The Lisa Pathfinder Simulator for the Science and Technology Operations Center: a case-study for reuse across the project life-cycle

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Overview

- Introduction
- The DFACS and SVF simulator
- Reuse approach:
  - Reuse strategy generality
  - DFACS reuse
  - SVF reuse
  - DFACS vs. SVF reuse
- Development process
  - Development iterations
  - Development approach and design guidelines
- Lessons learned and conclusions

Introduction

- The Science and Technology Operations Center (STOC) will be in charge of the operations of the LPF experiments

An experiment simulator is required in order to:

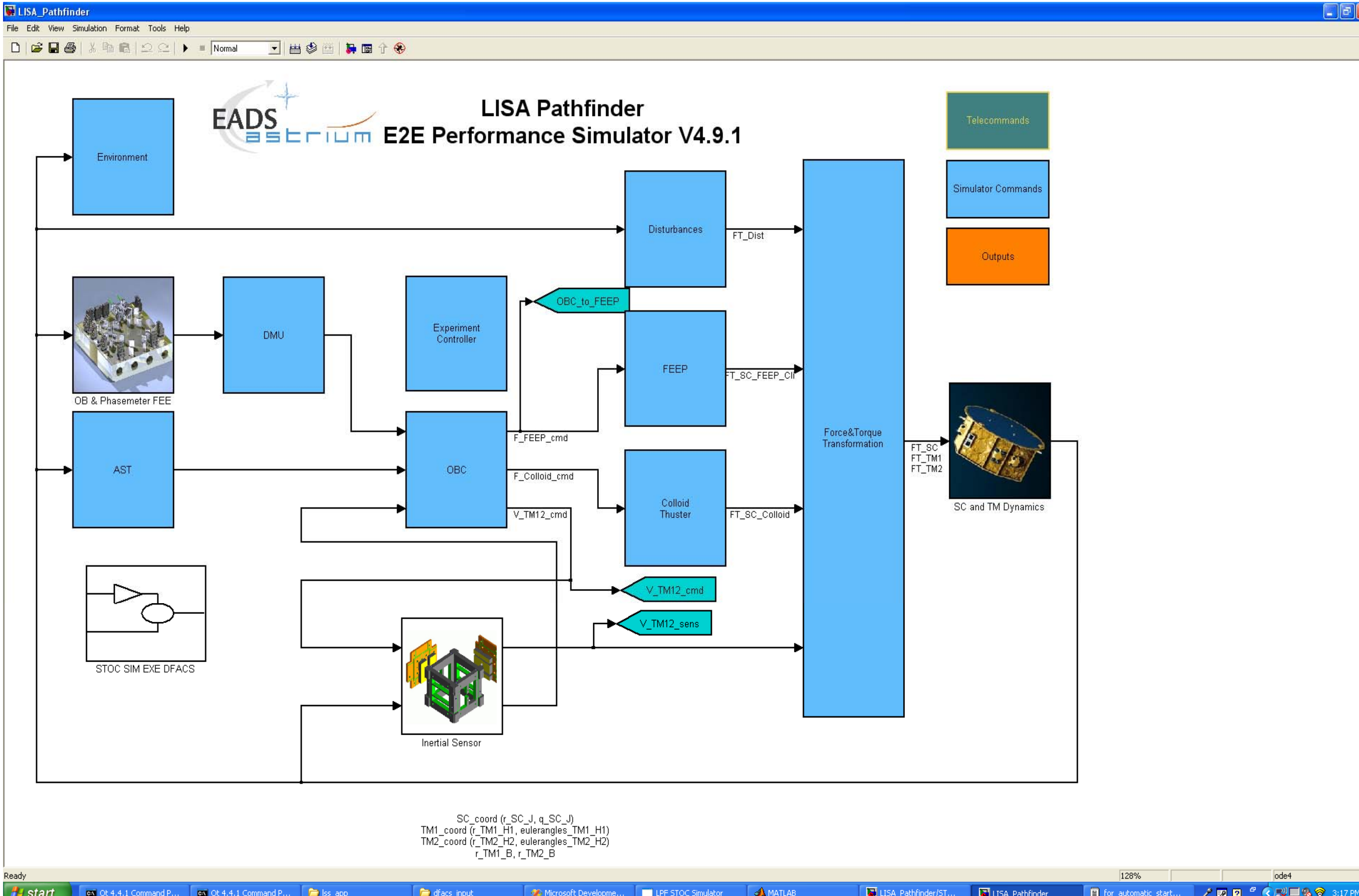
- Validate the LPF Technology Package run procedures
- Provide measurements to the LPF Data Analysis tools
- Incrementally update the modelling of the LPF instrument

The main driver for the development of the STOC simulator is the reuse of simulators already existing in the LPF project: the DFACS and SVF simulators

The DFACS Simulator

- It is Matlab/Simulink based
- It is a design simulator, originally conceived for the analysis of the Drag Free and Attitude Control System performance
- It served as a prototype for the on-boad control algorithms
- It runs on Windows
- It can run faster than real-time (x30)

Most (but not all) of the STOC users are familiar with Matlab/Simulink technologies. In any case, the direct usage of the DFACS would require a deep understanding of the underlying models' implementation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Simulator Commands
Outputs
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Experiment Controller
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Force&Torque Transformation
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F_FEEP_cmd
F_Colloid_cmd
V_TM12_cmd
Colloid Thuster
FT_SC_Colloid
FT_SC
FT_TM1
FT_TM2
SC and TM Dynamics
STOC SIM EXE DFACS
V_TM12_cmd
V_TM12_sens
Inertial Sensor
SC_coord (r_SC_J, q_SC_J)
TM1_coord (r_TM1_H1, eulerangles_TM1_H1)
TM2_coord (r_TM2_H2, eulerangles_TM2_H2)
r_TM1_B, r_TM2_B
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Qt 4.4.1 Command P...
lss_app
dfacs_input
Microsoft Developme...
LPF STOC Simulator
MATLAB
LISA_Pathfinder/ST...
LISA_Pathfinder
for_automatic_start...
3:17 PM

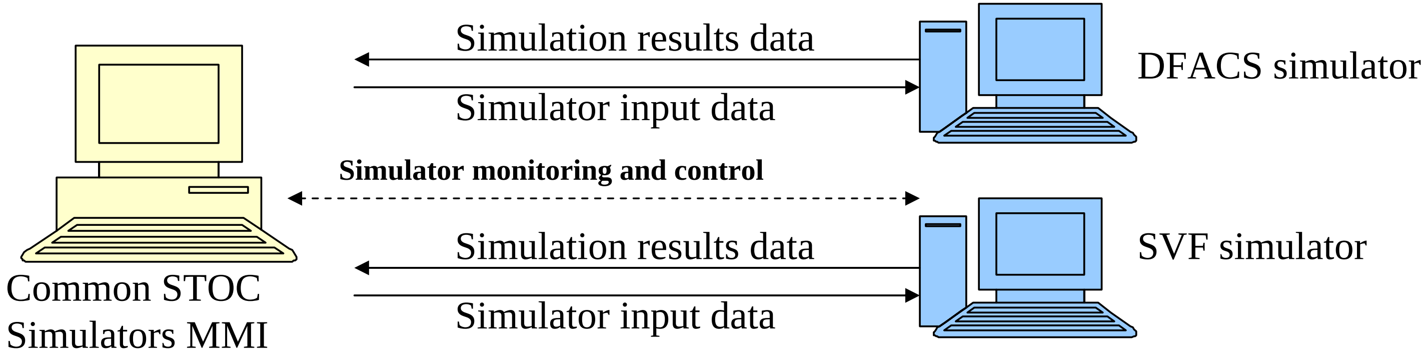
The SVF Simulator

- It is part of the ASTRIUM Model Based Development and Verification Environment (MDVE)
- It is used for the integration and debugging of the on-board software
- It is conceived for AIT
- It is a run-time system
- It is interfaced by means of Open Center, supporting Elisa script language
- Runs on a Linux machine (plus an additional machine for Open Center)

Open Center is a complete EGSE system. As such, it is quite complex to be used directly by the STOC users

Reuse approach (I)

- Simulation execution on DFACS or SVF
- Common STOC Simulators MMI
  - Definition of experiments and configurations
  - Management of simulations
    - Preparation of run-time data for DFACS and SVF
  - Collection of result data
    - Provide post-processing options

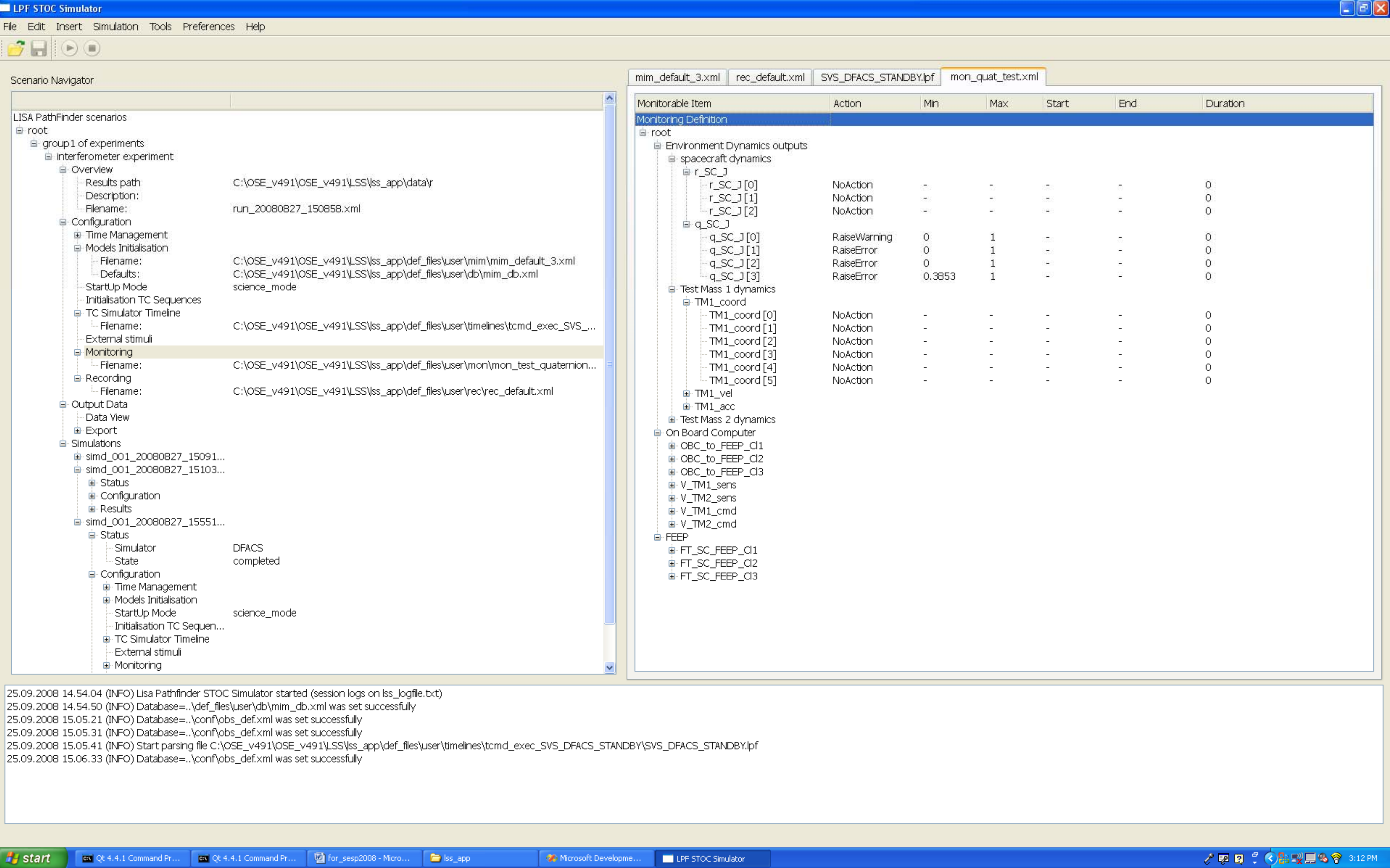


Reuse approach (II)

The configuration of each experiment is determined by a certain number of artefacts, defining:

- Initialisation values of the simulation models
- Other initialisation conditions (e.g. DFACS mode)
- The run procedure (TC sequence)
- Out-of-limit conditions (monitoring)
- TMs to be recorded for further data analysis
- External stimuli
- Predefined plots

Those artefacts are defined by means of a common MMI (for each artefact, the same editors applies to DFACS and SVF)


LPF STOC Simulator
File Edit Insert Simulation Tools Preferences Help
Scenario Navigator
LISA PathFinder scenarios
root
group1 of experiments
interferometer experiment
Overview
Results path C:\OSE_v491\OSE_v491\LSS\lss_app\data\r
Description:
Filename: run_20080827_150858.xml
Configuration
Time Management
Models Initialisation
Filename: C:\OSE_v491\OSE_v491\LSS\lss_app\def_files\user\mim\mim_default_3.xml
Defaults: C:\OSE_v491\OSE_v491\LSS\lss_app\def_files\user\db\mim_db.xml
StartUp Mode science_mode
Initialisation TC Sequences
TC Simulator Timeline
Filename: C:\OSE_v491\OSE_v491\LSS\lss_app\def_files\user\timelines\tcmd_exec_SVS_...
External stimuli
Monitoring
Filename: C:\OSE_v491\OSE_v491\LSS\lss_app\def_files\user\mon\mon_test_quaternion...
Recording
Filename: C:\OSE_v491\OSE_v491\LSS\lss_app\def_files\user\rec\rec_default.xml
Output Data
Data View
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Simulations
simd_001_20080827_15091...
simd_001_20080827_15103...
Status
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Results
simd_001_20080827_15551...
Status
Simulator DFACS
State completed
Configuration
Time Management
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TC Simulator Timeline
External stimuli
Monitoring
mim_default_3.xml rec_default.xml SVS_DFACS_STANDBY.lpf mon_quat_test.xml
Monitorable Item Action Min Max Start End Duration
Monitoring Definition
root
Environment Dynamics outputs
spacecraft dynamics
r_SC_J
r_SC_J [0] NoAction - - - - 0
r_SC_J [1] NoAction - - - - 0
r_SC_J [2] NoAction - - - - 0
q_SC_J
q_SC_J [0] RaiseWarning 0 1 - - 0
q_SC_J [1] RaiseError 0 1 - - 0
q_SC_J [2] RaiseError 0 1 - - 0
q_SC_J [3] RaiseError 0.3853 1 - - 0
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TM1_coord
TM1_coord [0] NoAction - - - - 0
TM1_coord [1] NoAction - - - - 0
TM1_coord [2] NoAction - - - - 0
TM1_coord [3] NoAction - - - - 0
TM1_coord [4] NoAction - - - - 0
TM1_coord [5] NoAction - - - - 0
TM1_vel
TM1_acc
Test Mass 2 dynamics
On Board Computer
OBC_to_FEEP_Cl1
OBC_to_FEEP_Cl2
OBC_to_FEEP_Cl3
V_TM1_sens
V_TM2_sens
V_TM1_cmd
V_TM2_cmd
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FT_SC_FEEP_Cl1
FT_SC_FEEP_Cl2
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25.09.2008 14.54.04 (INFO) Lisa Pathfinder STOC Simulator started (session logs on lss_logfile.txt)
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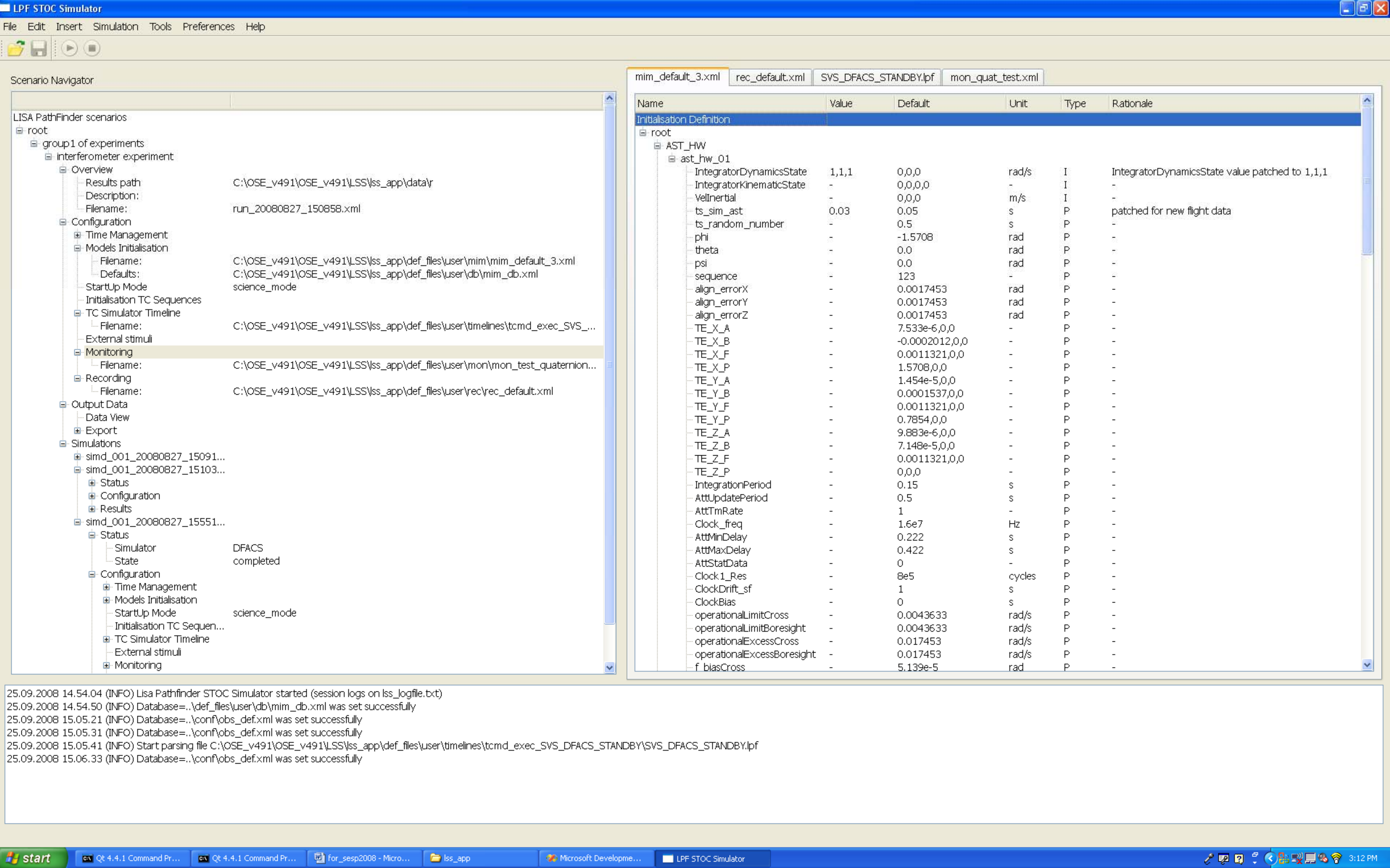
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mon_quat_test.xml
Name Value Default Unit Type Rationale
Initialisation Definition
root
AST_HW
ast_hw_01
IntegratorDynamicsState 1,1,1 0,0,0 rad/s I IntegratorDynamicsState value patched to 1,1,1
IntegratorKinematicState - 0,0,0,0 - I -
VelInertial - 0,0,0 m/s I -
ts_sim_ast 0.03 0.05 s P patched for new flight data
ts_random_number - 0.5 s P -
phi - -1.5708 rad P -
theta - 0.0 rad P -
psi - 0.0 rad P -
sequence - 123 - P -
align_errorX - 0.0017453 rad P -
align_errorY - 0.0017453 rad P -
align_errorZ - 0.0017453 rad P -
TE_X_A - 7.533e-6,0,0 - P -
TE_X_B - -0.0002012,0,0 - P -
TE_X_F - 0.0011321,0,0 - P -
TE_X_P - 1.5708,0,0 - P -
TE_Y_A - 1.454e-5,0,0 - P -
TE_Y_B - 0.0001537,0,0 - P -
TE_Y_F - 0.0011321,0,0 - P -
TE_Y_P - 0.7854,0,0 - P -
TE_Z_A - 9.883e-6,0,0 - P -
TE_Z_B - 7.148e-5,0,0 - P -
TE_Z_F - 0.0011321,0,0 - P -
TE_Z_P - 0,0,0 - P -
IntegrationPeriod - 0.15 s P -
AttUpdatePeriod - 0.5 s P -
AttTmRate - 1 - P -
Clock_freq - 1.6e7 Hz P -
AttMinDelay - 0.222 s P -
AttMaxDelay - 0.422 s P -
AttStatData - 0 - P -
Clock1_Res - 8e5 cycles P -
ClockDrift_sf - 1 s P -
ClockBias - 0 s P -
operationalLimitCross - 0.0043633 rad/s P -
operationalLimitBoresight - 0.0043633 rad/s P -
operationalExcessCross - 0.017453 rad/s P -
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f_biasCross - 5.139e-5 rad P -
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LPF STOC Simulator
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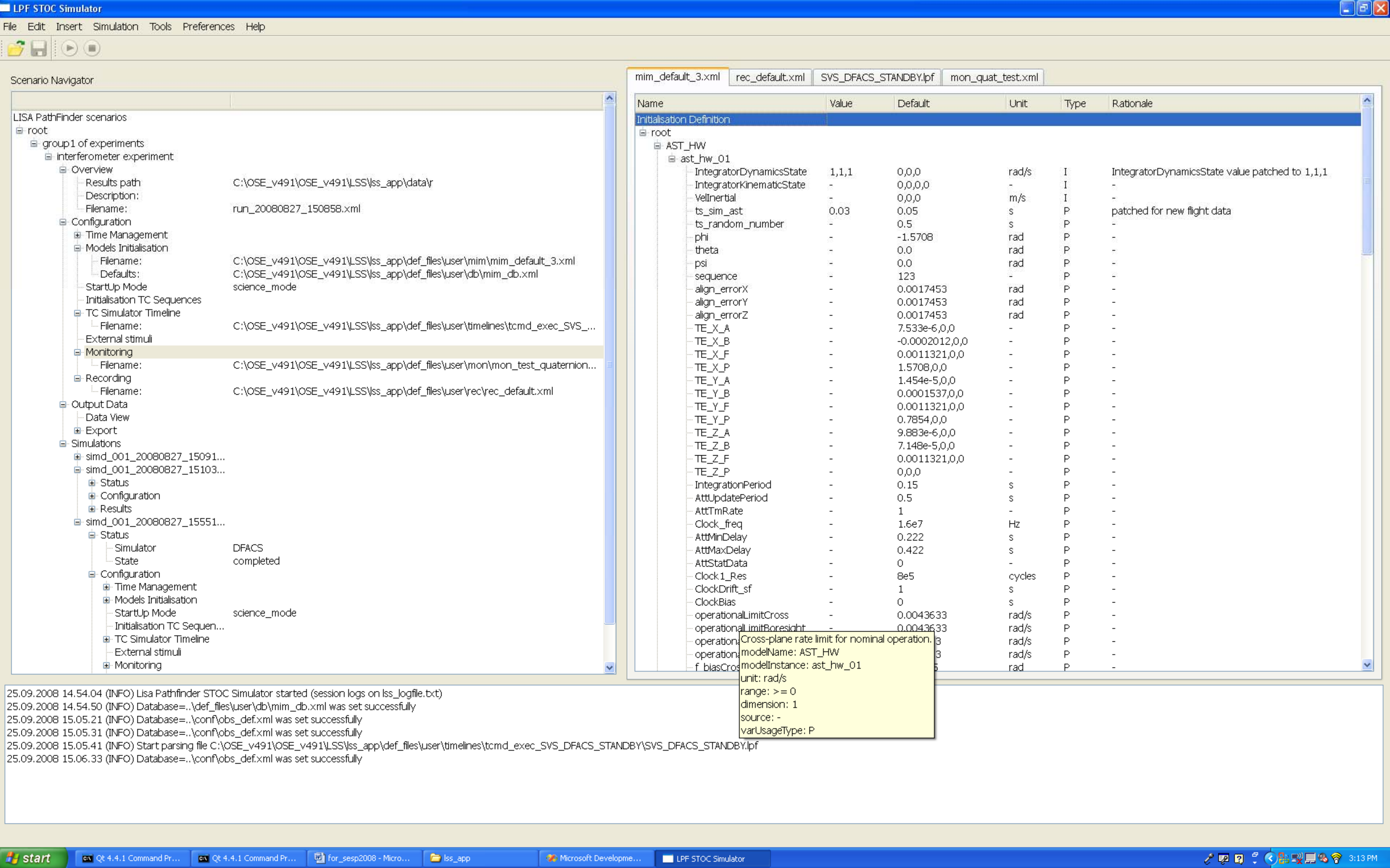

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simd_001_20080827_15103...
Status
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Simulator DFACS
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mim_default_3.xml
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mon_quat_test.xml
Name Value Default Unit Type Rationale
Initialisation Definition
root
AST_HW
ast_hw_01
IntegratorDynamicsState 1,1,1 0,0,0 rad/s I IntegratorDynamicsState value patched to 1,1,1
IntegratorKinematicState - 0,0,0,0 - I -
VelInertial - 0,0,0 m/s I -
ts_sim_ast 0.03 0.05 s P patched for new flight data
ts_random_number - 0.5 s P -
phi - -1.5708 rad P -
theta - 0.0 rad P -
psi - 0.0 rad P -
sequence - 123 - P -
align_errorX - 0.0017453 rad P -
align_errorY - 0.0017453 rad P -
align_errorZ - 0.0017453 rad P -
TE_X_A - 7.533e-6,0,0 - P -
TE_X_B - -0.0002012,0,0 - P -
TE_X_F - 0.0011321,0,0 - P -
TE_X_P - 1.5708,0,0 - P -
TE_Y_A - 1.454e-5,0,0 - P -
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TE_Z_F - 0.0011321,0,0 - P -
TE_Z_P - 0,0,0 - P -
IntegrationPeriod - 0.15 s P -
AttUpdatePeriod - 0.5 s P -
AttTmRate - 1 - P -
Clock_freq - 1.6e7 Hz P -
AttMinDelay - 0.222 s P -
AttMaxDelay - 0.422 s P -
AttStatData - 0 - P -
Clock1_Res - 8e5 cycles P -
ClockDrift_sf - 1 s P -
ClockBias - 0 s P -
operationalLimitCross - 0.0043633 rad/s P -
operationalLimitBoresight - 0.0043633 rad/s P -
Cross-plane rate limit for nominal operation.
modelName: AST_HW
modelInstance: ast_hw_01
unit: rad/s
range: >= 0
dimension: 1
source: -
varUsageType: P
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LPF STOC Simulator
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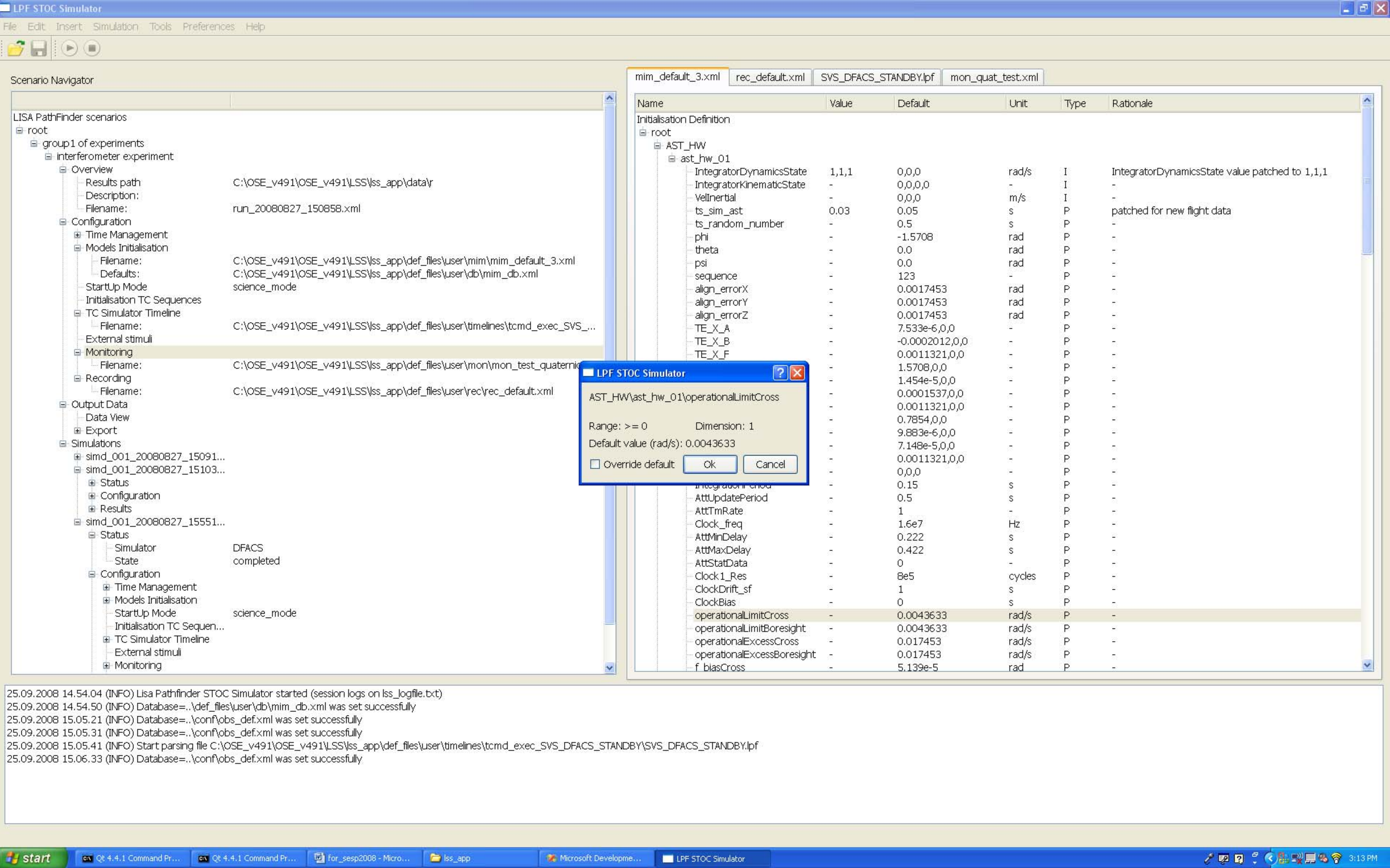
LPF STOC Simulator
File Edit Insert Simulation Tools Preferences Help
Scenario Navigator
LISA PathFinder scenarios
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interferometer experiment
Overview
Results path C:\OSE_v491\OSE_v491\LSS\lss_app\data\r
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StartUp Mode science_mode
Initialisation TC Sequences
TC Simulator Timeline
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External stimuli
Monitoring
Filename: C:\OSE_v491\OSE_v491\LSS\lss_app\def_files\user\mon\mon_test_quaterni
Recording
Filename: C:\OSE_v491\OSE_v491\LSS\lss_app\def_files\user\rec\rec_default.xml
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Name Value Default Unit Type Rationale
Initialisation Definition
root
AST_HW
ast_hw_01
IntegratorDynamicsState 1,1,1 0,0,0 rad/s I IntegratorDynamicsState value patched to 1,1,1
IntegratorKinematicState - 0,0,0,0 - I -
VelInertial - 0,0,0 m/s I -
ts_sim_ast 0.03 0.05 s P patched for new flight data
ts_random_number - 0.5 s P -
phi - -1.5708 rad P -
theta - 0.0 rad P -
psi - 0.0 rad P -
sequence - 123 - P -
align_errorX - 0.0017453 rad P -
align_errorY - 0.0017453 rad P -
align_errorZ - 0.0017453 rad P -
TE_X_A - 7.533e-6,0,0 - P -
TE_X_B - -0.0002012,0,0 - P -
TE_X_F - 0.0011321,0,0 - P -
AttUpdatePeriod - 0.5 s P -
AttTmRate - 1 - P -
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operationalExcessBoresight - 0.017453 rad/s P -
f_biasCross - 5.139e-5 rad P -
LPF STOC Simulator
AST_HW\ast_hw_01\operationalLimitCross
Range: >= 0 Dimension: 1
Default value (rad/s): 0.0043633
Override default
Ok
Cancel
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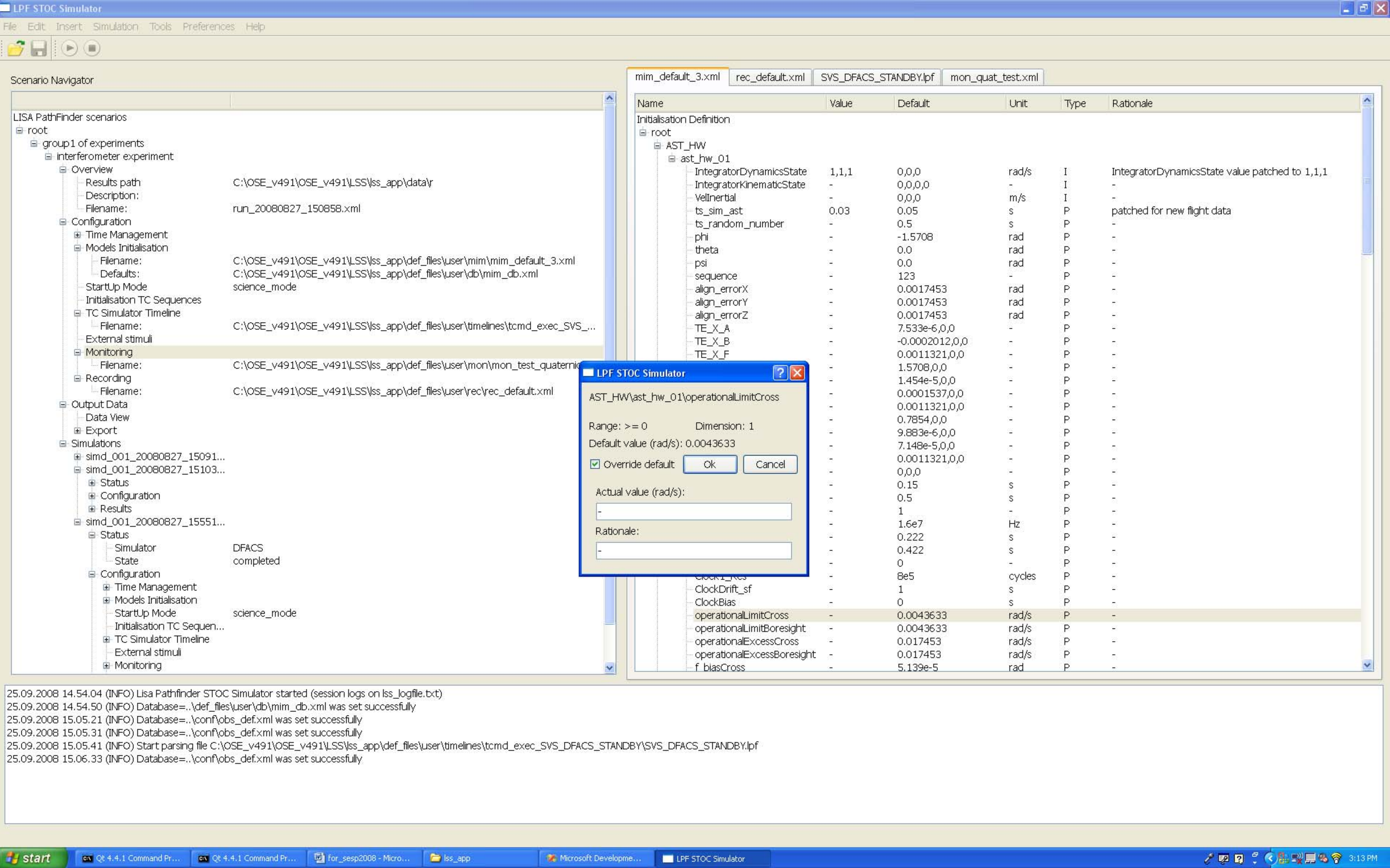

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ClockDrift_sf - 1 s P -
ClockBias - 0 s P -
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operationalExcessCross - 0.017453 rad/s P -
operationalExcessBoresight - 0.017453 rad/s P -
f_biasCross - 5.139e-5 rad P -
LPF STOC Simulator
AST_HW\ast_hw_01\operationalLimitCross
Range: >= 0 Dimension: 1
Default value (rad/s): 0.0043633
Override default Ok Cancel
Actual value (rad/s):
Rationale:
25.09.2008 14.54.04 (INFO) Lisa Pathfinder STOC Simulator started (session logs on lss_logfile.txt)
25.09.2008 14.54.50 (INFO) Database=..\def_files\user\db\mim_db.xml was set successfully
25.09.2008 15.05.21 (INFO) Database=..\conf\obs_def.xml was set successfully
25.09.2008 15.05.31 (INFO) Database=..\conf\obs_def.xml was set successfully
25.09.2008 15.05.41 (INFO) Start parsing file C:\OSE_v491\OSE_v491\LSS\lss_app\def_files\user\timelines\tcmd_exec_SVS_DFACS_STANDBY\SVS_DFACS_STANDBY.lpf
25.09.2008 15.06.33 (INFO) Database=..\conf\obs_def.xml was set successfully
start
Qt 4.4.1 Command Pr...
Qt 4.4.1 Command Pr...
for_sesp2008 - Micro...
lss_app
Microsoft Developme...
LPF STOC Simulator
3:13 PM

DFACS simulator reuse (I)

Analysis of the legacy system and compatibility with the existing DFACS interfaces

- Initialisation of parameters using Matlab scripts, generated from the common model initialisation artefacts, based on XML (and RTS DB)
- Definition of TC sequences interfacing the text format expected by the DFACS simulator

Need to adapt the DFACS TC layer, in order to accept SCOS-2000 TCs

DFACS simulator reuse (II)

Potential configuration control issues because of possible concurrent DFACS updates from the industry

Encapsulate STOC extensions requiring modifications to the DFACS (e.g. monitoring and recording artefacts) in S-functions or library blocks, in order to:

- support encapsulation automation
- Enhance flexibility (it easily allow chages in the set of observable TMs)

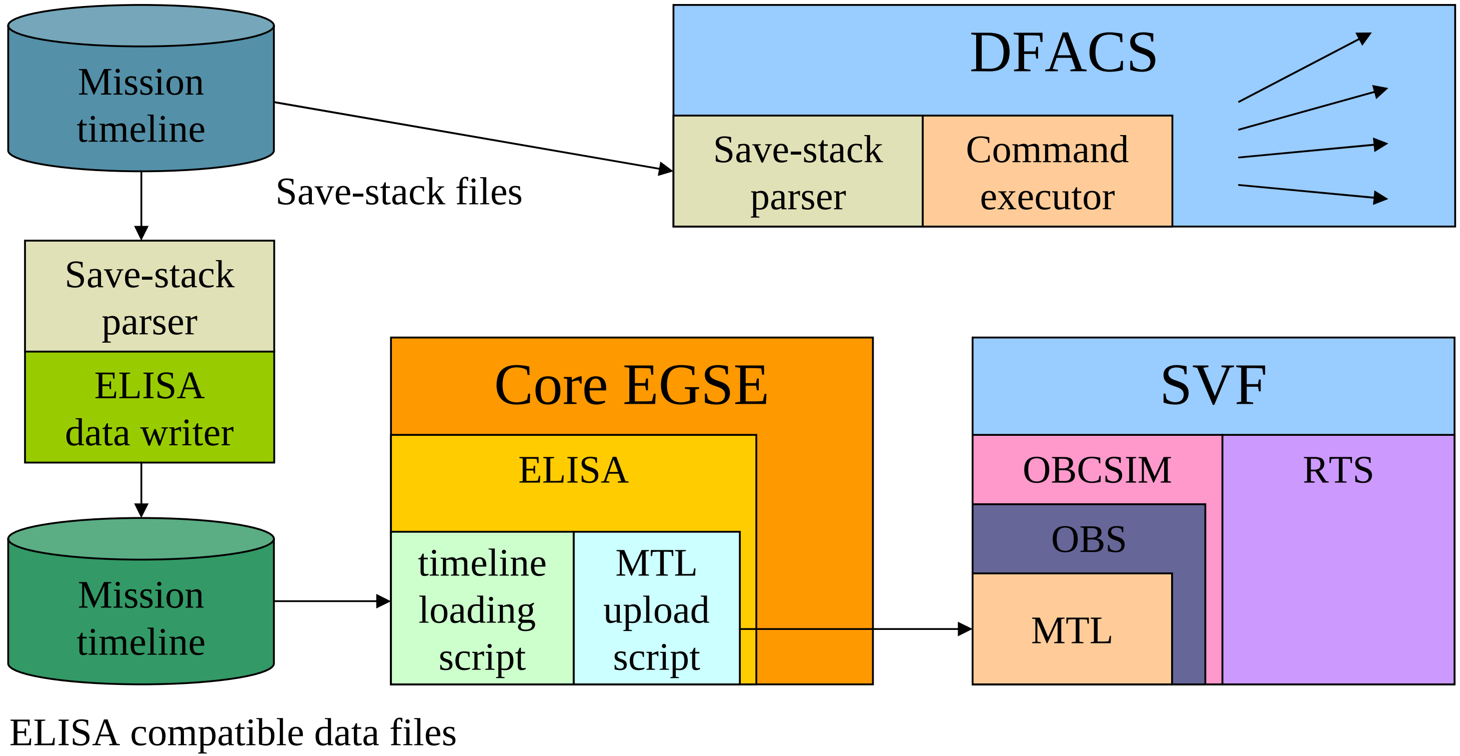
Reuse of Simulink built-in features (plots)

SVF simulator reuse

- SVF infrastructure will be used as black-box
  - Monitoring and control of the SVF via core EGSE
  - Will require manual interaction (start, monitoring, etc)
- Input data will be transformed into EGSE data
  - Model initialisation data by means of the common artefacts (and RTS DB)
  - Mission timeline and init TC sequence execution
    - Create generic ELISA scripts to load save-stack data and send to the OBS as MTL commands
  - Stimuli, monitors and recorders
    - Activated by generic ELISA scripts loading definition data (reuse XML format or use specific format for scripting)
- Recording data
  - Get SVF output data and store in results directory
    - Optionally post-process the data for STOC simulators use

DFACS vs. SVF reuse (I)

- Mission timeline loading and execution



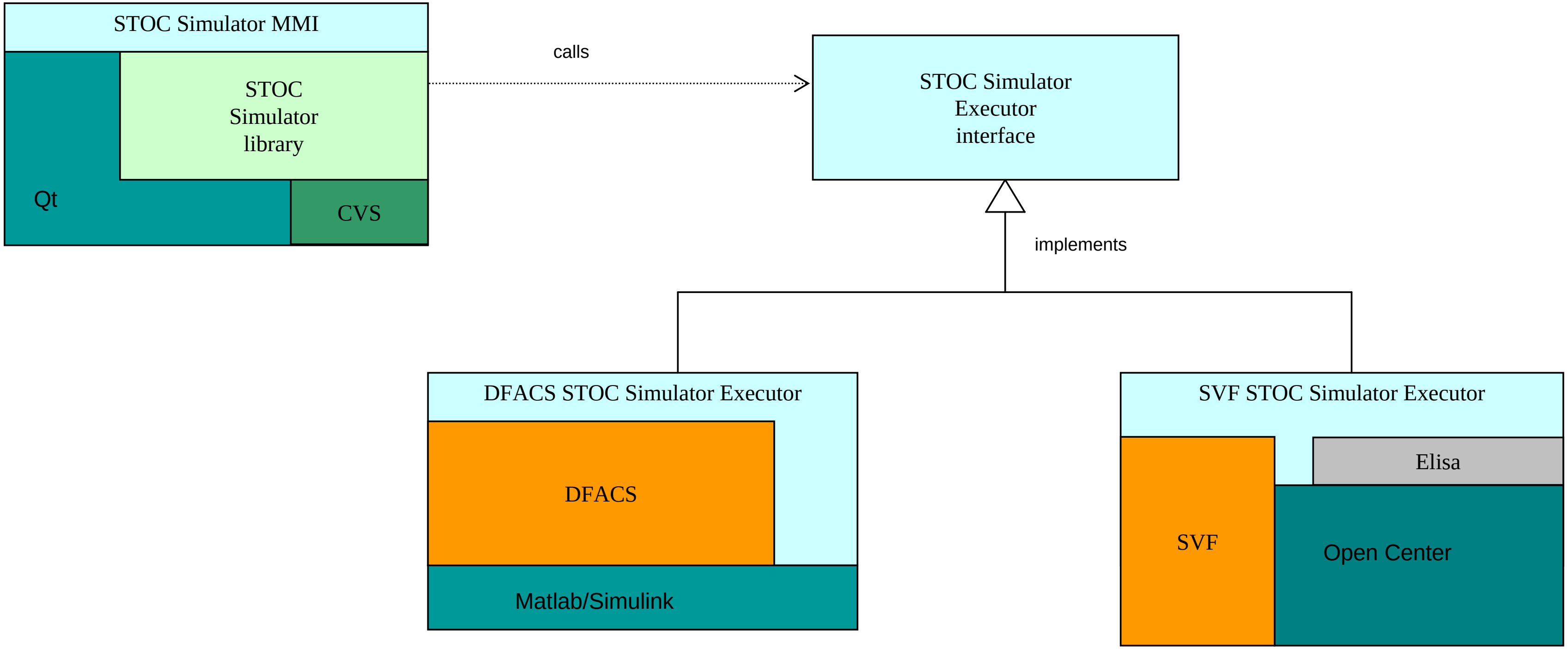
DFACS vs. SVF reuse (II)

Common Topic	DFACS envisaged implementation	SVF/OpenCenter envisaged implementation
Platform start	Automated start of the platform. Automated (or manual) start of the simulation	Manual start of the platform (first-time only) Manual start of the simulation.
Model initialisation (XML definition files)	Generation of M-files from the common XML	Generation of SVF XML ModelCharacFile,to be loaded via Elisa
TC sequences **(saved-stack files)**	Generation of DFACS text files.	Automated generation and up-load via a common Elisa script
Recording **(XML definition files)**	STOC extension in the Simulink environment.	Automated triggering of TM acquisition. Retrieval via “Manual ParamProduction” GUI” or Elisa
Monitoring **(XML definition files)**	STOC extension in the Simulink environment.	Elisa plug-ins into the OC monitoring feature. Possible manual initial selection.
Stimuli **(SVF-based format)**	STOC extension in the Simulink environment.	Direct reuse of the dedicated SVF stimuli feature.
Plots (XML files)	Simulink-based (link to external library).	Automated opening via Elisa.

Development iterations

- Follows the ECSS-E-40 standard
- Helpful usage of prototypes to support the discussion on:
  - MMI aspects
  - Complex use cases
- Intermediate informal deliveries are also foreseen to:
  - Familiarise the final users of the system
  - Get early feed-back
  - Facilitate further refinements
  - Avoid Big-Bang integrations
- A first version was delivered in September 2008 and contains most of the common parts of the STOC simulator and of the DFACS interface
- Two more major deliveries are foreseen this year

Development approach (I)

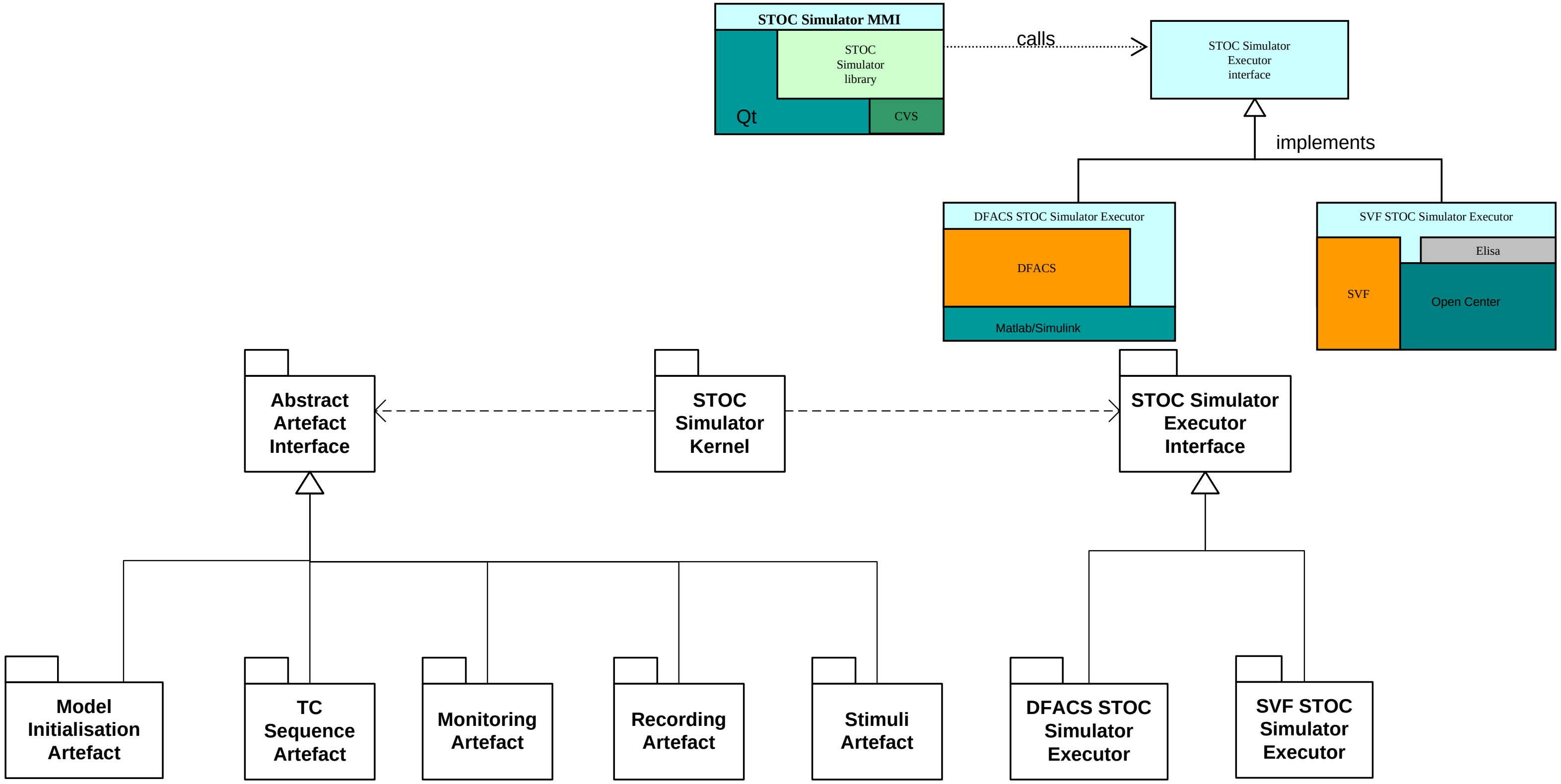


C++/Qt and CVS complete the run-time environment:

- Cross-platform tools and easy deployment (no VM)
- Mature products and wide user community
- STOC preferences

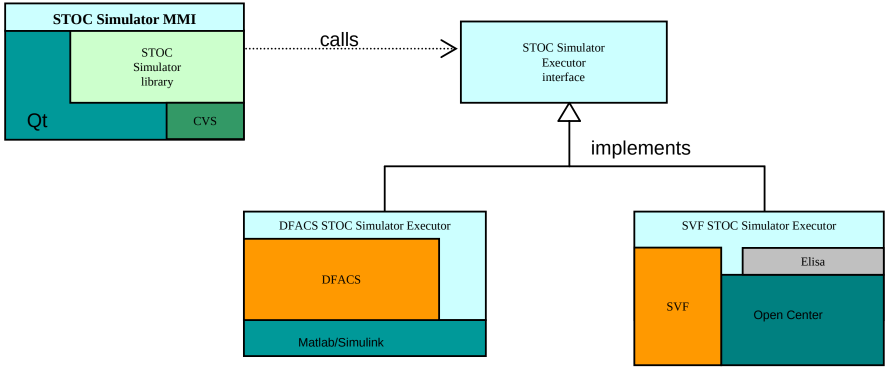
Development approach (II)

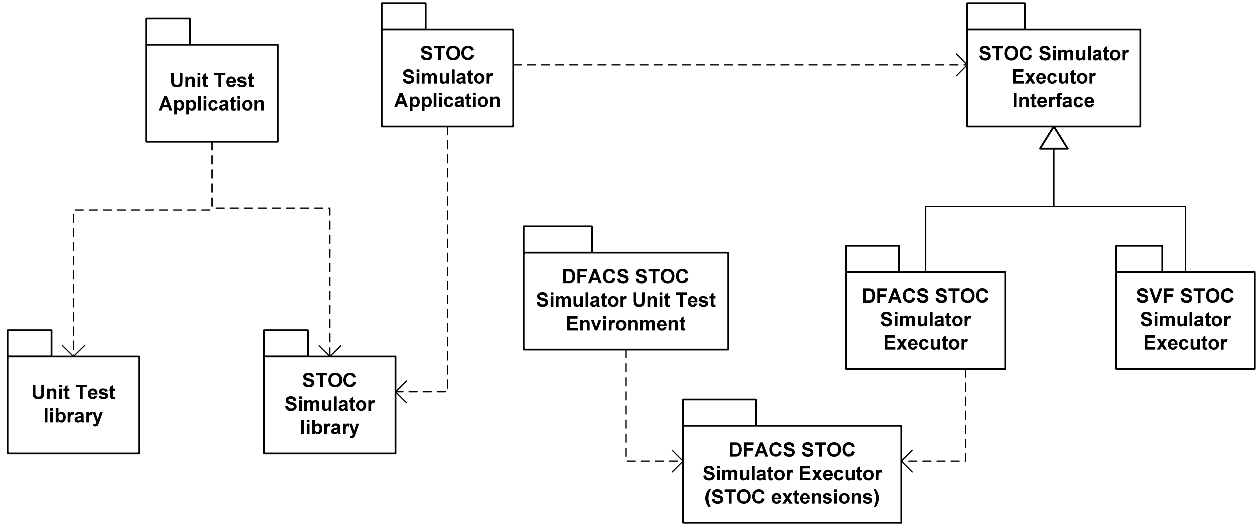
- Moderate usage of patterns and upfront design
- Automated documentation by means of Doxygen



Development approach (III)

- Emphasis on unit test automation





Conclusions

Main objective: Reuse of design and AIT simulators in an operational context

Main issues

- Different scope of the design simulator (TC adapter)
- Management of the concurrent development in the industry
- Difficulties to hide the full complexity of AIT simulators ("black-box" approach)

So far, satisfactory solutions were identified for all main issues

Conclusions

First indications:

- Significant reduction of the development cost
- Moderate encapsulation of the underlying simulations (user-friendly environment)
- Availability of complementary simulation strategies (fidelity vs. performance)
- Minimisation of the typical risks of completely new developments (uncertainty on the level of fidelity, heavy cross-validation w.r.t. validated platforms,…)
- Increased coherency of the simulation facilities across the project lifecycle

Any questions?

Requirements gathering (I)

- Reuse of the DFACS and SVF is the main driver for the technical requirements (need to privilege cross-platform frameworks)
- The content of the artefacts is expected to evolve during the preparation of the LPF mission (and during the mission itself). A user-friendly configuration control of the artefacts shall be provided by the STOC Simulator

Requirements were gathered with several interviews with the different stakeholders. A more structured meeting was organised before the PDR to discuss and refine the understanding of the requirements

Requirements gathering (II)

Prototyping proved useful to discuss:

- MMI aspects
- Complex case studies