The SVF–Lite Configuration
in the
End-To-End Avionics System
Test Bench Concept

Dubravka Ilić
Tuomas Räsänen
Space Systems Finland

SESP 2012
26/09/2012

Cristiano Leorato
Quirien Wijnands
ESA/ESTEC

European Space Agency

Presentation Outline

- **End-To-End Avionics System Test Bench (E2E-ATB)**
  - Overview
- **ESA SGEO SVF-Lite**
  - Idea / Goal
  - Architecture
  - Implementation
- **SVF-Lite Status, Results and Lessons Learned**

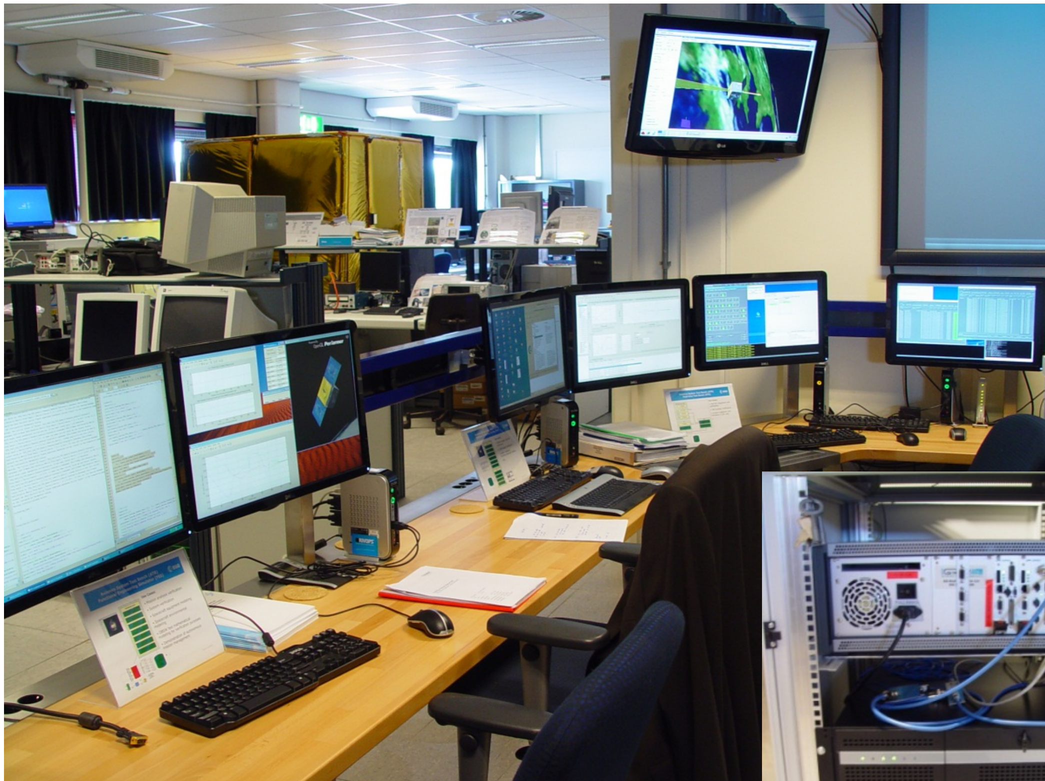
The End-To-End Avionics System Test Bench (E2E – ATB)

SESP 2012

26/09/2012

European Space Agency

Avionics System Test Bench (ATB)



ATB Console Desk in the ESTEC

Avionics Laboratory

The ATB is an **open** facility that allows technology and standards assessment, validation and demonstration in **context.**

Typical issues with technology verification and validation:

- Validation not performed "in context"
- Validation in a simplified environment or by similarity is simply not good enough
- Too costly to develop verification environments each time

Leon 2 Rasta Assembly, Simulator host and EGSE Reference Facility host

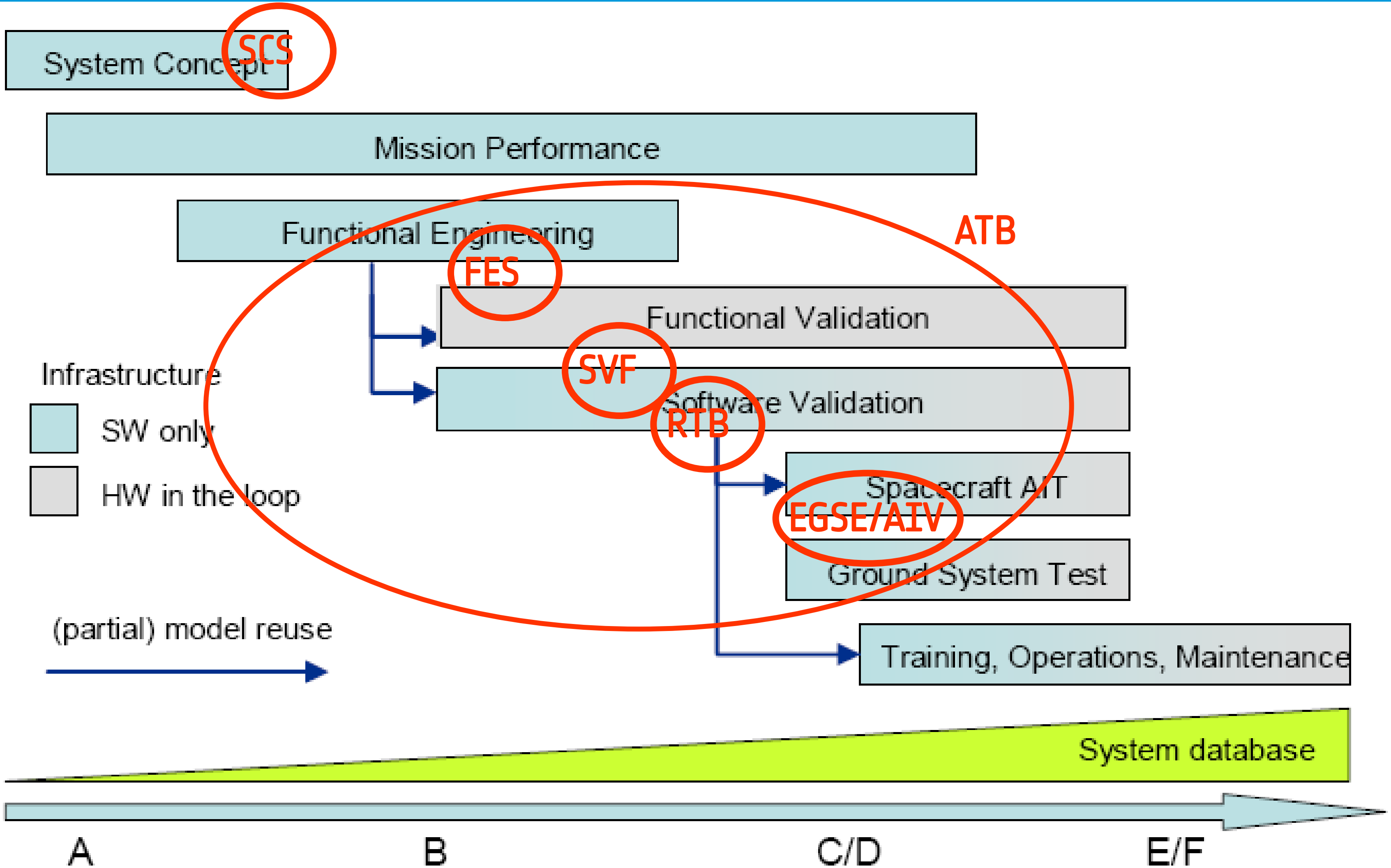
ATB: The main use cases

- **Standards and Technology Demonstration** – the ATB infrastructure is used as a representative environment for standards and technology assessments. Both development process and avionics application related standards and technologies are in the scope of this use case. The ATB infrastructure can be provided as a CFI as part of a study (TRP, GSTP etc.) contract.

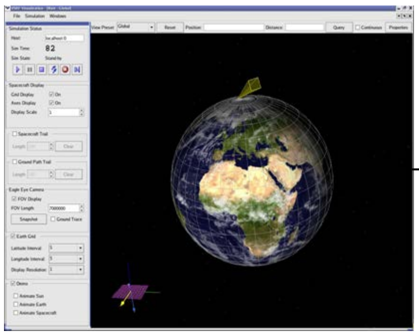
- **Technology Assessment in Support of Projects** – The ATB can be used in the support of projects when need rises to perform specific technology assessments (shadow engineering, independent validation etc.) in the area of avionics systems.

- **Staff Competence** – the ATB infrastructure deployed in the Avionics Lab is used as an in-house hands-on training facility for staff. The aim here is to maintain and improve the competences of the TEC-SW staff in avionics systems and the related standards and technologies.

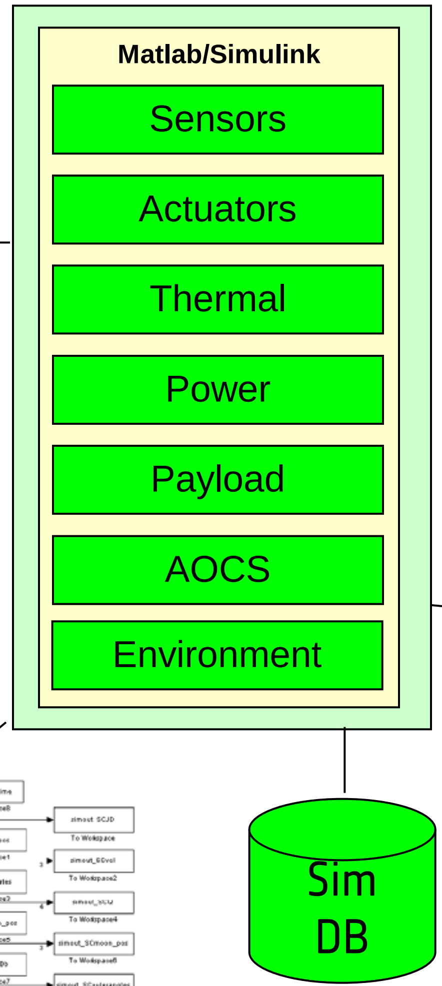
ATB: Lifecycle support (ETM-10-21)



ATB: Functional Engineering Simulator (FES)

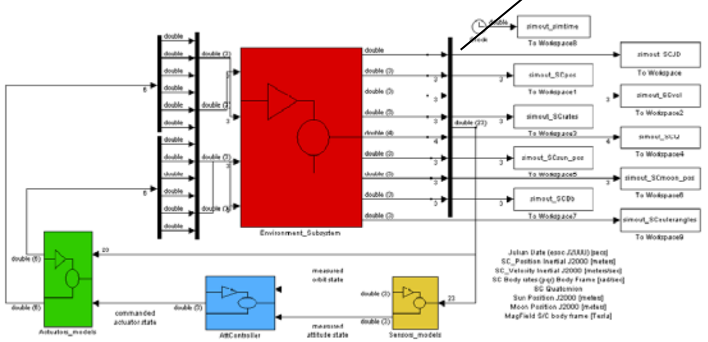


openIGS 3D visualisation

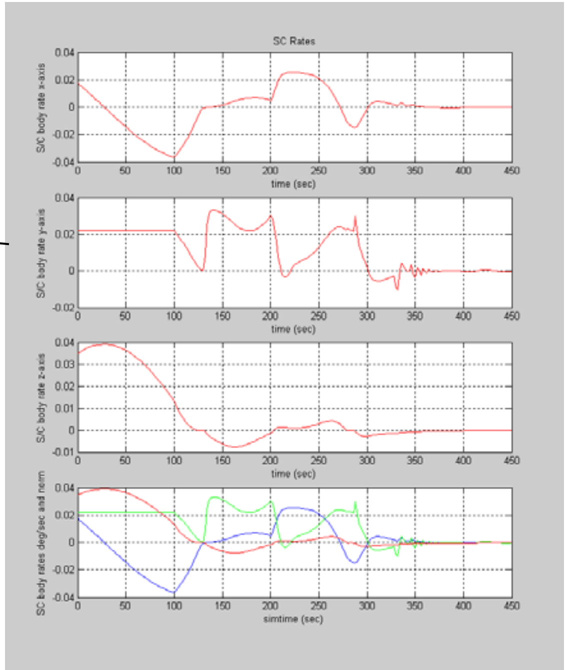


Examples of FES Use Cases:

- Mission Analysis Verification
- System / Subsystem Verification
- Spacecraft equipment modelling
- Spacecraft environment modelling
- OBSW / AOCS fast mathematical modelling for verification purposes
- Autonomous mission management demonstration.
- ...

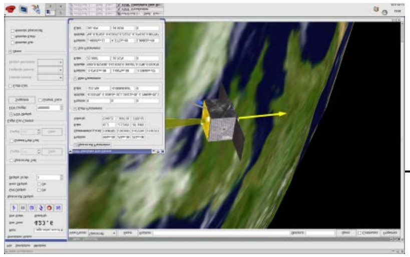


Simulink

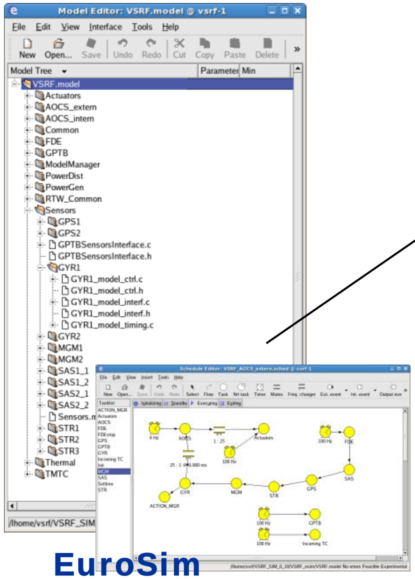


Plotting Results (Reference)

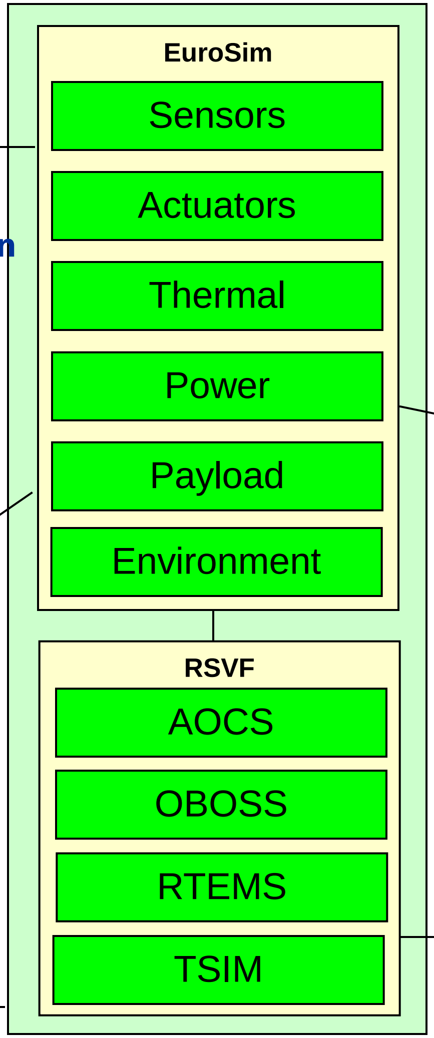
ATB: Software Validation Facility (SVF)

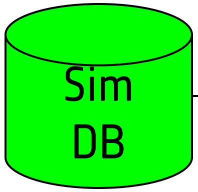


openIGS 3D visualisation



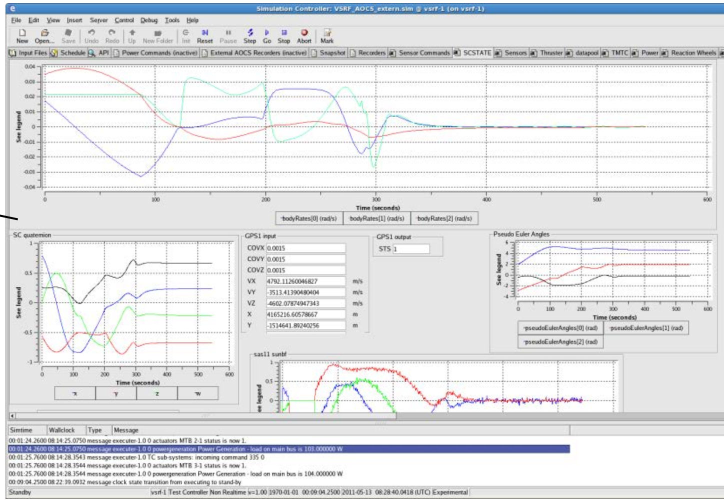
EuroSim

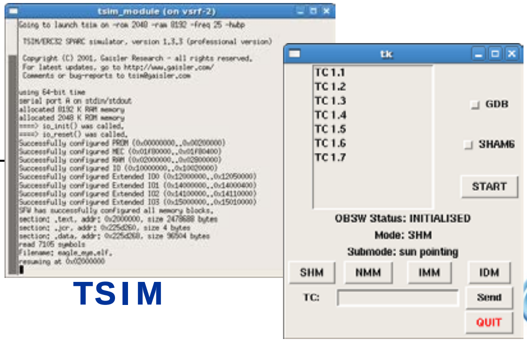




Examples of SVF Use Cases:

- **OBSW modes transition verification**
- **FDIR design verification**
- **OBSW validation, incl. regressing testing**
- **…**

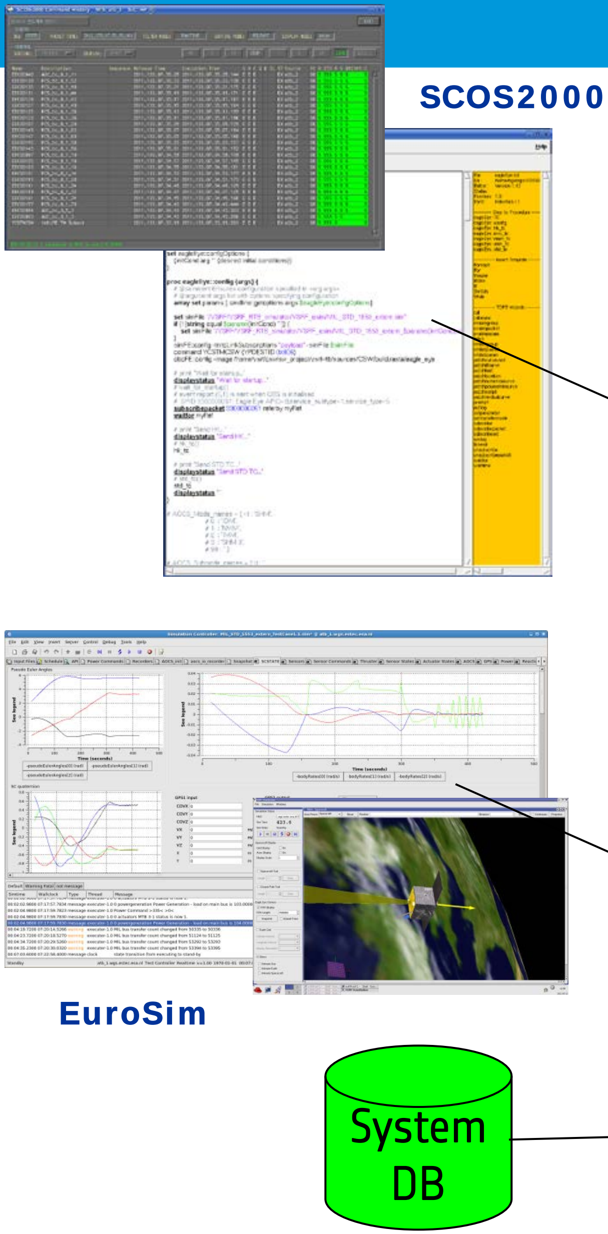


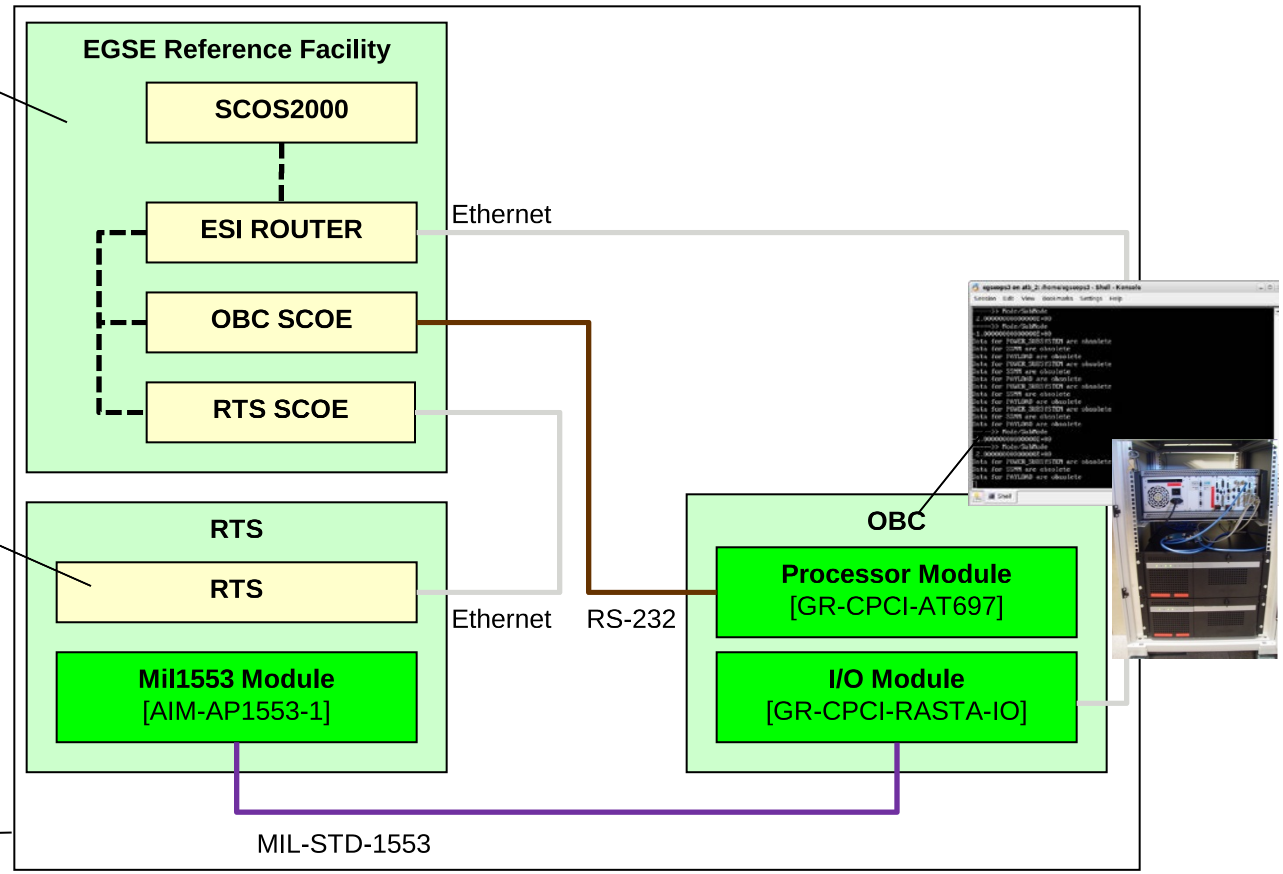


TSIM

ATB: Real Time Bench (RTB)

Examples of RTB Use Cases:
- **HW/SW integration and verification**
- **H/W function verification**
- **System validation with H/W in the loop**
- **...**

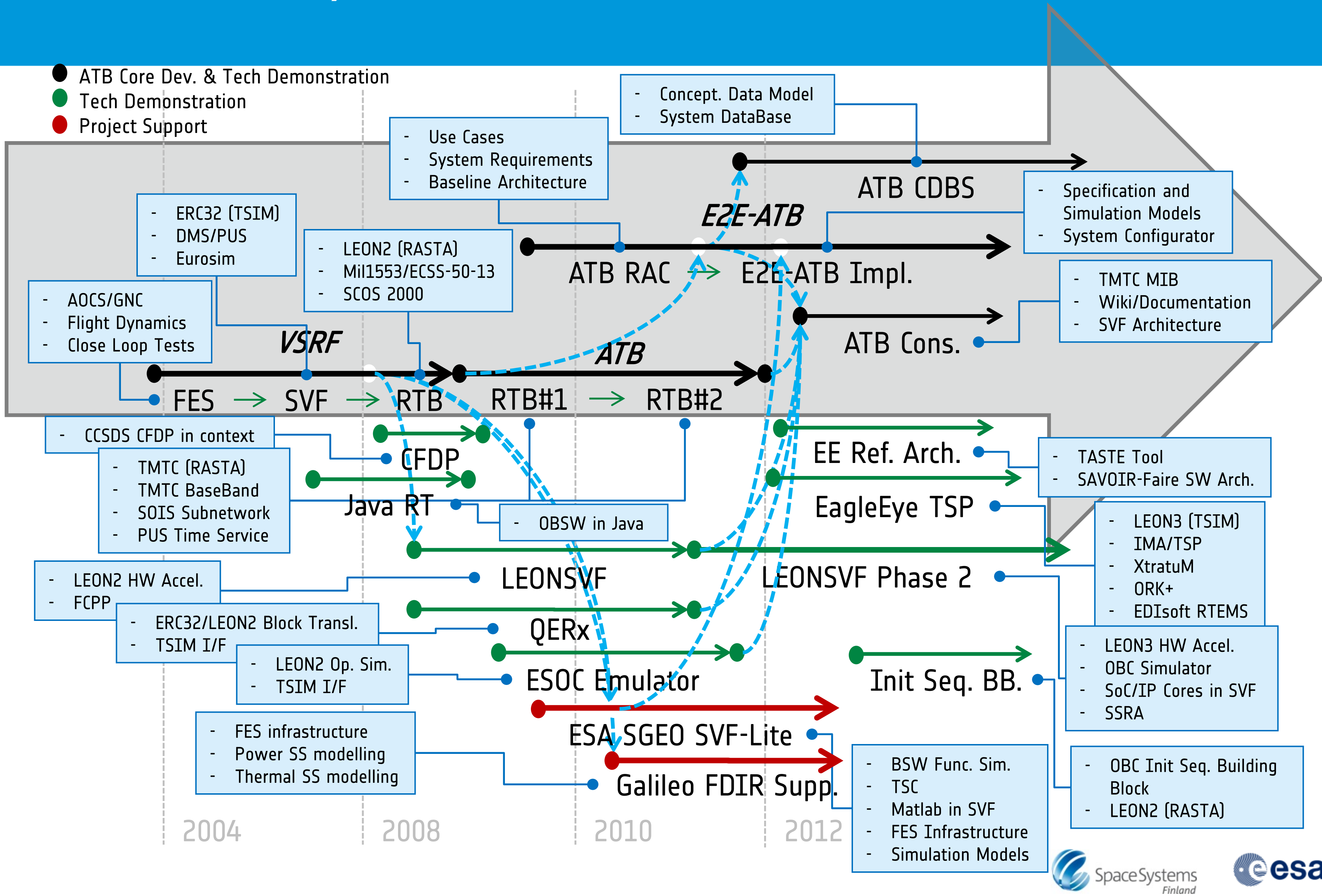




SpaceSystems Finland

esa

ATB: Past, Present and Future



E2E-ATB: Rationale

- **Knowledge, Experience, Lessons Learned → Top Down approach**
- **ATB – Requirements and Architectural Consolidation activity**
  - ➢ Consistent set of Use Cases, User Requirements and S/W Requirements, and a top level architecture captured in UML.

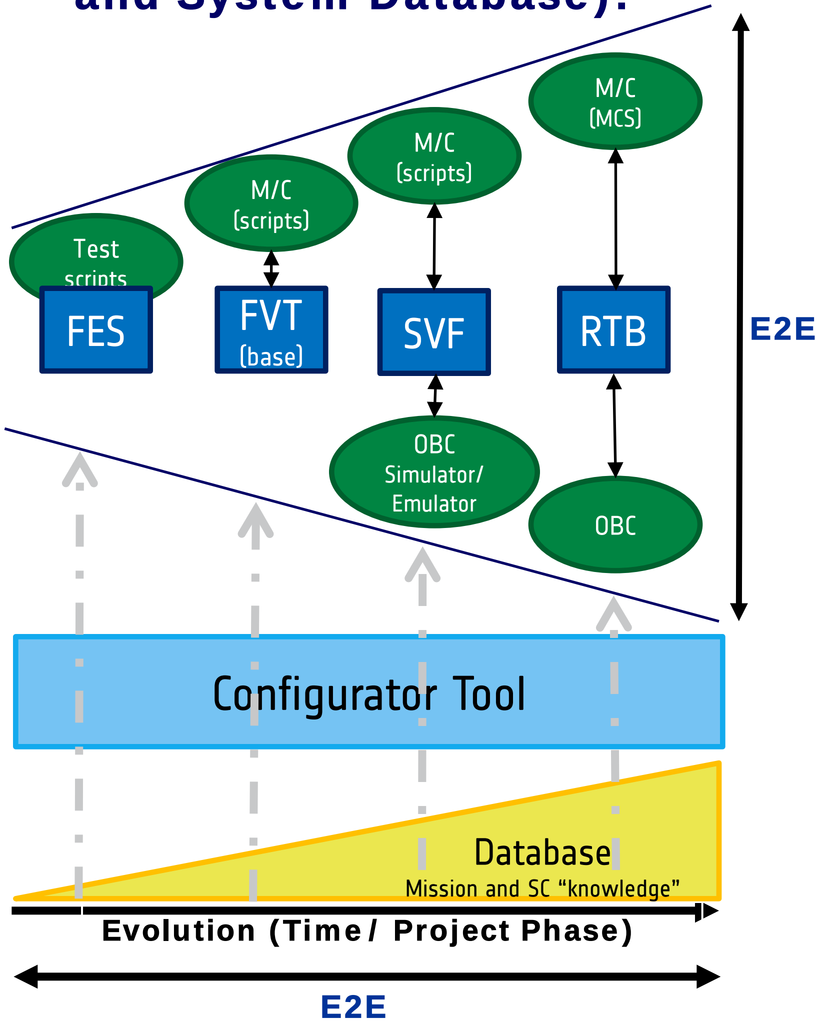
- **ATB – FES Enhancements activity**
  - ➢ FES Simulator architecture and definition of (models) interfaces
  - ➢ FES Infrastructure functionality
    - ➢ S/C H/W resembling architecture
    - ➢ Automated (Regression) Unit Testing
    - ➢ Interface, parameter and plotting definition using DB and Bus Objects

- **Currently ongoing implementation activity: E2E-ATB**
  - **E2E-ATB Technical domain improvements:**
    - Overall Architecture (taking into account the results of SSRA and SMP2)
    - Deployment approaches (using a Configurator Tool)
    - Implementation and Testing
    - (Maintainable) set of Documentation consistent with evolving models

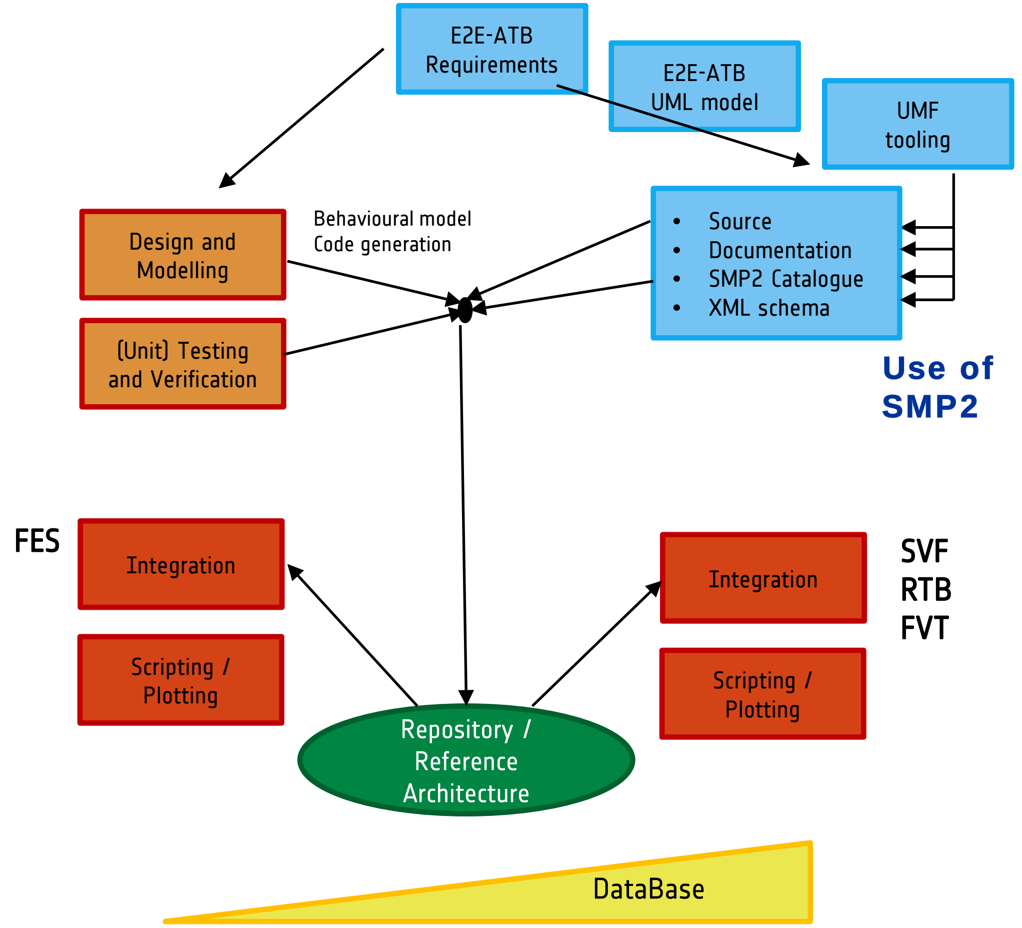
SpaceSystems Finland esa

E2E-ATB: 2 Main Challenges

- **Improve configurability and deployment (from Repository and System Database):**



- **Merge of 2 conceptually different simulation models:**

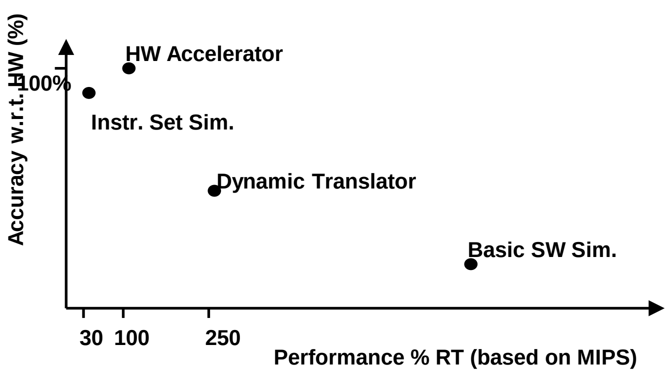


SpaceSystems Finland

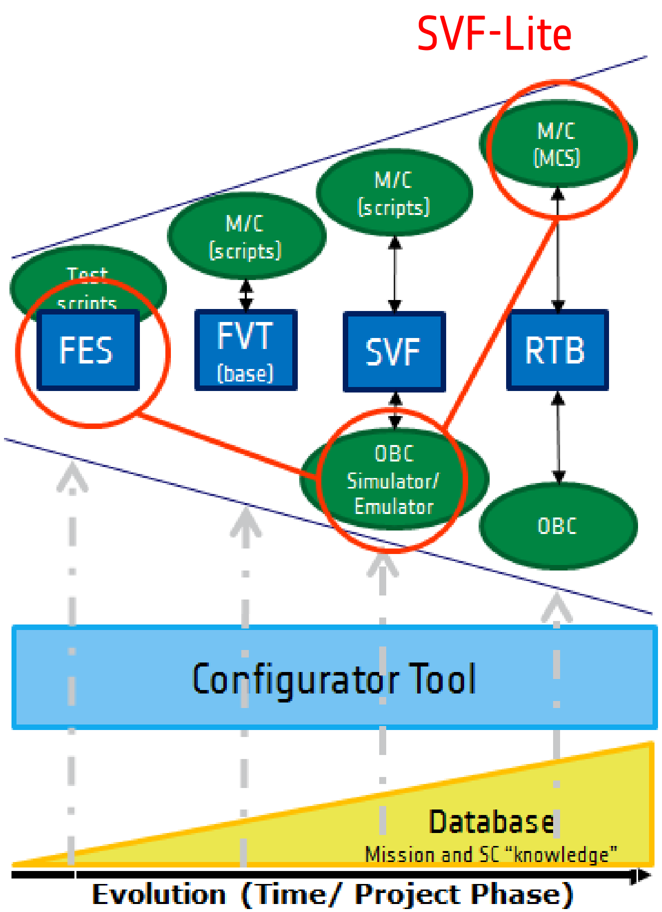
esa

E2E-ATB: SVF-Lite

- **Background / Rationale:**
  - ATB experience: "**Intermediate**" versions used for verification purposes.
  - ATB experience: simulator **porting** issues (modelling, interfacing, scheduling)
  - SVF performance:
    - To **increase performance** (at cost of representativity), by replacing TSIM by **BSW functional simulation**.
  - Direct use of **MCS** TM/TC scripts
  - Other **improvements (e.g FES infrastructure)**



Estimated performance increase



ATB SVF-Lite Concept

ESA SGEO SVF-Lite

SESP 2012

26/09/2012

European Space Agency

ESA SGEO SVF-Lite: Objectives

ESA SGEO SVF-Lite top-level objectives

All within the context of the 3 ATB Use-Cases:

The main objective of the ESA SGEO SVF is to provide **complementary** and **internal** support to the **ESA SGEO project team** for the purpose of **flight OBSW functional verification and validation**. In specific the area of **FDIR** on **System** and on **AOCS** level. This SVF will **not** replace the Industry SGEO SVF. However it is expected that the implementation efforts on the SVF-lite give **unmatched insight and review** capabilities in the Industrial SVF and OBSW (e.g. on interface level).

The activities will be focused on the **independent functional verification** of the software product. It would also be possible to perform re-assessment of engineering margins, feasibility and performance parameters as part of shadow engineering in specific cases.

The ESA SGEO SVF-Lite foresees to support the following SGEO activities:

OBSW Independent Verification

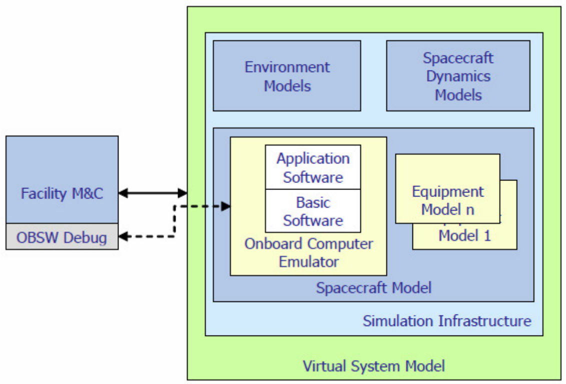
- Performance analysis
- AOCS functional verification
- AOCS onboard software verification
- Onboard software verification

- Specifically for **FDIR**, which is defined on system level and detailed on subsystem or equipment level and therefore spread over many areas, it is believed that the an SVF-Lite can contribute in providing a tool to probe, define and assess failure scenarios.

User Requirements driving design and implementation:

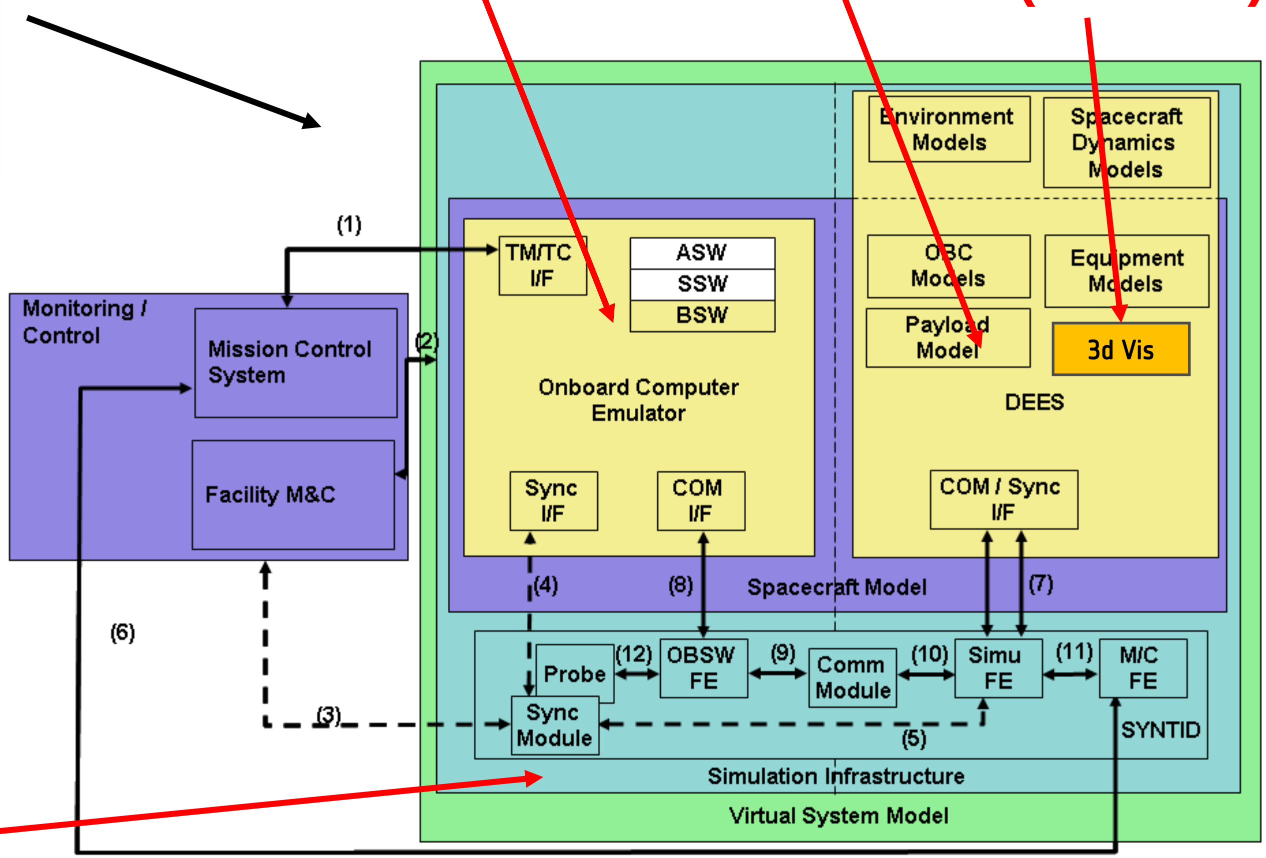
- Constraint to be able to run the **unaltered ASW**.
- Goal to be able to run/rerun the **original test cases from industry without any manual modifications to the test-scripts.**
- In **vice-versa**, the goal to be able to generate / develop new test cases and test-scripts to be run at industry facilities.
- Wish to execute in **faster than real time** mode.
- Wish to directly reuse the **FES (models and infrastructure)**

ESA SGEO SVF-Lite: Architecture (1/3)



SVF architecture (ETM-10-21)

SVF-Lite architecture



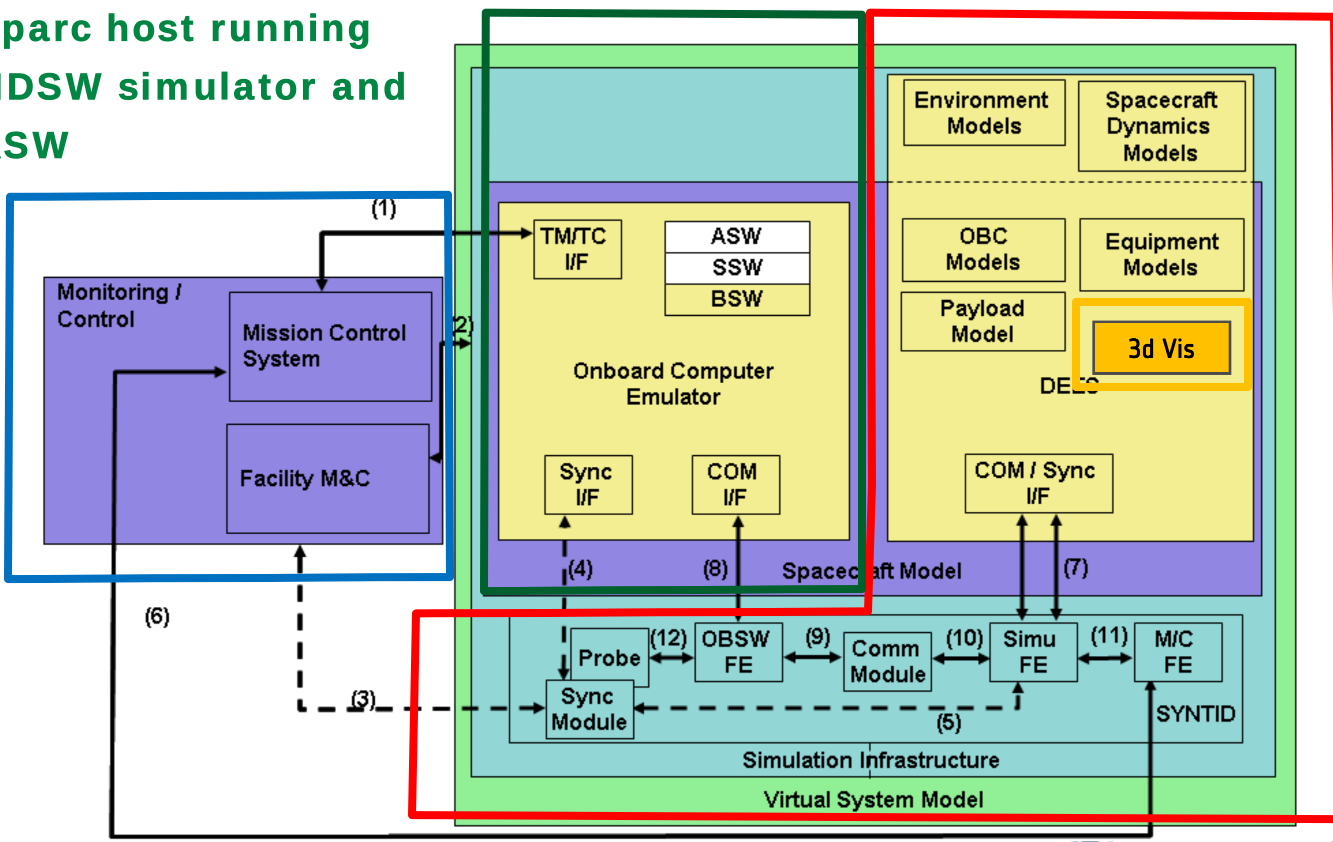
ESA SGEO SVF-Lite: Architecture (2/3)

- **2 configurations:**
  - **HDSW Simulator and ASW in loop**
  - SSF Device Simulator in loop

Linux host running Matlab DEES and Syntid

Sparc host running HDSW simulator and ASW

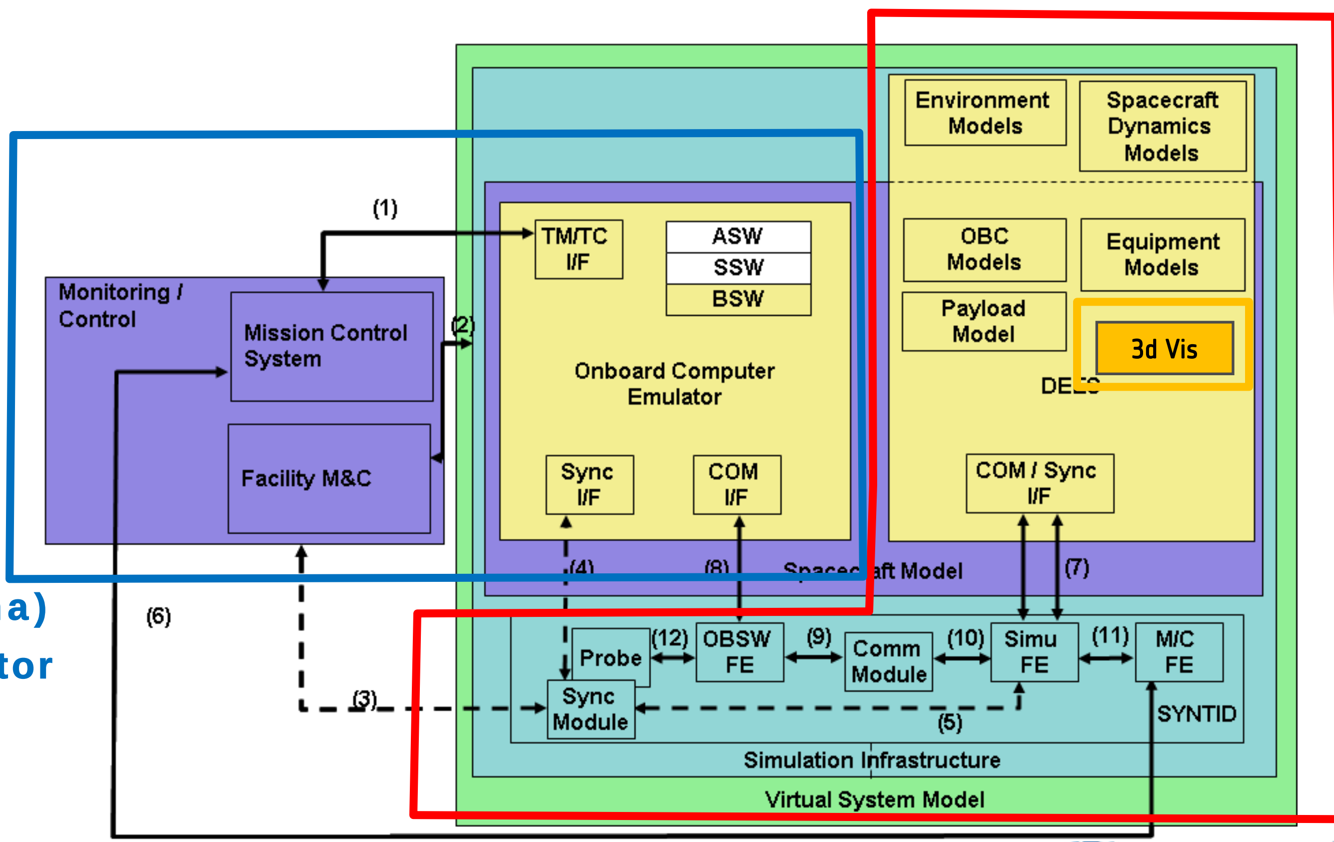
Windows host running TSC



ESA SGEO SVF-Lite: Architecture (3 / 3)

- **2 configurations:**
  - HDSW Simulator and ASW in loop
  - **SSF Device Simulator in loop**

Linux host running Matlab DEES and Syntid

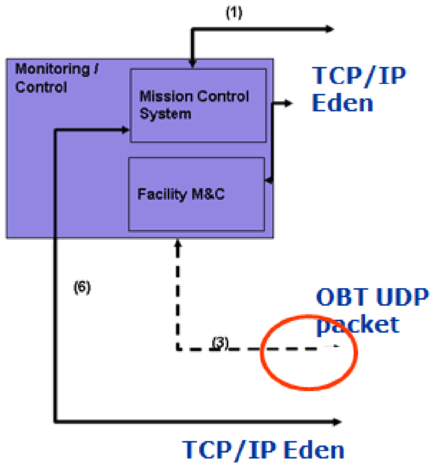


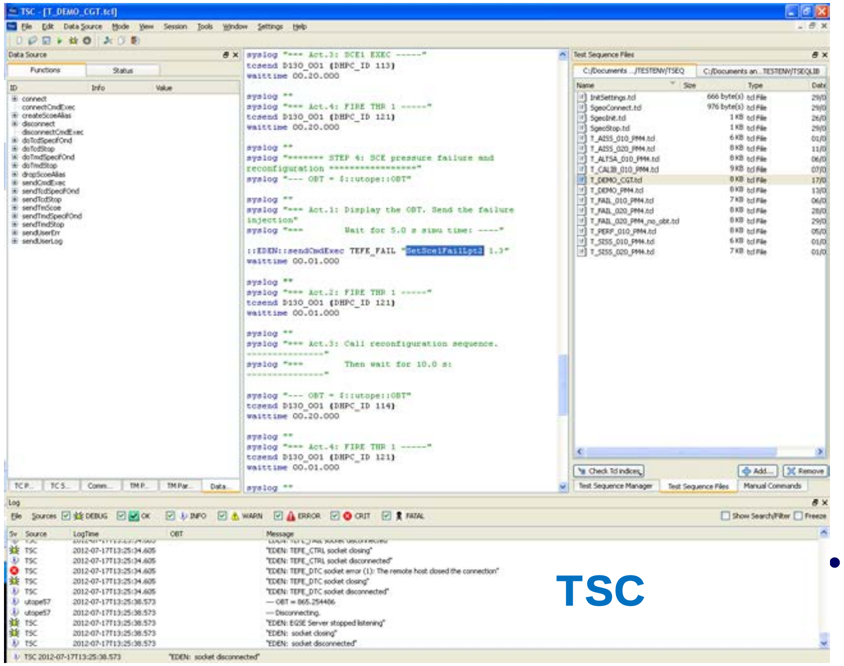
Windows host running TSC (Terma) and Device Simulator (SSF)

SpaceSystems Finland

esa

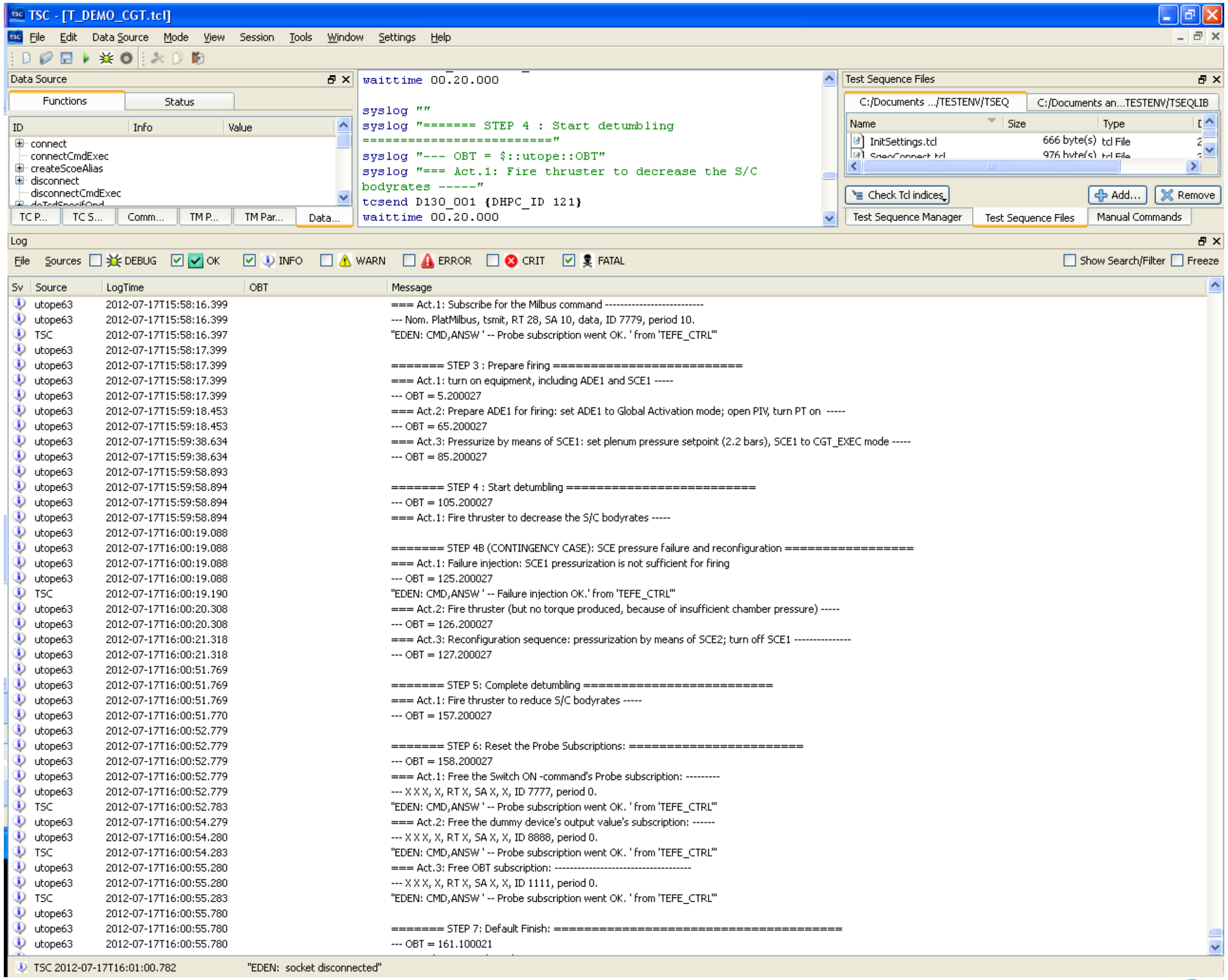
ESA SGEO SVF-Lite: Monitor and Control Component (1/2)





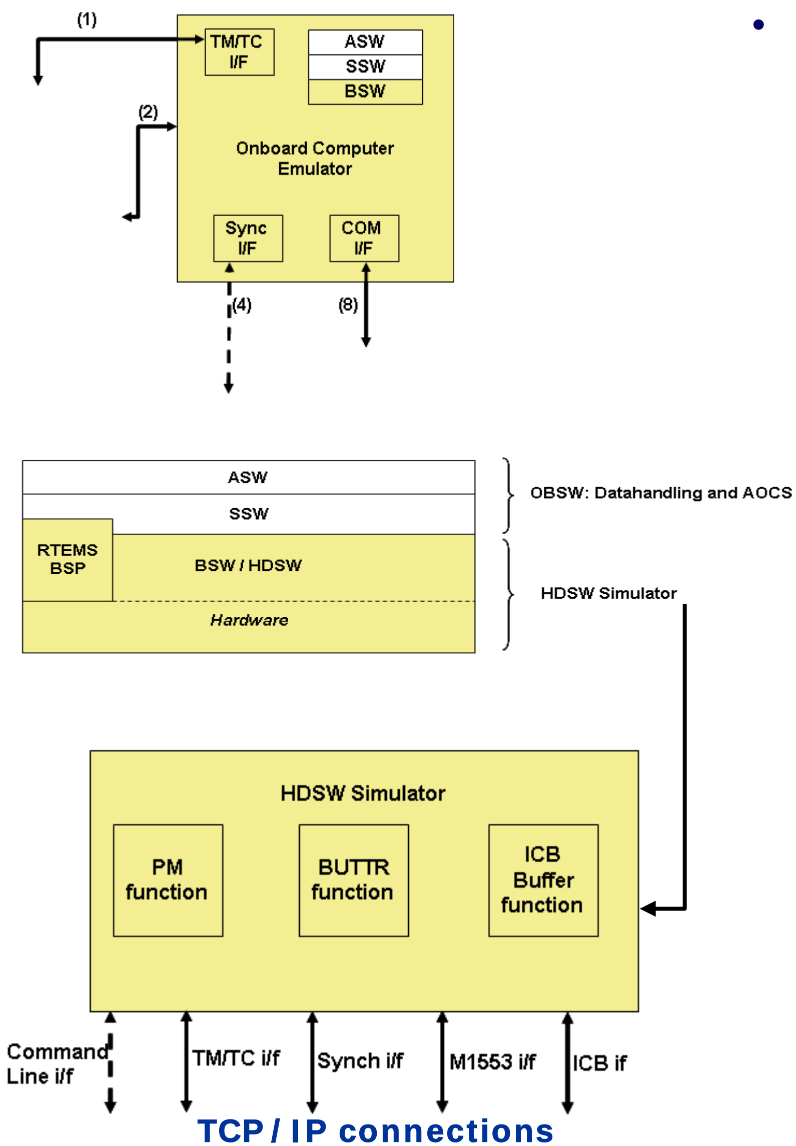
- **Monitoring and Control Component:**
  - Based on existing Terma product (TSC)
    - "light weight"
    - MIB files (+ merge with SCOE MIB)
    - uTope Scripts
  - Used to setup (e.g. acceleration and probing) and connect the components of the SVF-Lite,
  - Used to initialise all components consistently,
  - Single point to observe and interact with SVF (Ground TM/ TC and Failure Injection)
  - Used to monitor online or analysis data
- **Additional Feature was added to drive the TSC based on OBT UDP packet**

ESA SGEO SVF-Lite: Monitor and Control Component (2/2)



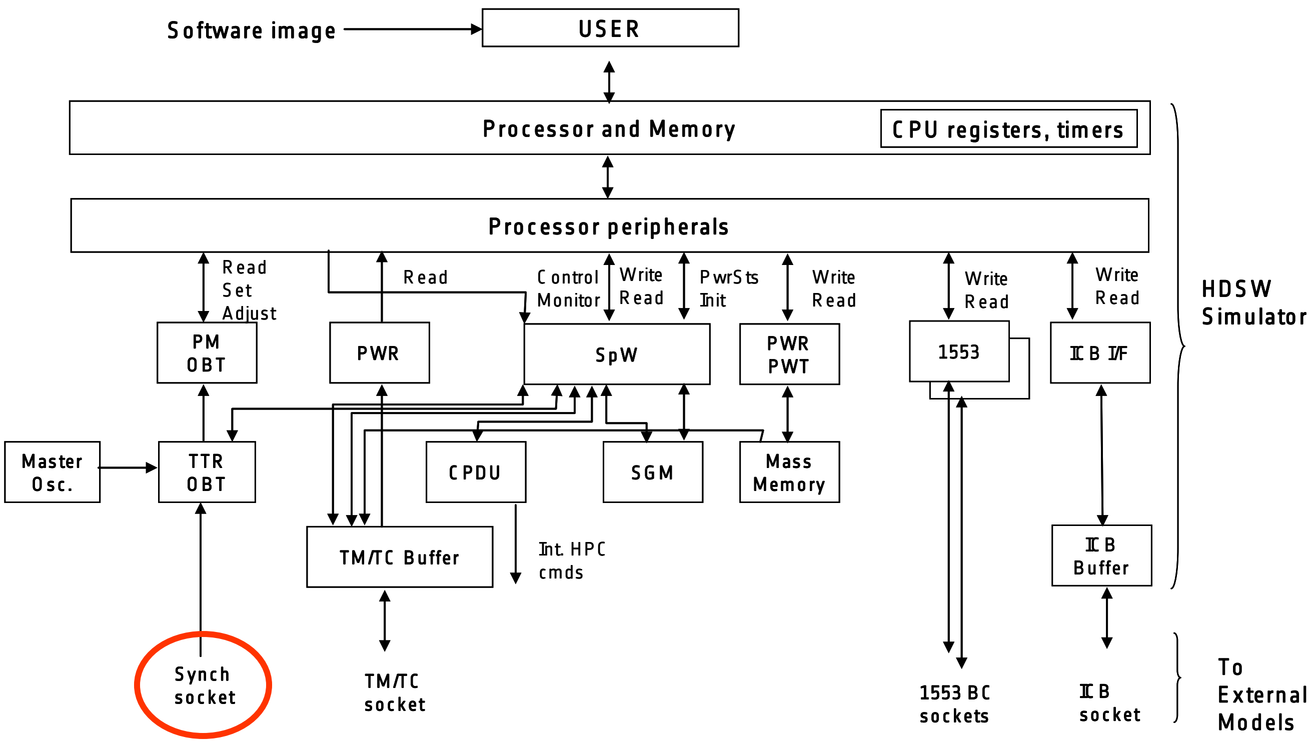
TSC logging

ESA SGEO SVF-Lite: OBC Simulator Component (1/3)



- **OBC simulator: HDSW and ASW**
  - HDSW Simulator is based on existing RUAG HSIM
  - It replaces the BSW and H/W layer (including the processor).
  - ASW & SSW layers are built with the HDSW simulator into a single executable
  - Compilation and execution on the Sparc Sunblade 100 host platform
  - Provided Interfaces:
    - TM/TC (TCP/IP)
    - Command / Test Interface
    - ICB and MIL Interfaces (TCP/IP)
    - “10hz” Synch Interface (TCP/IP)

ESA SGEO SVF-Lite: OBC Simulator Component (2/3): HDSW simulator



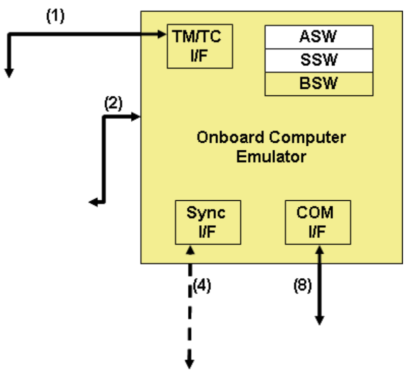
HDSW Simulator Functionality

HDSW simulator functions:

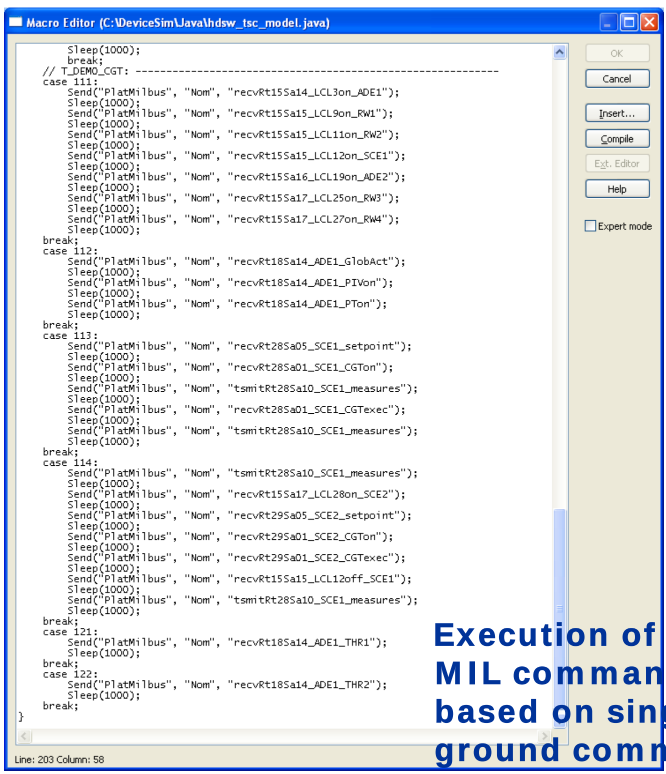
- **Packet TC decoder**
- **TM encoder**
- **Processing function (no alarm signal generation, no error detection and correction functions)**
- **Timing and Synchronisation**
- **SMU Mass Memory (simplified)**
- **SGM (simplified)**
- **RM (simplified)**

SpaceSystems Finland esa

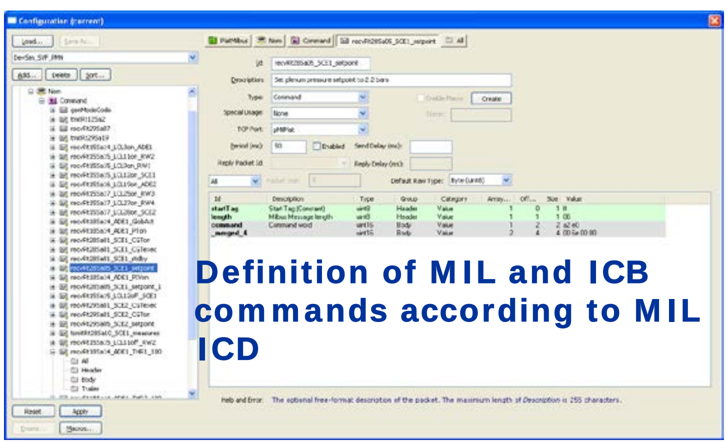
ESA SGEO SVF-Lite: OBC Simulator Component (3/3): Device Simulator



- **OBC simulator: Device Simulator**
  - Device Simulator is existing SSF product
  - Device Simulator replaces HDSW simulator and ASW (in terms of reception and handling of interfaces)
  - Provides MIL1553 and ICB commands to DEES
  - Preparation of test scenarios in accordance to ground commanding and to obtain reference results.

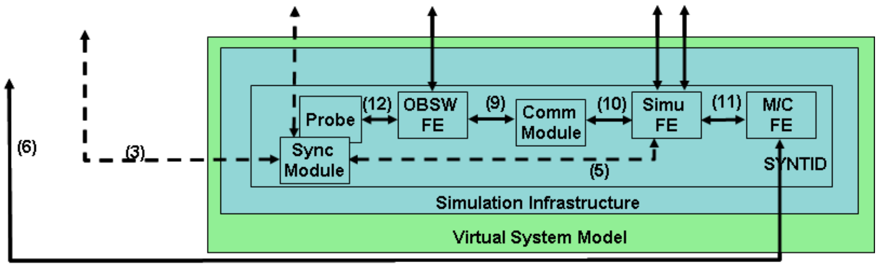


Execution of set of MIL commands based on single TSC ground command



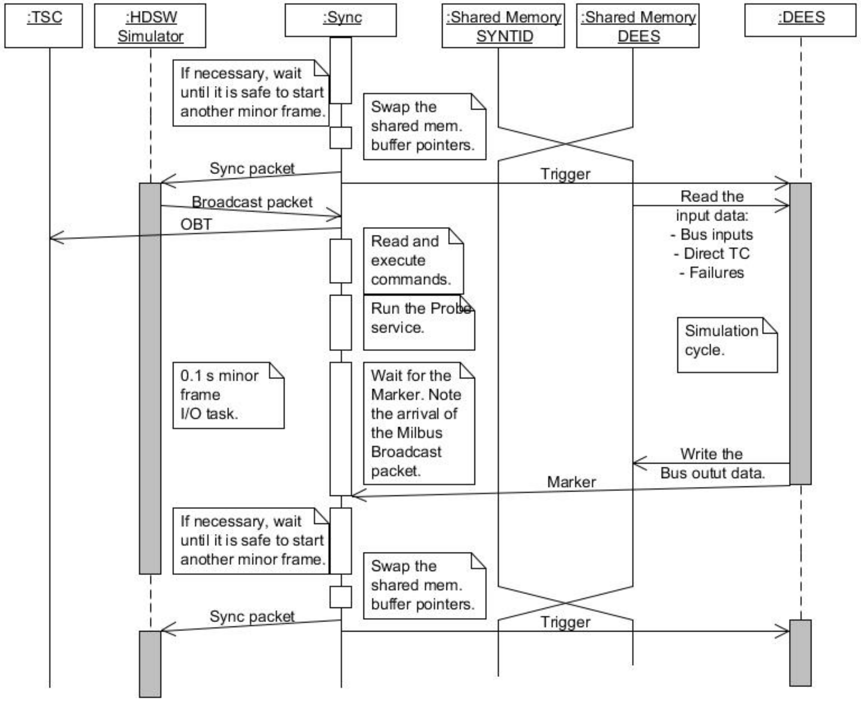
Definition of MIL and ICB commands according to MIL ICD

ESA SGEO SVF-Lite: SYNTID Component

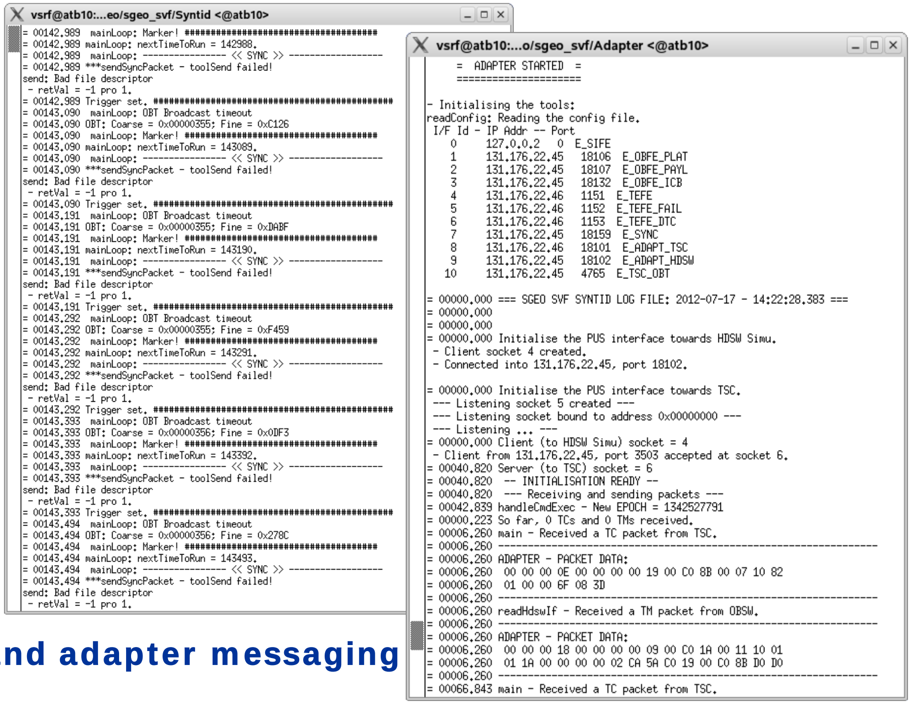


SYNTID

- **SYNTID Component:**
  - Data Exchange
  - Logging
  - Synchronisation
  - Probe

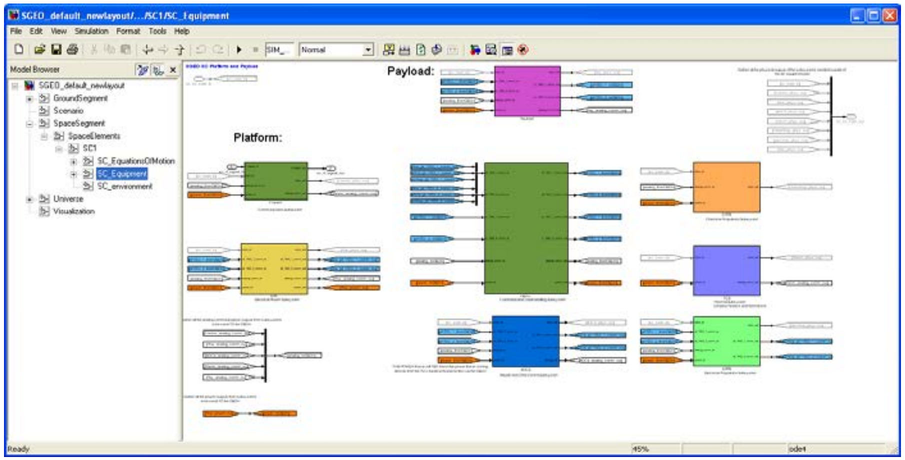


Synchronisation DEES, OBC simulator and TSC

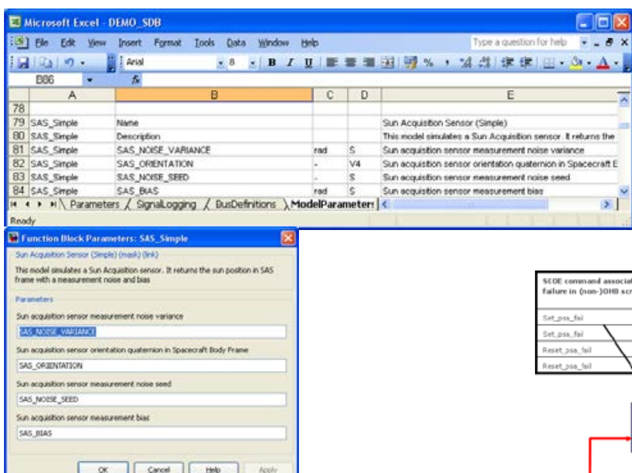


Syntid and adapter messaging

ESA SGEO SVF-Lite: DEES Component

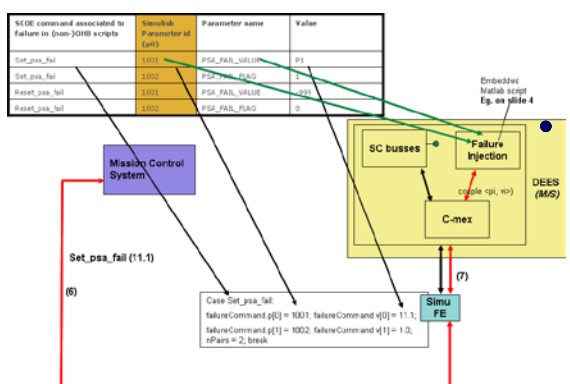


DEES
SC architecture



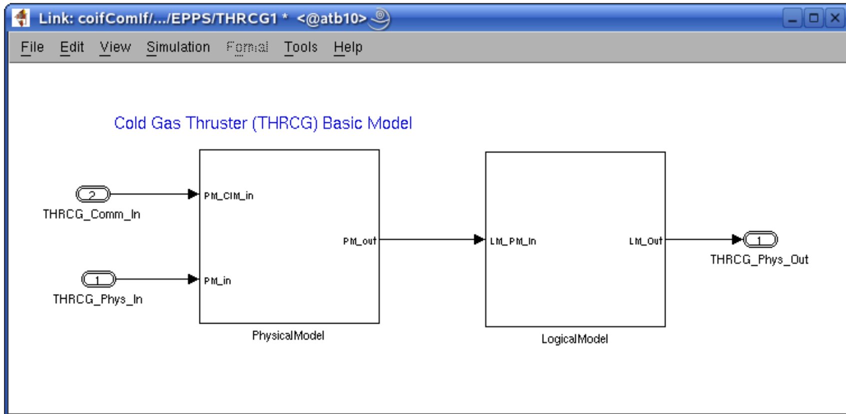
Parameterisation

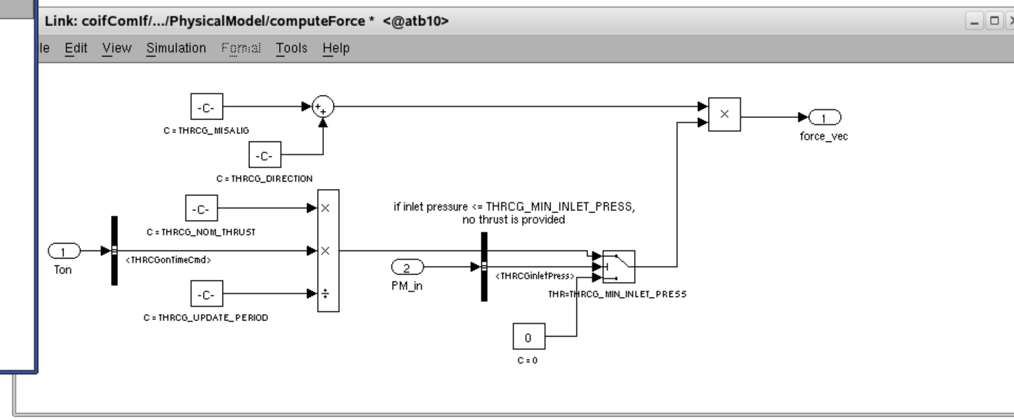
Failure
Injection



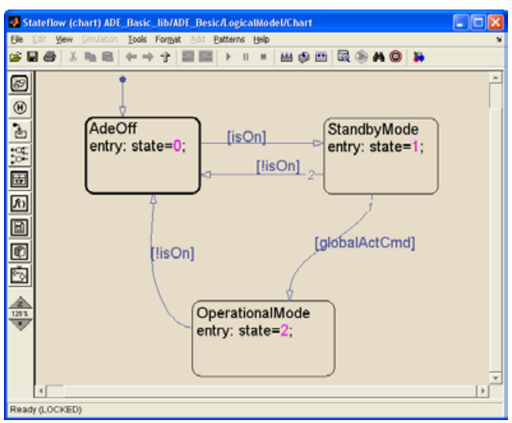
- **DEES Component:**
  - Direct FES reuse
  - Full representative closed-loop dynamic SC simulator
  - DEES DB:
    - ➢ Parameterisation
    - ➢ Interface definition
    - ➢ Failure definition
    - ➢ Automated plotting definition
- Interfaces:
  - ➢ Shared memory to SIM FE
  - ➢ Synchronisation via SYNTID

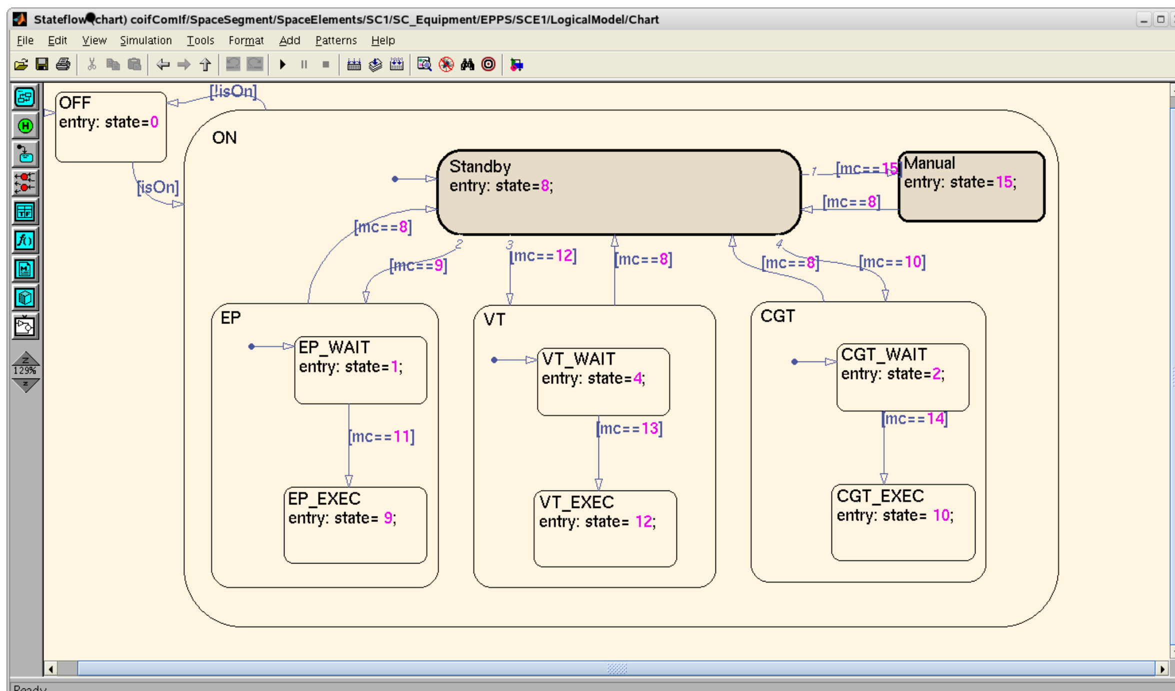
ESA SGEO SVF-Lite: DEES Component Modelling





Cold Gas Thruster model and minimum inlet pressure





Actuator Driver Electronics and Support Control Electronics Stateflow diagrammes

ESA SGEO SVF-Lite: DEES Component Simulation Model parameter definitions

Microsoft Excel - FES_SDB_temp

C285 | Thruster location (in SGF), needed for torque computation

	A	B	C	D	E	F	G	H	I
257	THRCG_DIRECTION_X	-	Thrust direction (direction cosines)		V3				
258	THRCG_DIRECTION_Y	-	Thrust direction (direction cosines)		V3				
259	THRCG_DIRECTION_Z	-	Thrust direction (direction cosines)		V3				
260	THRCG_MISALIG_X	-	Thrust misalignment		V3				
261	THRCG_MISALIG_Y	-	Thrust misalignment		V3				
262	THRCG_MISALIG_Z	-	Thrust misalignment		V3				
263	THRCG_NOM_THRUST	N	Nominal thrust		S				
264	THRCG_MIN_INLET_PRESS	Pa	Mimimum inlet pressure required to generate any thrust		S				
265	THRCG_LOCATION_X	m	Thruster location (in SGF), needed for torque computation		V3				
266	THRCG_LOCATION_Y	m	Thruster location (in SGF), needed for torque computation		V3				
267	THRCG_LOCATION_Z	m	Thruster location (in SGF), needed for torque computation		V3				
268	THRCG_UPDATE_PERIOD	s	Scheduling period of the numerical model		S				
269	THRCG_GRAVITY_SURFACE_CONST	m/s2	Gravity surface constant (g0), used in the mass consumption computation		S				
270	THRCG_SPECIFIC_IMPULSE	s	Specific impulse (Isp), used in the mass consumption computation (massCons= UPDATE		S				
271	THRCG_OVERWRITE_THRUST_FAIL_FLAG	-	Overwrite thrust failure flag (-1: no fail; 1=fail).		S				
272	THRCG_OVERWRITE_THRUST_FAIL_VAL_V1	N	Thrust vector provided when overwrite thruster failure is enabled		V3				
273	THRCG_OVERWRITE_THRUST_FAIL_VAL_V2	N	Thrust vector provided when overwrite thruster failure is enabled		V3				
274	THRCG_OVERWRITE_THRUST_FAIL_VAL_V3	N	Thrust vector provided when overwrite thruster failure is enabled		V3				
275	THRCG2_DIRECTION_X	-	Thrust direction (direction cosines)		V3				
276	THRCG2_DIRECTION_Y	-	Thrust direction (direction cosines)		V3				
277	THRCG2_DIRECTION_Z	-	Thrust direction (direction cosines)		V3				
278	THRCG2_MISALIG_X	-	Thrust misalignment		V3				
279	THRCG2_MISALIG_Y	-	Thrust misalignment		V3				
280	THRCG2_MISALIG_Z	-	Thrust misalignment		V3				
281	THRCG2_NOM_THRUST	N	Nominal thrust		S				
282	THRCG2_MIN_INLET_PRESS	Pa	Mimimum inlet pressure required to generate any thrust		S				
283	THRCG2_LOCATION_X	m	Thruster location (in SGF), needed for torque computation		V3				
284	THRCG2_LOCATION_Y	m	Thruster location (in SGF), needed for torque computation		V3				
285	THRCG2_LOCATION_Z	m	Thruster location (in SGF), needed for torque computation		V3				
286	THRCG2_UPDATE_PERIOD	s	Scheduling period of the numerical model		S				
287	THRCG2_GRAVITY_SURFACE_CONST	m/s2	Gravity surface constant (g0), used in the mass consumption computation		S				
288	THRCG2_SPECIFIC_IMPULSE	s	Specific impulse (Isp), used in the mass consumption computation (massCons= UPDATE		S				
289	THRCG2_OVERWRITE_THRUST_FAIL_FLAG	-	Overwrite thrust failure flag (-1: no fail; 1=fail).		S				
290	THRCG2_OVERWRITE_THRUST_FAIL_VAL_V1	N	Thrust vector provided when overwrite thruster failure is enabled		V3				
291	THRCG2_OVERWRITE_THRUST_FAIL_VAL_V2	N	Thrust vector provided when overwrite thruster failure is enabled		V3				
292	THRCG2_OVERWRITE_THRUST_FAIL_VAL_V3	N	Thrust vector provided when overwrite thruster failure is enabled		V3				

Parameters / SignalLogging / BusDefinitions / ModelParameters

Ready

Simulation Model Parameter definition

ESA SGEO SVF-Lite: DEES Component SCE telemetry and calibration

DEES Simulation Model Bus TM definition

Microsoft Excel - FES_SDB_temp

J282

	Bus name	Element name	Description	Units	Dimensions	Type	TypeInBus	Conversion	SA	DataWord	DataPosition	UsedBits	Updat
282	SCE_Basic_Power_Out_T	SCEpowerCons	SCE power consumption This field is modeled according to simulation parameter.	W	S	double							
283	SCE_Basic_Phys_Out_T	pressToEpta1	pressure to the EPTA1 system	bar	S	double							
284	SCE_Basic_Phys_Out_T	pressToEpta2	pressure to the EPTA2 system	bar	S	double							
285	SCE_Basic_Phys_Out_T	pressToCgt	pressure to the CGT system	bar	S	double							
286	ADE_Basic_Comm_In_T	memoryLoadReceived	1= memory load command received since last call	-	S	double	int		14	1	0	[illegible]	"TRUE"
287	ADE_Basic_Comm_In_T	memoryLoadWord1	memory load command. Refer to SGEO-THA-ICD-0003 issue 4.0 (January 2011)	-	S	double	int		14	1	0	16	
288	ADE_Basic_Comm_In_T	memoryLoadWord2	memory load command	-	S	double	int		14	2	0	16	
289	ADE_Basic_Comm_In_T	memoryLoadWord3	memory load command	-	S	double	int		14	3	0	16	
290	ADE_Basic_Comm_In_T	memoryLoadWord4	memory load command	-	S	double	int		14	4	0	16	
291	ADE_Basic_Comm_In_T	memoryLoadWord5	memory load command	-	S	double	int		14	5	0	16	
292	ADE_Basic_Comm_In_T	memoryLoadWord6	memory load command	-	S	double	int		14	6	0	16	
293	ADE_Basic_Comm_In_T	memoryLoadWord7	memory load command	-	S	double	int		14	7	0	16	
294	ADE_Basic_Comm_In_T	memoryLoadWord8	memory load command	-	S	double	int		14	8	0	16	
295	ADE_Basic_Comm_Out_T	hkRegister0	Housekeeping register 0	-	S	double	int		8	1	0	16	
296	ADE_Basic_Comm_Out_T	hkRegister1	Housekeeping register 1	-	S	double	int		8	2	0	16	
297	ADE_Basic_Comm_Out_T	rejectedTccounter	Currently modeled as zero data	-	S	double	int		8	3	0	16	
298	ADE_Basic_Comm_Out_T	tv1onTime	last received commanded value for the thruster Rationale: according to EPPS SW Spec issue 2 page 90. Note that this definition does NOT depend on Synch considerations!	-	S	double	int		8	4	0	16	
299	ADE_Basic_Comm_Out_T	tv2onTime	last received commanded value for the thruster Rationale: according to EPPS SW Spec issue 2 page 90. Note that this definition does NOT depend on	-	S	double	int		8	5	0	16	
300	ADE_Basic_Comm_Out_T	tv3onTime	last received commanded value for the thruster Rationale: according to EPPS SW Spec issue 2 page 90. Note that this definition does NOT depend on	-	S	double	int		8	6	0	16	
301	ADE_Basic_Comm_Out_T	tv4onTime	last received commanded value for the thruster Rationale: according to EPPS SW Spec issue 2 page 90. Note that this definition does NOT depend on	-	S	double	int		8	7	0	16	

Parameters

Ready

Calibration

Microsoft Excel - FES_SDB_temp

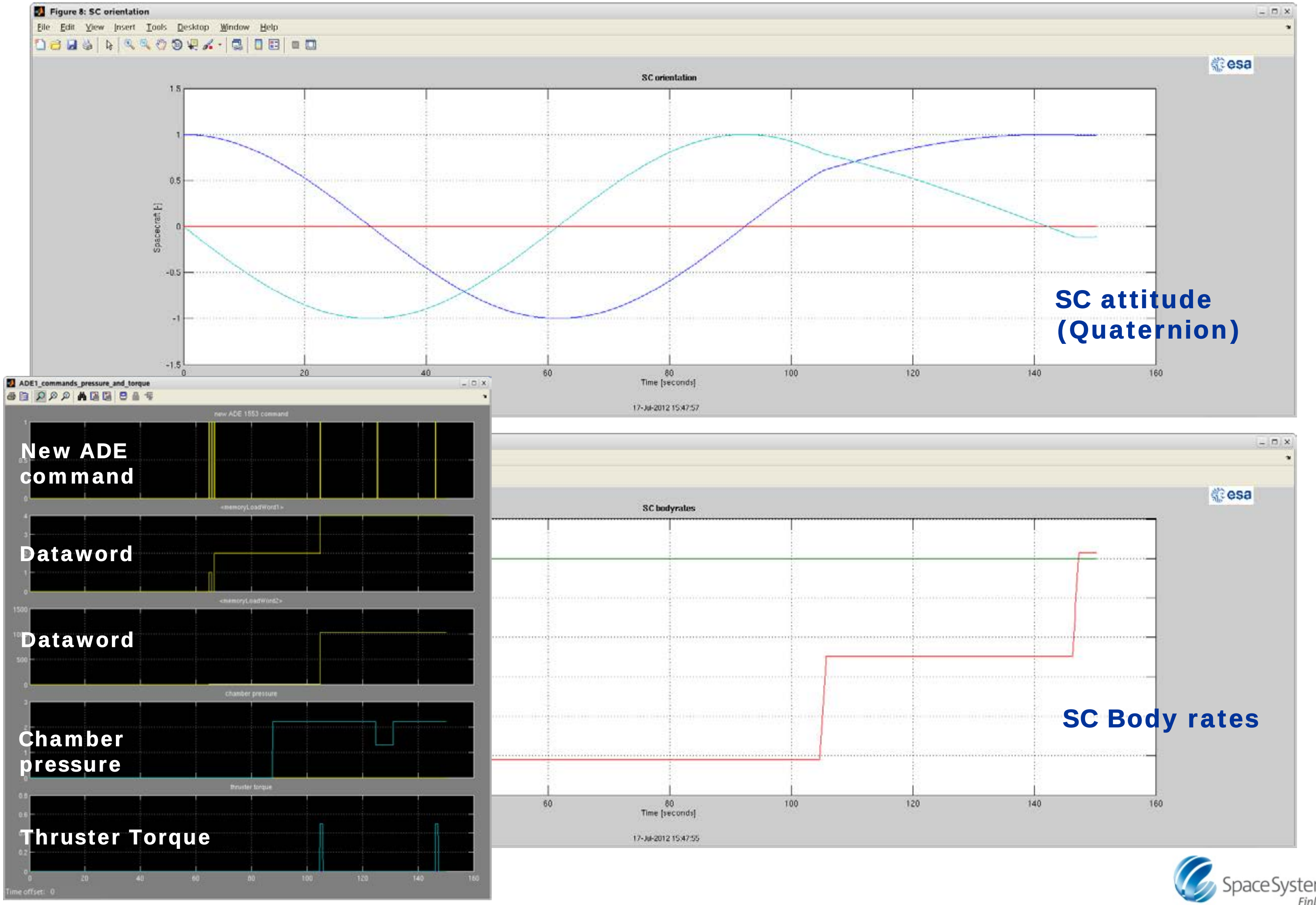
E1 Reference frame

	Bus name	Element name	Description	Units	Dimensions	Type	TypeInBus	Conversion	SA	DataWord	DataPosition	UsedBits	Update
181	SCE_Basic_Comm_In_T	t4_r	Delay after the downstream valve pulse.	LSB	S	double	uint	x	4	4	1	15	
182	SCE_Basic_Comm_In_T	tinhibithealth_r	Inibition duration for health check.	LSB	S	double	uint	x	4	5	0	16	
183	SCE_Basic_Comm_In_T	tinhibitthermo_r	Inibition duration for lpt check.	LSB	S	double	uint	x	4	6	1	15	
184	SCE_Basic_Comm_In_T	ppl_r	Set point of plenum pressure.	bar	S	double	uint	0.005*x	5	1	6	10	

Parameters / SignalLogging / BusDefinitions / ModelParameters

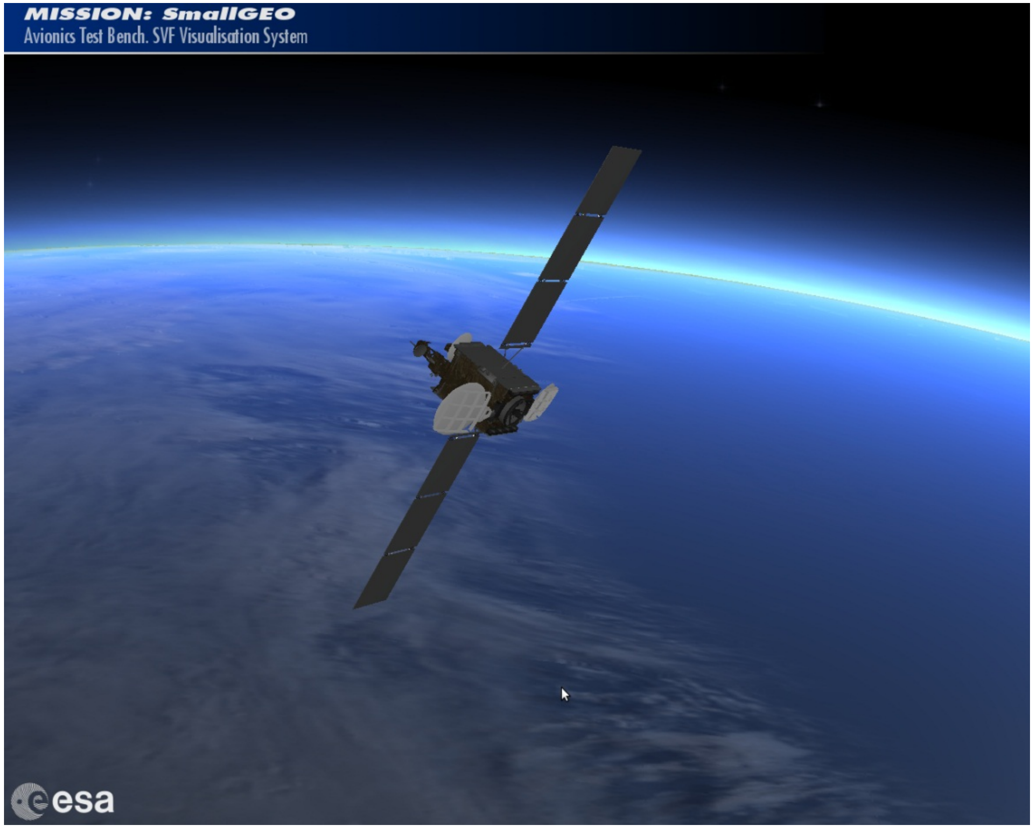
Ready

ESA SGEO SVF-Lite: DEES Component Test Results plotting



ESA SGEO SVF-Lite: 3D Visualisation Component

- **3D visualisation**
  - Intuitive comprehension results
  - Based on Missive (e.g. Stereoscopic capabilities)
  - Using SGEO CAD model
  - TCP/IP connection



SGEO 3D visualisation

SpaceSystems Finland

esa

Space Systems Finland

esa

SVF-Lite Concept:
Status, Results, Lessons Learned

SESP 2012

26/09/2012

European Space Agency

ESA SGEO SVF-Lite: Status

- **Current status of the SVF-Lite configuration:**
  - **Full infrastructure deployed** (TSC, SYNTID, OBC Simulator, Visualisation and DEES (incl. environmental models and most of SGEO platform RT simulation models).
  - **2 Configurations**:
    - HDSW Simulator with V2 of ASW
    - Device Simulator doing MIL-1553 and ICB IO
  - **Acceleration factor:** currently at 5x times faster than Real Time
    - Profiling of DEES shows 10x times faster within grasp
    - End-goal is still appr. 20x times faster

SpaceSystems Finland

esa

ESA SGEO SVF-Lite: Results (1/2)

Functionality wise: the SVF-Lite leverages from different concepts of FES and "traditional SVF" and RTB:

1. **FES part:**
    - Direct reuse of Matlab/Simulink FES environment
        - **Openness** of simulator infrastructure
        - **Direct insight** into Simulation Models
    - FES architecture and infrastructure **using scripts**, **strict bus definitions** and **high degree of parameterisation** of:
        - **Simulation Models** including **failure injection**.
        - **Plotting** of data
    - Integration of Simulation Model **documentation**
    - **Coding** and **acceleration capabilities** for the DEES

ESA SGEO SVF-Lite: Results (2/2)

Functionality wise: The SVF-Lite leverages from different concepts of FES and "traditional SVF" and RTB (cont.):

2. **RTB part:**
   - Reuse of Monitoring and Control system, **TSC** in this case.
     - Light-weight SCOS
     - Use **of actual MIB** files for TM/TC definitions
     - Possibility of rerunning **test scenarios** from Industry (use of uTope)
     - **Separation** of OBSW MIB and SCOE MIB
     - **New** in this case: **accelerated** mode of TSC
3. **SVF part:**
   - Use of **HDSW Simulator** for acceleration at cost of representativity.

ESA SGEO SVF-Lite: further acceleration improvements

- **Further improvements / consolidation to speed up system**
  - **Merging of Hosts** versus usage of network
  - **OBSW** with **marker** (TBC)
  - **ICB** tuning and **MIL1553 TM** acquisition (autonomous SYNTID-response fixed TM)
  - Acceleration of **DEES**:
    - Simulink solver (discrete or continuous versus hybrid system),
    - Accelerator mode / code generation,
    - Dedicated (project specific) Simulation Models (granularity)
  - Connection and usage of **other OBC emulators / simulators**

ESA SGEO SVF-Lite: Lessons Learned / Conclusions

- **Unsurpassed reviewing** capabilities for the ESA SGEO project team!
  - Running ASW on independent SVF
  - Knowledge digging (reviewing) while modelling
- **Benefits of direct FES reuse** has to be traded versus **performance**:
  - Infrastructure: used solver, online plotting and monitoring
  - Simulation Models: level of detail, modelling techniques (e.g. failure injection)
  - **Of course in some cases trade-off possible!**
- **Performance increase of HDSW Simulator** and ASW versus **representativity** (TBC))
- **Use of Device Simulator** for obtaining reference results and for modelling against ICD
- **Not always possible to rerun** the industrial scripts, because of **different SCOE TC**
- **Importance of centralized data management** (TM/TC definitions, Interfaces, Simulation Model parameters, failure injections, RT data specification)

SpaceSystems Finland esa

Thank You.

Questions?

SESP 2012

26/09/2012

European Space Agency