Management of Modeling and Simulation Processes and Data for Space System Applications

MARIA, R.B. [1], SOUZA, M.L.O.[2]

[1]Instituto Nacional de Pesquisas Espaciais, São José dos Campos, SP, Brasil
M.Sc. Candidate at the Course of Space Engineering and Technology (ETE)/Engineering and Management of Space Systems (CSE).

[2]Instituto Nacional de Pesquisas Espaciais, São José dos Campos, SP, Brasil

rodrigo.britto@inpe.br

Abstract. *Currently, Modeling and Simulation (M&S) are part of the "dreams" of many organizations due to their power and versatility; but are also part of their "nightmares" due to the amount and variety of processes and data. To handle this problem, solutions have been proposed and denominated Simulation Process and Data Management (SPDM). This paper summarizes one such solution studied in an ongoing Master Dissertation: how an organization developing a space system must manage its modeling and simulation processes and data generated by them, according to the ECSS standards. The method used in this work consists in stating the problem and its requirements, investigating solutions, verifying the chosen solution, and validating it. The final solution consists in an environment integrating two software (RCE and VirSat) developed by the German Aerospace Center (DLR), and a methodology for using this integration. This intends to be considered by organizations, like INPE, using M&S heavily.*

Keywords: Modeling and Simulation Processes; Simulation Governance; Data Management.

1. Introduction

The management of modeling and simulation processes and data is a key aspect of product development, as it enables the perpetuation of the technical memory of organizations. It allows the reuse of best practices and is the base for continuous improvement processes.

This technology became known in the past few years as Simulation Process and Data Management (SPDM), an acronym created by NAFEMS (formerly known as National Agency for Finite Element Methods and Standards), an international not-for-profit organization dedicated to the establishment and dissemination of best practices in engineering modeling, analysis, and simulation. Software vendors, recognizing the need for the deployment of SPDM in engineering organizations, have developed SPDM systems that are able to manage digital assets from simulation such as workflows, models, solvers and results.

Organizations interested in the increase of profitability and product quality, as well as reducing the time-to-market of their products, can benefit from SPDM. They can either develop their own SPDM systems, or deploy out-of-the-box SPDM systems from software vendors. The German Aerospace Center (DLR), has developed its own software for managing modeling and simulation processes and data, the Remote Component Environment (RCE), which is made freely available as open source software. RCE is a software framework that can be extended for specific applications. For satellite development purposes, DLR has extended RCE to create the Virtual Satellite (VirSat) software, which is not open source but can be downloaded and used by any organization.

The objective of this work is to analyze how RCE and VirSat can be used to manage digital assets from models and simulations in the context of a satellite development project.

2. Method

This work began with the identification of the stakeholders and the definition of the problem, which was later translated into stakeholder requirements. Then, the requirements that the system to be proposed should attend were defined. In the sequence, RCE and VirSat were individually installed and configured to investigate solution alternatives. An integration of RCE and VirSat was conceived and proposed as the solution, which was later developed. The solution was verified to check if system requirements were being met. Finally, a space system use case of simulation management was developed using the proposed solution, to validate it.

3. Results and Discussion

People working with Modeling and Simulation (M&S) at the National Institute for Space Research (INPE) in Brazil, were identified as the main stakeholders of the system to be developed. An interview was conducted with Suely Romeiro, an INPE M.Sc. Candidate working with M&S, to identify the organization needs and later derive its requirements.

The need statement which defines the problem to be solved is: "M&S people at INPE need a solution to preserve the technical memory of the organization, allowing them to reuse engineering design data from past projects". The need statement was later translated into preliminary stakeholder requirements, which can be seen in Table 1.

Table 1. Stakeholder requirements

Requirement #	Stakeholder Requirements
STKH01	M&S people at INPE shall be able to manage parameters of space systems and subsystems for simulations of space missions.
STKH01.1	M&S people at INPE shall be able to store parameter values of space systems and subsystems for simulations of space missions.
STKH01.2	M&S people at INPE shall be able to retrieve parameter values for each design revision of space systems and subsystems.
STKH02	M&S people at INPE shall be able to manage simulation processes and data used in the design of systems and subsystems.
STKH02.1	M&S people at INPE shall be able to identify simulation workflows

	and data used for each system and subsystem design.
STKH02.2	M&S people at INPE shall be able to correlate input parameters from a given system or subsystem design to the simulation workflow that used them.
STKH02.3	M&S people at INPE shall be able to correlate output parameters from a given system or subsystem design to the simulation workflow that originated them.
STKH02.4	M&S people at INPE shall be able to include software developed by them into the simulation workflows.

These requirements were later translated into preliminary system requirements, which can be seen in Table 2. The system referenced here means the complete solution to attend the stakeholder's needs.

Table 2. System requirements

Requirement #	System Requirements
SYS01	The system shall let its user control parameters of space systems and subsystems for simulations of space missions.
SYS01.1	The system shall let its user store simulation parameter values for each design revision of a space system or subsystem.
SYS01.2	The system shall let its user identify simulation parameter values for each design revision of a space system or subsystem.
SYS02	The system shall let its user control simulation processes and data used in the design of systems and subsystems.
SYS02.1	The system shall let its user identify simulation workflows and data used for each system and subsystem design.
SYS02.2	The system shall let its user identify the correlation between input parameters from a given system or subsystem design and the simulation workflow that used them.
SYS02.3	The system shall let its user identify the correlation between output parameters from a given system or subsystem design and the simulation workflow that originated them.
SYS02.4	The system shall let its user integrate user-developed software into the simulation workflows.

To propose a solution to attend these requirements, an important constraint is the limited budget available to invest in software licenses and hardware infrastructure, as well as in software development. Then, only open source software solutions were investigated.

One of these solutions is the Open Concurrent Design Tool (OCDT), a client/server software package developed under a European Space Agency (ESA) contract to enable efficient multi-disciplinary concurrent engineering of space systems in the early life cycle phases. OCDT implements a standard semantic data model defined in Annex A of the ECSS-E-TM-10-25 Technical Memorandum, titled System Engineering - Engineering Design Model Data Exchange [ESA, 2017]. However, OCDT is only available to people working for (or enrolled as student at) organizations that legally reside in an ESA member state or cooperating state, so it could not be tested.

Another investigated solution was the Remote Component Environment (RCE), an open source software framework developed since 2005 by DLR [SEIDER et al., 2012]. RCE was developed to provide engineers of different disciplines with a common collaborative environment, allowing them to share data and tools in a managed way. RCE allows the development of collaborative workflows where each engineer can be responsible for one step of the simulation process. Built with reuse as one of its core requirements, the RCE software framework was used as a basis for two other systems developed by the DLR: the Chameleon, an environment for preliminary aircraft design, and the Virtual Satellite (VirSat), a support application for concurrent engineering sessions for space applications.

As both RCE and VirSat were available for download and use, they were evaluated and selected as the base for the simulation process and data management system to be used at INPE.

RCE can be used to create a peer-to-peer network to exchange simulation processes and data among their users. Any RCE user can create individual applications (known as "components" in RCE) or complete simulation workflows (connected components exchanging data among themselves) and share them in the network. Simulation runs and data used by them are accessible to any user, from any computer logged into the RCE network.

VirSat also implements the standard semantic data model defined in Annex A of the ECSS-E-TM-10-25 Technical Memorandum. Using VirSat, a space system can be modeled as a hierarchy of systems, subsystems, and components. Each of them can be assigned parameters that comply with the Quantities, Units, Dimensions, Values (QUDV) standard of SysML [OMG, 2017] and calculations using these parameters. As an example, system A is composed of subsystems A1 and A2. The system and subsystems have parameters to indicate their masses. System A can have a calculation (in form of an equation) to automatically compute the parameter value for the total system mass, by adding the parameter values that represent the masses of the subsystems. The calculation engine in the background automatically verifies the units and converts them, if necessary.

VirSat uses a Subversion (SVN) repository as its central database. All users connect to this database to download and upload system information, which is written in XML format. Users can commit their data changes (as new parameter values) and SVN keeps track of them, so it is possible to assess any previously submitted data. Also, for each system, subsystem and component, VirSat creates a folder under the "fileStore" directory named with an unique identification composed of a random combination of letters and numbers. All data copied to these folders become part of the system, subsystem and component definition and are also versioned by SVN.

One of the drawbacks of VirSat is its lack of an advanced simulation capability. It is only currently possible to define basic parameter calculations such as additions or multiplications. It is possible, however, to map parameter values to Microsoft Excel® spreadsheet cells and write more elaborate equations using Excel.

The solution proposed to meet the system requirements shown in the Table 2 is an integration of RCE and VirSat. An RCE application that exchanges parameter values with VirSat was developed. This application reads input parameter values from VirSat, uses them to run a customizable simulation in RCE and then writes the simulation results as updated parameters back in VirSat. This application compensates for the lack of VirSat advanced simulation capabilities. Another RCE application was developed to publish simulation workflows, including its data, to the VirSat SVN repository. This allows a user to keep track not only of the parameter values, but also of the simulation data that generated them.

Test runs using the proposed solution were used to verify the requirements. A test space system was created in VirSat, including test input parameters. The first commit was made in the SVN repository to save the changes. Then the RCE application that exchanges parameter values with VirSat was run. This application read the input parameters from VirSat, based on the system unique identification number, ran a test simulation, and wrote its outputs back to VirSat as updated output parameters. Then the RCE application that publishes simulation workflows was run to publish the simulation data to the system folder under the "fileStore" directory of VirSat. A second commit was made in the SVN repository to save the changes. This time, not only the parameter values were updated, but also the files used in the simulation were saved in the central repository under the same revision number.

A space system use case was developed to validate the proposed solution. It consists in the development of an Attitude Control System (ACS) for a satellite. The system was modeled using MATLAB® and Simulink®. A system hierarchy was created in VirSat, defining the ACS as a new subsystem. The variables used to initialize the simulation in Simulink were modeled as subsystem parameters in VirSat, which can be seen in Figure 1.

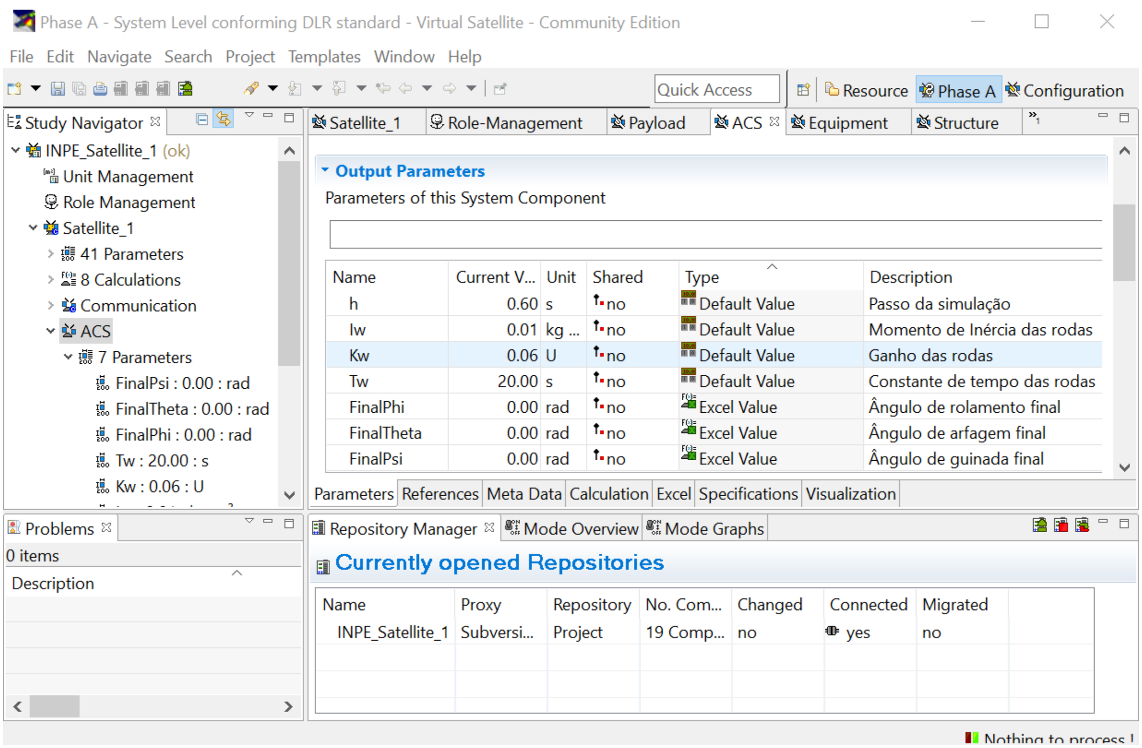

Figure 1. Virtual Satellite user interface.

A simulation workflow to run the Simulink model was created in RCE, including the applications needed to integrate it to VirSat, which can be seen in Figure 2. To keep track of parameter changes, they need to be defined first in VirSat, and then used in RCE to simulate the system behavior. The workflow was created in such a way that the input parameter values are saved as MATLAB m-files to initialize the simulation. At the end of the simulation run, MATLAB writes an output file that is read by RCE. Output variable values are read from this file and written in VirSat as output parameter values. Additional data generated by MATLAB and Simulink, such as text files containing time-history curves of selected variables, can be exported by RCE to the VirSat SVN repository and committed as many times as necessary during the system development.

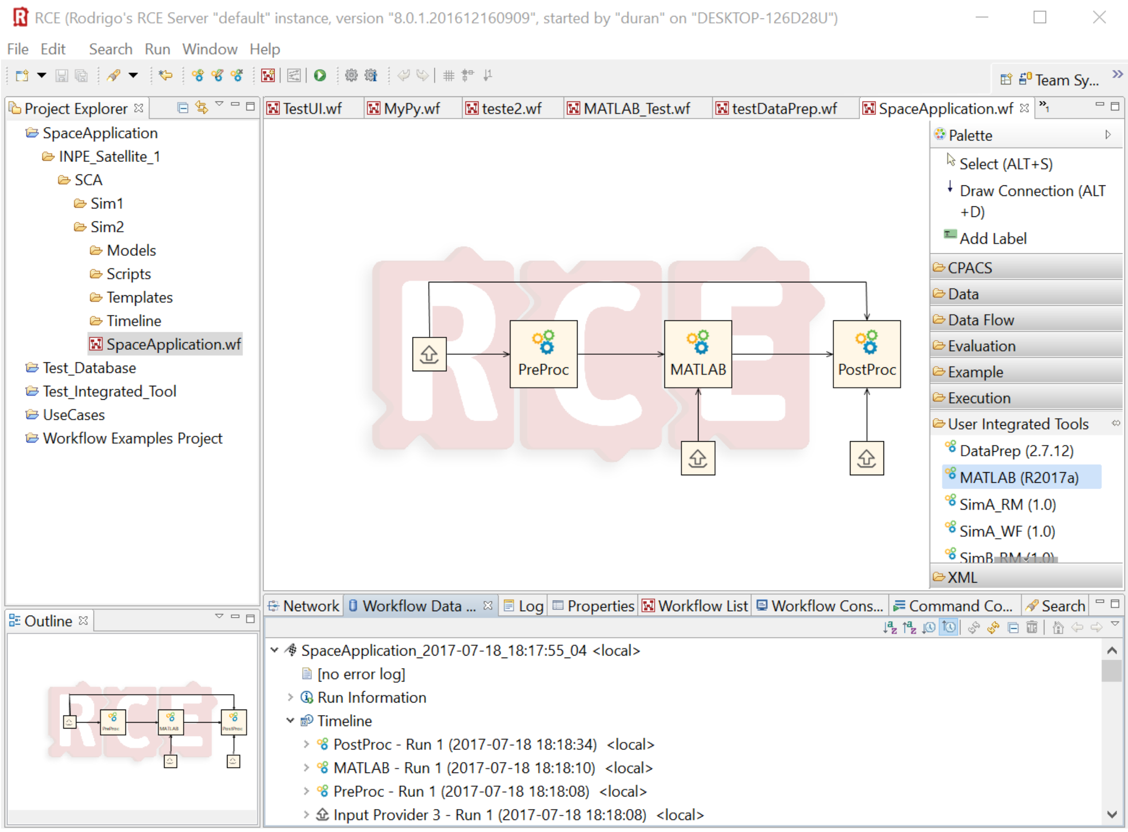

Figure 2. RCE user interface.

4. Conclusion

The management of M&S processes and data preserves the technical memory, allows the reuse of tools and methods and accelerates product development. The proposed solution of integrating the RCE and the VirSat, developed by DLR, is a low cost and viable solution to manage processes and data which has already been proved in practice by DLR, is being studied in an ongoing Master Dissertation, and was summarized in this paper, intending to be considered by organizations, like INPE, using M&S heavily.

References

ESA (2017). “OCDT Community Portal”. Available in https://ocdt.esa.int/. Accessed on: July 25, 2017.

OMG (2017). “OMG SysML Portal: Quantities, Units, Dimensions, Values (QUDV)”. Available at http://www.omgwiki.org/OMGSysML/doku.php?id=sysml-qudv:quantities_units_dimensions_values_qudv. Accessed on July 25, 2017.

SEIDER, D.; LITZ, M; SCHREIBER, A.; FISCHER, P. M.; GERNDT, A. (2012) “Open source software framework for applications in aeronautics and space”. In: IEEE Aerospace Conference, 2012, Big Sky, MT, USA. Proceedings... IEEE Xplore Digital Library, 2016, p. 1-11. Available at: <http://ieeexplore.ieee.org/document/6187340>. Acessed on: April 2nd, 2015.