HOW SMP SUITS THE NEEDS FOR THE EUROPEAN SPACE SECTOR

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ABSTRACT
There is hardly any paper dealing with the topic of simulation and modelling for space applications without touching on the topic of model reuse. Simulation and modelling plays a key role during the entire lifecycle of a space project and the investments done in simulation models is a significant part of the overall cost of any space project. Due to this, it is natural that several ways have been invented to reduce the cost of simulation modelling by increasing model reuse. This paper will concentrate on how the ECSS-E-TM-40-07 Simulation Modelling Platform specification can be used as a fundament to build up an entire effective approach to simulation and modelling covering the entire space project
It will look at several areas like:

- Model development techniques covering the typical software development lifecycle, specification, design, implementation, testing.
- Model evolution from early concept studies (Phase A activities) until high fidelity models (Phase E activities).
- Model reuse between projects for models with similar requirements.
- Model design for reuse by applying reference architectures.
- Model exchange between organisations by building Library of Models.

Finally, by as well taking into account the importance of platform independency, the paper will show how the ECSS-E-TM-40-07 supports all the needs of the European Space Sector.

Keywords: Space, SMP

1. INTRODUCTION

Simulation techniques have been used with great success to support different aspects of a satellite mission lifecycle. However, this often involved the development of numerous simulators which were very different in terms of use-cases, size and scope. Often these simulators may have been implemented using different tools and approaches, and potentially running on different platforms under different operating systems.

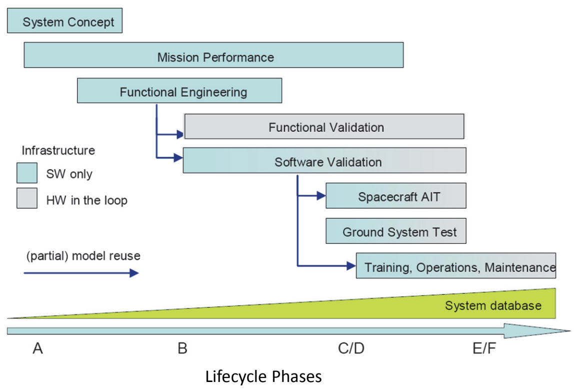

Figure 1: Simulation used across the mission lifecycle[1]

Building on these company-focused approaches, the use of simulation to support the system engineering activity has now also become part of ECSS – the ECSS-E-TM-10-21A Technical Memorandum (2010). ECSS-E-TM-10-21A identifies a set of simulation facilities (systems) deployed at various points (phases) throughout the lifecycle, each fulfilling a particular set of use-cases. In reality some of the individual identified facilities may in fact be combined into a single configurable multi-role system. This approach is far more logical and cost-effective compared to the development of a set of separate bespoke systems. However, it places a large emphasis on model re-use and simulation facility re-use throughout the lifecycle.
The ability to re-use models effectively and efficiently places a large emphasis on portable and configurable models, and the adoption of suitable standards (covering portability, model design, and simulator architectures). The re-use objective therefore has to be a planned part of the overall model or simulator development process. The fundamental aspects of reuse are shown in 0. This paper will describe each level in more detail as well as the use cases this reuse pyramid allows.

[1] Figure reproduced from ECSS-E-TM-10-21A

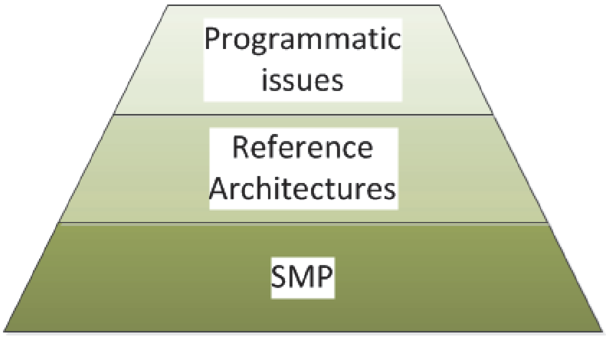

Figure 2: Reuse pyramid

2. THE SMP STANDARDS

In order to promote and support simulation model re-use, and facility re-use, the European Space Agency (ESA) has undertaken several key initiatives.
The Simulation Model Portability standard (SMP) was initiated by ESA in 1999. Work on the second version of the standard started in 2005 focuses on:

- model development and integration,
- and inter-model communication

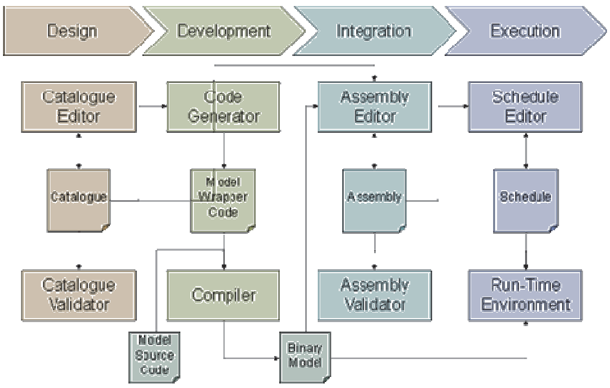

Figure 3: Model lifecycle and SMP2 artefacts

This process is most efficient when supported by suitable SMP2 tools, in particular allowing the user to create an SMP2-based design, and in general to handle the various SMP2 artifacts. This topic is covered in more detail in section 2.1 below.

Table 1: Development Environments and Run Time Environments

Development environments	Run Time environments
UMF SimVis	SIMSAT (ESA) Basiles (CNES) SimTG (Astrium) EuroSim (EuroSim Consortium)

In the past few years SMP2 has been revised into a Technical Memorandum within ECSS, ECSS-E-TM-40-07 (2005). Future follow-on activities are anticipated to transform this into an SMP standard within ECSS.

2.1. Modelling Environments and Tools

The SMP standard requires tooling support before it can be applied effectively. It also allows effective tools to be developed that aid the development process of models.

2.1.1. ESA Universal Modelling Framework (UMF)

UMF (Universal Modelling Framework) is an example of a tool enabling efficient development of models and integration of simulations with SMP (Fritzen et al. 2013).
A short overview of the steps are provided in 0:

- Requirements can be imported and mapped to design in UML.
- A UML based design approach is used to capture the models design in a platform independent way. From the UML design, SMP catalogues describing the models are exported.
- Based on the SMP catalogues, code generation and merging are supported to allow efficient implementation of the models behaviour.
- An extensive suit for testing of SMP models both at unit level and integration level are provided.
- Finally, the models can be packaged, and integrated into a ready to be started simulation. It can be distributed via the Library Of Models together with auto-generated documentation covering both user manuals and design documentation.

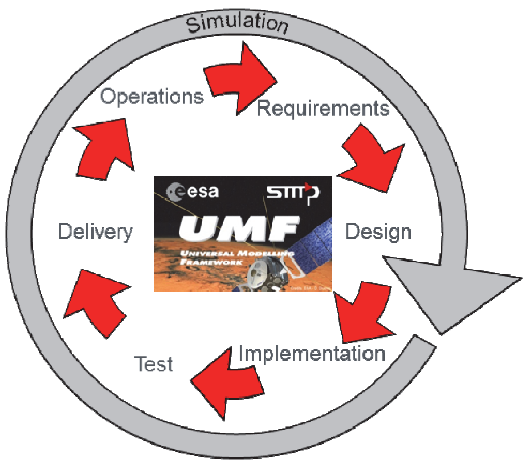

Figure 4: Model development cycle with UMF [9]

3. REFERENCE ARCHITECTURES

In addition to standards such as SMP2 a suitable reference architecture are required to effetely re-use model. Reference Architectures adds semantics for spacecraft system simulation which is not addressed by SMP-2 which is agnostic to the specific domain being simulated.
Within the space domain, two flavours of Reference Architectures exist today with different aims and use.

3.1. Intrusive Reference Architectures

ESA's European Space Operations Centre (ESOC) has created a so-called Reference Architecture (REFA) which is actively used at the core of the design of their SMP2-based Operational Simulators. Its use within ESOC simulators promotes consistency in design across the different mission satellite simulators, and further facilitates the re-use of SMP2 models.

REFA defines a set of standard interfaces between common satellite subsystems' models within the satellite simulator, and a set of base SMP2 models (REFA Interface Control Document, 2011). In addition to using REFA as-is, a simulator developer can also extend the REFA interfaces or models via inheritance to suit the design needs for a particular simulator.

3.2. Pure interface based Reference Architectures

SSRA (2010) and ISIS (2011) provides a basis for the Virtual System Model described in ECSS-E-TM-10-21A [1]. It defines an SMP2 reference architecture supporting the re-use of simulation models across various mission lifecycle phases and simulation facilities, or even across missions. ISIS strictly focus on interfaces to allow for model exchange between organizations and allow interoperability of models.

3.3. Overview of differences between reference architecture approaches

The following table show a short summary of the areas that may be covered by each of the types of Reference architectures:

Table 2: Standardization Area

Standardization area	IF based	Intrusive
Interfaces	X	X
Operability		X
Development approach		X
Common base classes		X
Approach for tracing/ debugging		X
Approach for installation and versioning		X

3.4. Current status in Europe

Several reference architectures have been developed in Europe during the last years to enable efficient reuse aiming at solving specific problems of specific organizations. This proliferation of reference architectures underline the fundamental need for standardization also in this field. However since most of the exiting solutions have been developed without taking the overall problem into account, it is currently problematic to achieve reuse between organizations using different architectures.

ESA is however currently initiating work to harmonize the various reference architectures used to ensure compatibility between Interface based and intrusive architectures in the various organizations.

4. PROGRAMMATIC ISSUES

4.1. Model exchange in practice

In order to efficiently reuse models, it is not sufficient to only overcome the technical issues of model integration. It is also required an easy way to in practice transferee models from Organization A to B, as well as a central place where the it is possible to get an overview of the available models.

To achieve this, a "Library of Models" (LoM) is needed. This is similar to common practice for release management via a Repository Manager (For example http://www.sonatype.org/nexus/).

Such a LoM must provide facilities to:

- Upload and download simulation models both in binary and source code format.
- Allow restricting access to models depending on license issues
- Provide protection for IPR issues.
- Provide standardized tags and attributes for models to allow for easy identification of suitable models.

5. MAJOR USE CASES FOR SMP

Following use-cases describes the different situations where SMP can be applied:

1) The SMP standard allow model exchange process between customer and supplier. Typically the supplier being a System integrator, i.e. an organization developing complete simulation solutions as part of the overall system to be developed. The customer either being the Spacecraft operators for operational simulators or other entities for Independent Design Verification.

2) The SMP standard allows outsourcing of simulation model developments, so that the System Integrator can concentrate on integration of models developed by domain experts. Such outsourcing clearly relay on a well-defined reference architecture as well.

3) The SMP standard allows model reuse by allowing system integrators to build a library of models suitable for reuse. The simulators can then be built by assembling already developed and validated models.

4) The SMP standard allows simulator end users (customers) to customize their simulation solutions by replacing a simulation model with its own custom version. Clearly such replacing imply a heavy revalidation of the overall system.

5) The SMP standard allow portability of simulations from one Run Time environment to another. This allows different organizations to harmonize internally on standard simulation environments, while still exchange simulation models with other organizations using other environments.

All of these use cases are summarized in 0.

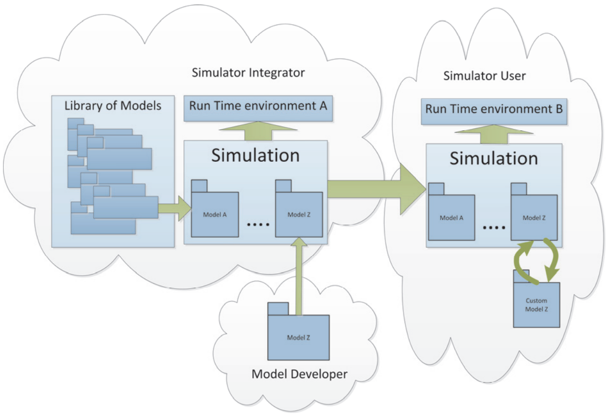

Figure 5: Summary of model exchange scenarios

6. CURRENT STATUS AND ISSUES

SMP is frequently used within the Space community, but a wide spread usage also outside the space domain is currently not taking place largely due to:

- It is a significant cost to upgrade existing tools to support the standard.
- Most larger organization has inhouse existing solutions that is suitable for their own development.
- Simulation technology is seen as “key competence” for several companies, hence there is no interested in standardizing it, since this would open it up for external competition.
- There is a need for standardization on reference architectures as well.

There are however resent signs that some of these issues may be resolved:

- Mathworks are evaluating to support SMP within Mathlab, hence removing the need for a SMP development or runtime environment to use the SMP standard.
- Organizations are realizing that it is extremely costly to maintain a state of the art internal simulation infrastructure, hence model portability raises on the agenda in several major European Companies.

7. SUMMARY AND CONCLUSIONS

The paper has described how SMP enables effective reuse of simulation and modelling in the entire Space sector. A review of the current status and issues focusing on the tree levels in the reuse pyramid has been done:

- Standardization (SMP)
- Reference Architectures
- Programmatic issues

This shows how SMP are used as a fundamental building block to achieve cost effective reuse for the need of the European Space Industry for the next decades to come.

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