Reference:
SPB-S2SA-TN-006

Issue:
1.0DRAFT

Date:
19/04/2023

S2SA

From System to Simulator Architecture

Executive Summary Report

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Abstract

This document contains the executive summary report for the From System to Simulation Architecture study performed under the ESA contract 4000135630/21/NL/AS by the consortium composed of SPACEBEL, Telespazio Germany, Airbus Germany and Thales Alenia Space France. The present document is the ESR deliverable identified in the Statement of Work.

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Document Change Log

Issue	Date	§ or Page	Relevant Information
1.0	19/04/2023	All	First version submitted to the FR

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None.

1 INTRODUCTION

This document contains the executive summary report for the From System to Simulation Architecture study performed under the ESA contract 4000135630/21/NL/AS by the consortium composed of SPACEBEL, Telespazio Germany, Airbus Germany and Thales Alenia Space France. The present document is the ESR deliverable identified in the Statement of Work.

2 Applicable and Reference Documents

The following tables identify applicable and reference documents for the project. In the body of the text these documents are referenced as listed here below. Without any indication of issue, the latest issue is applicable. If one issue is indicated, only that issue of the document is applicable.

Ref.	Code	Title	Issue	Date
AD01	ESA-TRP-TECSWG-SOW-021360	Statement of Work	1.0	25/02/2021
AD02	SPB-S2SA-O-1106B	Proposal – Technical Part	1.0	17/06/2021
AD03	ECSS-E-TM-10-21A	System modelling and simulation	A	16/04/2010
AD04	ECSS-E-ST-40-07	Simulation modelling platform	C	02/03/2020
AD05	GIT-TEN-T01-0918	Configuration Database Need for Modelling and Simulation Final Report	1.0	09/07/2020
AD06	OSMoSE-SSO	https://mb4se.esa.int/OSMoSE_Main.html https://csde.esa.int/git-repos/OSMoSE/ontology.git	main	August 2022
AD07	SSRA	SSRA documentation package	1.0	09/11/2011
AD08	REFA	REFA documentation package	3.2	15/02/2019
AD09	ISIS	ISIS documentation package	7.1	23/11/2021

Table 2-1: Applicable Documents

Ref.	Code	Title	Issue	Date
RD01	SSL-10883-FR-001	SAVOIR Electronic Data Sheet Definition SAVOIR EDS Final Report	1.0	22/10/2020
RD02	CCSDS 876.0-B-1	Spacecraft Onboard Interface Services XML Specification for Electronic Data Sheets	1	April 2019

Table 2-2: Reference Documents

3 TERMS, DEFINITIONS AND ABBREVIATED TERMS

EDS	Electronic Data Sheet
FDIR	Failure Detection Isolation and Recovery
HiL	Hardware-in-the-Loop
ISIS	CNES Initiative for Space Innovative Standards
(Capella) LA	Logical Architecture
MBSE	Model Based System Engineering
ORM	Object Role Modelling
OSMoSE	Overall Semantic Modelling for System Engineering
(Capella) PA	Physical Architecture
RAMS	Reliability, Availability and Maintainability Study
REFA	ESOC simulation Reference Architecture
(Capella) SA	System Analysis
SC	Spacecraft
SMP	Simulation Modelling Platform
SSO	Space System Ontology
SSRA	Space Simulation Reference Architecture
TBC	To Be Confirmed
TBD	To Be Defined
TBW	To Be Written
UML	Unified Modelling Language

4 STUDY SUMMARY REPORT

This document reports the performed work and achievements in the From System to Simulation Architecture (FS2SA) study realised by the consortium composed of SPACEBEL, Telespazio Germany, Airbus Defence & Space and Thales Alenia Space. In short, FS2SA investigates the exchange of information between the MBSE world and Electronic Data Sheet (EDS) on one hand with the Simulation world on the other hand. The document is organised in the following sections, which correspond exactly to the FS2SA study workflow:

- The Study Objectives chapter (§4.1) explains our understanding of the study objectives that allows us to proceed in an efficient and effective way.
- The Study Logic chapter (§4.2) describes the followed logic to realise the study objectives.
- The Study Schedule chapter (§4.3) reminds the major events and milestones of the study and provides a comparison between the planned schedule and the actual schedule.
- The Study Workflow chapter (§4.4) describes the Analysis phase performed in the study following the predefined Study Logic.

The Conclusions and Lessons Learned chapter (§5) contains the conclusions drawn and lessons learned from this study.

4.1 Study Objectives

Let us remind first the objectives of the FS2SA study as stated in the SoW:

OBJ1	To improve the automation of the information exchange between the spacecraft subsystems and units and the simulation model development, configuration and validation
OBJ2	To improve the automation of the information exchange between the spacecraft system and the simulator assembly, scheduling and its mission specific configuration.
OBJ3	To define how the information identified in the above objectives can be integrated in the simulation architectures typically used in the European space domain.

OBJ1 concerns the information related to the equipment units in a spacecraft (Sensor, Actuator, Payload) describing their internal design, behaviour and external interfaces. In a "paper" documentation base, this information can usually be found in the equipment Design Description Document (DDD), the Interface Description Document (ICD), the User Manual (UM), etc. This kind of information can also be provided by the equipment manufacturer in the "electronic" format known as Electronic Data Sheet (EDS). The CCSDS has standardised this EDS format (see [**RD02**]) and the SAVOIR-EDS (see [**RD01**]) study has mapped a metamodel on this CCSDS EDS standard (sort of tailoring the use of EDS for space equipment). So, **OBJ1** will investigate on how information found in the EDS can be used to develop simulation models of the corresponding equipment units. Ideally, the study should define a method to generate the equipment simulation models from the available EDS information.

OBJ2 concerns the information related to the spacecraft as a whole, i.e. an assembly of the equipment units and their inter-connections as well as their configuration for the specific space mission assigned to the spacecraft. In a "paper" documentation base, this information can be found for example in the Spacecraft

Communication Interface Control Document (S/C Comm ICD). This kind of information originates usually from System Engineering and the Spacecraft System Database. In this case, we are especially interested in the information found in Model-Based System Engineering (MBSE) as the primary aim of MBSE is to replace "paper" documents by equivalent "electronic" documents. So, the **OBJ2** will investigate on how information found in MBSE can be used to develop simulators of the corresponding spacecrafts. Ideally, the study should define a method to generate the simulators from the available system information.

OBJ3 considers the use of existing simulation reference architectures to define the semantics and formats of the simulation models and simulators obtained from EDS and MBSE information (EDS and MBSE can be seen as the source of the data). There exist currently three reference architectures defined in the European simulation word: CNES ISIS [**AD09AD09AD09**], ESOC REFA [**AD08**] and ESTEC SSRA [**AD07**]. ISIS and REFA are actually used in spacecraft simulators while SSRA has never been used. The main added value brought by SSRA is its complete metamodel which contains the formal definitions of simulation models and simulators used in space simulation (the ISIS interfaces were actually inspired by system interfaces defined in SSRA).

The study objectives can thus be summarized according to the following figure:

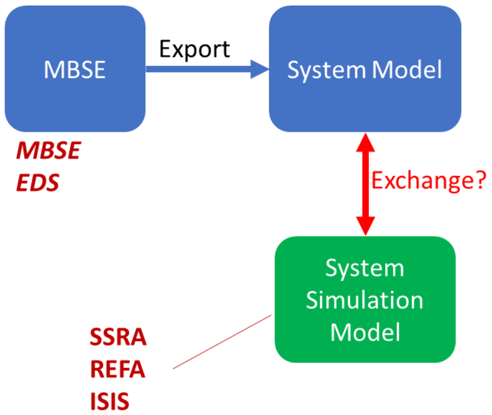

Figure 4-1. Exchange MBSE, EDS and Simulation

In the figure, it can be seen that EDS is associated with the MBSE domain, this can be easily explained: when mentioning EDS, it is usually understood as the CCSDS EDS standard but as it is expressed in electronic format (i.e. XML), it can be considered as MBSE information as well. Therefore, it can perfectly be stated that the FS2SA study investigates the exchange between MBSE and Simulation where MBSE englobes both System Information and EDS.

A MBSE development environment allows to create a System Model. On the Simulation side, we use to work on a corresponding System Simulation Model (e.g. the Virtual System Model as described in ECSS-E-TM-10-21 [**AD03**]). The FS2SA goal is thus to investigate on the exchange between the MBSE System Model and the System Simulation Model, which can be realised in various forms using the existing ISIS, REFA, SSRA reference architectures.

For the terminology used in the rest of this document, following associations will apply:

Terminology	Simulation Element	Information source
Simulation Model	SC Equipment Unit Model	EDS (CCSDS EDS, can be considered as MBSE)
Simulator	SC Simulator	MBSE (System Information from MBSE development environment)

4.2 Study Logic

In order to tackle the study of the exchange between MBSE and Simulation, the same work approach has been applied to both MBSE information sources, i.e. EDS for Simulation Models and MBSE System Information for Simulators. This is illustrated in the following figure where two distinctive lanes of work were identified when the study starts.

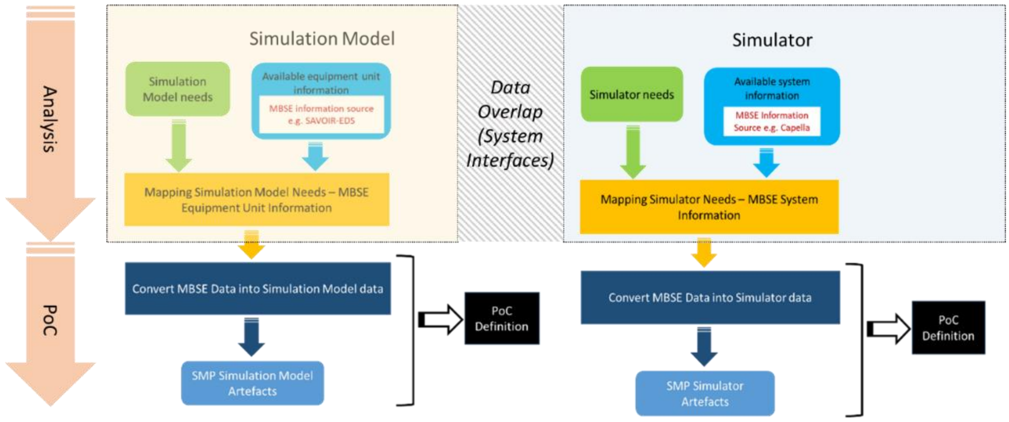

Figure 4-2. Study logic showing the 2 work lanes and overlaps

In each work lane, the work is divided in an Analysis phase and a Proof-of-Concept phase, which starts when the analysis reaches a stable state.

In the Analysis phase, the same workflow is followed:

- First, simulation needs are identified, i.e. which information is needed to serve the development of simulation models and simulators?
- In parallel, available equipment unit and system information are identified, i.e. which information can be provided by the considered MBSE (englobing EDS) information sources?
- Finally, the mapping between the simulation needs and the MBSE information is analysed to verify whether the needs can be completely/partially satisfied, i.e. do we have all information available to develop simulation models and simulators?

From the start of the analysis phase, some overlaps can be identified. The overlaps are located at the boundary of spacecraft equipment units: i.e. the so-called System Interfaces, which comprise the connections of the equipment unit to the spacecraft electrical harness (discrete commands and acquisitions, data links and buses…). It was decided to continue the analysis without taken into account these overlaps but the issue is kept in mind for the reporting at the end of the study.

It is important to mention that this is the initially planned approach for the study. The process was executed completely in each respective lane. But at the end, a merge of the lanes occurred due to the merge of the considered MBSE sources into one single source, which is the OSMoSE Space System Ontology [**AD06**]. The purpose of the merge is to reach a common information model expressed in a common semantics and data format for the various sources of information (i.e. EDS, MBSE System Information, various Simulation reference architectures) which are considered in the study. Consequently, following the merge, one common PoC has been realised. This change in the work logic will be explained further in the following sections.

The following sections will describe the main outcome of the work performed in the study.

4.3 Study Schedule

The following table reminds the major milestone dates of the FS2SA studies. Both the planned date and the actual date of each milestone are shown.

Event	Meeting	Description	Relative Time	Planned Date	Actual Date
KO	Kick-Off	Study start	T0	27/09/2021	07/10/2021
WS1	Workshop 1	Workshop about the information exchange between equipment unit and simulation model	T0 + 2m	27/11/2021	06/12/2021
WS2	Workshop 2	Workshop about the information exchange between system and simulator	T0 + 4m	27/01/2022	11/02/2022
CDR	CDR	Review mapping MBSE/EDS and Simulation	T0 + 8m	29/05/2022	12/07/2022

		Changed scope: instead of starting two PoC, further integration with OSMoSE SSO was wanted and resulted in one single PoC			
WS3	Workshop 3	Review integration with OSMoSE SSO Define Proof-of-Concept	T0 + 10m	29/07/2022	15/12/2022
FR	Final Review	End of the study review	T0 + 12m	28/11/2022	19/04/2023
FP	Final Presentation	Final presentation at the FP Days (ESTEC)			**TBD**

Table 4-1. Study Planned and Actual Schedule

Internal meetings within the study consortium were organised when necessary for technical discussions and to exchange on the progress status in each phase.

Progress meetings with ESTEC were organised between milestones to provide the progress status or to define the way forward (e.g. when the work scope changed between CDR and WS3).

4.4 Study Workflow

4.4.1 Identification of the Simulation Needs

The following figure illustrates the work flow in this first step of the Analysis phase. Input comprises the ECSS-E-TM-10-21 document [**AD03**] and the consortium experience in simulation development.

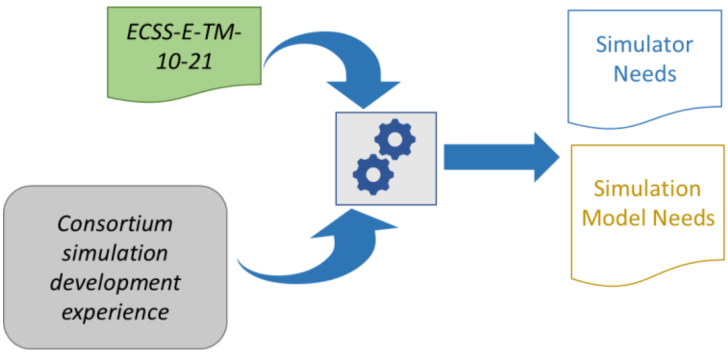

Figure 4-3. Identification of the Simulation needs

The detailed outcome of this step is provided in the study documentation. It is essentially a list of simulation model and simulator needs, which are without surprise:

- Spacecraft architecture and design documentation
- Equipment unit documentation
- Number of equipment unit instances and their related inter-connections
- Equipment unit properties
- Equipment unit interfaces (electrical, data), states, modes and behavior

4.4.2 Identification of the Equipment and System Information

The following figure illustrates the work flow in this second step of the Analysis phase. Input comprises the CAPELLA tool as a real MBSE information source (see https://www.eclipse.org/capella/) and the SAVOIR-EDS study results [[**RD01**]].

This is illustrated by the figure below.

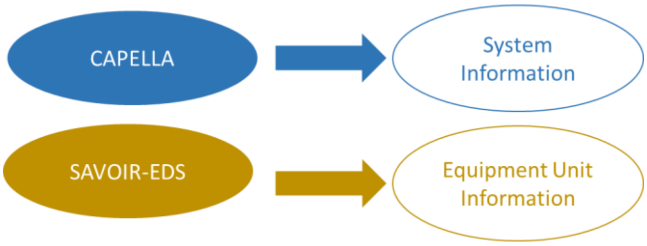

Figure 4-4. Identification of the Equipment and System Information

The detailed outcome of this task is provided in the study documentation.

4.4.2.1 Mapping MBSE, EDS and Simulation

The next step in the work flow is to find a mapping between the Simulation needs and the available MBSE, EDS information, i.e. in other words, the mapping between the Simulation concepts and the MBSE, EDS concepts. At this stage, the mapping has to be investigated separately for the EDS and for the MBSE System Information. In all cases, the work is done staying at the level of the respective conceptual models.

Therefore, input to the mapping analysis include the already known models: CAPELLA, SAVOIR-EDS and SSRA.

During this phase of the study a new actor was introduced: the OSMoSE Space System Ontology (SSO) [**AD06**], which is based on the Object Role Modelling (ORM) formalism. Actually, we were looking at the MBSE part (called the MBSE universe of discourse in ORM terminology) of the SSO defined in OSMoSE.

As usual, this process is illustrated in the following figure and details are provided in the next sections.

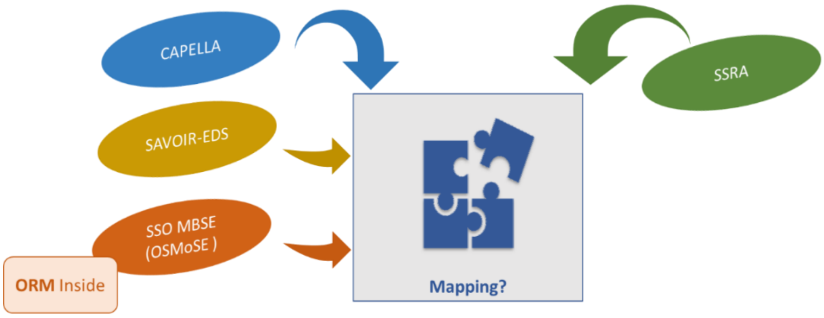

Figure 4-5. Mapping MBSE, EDS and Simulation

The goal here is to find equivalence of the concepts between the CAPELLA, SAVOIR-EDS, OSMoSE SSO MBSE universes and the SSRA universe.

4.4.3 First step, mapping by introspection

In a first step, the work was done "on paper" by introspection at the various models input: SAVOIR-EDS, CAPELLA, OSMoSE SSO (on the MBSE side) and SSRA (on the Simulation side).

Actually, before looking at the OSMoSE SSO (because not available yet at the time), we could analyse the ontology developed as part of the ConfigDB study [**AD05**], which is modelled already on ORM. The ConfigDB ontology translates in ORM the conceptual models originating from several sources:

- CAPELLA ARCADIA model
- DLR Spacecraft Parts model
- SSRA model

The ConfigDB analysis outcome applies as well to the OSMoSE SSO MBSE ontology because there are a lot of similarities between the two ORM models. Actually, the OSMoSE model is based for a great part on the Capella model because the goal of OSMoSE is to define a common semantics/format among all the MBSE tools which can possibly be used by major actors in the European space industry (i.e. ESA, CNES, DLR, ADS, TAS, OHB…).

Analysis of the mapping to CAPELLA (and of course the related part in the ConfigDB/OSMoSE ontology) has been supported by Thales Alenia Space in the study consortium.

On the EDS side, the SAVOIR-EDS was analysed with success. No particular issues are raised.

Below is a table that summarises the mapping results for both Simulation Models and Simulators.

Capella	SAVOIR-EDS	SSO MBSE	SSRA
Data Types	EngineeringData	X	ValueType
PhysicalComponent	BehaviouralView/ Equipment	Physical Component	EquipmentModel
ComponentPort **PhysicalPort**	ElectricalView/ Interface End Bus Signal Type EngineeringData/ NetworkPacket and Component AnalogEngineeringParameter DigitalEngineeringParameter	ComponentPort Physical Port	SystemIFLayerModel
StateMachine	BehaviouralView/ StateMachine Modes and Transitions	StateMachine	OperationalModel
LocalFunction **PhysicalFunction**	Behavioural View/Functional Behaviour Functional View/External or Internal Signals Functional View/Functional Data Power View/ PowerConsumptionInEquipmentMode Power View/ PowerDissipationInEquipmentMode	Function	CoreFunctionalModel
Actor or LogicalActor	N/A	Actor	PhysicalModel
X	N/A	X	Central Solver
PropertyValue **PropertyValueGroup**	EngineeringData	X	SimVarDefinition (type VT_PARAMETER)
ComponentPort **ComponentExchange** **ExchangeItem**	See EquipmentModel mapping	ComponentPort ComponentExchange ExchangeItem	SimVarDefinition (types VT_INPUT, VT_OUTPUT)
ComponentPort **Interface**	See EquipmentModel mapping	ComponentPort ComponentExchange ExchangeItem	Standard Simulation Port TmTcStreamPort
PhysicalPort **ComponentPort** **Extensions** **ViewPoints**	See EquipmentModel mapping	ComponentPort ComponentExchange ExchangeItem	SystemIfPort

FunctionalPort or ComponentPort	See EquipmentModel mapping	ComponentPort ComponentExchange ExchangeItem	PhysicalIfPort DynamicsIfPort PowerIfPort ThermalIfPort MagneticIfPort
FunctionalPort or ComponentPort	See EquipmentModel mapping	ComponentPort ComponentExchange ExchangeItem	ExternalIfPort
X	N/A	X	ODE Port
X	See SystemIFLayerModel mapping	X	Calibration/Conversion
Containment relationship	See EquipmentModel mapping	Containment fact types	Container
X	See Behavioural View	X	Schedulable Function
Error Model	See Functional View	X	LocalFunc FailureCase
REC and RPL feature to instantiate Components	N/A	X	SimulationModelUsage or SimulationModelOccurrence
PhysicalLink	N/A	PhysicalLink	System I/F Network
LogicalSystem **PhysicalSystem**	N/A	X	BenchDefinition BenchUsage BenchOccurrence
PhysicalLink	N/A	PhysicalLink	System I/F Network

Table 4-2. Mapping MBSE, EDS and Simulation

X: mapping could not be found

N/A: this mapping is out of the scope covered by the model

4.4.3.1 Main conclusions

In the above tables, it can be seen that the following Simulation concepts (from SSRA, which is the reference model for the Simulation world) are not covered or partially covered in the MBSE models (see the **X**):

- Physical Models
- Data Types
- Physical Link detailed semantics
- Model scheduling and dynamics
- Instantiation of simulation models (equivalent to say instantiation of equipment units, simulators and benches)

A more in-depth look to the table reveals that the degree of mapping coverage varies from one MBSE source to another:

- From the Simulation point of view, the SSO MBSE is:
  - Missing the Data Type concept
  - Missing the Property (configuration parameter of a Simulation Model) concept
  - Detailed semantics of the Connections between Equipment. (e.g. detailed definition for MilBus 1553, Spacewire… protocols not possible)
  - Missing the Instantiation concept for Equipment Unit (Simulation Model) as well as for the complete Spacecraft (Bench or Simulator)

- From the Simulation point of view, mapping with SSO EDS and CAPELLA is ok.
- None of the MBSE models supports:
  - Model scheduling aspects
  - Spacecraft environment & dynamics simulation

4.4.4 Second step, mapping through the ORM formalism

To define formally the MBSE-Simulation mapping, it is necessary to express all involved models in the same formalism (semantics and data format), i.e. an information model of the mapping needs to be formally defined. This formalism has been chosen as ORM, that is used by the OSMoSE SSO and that seems to be suitable to allow reaching the unification of all MBSE models: indeed, as the part of the SSO used in the first mapping step is a model of the MBSE universe of discourse, it is not difficult to imagine that EDS and Simulation can be created as two additional universes of discourse. When done, the mapping can be performed directly within the SSO using the ORM mechanisms. This will allow us to formalize correctly the mapping between the MBSE/EDS worlds and the Simulation world.

This means that we need to:

- Create and integrate the SAVOIR-EDS and SSRA Universes of Discourse in the Space System Ontology by translating their respective UML models to ORM.
- Then, the mapping can be performed within the SSO with both three models which are now available in ORM.

The work is illustrated in the following figure.

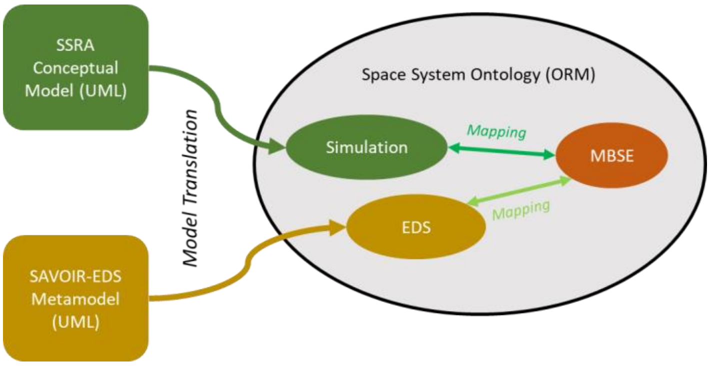

Figure 4-6. Mapping MBSE, EDS and Simulation through OSMoSE

Unsurprisingly and validating the work in the first step, the same mapping results are obtained (see Table 4-2 above for details).

4.5 Proof-Of-Concept

4.5.1 Proof-of-Concept Definition

Following the finalization of the MBSE, EDS and Simulation mapping through the OSMoSE SSO ORM model (i.e. all MBSE, EDS and Simulation UoD are reunified in the Space System Ontology ORM model), it was proposed to develop a small but representative Proof-of-Concept space simulator. The PoC simulator consists of an On-Board Computer simulation model connected to 3 Star Tracker simulation models via a MilBus 1533 bus plus a simple State Machine defined for the Star Tracker as shown below:

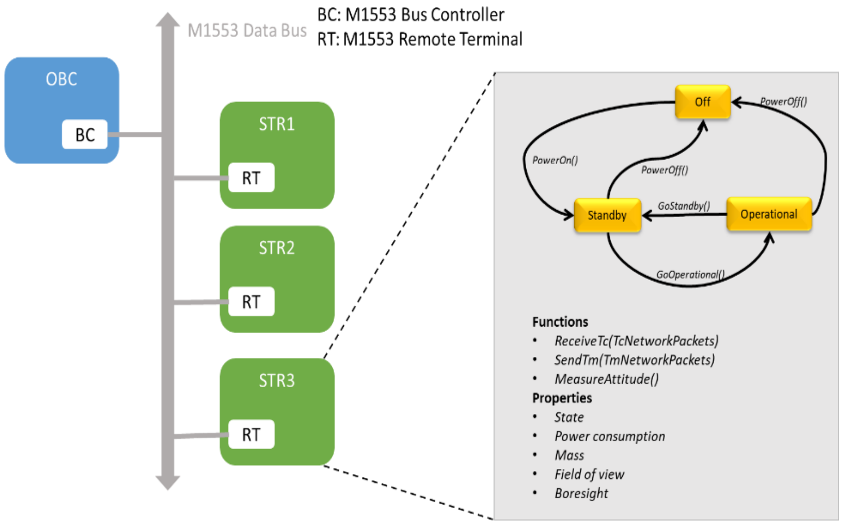

Figure 4-7. PoC simulator architecture

The goal is to generate the PoC simulator (defined by its associated SMP Catalogues and Assemblies) from the SSO data (i.e. populated database or Physical Model for the MBSE, EDS, SSRA UoD).

Thus, for the PoC, we specified which database tables are involved and populated. Only the database tables on the MBSE and EDS sides are populated, the Simulation side tables were populated automatically by the PoC software using the mapping defined in the analysis phase. Non-covered data (e.g. instantiation of models, data types… as depicted in the mapping conclusions) are provided on the Simulation side only by populating the corresponding tables in the database.

4.5.2 Proof-of-Concept Software Architecture

It was decided to implement the PoC in Python and to use PostgresQL as the underneath relational database.

Python is a programming language suitable to implement prototyping software such as the PoC. It is a complete, well-designed, heavy typed language, with very good supporting libraries and finally with a simple and intuitive syntax allowing a quick learning curve. This PoC is a very good opportunity to use Python for developing software which is otherwise developed usually in heavier languages such as Java.

There is no need to talk further about PostgresQL database, which is already a well-known database. The reason why it was chosen by the PoC is because PostgresQL is one of the SQL formats supported by the NORMA tool when exporting the ORM model to its corresponding Logical Model and because it is already used in the OSMoSE SSO community. Access to PostgresQL is also well supported in Python.

The PoC software architecture is shown in the following figure.

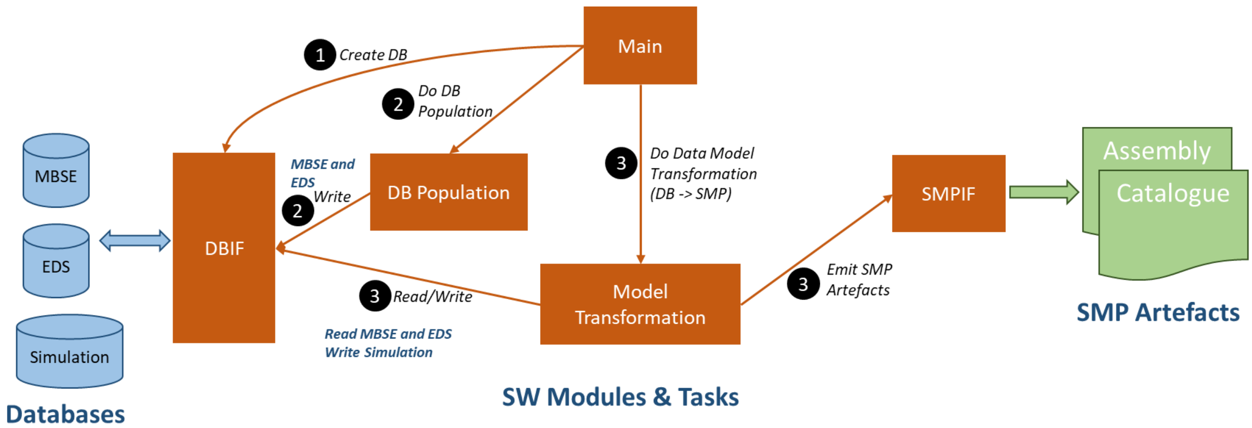

Figure 4-8. PoC software architecture

5 CONCLUSIONS AND LESSON LEARNED

5.1 MBSE/Simulation Information Exchange

The initial planned study logic (see Figure 4-2) was not followed completely, especially for the PoC phase. There was at the beginning (mapping step 1) a clear separation of the work lanes dedicated respectively to the Simulation Model/EDS and to the Simulator/MBSE System Information. But when the focus on the OSMoSE SSO was introduced, becoming the single data source offering the semantics and format that can unify all the data sources, an additional step (step 2) was taken. The study logic became like shown in the following figure:

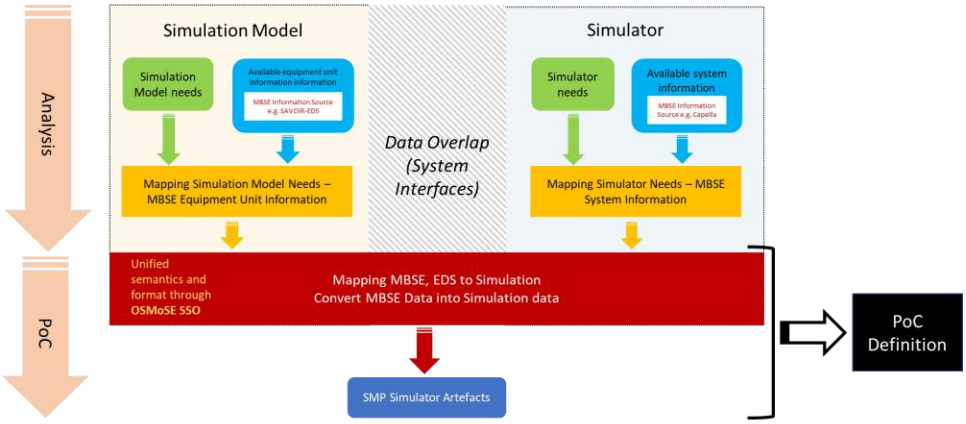

Figure 5-1. Actual Study Logic

It is believed that is the way that model transformation from MBSE to Simulation should follow, i.e. a common framework unifying data semantics and format should be the basis of the model transformation. Whether this has to be the OSMoSE SSO is still to be further studied because according to the mapping found in this FS2SA study, we can summarise our findings as follows:

- Information exchange between Simulation and CAPELLA, as a typical real MBSE tool/infrastructure, is possible: no major issues or gaps identified
- However, the information exchange between Simulation and the SSO MBE is incomplete: gaps identified for the following concepts
  - Data types
  - Instantiation of concepts
  - Properties
  - Physical link semantics

Furthermore, we can conclude that we need to be careful with the terminology/vocabulary used when exchanging information between MBSE and Simulation because that can be quite different from the two worlds. As a good example, a common understanding of the "instantiation" term in both worlds was not at all obvious to reach.

We understand also that the OSMoSE SSO MBSE universe is a conceptual model defining generic concepts independent of MBSE infrastructures/tools. In this case, it is normal that the concepts therein cannot be mapped completely to the simulation concepts, which are defined in a quite exhaustive way in SSRA. Further analysis or extensions of the SSO MBSE to cover specific discipline aspects (such as Data Handling, Power, Thermal, AOCS…) are necessary to complete the modelling in the Space System Ontology.

Finally, despite the interactions with the SSO experts during the study, it was difficult to understand the full scope and future application of the OSMoSE Space System Ontology? Following questions are still unanswered (or further clarifications are needed):

- Will the SSO serve the System Engineering purpose, for example being integrated in a MBSE development process? It is hard to understand yet how the SSO will be integrated in the System Engineering process because it is not yet mature enough to be deployed and used in practice in the Industry.

- Or will it serve the MBSE data exchange purpose between MBSE tools which otherwise work with incompatible format data? One can imagine that the SSO is integrated in a Data Hub and serves as an intermediate data model to convert the data model of MBSE Tool A to the data model of MBSE Tool B. Making this data conversion scheme possible can obviously enable exchange of data models between different incompatible MBSE tools/environments. Note also that the concept of Data Hub does not only allow conversion of MBSE models between tools but allows as well exchanging data between worlds (MBSE, Disciplines, Simulation…).

Another issue, which we believe is a major one, to address (for example, in a follow-up study) is to further investigate on what could be the unique data source for equipment unit data. Indeed, when creating the EDS UoD in the SSO, we realise that the equipment unit data source is not unique:

- First data source: actual Electronic Data Sheet delivered by the manufacturer in the CCSDS EDS format (which is usually tailored by the System Integrator). This is reflected in the SSO EDS UoD based on SAVOIR-EDS that we created during this study.
- Second data source: the data could also come (it is possible to model this data) from the MBSE environment itself. For example, both SSO MBSE and Capella can model equipment unit data. This is especially relevant for unit information that is not provided by the manufacturer but added at System Integration level, such as performance measurements. In this case the Equipment Unit information could reside in the MBSE domain, with the EDS being integrated in the MBSE tool (EDS information is mapped to the concepts of the data model governing the MBSE tool).

In any case, parallel presence of SSO MBSE and SSO EDS models implies a strong overlap and duplication of information, that needs to be solved.

5.2 Software Technologies

The FS2SA study consortium, which uses to work with Object Oriented formalism (mainly UML), has no deep experience with Object Role Modelling (ORM). It is thus difficult to bring in our contributions to ORM based modelling. However, we have contributed to the creation of the EDS and Simulation UoD in the SSO and we could have identified some issues when implementing the PoC (see [**Error! Reference source not found.**]). These models should be further reviewed and corrected if necessary by the SSO experts if found interesting in future works. Going from OO to ORM is of course feasible but is found somehow difficult because that transition implies usually a mind-switch in the reasoning and thinking process. We could also observe that tool support of ORM is quite limited: it seems that NORMA Pro is the only tool that satisfies the needs in ORM modelling. While this limitation in tooling does not exist for UML design tools (MagicDraw, Enterprise Architect, Papyrus, Sirius…).

In addition, it has been found that Python is particularly efficient and productive to process MBSE data and in the interaction with databases. The same observation applies to the use of Python to produce SMP artefacts (Catalogues and Assemblies). It is a good candidate in later development related to the exchange between MBSE and Simulation for replacing heavier language such as Java (note that said, the light/heavy statement remains a quite subjective notion).

5.3 MBSE and Simulation Exchange Long Term Vision

During a Model Based System Engineering process, that could cover the whole development cycle of a space system, needs for Simulation will occur at one moment or another. This means that information exchange will become a requirement. Therefore, the seamless and close integration of Simulation in the MBSE process should be the long-term goal. Generation of simulation models and simulators from MBSE data can then be achieved through what is called a Data Hub, that is able to convert incoming data to outgoing data supporting various data semantics and formats – the OSMoSE SSO could become the unifying MBSE data model to serve the Data Hub purpose. Feedback from this FS2SA study could be considered as a first step to develop the MBSE Data Hub.

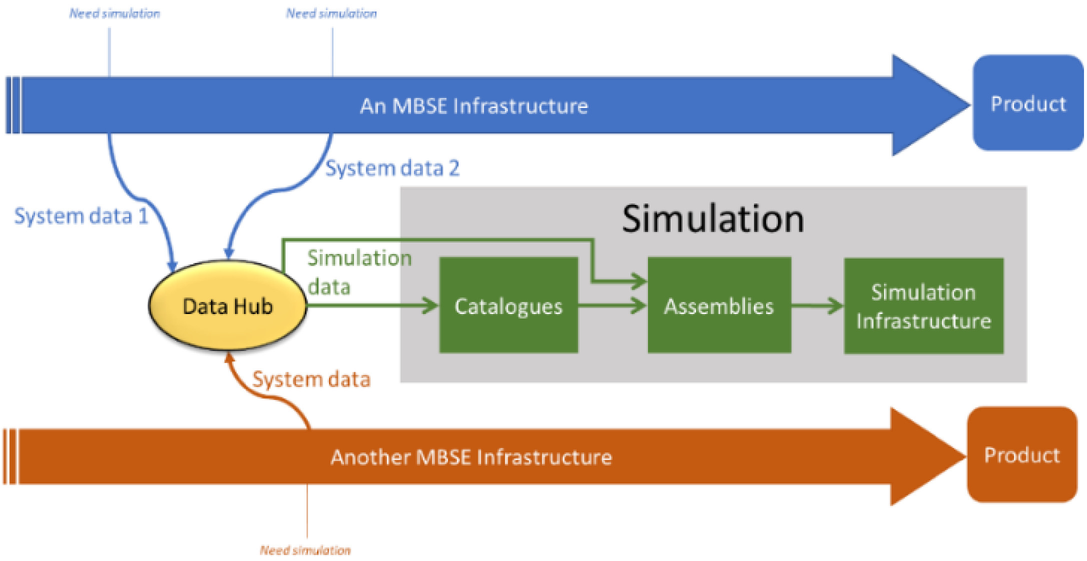

Figure 5-2. Vision of a possible MBSE and Simulation integration

Program:
S2SA

Project:
From System to Simulator Architecture

Document Title:
Executive Summary Report

Reference:
SPB-S2SA-TN-006

Issue:
1.0DRAFT

Date:
19/04/2023

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