SMP: A Step Towards Model Reuse in Simulation

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Rationale

Within ESA's broad range of space programmes, simulators are continually being developed for many different purposes – typically engineering, verification, operations preparation and training – in a more or less independent manner. Up to now, it has not been easy to take advantage of the obvious commonality between these simulators within one project because they were developed following different design guidelines. There was basically a lack of standards that could be applied to support the reuse of simulation products.

A standard specification for the interface between simulator models and simulator infrastructures – the 'Simulation Model Portability (SMP) Standard' – has been established and validated in the framework of an ESA initiative, with the participation of the main companies involved in spacecraft simulation. This will facilitate the implementation of a 'plug-and-play' approach for simulators and will allow for rationalisation of simulation developments by reusing existing models independently of the tool for which they have originally been developed. In particular this will allow the exchange of models between flight-segment simulators and the simulators used to support operations and training.

The rationalisation of simulation developments is now being actively pursued within ESA and a clear objective is the exploitation of commonality between simulators, first within the same project and then across projects. This implies 'portability' of spacecraft models from one platform to another, since different platforms are used at different companies and ESA sites. Achieving that portability requires the following steps:

– The architecture of the simulator must implement a clear separation between: the simulation models representing the spacecraft and its environment, i.e. the project-specific parts of the simulator; the general-purpose part of the simulator, namely the simulation framework (also called simulation infrastructure or simulation tool). This separation is already enforced on most simulator developments by the use of off-the-shelf simulation tools.
– A standard interface specification between models and simulator frameworks needs to be defined, in order to apply the 'plug-and-play' approach already well-established in other software areas. This has recently been done by ESA and is the main focus of this article. Compliance with such a standard interface will ensure portability for both simulation models and simulation tools.
– In addition to being compliant with the standard interface specification, models must be properly documented, validated and easily accessible, if reuse is to be successfully applied. We also identify here how these aspects are supported in the present concept and what developments are required in the future to support simulation rationalisation.

Objectives of the SMP standard

The main purpose of the SMP standard is to promote the re-use of simulation models by ensuring their portability from one simulation platform, or infrastructure, to another. The SMP standard has been developed to fulfil the following objectives:

– Minimise model interactions with their simulation environment.
– Standardise interfaces between models and the simulation infrastructure.
– Make models understandable for other developers.

To achieve these goals, the SMP standard defines a set of specifications for coding and documenting models, with particular emphasis on their interfaces, i.e. their visible part to the rest of the simulation:

– *Simulation Model Interface (SMI) specification*
The SMI specification defines a set of services to be provided both by the models to the simulation infrastructure and by the simulation infrastructure to the models.
– *Portability guidelines*
The portability guidelines provide a list of recommendations for developing a model that is as portable (i.e. re-usable) as possible.
– *Document template*
Appropriate standardised model documentation is a key factor in facilitating software re-use. The standard defines a model document template which, if completed, should ensure that all of the important aspects of the model are accurately described.
– *Compliance test*
As well as defining compliance tests for each of the guidelines, the SMP standard defines a system that should be used to test the model's compliance.

A concerted ESA-Industry effort

The SMP standard is the result of a concerted effort involving both ESA and Industry. Two sections of ESA's Technical and Operational Support Directorate (to which the authors of this article belong), representing the mission-operations simulation requirements at ESOC and the spacecraft-development requirements at ESTEC, jointly undertook the establishment of a technical specification to ensure portability of simulation models between the two domains. This was based on preliminary user requirements put together under ESA co-ordination by a working group with the participation of the main European companies involved in simulation tool development. Industry was also invited to support the development of the standard specification, to ensure that the outcome would fulfil the industrial requirements as well as the requirements laid down by ESA, and also that the standard would be easy to adopt.

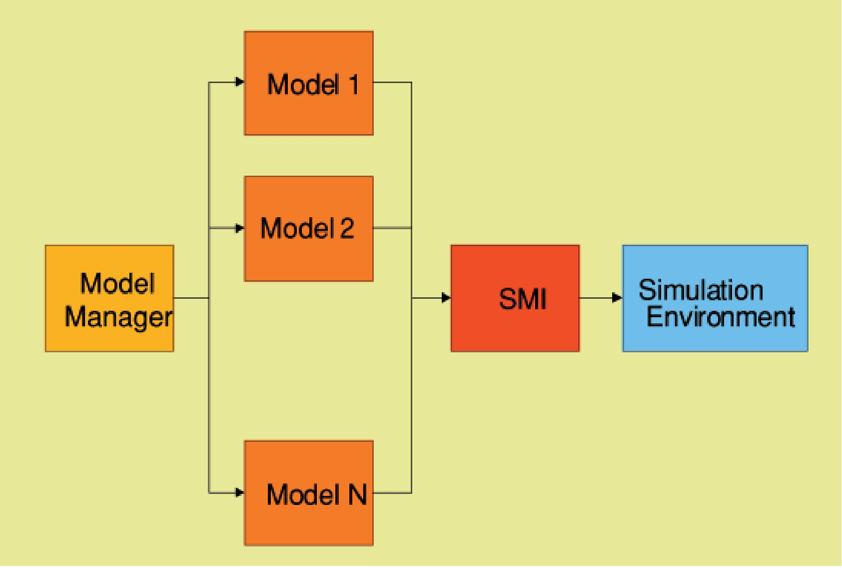


Figure 1. Architecture of an SMP-compliant simulator

Available SMP products

The main SMP product is the model interface specification. In order to validate it, a software implementation was developed and integrated with existing simulation infrastructures. The complete documentation is contained in the SMP Handbook, consisting of three volumes:
– Volume 1: SMP User Manual General Concepts.
– Volume 2: SMP Software User Manual, which describes the installation, building and execution procedures for the software associated with the SMP.
– Volume 3: SMP Interface Specification, which is the Simulator Model Interface (SMI) Specification Reference, describing the SMI software types and services available, classified by category.

The SMP software consists of:
– The generic software, independent of the simulation infrastructure used.
– The specific software (plug-ins) required to implement the SMP standard in a particular simulation infrastructure. Two such plug-ins are currently available:
  • SIMSAT SMP Plug-in
  • EUROSIM SMP Plug-In
– SLIMSAT: a freeware SMP-compliant simulation environment available on-line for learning, model-development and testing purposes.

Users of the SMP standards

There are three categories of SMP user:
– Model developers, who need to know the simulator model interface specification as contained in Volume 3 of the SMP Handbook.
– Simulation Infrastructure vendors, who need to adapt their simulation infrastructure to be SMP-compliant and therefore need to know the simulator model interface specification as contained in Volume 3 of the SMP Handbook. They also need the generic, or simulation-infrastructure-independent software implementing the standard and the corresponding User Manual (Volume 2 of the SMP Handbook). They then have to develop the infrastructure-dependent software interface for their particular simulation infrastructure.
— Simulator developers, or model integrators, who have to build a simulator, and who need to know the interface specification (Volume 3 of the SMP Handbook) and the SMP Software User Manual (Volume 2 of the SMP Handbook).

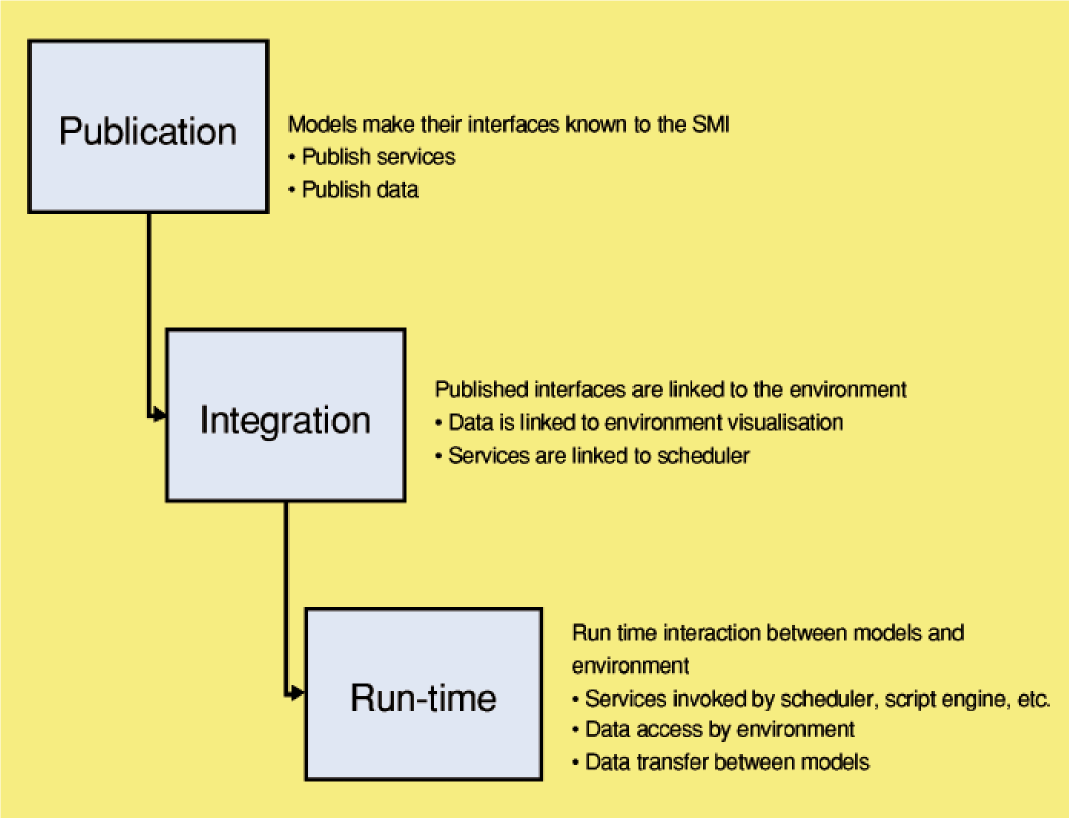


Figure 2. Application of the SMP standard to the different simulation phases

All of these categories of SMP user need to be familiar with the general concepts (Volume 1 of the SMP Handbook).

Technical details

An SMP-based simulation system

A typical SMP-based simulator will consist of four components, as illustrated in Figure 1 (the 'simulation environment' is equivalent to the simulation 'infrastructure' or 'tool').

1. Models

The models are the functional representation of the various physical elements being simulated, e.g. satellite dynamic model, spacecraft subsystem model, position and environment model, thermal model, ground equipment model, etc.

2. Model Manager

The Model Manager is implemented by the simulator developer. It links together all of the individual model components. The Model Manager's task is to manage the initialisation of the models, to establish the connections between the models and the environment, and to control the interactions between models. The general purpose of the Model Manager is generic, and it is therefore identified here as a component of the overall SMP system.

3. SMI Software

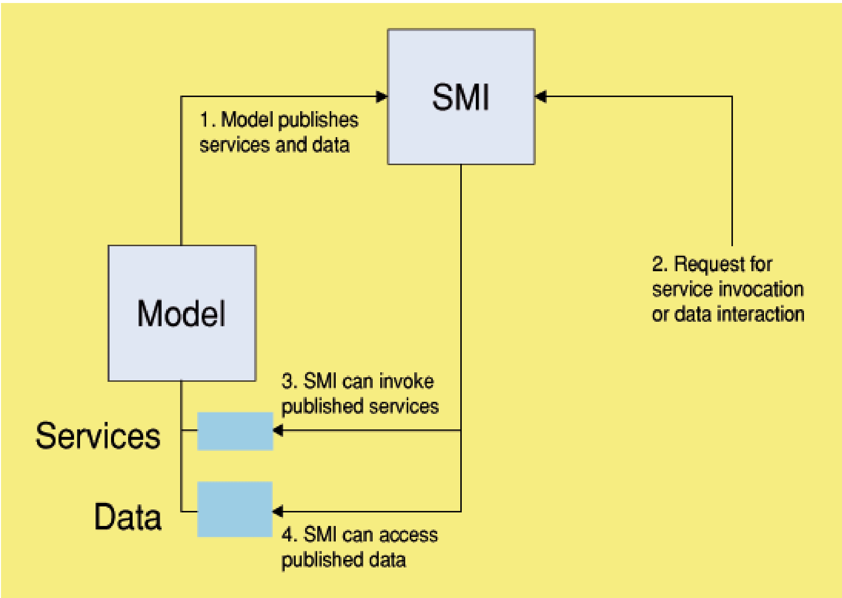
The SMI software component acts as the interface between the models and the simulation environment. It provides a set of standardised services that the models use to interact with the simulation environment. These standard interfaces are referred to as the Simulation Model Interface, or SMI.

4. Simulation Environment.

The Simulation environment provides the typical simulation support functions that apply to any spacecraft simulator, including:

– time-keeping (event handling, scheduling, etc.)
– public-data handling
– public-data visualisation (alphanumeric displays, graphs, etc.)
– simulator commanding

Figure 3. Interaction between simulation models and simulation infrastructure through the Simulation Model Interface (SMI)



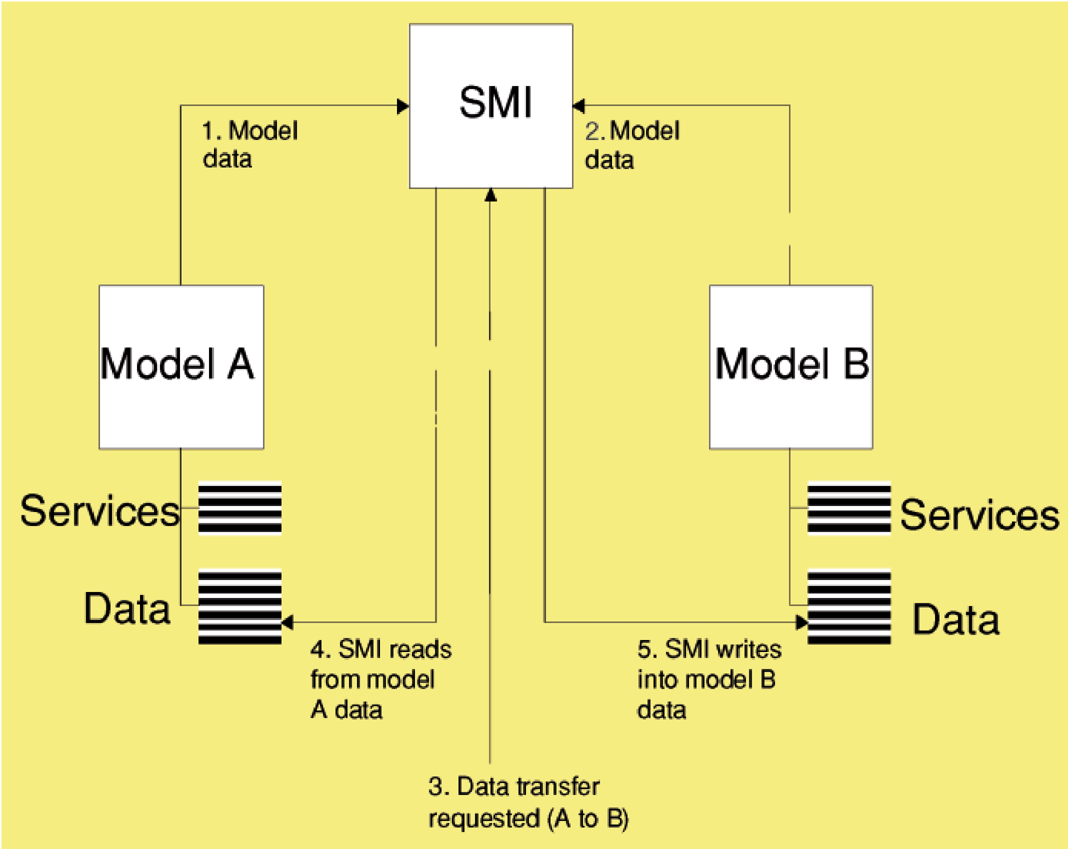


Figure 4. Data transfer from one model to another via the Simulation Model Interface (SMI)

– saving/restoring of break points or simulator states.

Simulation operational phases
The three operational phases for a typical SMP-compliant simulation system are shown in Figure 2:

– *Publication phase:* making the SMP system component interfaces known using the publishing services of the SMI. The Model Manager 'publishes' the individual models that are in the simulation system, and then 'calls' each of the published models so that it can publish its own internal services and data (Fig. 3).
– *Integration phase:* integrating all of the services and data that have been published into the environment. The Model Manager uses the SMI environment services to add published services to the environment schedule, so that they are invoked in the run-time phase.
– *Run-time phase:* executing the models in a simulation. In this phase, models can use the SMI services to write log messages and get simulation time. The Model Manager can also use SMI data-transfer services to move data from one model to another (Fig. 4).

Current and future work
The SMP standard specification has achieved a stable status and has been frozen. A Configuration Control Board (SMP CCB) has been established, under ESA co-ordination and involving industrial simulation infrastructure vendors, to decide upon future upgrades to the specification. Any company is invited to join either as a full member, if committed to compliance with the standards, or as an observer. The implementation of upgrades to the specification and to the associated software, including corrective maintenance of that software, is managed by ESA.

In parallel with the development of the specification, a validation exercise involving the simulation infrastructures SIMSAT and EUROSIM has been carried out. SIMSAT is ESA's simulation infrastructure for the development of simulators to support operations preparation. EUROSIM is a commercial-off-the-shelf real-time simulation infrastructure used in a number of ESA projects. The resulting demonstration systems are available as examples.

Other companies involved in simulation infrastructures, either vendors or satellite prime contractors who have participated in the settingup of the SMP requirements, are planning to make their infrastructures compliant with the SMP standard specification.

Support to industry willing to adopt this standard is provided, inter alia, by means of a Web site (http://www.estec.esa.nl/smp/) from which it is possible to download the SMP

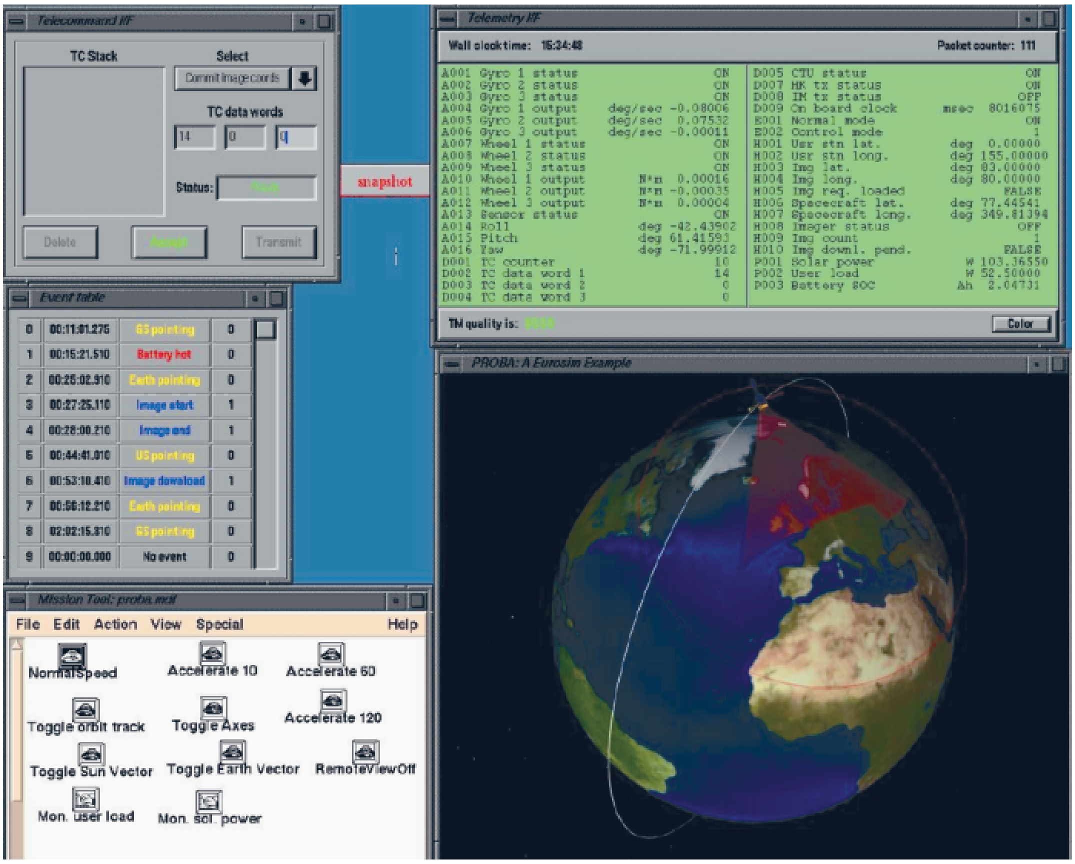


Figure 5. A screen from the Project Test Bed simulator for the PROBA satellite, showing the telemetry and telecommand windows, the onboard event table, a three-dimensional view of the satellite orbiting the Earth, and the mission-tool panel

Handbook, the generic SMP software, as well as the associated examples and test suites. From this Web site, the user can subscribe to a list server and become part of the discussion forum. The Agendas and Minutes of the Configuration Control Board meetings will also be accessible from this Web site, as well as any related papers and publications.

The SMP standard is already being applied:

– at the European Space Operations Centre (ESOC), where new simulators are based on SIMSAT-NT, the new version of SIMSAT, compliant with the SMP standard. The first satellite simulators to follow these standards will be those for ESA's Rosetta and Mars Express missions
– in the Galileo Programme (devoted to the development of the European satellite navigation infrastructure), which has chosen to apply the SMP standard in the development of the GalileoSat System Simulation Facility (GSSF)
– in the Project Test Bed, a satellite simulation test-bed available at ESTEC to support early project phases. Based on EUROSIM, it has been upgraded to the SMP standard (Fig. 5).

It is envisaged to formalise the SMP standard specification by submitting it to the European Co-operation for Space Standardization (ECSS) organisation for formal review and, hopefully, adoption as an ECSS standard.

To further promote the reuse of simulation models, it is foreseen to establish a model repository for verified models that conform to the SMP standard, thereby facilitating their integration into any SMP-compliant simulation platform. The SMP model document template will define a standard format that will provide the minimum necessary information to the users of the repository regarding the adequacy of the model for the intended purpose.

Conclusions

The SMP standard specification is increasingly being made applicable to ESA projects. The main real-time simulation tools used in these projects are becoming compliant with the SMP standard specification, which should soon be raised to a formal ECSS standard.

ESA is supplying a software implementation of the SMP standard specification to facilitate its adoption by simulation-tool vendors as well as model developers. A Web site set up for this purpose allows the necessary documentation and software to be easily downloaded from http://www.estec.esa.nl/smp/.

Further work is required to promote the reuse of models. A prototype of the model repository needed to facilitate access to well-documented and validated models is foreseen within the framework of the ESA R&D programme.