Evolution of the Operation Simulator Infrastructure at ESOC: SIMULUS Next Generation

Workshop on Simulation and EGSE for Space Programmes (SESP)
28-30 March 2017

ESA-ESTEC, Noordwijk, The Netherlands

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INTRODUCTION

This paper introduces the SIMULUS Next Generation Study (SIMULUS NG) and its rationales and objectives. It explains the scope of the study and the progress made since the Kick Off in November 2016.

At the European Space Operations Centre (ESOC), the ground and space segment operational simulators are based upon SIMULUS. SIMULUS comprises approximately 2 million lines of code across 10 separate software developments spanning 15 years and multiple Operating Systems, from VMS through Windows NT to the current SLES 12 platform. The range of missions it must currently support for simulator development and execution are interplanetary single spacecraft missions to Low Earth Orbit high data rate, high visibility missions to observatory missions. The level of customisation for a mission simulator from the SIMULUS infrastructure varies depending on the budget, timescale and mission specific modelling accuracy required. The main discussion points arising from the first 3 day workshop are presented together with the list of potential prototypes and proof of concepts planned for 2017.

What are the future problems?

Individual spacecraft and missions operated from ESOC are continuously increasing in complexity and performance. The simulations infrastructure must similarly evolve to improve modelling, model exchange and development and to introduce novel concepts into the infrastructure. To support ESA missions launching in 2025 onwards requires SIMULUS infrastructure development starting 2018.
An analysis of the probable new requirements on simulator infrastructure is therefore needed and supported by selective prototyping and proof of concept implementation.
The main challenges to be addressed are the widening scope and variety of use cases for simulation in the future. Simulation solutions for the next decade must support missions ranging from small, cheap missions based upon off the shelf components to highly complex international exploration missions incorporating humans in the loop. This implies that all aspects of the current infrastructure be analysed including performance, model development, portability and re-usability and the modernisation of the current technology stack, while taking into account economic issues and the risk/benefit of migrating already operationally mature systems.
This trade-off analysis needs in particular to consider the needs of future missions and also novel capabilities, such as the capability to automatically synchronise in a semi real-time manner the high fidelity simulator models with the real spacecraft status based on telemetry. Such capability would potentially allow the early identification, detection and investigation of problems in the real spacecraft, in addition to improving the feedback loop from real flight experience back into the simulation domain.

How can we improve SIMULUS?

The SIMULUS NG study kicked off in November 2016 is “outward looking”. There is a large focus on standards, domains, techniques, and workshops with users outside of the traditional domain of SIMULUS, including:

- The FMI standard used in simulations in the automotive industry.
- Astronaut-in-the-loop training systems, Robotic systems, etc.
- Support for re-use of models from simulators used earlier in the mission lifecycle, Software Validation Facilities, or from other operational simulators.
- Similarities and differences between various Reference Architectures in use in Europe.
- Mechanisms to integrate models from other environments such as Matlab/SIMULINK etc.
- Analysis of the advantages offered by other simulation infrastructures and environments, including prime satellite contractors and agencies to increase synergies and facilitate model reuse.
- Analysis of software technologies and techniques used outside of the simulation domain, especially in the European Ground Segment Common Core (EGS-CC)

In addition to the SIMULUS-NG study, ESOC is constantly following progress within Europe in the Simulation domain. This includes activities to promote SMP and incorporate suggestions that may improve cooperation within Europe into the evolution of Operational Simulator Infrastructure. One example of this is the attempt to make UMF open source and improve its toolset to facilitate its use by a larger community.

Three workshops are scheduled for a variety of topics as in Figure 1, which targeted both users and developers of the Operational Simulators. The first workshop was held in January 2017.

24/01/2017	25/01/2017	26/01/2017
Astronaut in the loop	Future interfaces PI - MCS - GS - SC	Trends in S/C avionics systems and the impact it will have on spacecraft simulation models
Robotic exploration	Delay/Disruption Tolerant Networks	
Coffee break	Coffee break	Coffee break
Constellations	File Based Operations CFDP	Software Validation facilities
	RF standards	
Multiple Spacecraft	TM/TC standards	SVF contd.
Small low cost missions, Cheaper/small mission concepts	PUS	
		Coffee break
Coffee break	Coffee break	Savoir and SOIS / Electronic data sheets
Sims Campaign Review - Interview Reports	MO services	

Figure 1 Workshop 1 Topics

Following the workshop a report is compiled listing the discussion points per topic and the possible areas for SIMULUS improvements or noted commonalities. As each topic was only discussed for one or two hours, further investigation and analysis of the impact on SIMULUS is performed after the workshop and also presented in the report. Prototype and proof of concept candidates are currently being selected and implementation will start in Summer 2017.

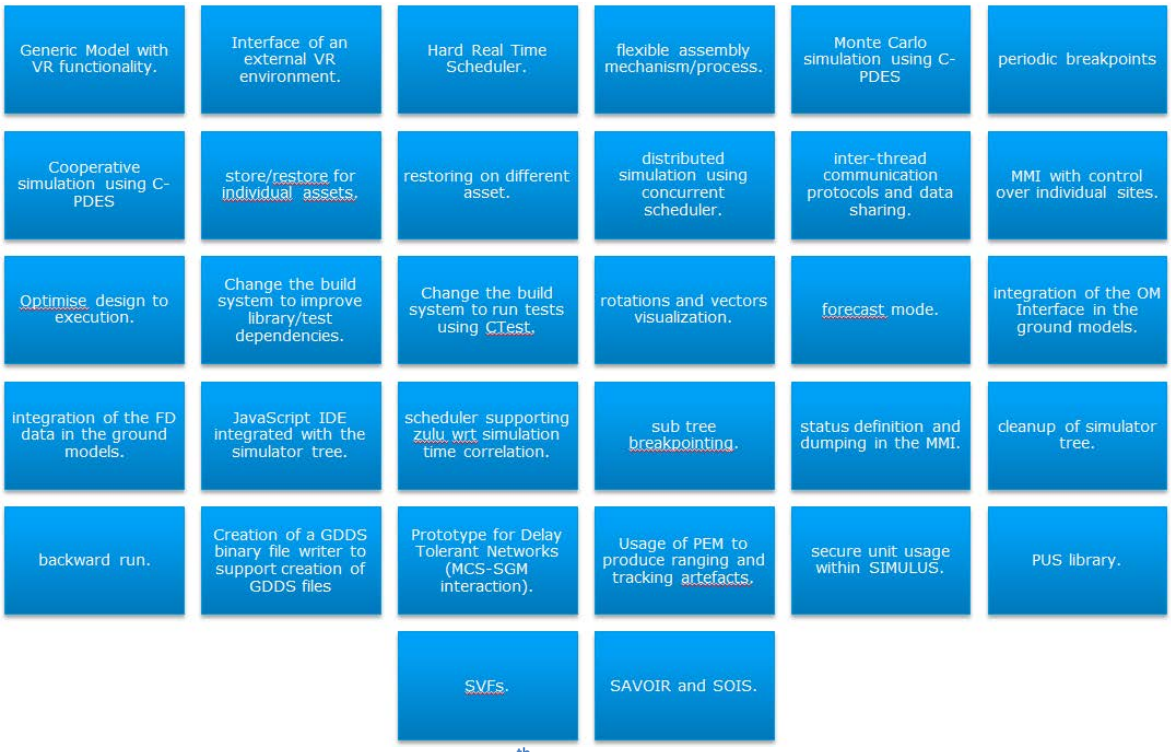

Figure 2 Workshop 1 Prototype Candidates (as of 15th March 2017)

Workshop 2 will focus on developers. Day 1 investigates the potential to automatically produce a near real time simulator state based on real (flying) spacecraft telemetry, and which other interfaces are needed to complete the data set on ground. This enables higher automation of simulator state setup, testing and mission product validation. With such data available a direct and autonomous comparison between such a 'digital twin' and a nominal simulator may be possible. Non-conformances and unit/parameter trends monitoring can be improved and better optimisation of mission planning products.
Day 2 discusses potential advantages and commonalities of existing simulation development and runtime environments in use in the European space simulation domain. Support from satellite prime simulation sections and agencies is encouraged. A further analysis of the existing SIMULUS technology stack will also be discussed.
The prototype, proof of concept list and new SIMULUS requirements will be iterated post Workshop 2 and implementation will begin.

3/5/17: Co Simulation		4/5/17: Technology Stack
FMI Standard		• Technology stack • Validation approach
OpenMI, OPC Unified Architecture, 4DIAC		• Data model • Handling of CFIs
Digital Twin in the automotive industry		• Procedure execution • MORE-CC
Digital Twin demo		• MORE framework
Simulator state synchronization mode		System commonalities • Automated logging • Data analysis tools • Visualisation tools • Automatic testing tools • Mission automation tools
Detection of S/C anomalies by comparing simulator with real TM		

Figure 3 Workshop 2 Topics