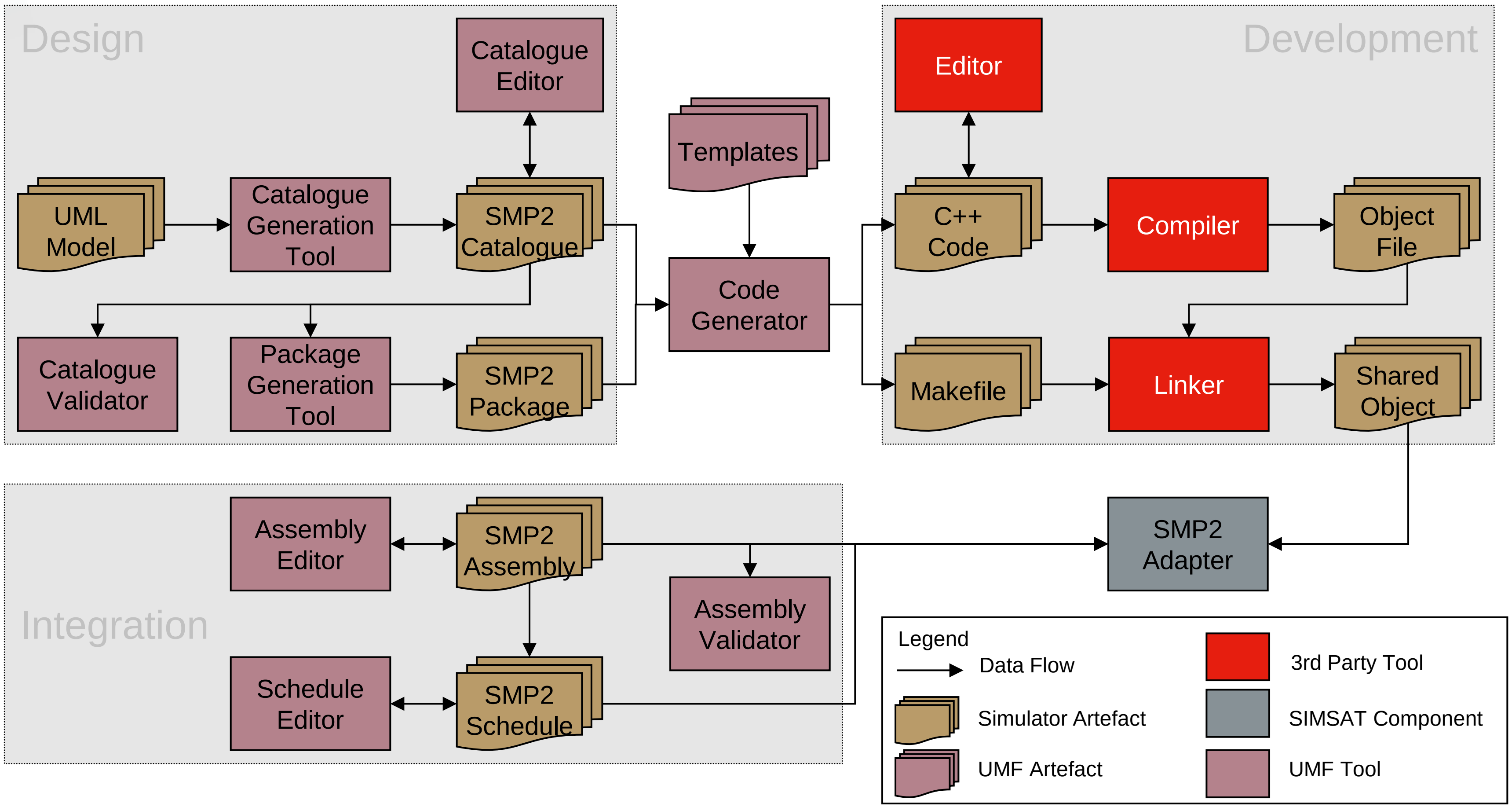
SMDL MODEL DRIVEN DESIGN PROCESS

Usage of UMF Tools in the context of SMDL Model Driven Design (MDD)



SMDL MODEL DRIVEN SOFTWARE DEVELOPMENT USING SMDL

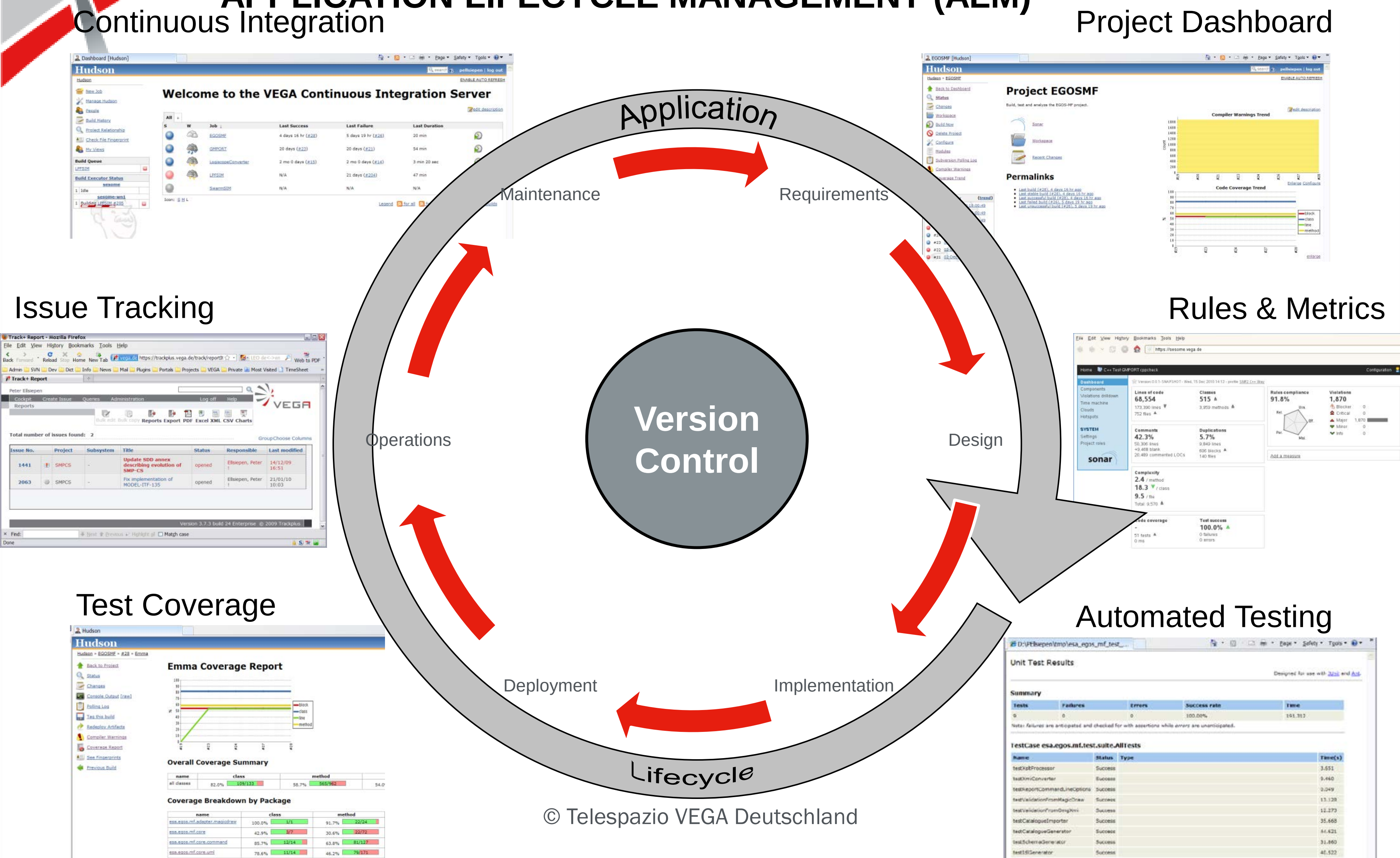
Usage of UMF Tools in the context of SMDL Model Driven Software Development



PROCESS OBJECTIVES

- Reduce Development Cost
- Increase Number of Deliveries (“Incremental” or “Agile” approach)
- Compress Schedule
- Provide Transparency of current Status
- Subcontract at least 40% of the Development to a Qualified Partner (QPA)
- Share Hardware Resources between Missions

APPLICATION LIFECYCLE MANAGEMENT (ALM)



SYSTEM ENGINEERING AND SOFTWARE MANAGEMENT ENV.

Telespazio
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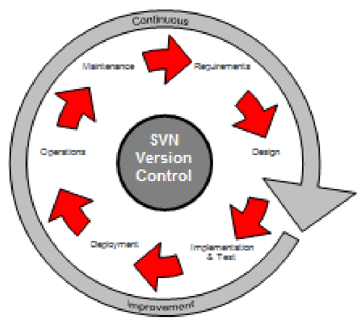
SESOME

The Telespazio VEGA System Engineering and
Software Management Environment



Application	Purpose	URL
Jenkins	Continuous Integration	https://sesome.telespazio-vega.de/jenkins https://sesome.telespazio-vega.de/hudson
sonarqube	Quality and Metrics	https://sesome.telespazio-vega.de/sonarqube https://sesome.telespazio-vega.de/sonar (old)
	Repository Browsing	https://svn.telespazio-vega.de/viewvc
	Repository Access	Example for "sample" repository: https://svn.telespazio-vega.de/svn/sample
	Issues and Tasks	https://jira.telespazio-vega.de/

JENKINS


Coverage Pipeline
Run
History
Configure
Add Step
Delete
Manage
Initialize-Cov-...
Documentation...
Package-Cov-B...
Memory-Cov-B...
Test-Cov-BCSIM
Collect-Cov-BC...
Quality-Cov-BC...
/GIMUS_SIMULUS_5.4_COTS/COTS
#313 Initialize-Cov...
May 26, 2014 6:59:32 PM
17 min
#301 Documentati...
May 26, 2014 7:17:14 PM
8 hr 8 min
#304 Package-Cov...
May 27, 2014 3:26:08 AM
22 min
#281 Memory-Cov-...
May 27, 2014 3:51:19 AM
6 min 13 sec
#322 Test-Cov-BCS...
May 27, 2014 3:51:19 AM
8 min 33 sec
#315 Collect-Cov-B...
May 27, 2014 3:59:58 AM
21 min
#299 Quality-Cov-...
May 26, 2014 7:17:14 PM
32 min

VALGRIND

Jenkins | search | pfritzen | log out

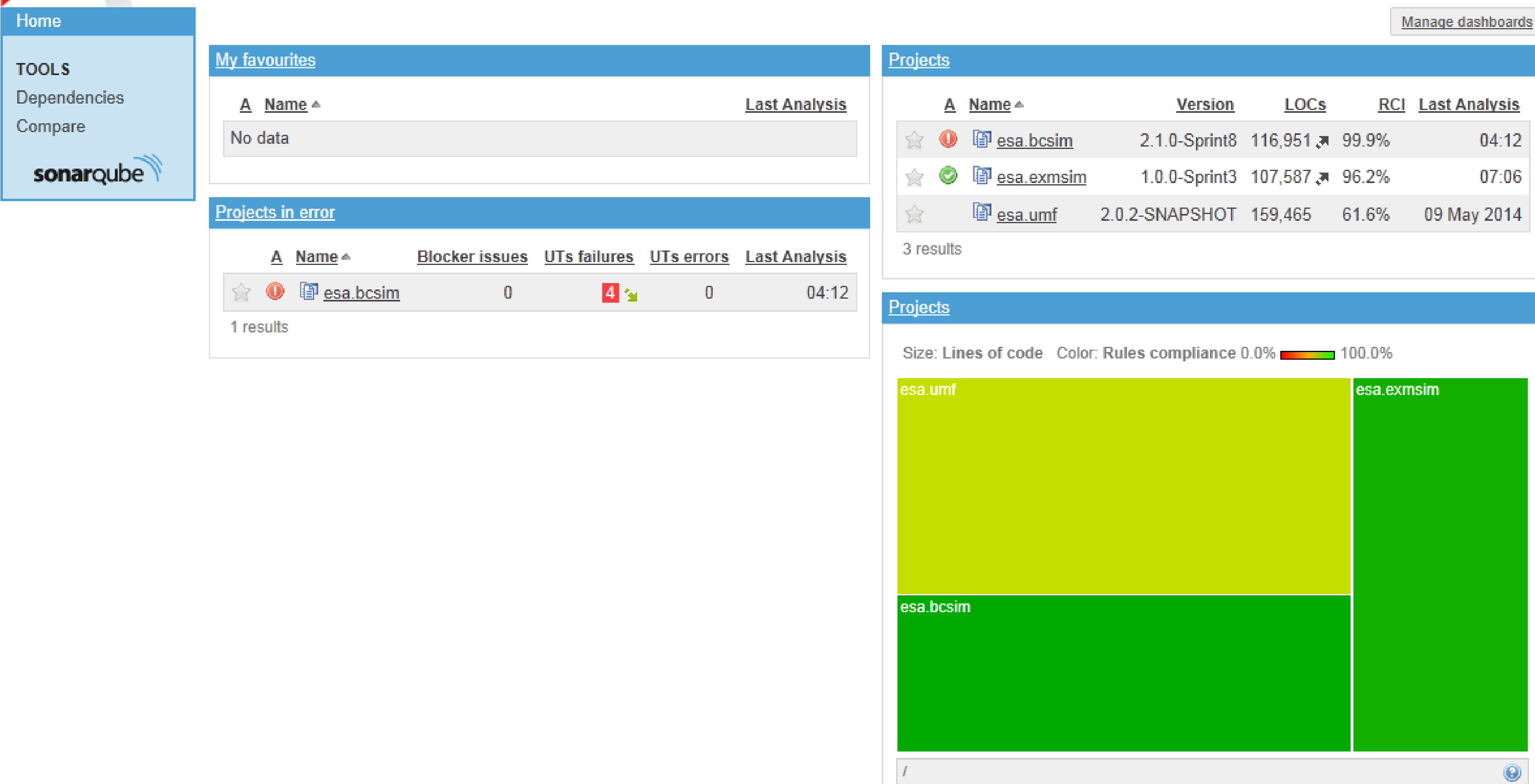
Jenkins › TPZV › SNT › EXMSIM › EXMSIM Coverage Pipeline › Memory-Cov-EXMSIM › #144

- Back to Project
- Status
- Changes
- Console Output
- Edit Build Information
- Delete Build
- Parameters
- Tag this build
- See Fingerprints
- **Valgrind Result**
- Failure Cause Management
- Downstream build view
- Build Artifacts As Maven Repository
- Build Graph

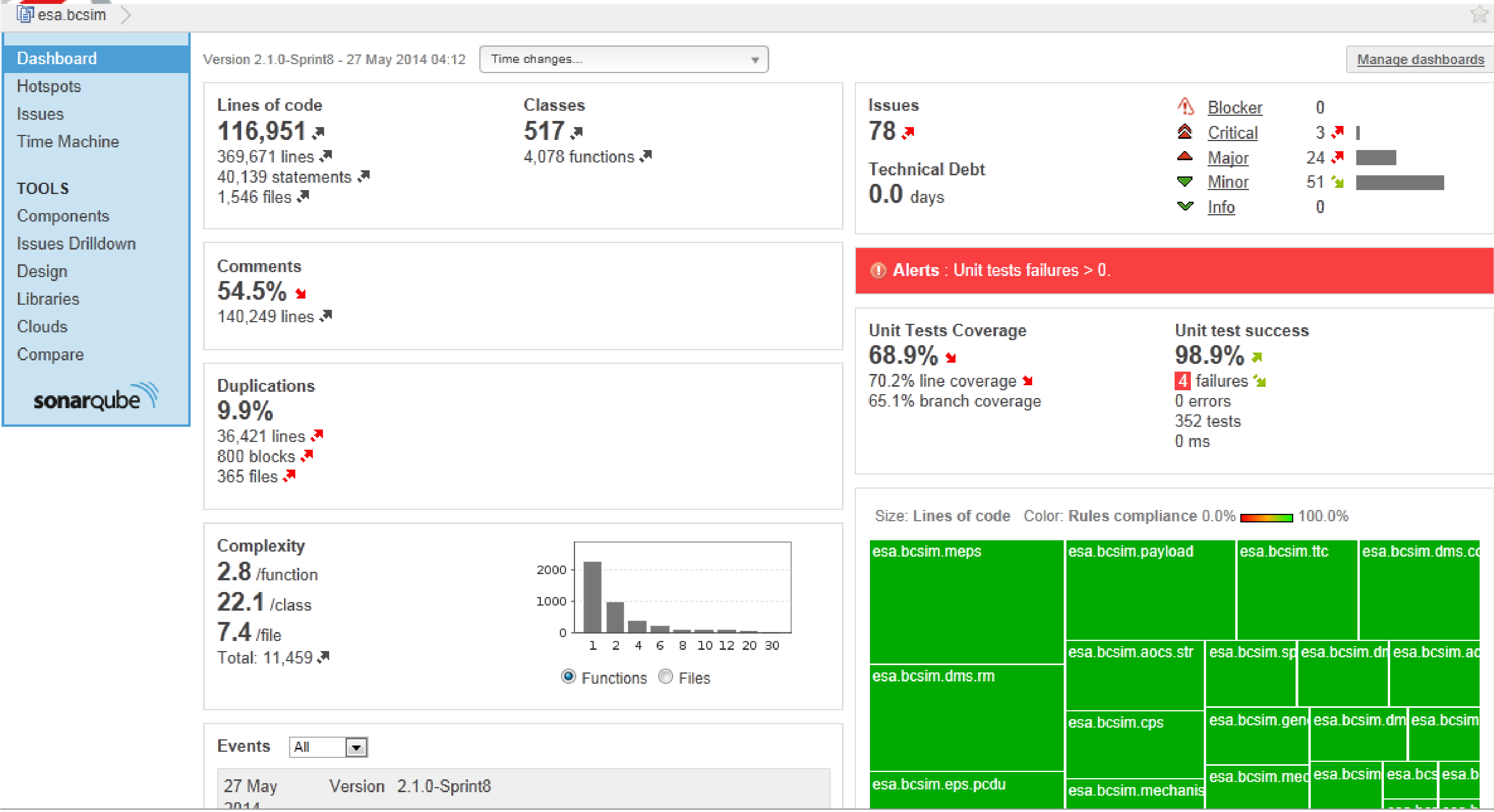
Valgrind Result (Processes Overview)

Process	Parent	Errors	Bytes Leaked
esa.exmsim.assemblies.itest (19156)	16624	Leak (definitely lost) 3 Uninitialized Condition 11	Definitely Lost 17125408
esa.exmsim.eps.itest (24779)	16624		
esa.exmsim.eps.itest (25109)	16624	Uninitialized Condition 27	
esa.exmsim.eps.itest (24258)	16624		
esa.exmsim.eps.itest (24709)	16624	Uninitialized Condition 2	
esa.exmsim.eps.itest (2476)	16624		
esa.exmsim.eps.itest (2631)	16624		
esa.exmsim.eps.itest (23146)	16624		
esa.exmsim.eps.pcu.utest (23429)	16624		
esa.exmsim.generic.utest (16651)	16624		
esa.exmsim.gnc.css.itest (23530)	16624		
esa.exmsim.gnc.css.utest (16740)	16624	Leak (definitely lost) 3	Definitely Lost 5252
esa.exmsim.gnc.imu.itest (21554)	16624		
esa.exmsim.gnc.imu.utest (16786)	16624	Leak (definitely lost) 2	Definitely Lost 3990

SONARCUBE


Home
TOOLS
Dependencies
Compare
sonarqube
Manage dashboards
My favourites
A Name Last Analysis
No data
Projects in error
A Name Blocker issues UTs failures UTs errors Last Analysis
esa.bcsim 0 4 0 04:12
1 results
Projects
A Name Version LOCs RCI Last Analysis
esa.bcsim 2.1.0-Sprint8 116,951 99.9% 04:12
esa.exmsim 1.0.0-Sprint3 107,587 96.2% 07:06
esa.umf 2.0.2-SNAPSHOT 159,465 61.6% 09 May 2014
3 results
Projects
Size: Lines of code Color: Rules compliance 0.0% 100.0%
esa.umf
esa.exmsim
esa.bcsim

DASHBOARD


esa.bcsim
Dashboard
Hotspots
Issues
Time Machine
TOOLS
Components
Issues Drilldown
Design
Libraries
Clouds
Compare
sonarqube
Version 2.1.0-Sprint8 - 27 May 2014 04:12
Time changes...
Manage dashboards
Lines of code
116,951
369,671 lines
40,139 statements
1,546 files
Classes
517
4,078 functions
Issues
78
Technical Debt
0.0 days
Blocker 0
Critical 3
Major 24
Minor 51
Info 0
Comments
54.5%
140,249 lines
Alerts : Unit tests failures > 0.
Duplications
9.9%
36,421 lines
800 blocks
365 files
Unit Tests Coverage
68.9%
70.2% line coverage
65.1% branch coverage
Unit test success
98.9%
4 failures
0 errors
352 tests
0 ms
Complexity
2.8 /function
22.1 /class
7.4 /file
Total: 11,459
2000
1000
0
1 2 4 6 8 10 12 20 30
Functions
Files
Size: Lines of code Color: Rules compliance 0.0% 100.0%
esa.bcsim.meps
esa.bcsim.payload
esa.bcsim.ttc
esa.bcsim.dms.cc
esa.bcsim.dms.rm
esa.bcsim.aocs.str
esa.bcsim.sp
esa.bcsim.dr
esa.bcsim.ac
esa.bcsim.cps
esa.bcsim.gen
esa.bcsim.dm
esa.bcsim
esa.bcsim.eps.pcdu
esa.bcsim.mechanis
esa.bcsim.med
esa.bcsim
esa.bcs
esa.b
Events
All
27 May 2014
Version 2.1.0-Sprint8

HOTSPOTS

esa.bcsim

- Dashboard
- Hotspots
- Issues
- Time Machine

TOOLS

- Components
- Issues Drilldown
- Design
- Libraries
- Clouds
- Compare

sonarqube

Version 2.1.0-Sprint8 - 27 May 2014 04:12 | Time changes... | Manage dashboards

Most Violated Rules (Any severity) — More

Parenthesis in expressions	23
Access to members data	16
Copy constructor	9
Default constructor	8
Destructor	6

Most Violated Resources — More

Definitions.h	0	0	7	2	0
Definitions.h	0	0	3	3	0
Definitions.h	0	0	3	2	0
Definitions.h	0	0	3	2	0
Definitions.h	0	0	3	2	0

Hotspots by Unit tests duration — More

esa.bcsim.scenario.stest.02	0 ms
StrNominalTest	0 ms
PressureRegulatorTest	0 ms
ArrayPowerRegulatorTest	0 ms
MepsTest	0 ms

Hotspots by Uncovered lines — More

StrFunctionalModel.cpp	1,354
Dans.cpp	979
Fpga.cpp	354
SdramController.cpp	277
RfLinkHelper.cpp	269

Hotspots by Complexity — More

StrFunctionalModel.cpp	462
FunctionalModel.cpp	440
Dans.cpp	341
Fpga.cpp	247

Hotspots by Complexity /function — More

TcTmModule.cpp	11.3
PowerSupplyUnit.cpp	11.3
SpaceWireController.cpp	10.2
Dans.cpp	9.5
FunctionalModel.cpp	9.2

TIME MACHINE

esa.bcsim

- Dashboard
- Hotspots
- Issues
- Time Machine

TOOLS

- Components
- Issues Drilldown
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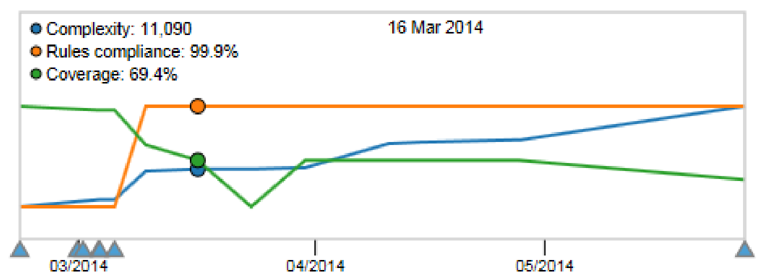
sonarqube

Version 2.1.0-Sprint8 - 27 May 2014 04:12 | Time changes... | Manage dashboards



	17 Dec 2013	21 Feb 2014 2.1.0	27 May 2014 2.1.0-Sprint8
Lines of code	106,065	108,960	116,951
Lines	340,007	346,182	369,671
Statements	36,162	37,608	40,139
Files	1,514	1,529	1,546
Classes	504	510	517
Functions	3,796	3,907	4,078
Accessors			

	17 Dec 2013	21 Feb 2014 2.1.0	27 May 2014 2.1.0-Sprint8
Comments (%)	54.3%	54.0%	54.5%
Comment lines	126,069	127,906	140,249

	17 Dec 2013	21 Feb 2014 2.1.0	27 May 2014 2.1.0-Sprint8
Issues	0	140	78
Blocker issues	0	0	0
Critical issues	0	7	3
Major issues	0	4	24
Minor issues	0	129	51
Weighted issues	0	176	138

	17 Dec 2013	21 Feb 2014 2.1.0	27 May 2014 2.1.0-Sprint8
Complexity	10,431	10,869	11,459
Complexity /function	2.7	2.8	2.8
Complexity /class	20.7	21.3	22.1
Complexity /file	6.9	7.1	7.4

	17 Dec 2013	21 Feb 2014 2.1.0	27 May 2014 2.1.0-Sprint8
Coverage		70.8%	68.9%
Line coverage		73.0%	70.2%
Branch coverage		64.8%	65.1%

COMPONENTS

esa.bcsim

Dashboard
Hotspots
Issues
Time Machine

TOOLS
Components
Issues Drilldown
Design
Libraries
Clouds
Compare

sonarqube

Name	Rules compliance	Coverage	Build time	Links
esa.bcsim	99.9%	68.9%	04:12	

Name	Rules compliance	Coverage	Build time	Links
esa.bcsim.aocs.fss	100.0%	92.5%	04:12	
esa.bcsim.assemblies	100.0%	85.5%	04:12	
esa.bcsim.ttc	99.8%	83.1%	04:12	
esa.bcsim.eps.bat	100.0%	82.5%	04:12	
esa.bcsim.aocs.rwl	99.9%	78.8%	04:12	
esa.bcsim.eps.sa	99.8%	78.1%	04:12	
esa.bcsim.cps	100.0%	78.0%	04:12	
esa.bcsim.aocs.imu	99.8%	76.9%	04:12	
esa.bcsim.dms.tctm	100.0%	75.5%	04:12	
esa.bcsim.mechanisms.magboom	100.0%	74.6%	04:12	
esa.bcsim.eps.pcdu	99.8%	74.6%	04:12	
esa.bcsim.dms.ssmm	100.0%	74.0%	04:12	
esa.bcsim.tcs	99.9%	73.7%	04:12	
esa.bcsim.dms.rm	100.0%	73.1%	04:12	
esa.bcsim.generic	100.0%	69.3%	04:12	
esa.bcsim.dms.common	100.0%	69.2%	04:12	
esa.bcsim.dms.riu	100.0%	69.1%	04:12	
esa.bcsim.datalinks	100.0%	67.7%	04:12	

ISSUES DRILLDOWN

esa.bcsim

- Dashboard
- Hotspots
- Issues
- Time Machine

TOOLS

- Components
- Issues Drilldown
- Design
- Libraries
- Clouds
- Compare

sonarqube

Profile Sonar way with Logiscope | Time changes...

Severity	
Blocker	0
Critical	3
Major	24
Minor	51
Info	0

Rule	
All variables must be initialized before being used	2
Pointer initialization	1
Access to members data	16
Destructor	6
Prefer C++-style casts	1
Try blocks in destructors	1

esa.bcsim.eps.pcdu	16
esa.bcsim.mechanisms.sada	15
esa.bcsim.mechanisms.apme	12
esa.bcsim.ttc	8
esa.bcsim.meps	8
esa.bcsim.eps.sa	7

esa/bcsim/eps/pcdu/mpo	11
esa/bcsim/mechanisms/sada/mpo	10
esa/bcsim/meps	8
esa/bcsim/ttc	8
esa/bcsim/mechanisms/apme/hgama	6
esa/bcsim/eps/pcdu/mtm	5

Definitions.h	9
Definitions.h	6
Definitions.h	5
Definitions.h	5
Definitions.h	5
Definitions.h	5

Bulk Change

Se.	Status	Description	Component	Assignee	Action plan	Updated
	Open	writeValue = static_cast<::Smp::UInt16 >((buffer[itRegister]) & 0xFFFF)	esa.bcsim esa/bcsim/dms/rm/MemoryLogicBase.cpp			26 Apr 2014
	Open	((breakwireExecuted == false) && (enabled == true) && (breakwireEvent.ge...	esa.bcsim esa/bcsim/eps/pcdu/mpo/Dplm.cpp			04:12
	Open	((i < (static_cast<::Smp::Int64 >(MPO_FPGA_EEPROM_BYTE_SIZE) / 2)) && (...	esa.bcsim esa/bcsim/eps/pcdu/mpo/Fpga.cpp			04:12
	Open	block.get_Data()[0 + k * 2] = static_cast<::Smp::Int8 >(buffer[k] & 0xFF)	esa.bcsim esa/bcsim/eps/pcdu/mpo/Fpga.cpp			03 Mar 2014
	Open	DplmSelection	esa.bcsim			03 Mar 2014

SUBVERSION

SubversionEdge by CollabNet | Roots | Changeset | Change Log | Directory | Logged in as: pfritzen | Help

[bcsim] / trunk / Src

/trunk/Src r3764

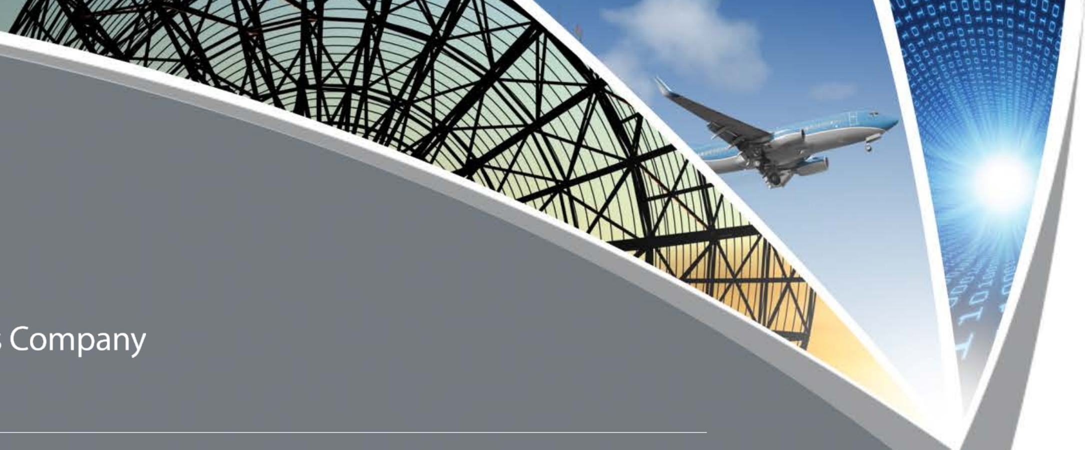
File	Rev.	Age	Author	Last log entry
../				
esa.bcsim/	3673	6 weeks	pellsiepen	sim#2033 simulus5#119: Updated solution Makefile and associated template such th...
esa.bcsim.aocs/	3617	2 months	dsegneri	Merged SIMULUS_5.4 branch into trunk
esa.bcsim.aocs.fss/	3617	2 months	dsegneri	Merged SIMULUS_5.4 branch into trunk
esa.bcsim.aocs.imu/	3759	7 days	fmatera	IMU-FCE integration improved
esa.bcsim.aocs.rwl/	3722	3 weeks	dsegneri	Change needed to be compatible with two REFA varsions
esa.bcsim.aocs.str/	3693	6 weeks	fmatera	Initialization of STR power on state updated in StrFunctionalModel
esa.bcsim.assemblies/	3731	2 weeks	clourenco	BepiSIM#306: Added a switchWhileOff bool field which, when true, allows the TSW ...
esa.bcsim.configurations/	37 View directory revision log		tera	IMU-FCE integration improved
esa.bcsim.cps/	3713	4 weeks	clourenco	Moved Thruster's lastUpdateTime and firingUpdateEventId fields into the model. A...
esa.bcsim.datalinks/	3720	3 weeks	ezanatta	Corrected non compliances to coding standard rules from Format Checker
esa.bcsim.dms/	3720	3 weeks	ezanatta	Corrected non compliances to coding standard rules from Format Checker
esa.bcsim.dms.common/	3738	2 weeks	dsegneri	Provided fix for SPR BepiSIM#275. Design needs to be updated and test implemente...
esa.bcsim.dms.fce/	3720	3 weeks	ezanatta	Corrected non compliances to coding standard rules from Format Checker
esa.bcsim.dms.obc/	3720	3 weeks	ezanatta	Corrected non compliances to coding standard rules from Format Checker
esa.bcsim.dms.pm/	3721	3 weeks	mirvine	Add UART2 register used by OBSW during boot (but UART2 not used during run of ap...

REFERENCES

- Some images have been taken from www.esa.int and are Copyright by ESA
- Some information has been taken from www.wikipedia.org

Telespazio

A Finmeccanica/Thales Company



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