Data Collection Subsystem Modeling and Simulation Using Simulink

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Abstract. *TThis article presents the result of an experiment developed during the short internship of the Winter Introductory Course on Space Engineering and Technology at INPE which supported the SIMCBERS simulator modeling and verification. It was implemented a performance model of the Data Collection Subsystem using Simulink. The results that came from this experiment were very satisfying, because it was possible to demonstrate, in an easy and quick implementation of the Subsystem in a graphic language, how to verify the performance requirements and to validate the behavior models of a subsystem.*

Keywords: Modeling & Simulation, Verification & Validation, Data Collection Subsystem (DCS).

1. Introduction

The Winter Course on Space Engineering and Technology takes place at Brazilian Institute of Space Research (INPE) every winter term. Its main goal is to give to undergrads basic information on space engineering and technology. The activities include seminars to present INPE's research areas and a short internship in which the student can develop a practical activity. [CI 2016]

The practical activity of the short internship, developed in 2016 under our tutoring, consisted of implementing and to simulating a Subsystem Model of the CBERS-4 Satellite Operational Simulator (SimCBERS), under development, and to compare the results against the results of the existing simulations. The developed activity included, mainly, three areas: (i) Modeling and Simulation, (ii) Verification and Validation, (iii) Satellite Subsystem.

The main goal of the proposed activity was to validate the concept adopted to model the subsystem, now using another platform, in this case Simulink, as a way to

identify the difficulties in the interpretation of these concepts, which are a problem during the development stage. Thus, the subsystem chosen to be implemented in the Simulink was the Data Collection Subsystem (DCS), since DCS is a small subsystem compared to others CBERS Subsystems, and there was and and already tested and validated implemented version running in the simulator.

The challenge was to deal with the short period of time available to execute the activity and the student immaturity related to the propose activity.

This article presents the developed activities during the internship period and, shows that the concept used to implement the models, in the context of the simulator, is easy to understand by an amateur programmer.

From now on, the models implemented in the SimCBERS context (including DCS) will be called "SimCBERS-Model"and the model implemented in Simulink will be called of "Simulink-Model".

2. Simulation Supporting the Verification & Validation Activities

Validation demonstrates that "the right system has been done", while the verification demonstrates that "the system has been done right". [NASA 2007]

One important technique that supports verification and validation activities is the simulation, which allows to measure the performance and/or evaluate the functions of the artifact under verification [Eickhoff 2009] at different stages of the lifecycle development, which can generates some benefits, such as reduction of risks and costs.

The latest and more complex simulator described by [ECSS 2010]] for satellite mission verification and validation is the Operational Simulator. In this kind of simulator the activities of modeling and simulation are performed to ensure that the ground segment and the operation team are ready to support the activities of satellite monitoring and control after its launching. Between the main objectives of the Operational Simulator, it's highlighted: (i) Validation of the proceedings of flight control; (ii) Operational Team Training; and (iii) Support to problems resolutions and maintenance during the Satellite operation.

The Operational Simulator should represent the behavior of the satellite and the payload in such a way that the telemetries of the simulated satellite and the actual satellite are indistinguishable to the operational team.

3. CBERS Satellite

The satellite Sino-Brasileiro of Earth Resources (CBERS, in English, *China-Brazil Earth Resources Satellite*), illustrated in the Figure 1, is a result that comes from a partnership between Brazil and China in the space segment. CBERS-4, currently in operation, has 15 subsystems [CBERS 2016], including payloads and service subsystems.

It is a complex of the satellite with a high level of investment – around US\$150 millions from each country [CBERS 2016]. Thus, it is necessary to use tools that support the satellite's operational activities after its launch, as an operational simulator.

SERVICE MODULE
- OBDH (On-Board Data Handling)
- AOCS (Attitude and Orbit Control)
- TTCS (Telemetry, Tracking and Command S-Band)
- TCSS (Thermal Control)
- SYCS (System Circuitry)
- EPSS (Electrical Power Supply)

PAYLOAD
- PAN (Panchromatic Camera)
- IRS (Infrared Scanner)
- PIT (PAN and IRS Data Transmission)
- MUX (Multispectral Camera)
- WFI (Wide Field Imager)
- MWT (MUX and WFI Data Transmission)
- DDR (Digital Data Recorder)
- DCS (Data Collection)
- SEM (Space Environment Monitor)

Figure 1. Conceptual View of CBERS−4. [CBERS 2017].

3.1. SimCBERS - CBERS-4 Satellite Operational Simulator

According to [Ambrosio et al. 2006], the SimCBERS simulator performs simulation with a reasonable level of fidelity, which makes the simulator an essential tool to support operational activities by analyzing satellite behavior, including interaction between the subsystems, in normal and abnormal situations. In this context, the simulator includes the following models: space environment, the CBERS subsystem and the ground station communication.

The subsystem models are implemented in a language independent of the simulator core language and are subsequently connected to, interpreted and executed by the simulator. This work is focused on the subsystem virtual model, whose functional specification is described in [Tominaga et al. 2012].

4. Data Collection Subsystem (DCS)

According to [Teixeira Junior et al. 2011] the DCS is responsible for collecting environmental data from data collection platforms (DCPs) distributed throughout Brazil. The environmental data such as humidity, pressure, temperature, wind direction and speed are subsequently retransmitted to the ground stations located in *Cuiabá* and *Alcântara*, which send them to the Mission Center located in *Cachoeira Paulista* for processing and ditribution to users. The DCS subsystem, whose photo is shown in Figure 2, is composed of the following equipment: (i) transponder; (ii) UHF Transmitter; (iii) Diplexer; (iv) Coaxial cables [OMNISYS 2016].

The electrical-behavioral characteristics of the DCS subsystem were established and represented following the view and modeling rules described in [Tominaga et al. 2012, Tominaga and Ambrosio 2012], , while the model technical specification (programming language independent) of the DCS models is given in [Ambrosio et al. 2016]. Based on the model specification, the DCS was implemented and connected to the simulator.
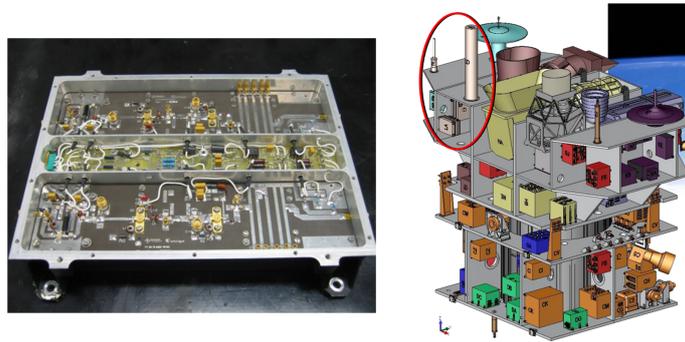
Figure 2. DCS photo, left. DCS inside CBERS, right. [OMNISYS 2016]

5. Simulink-Model Implementation and Results

The Simulink-Model was implemented using the Finite State Machine Notation (MEF), in accordance with [Ambrosio et al. 2016], which presents the behavioral model of the DCS. Thus, from the DCS Technical Specification, both the Simulink-Model and SimCBERS-Model were generated, as illustrated in the Figure 3. The DCS SimCBERS-Model already validated generated reliable results, which made possible the compassion with the results of Simulink-Model.
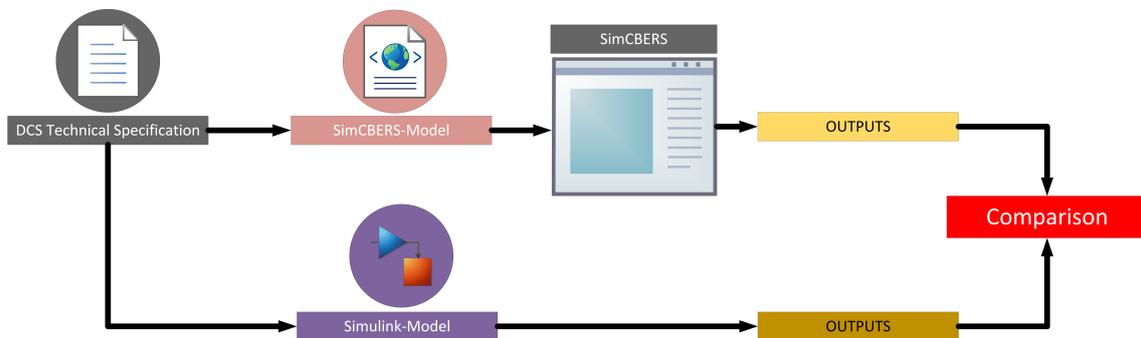
Figure 3. Models Comparison.

Figure 4 presents the DCS Simulink-Model.
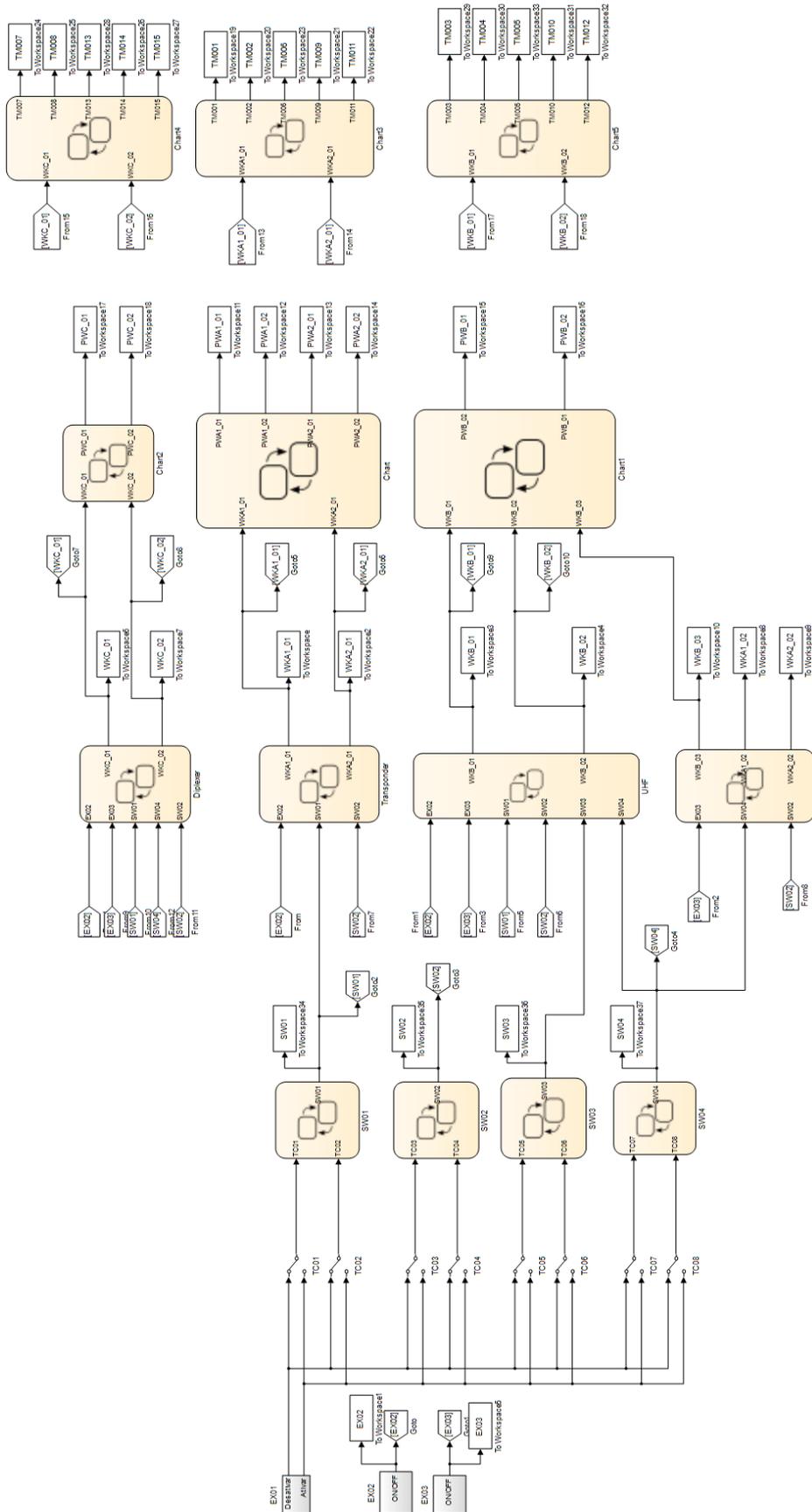
Figure 4. Modelo-*Simulink* do DCS.

In order to simplify the implementation, we used "0" to represent situations in which keys and equipment were turned off or disabled and to inform the subsystem when a telecommand is not send, and "1" to represent the situations in which the switches and equipment were switched on or activated and to inform to subsystem a telecommand was sent.

Figure 5, presents the detailed Simulink-Model, where it is observed: (a) telecommands, (b) switches, (c) equipment working state, (d) power consumption e (e) telemetry.
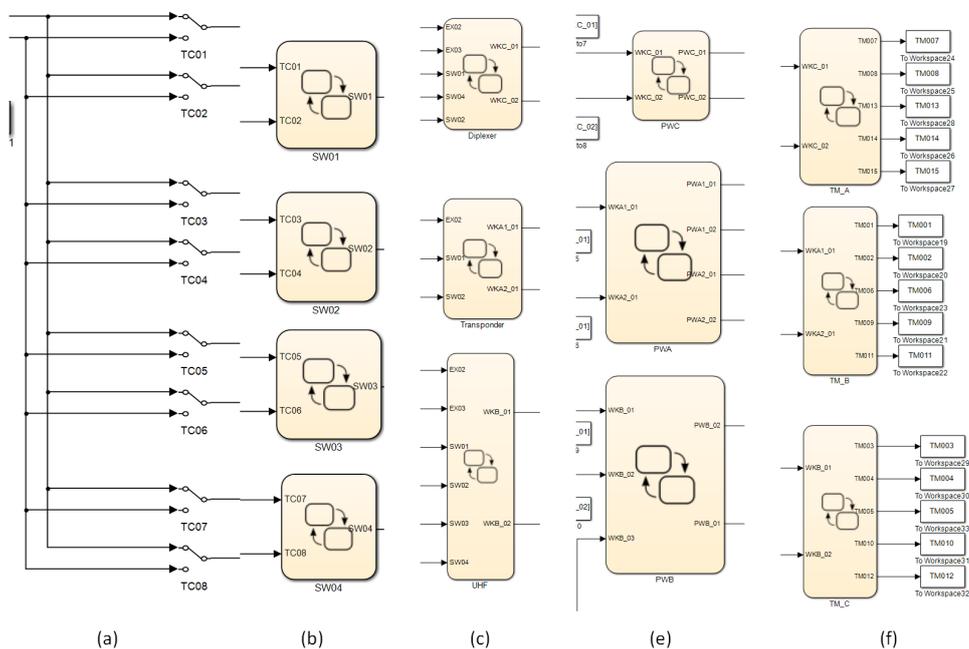
Figure 5. Detailed Simulink-Model.

In the Simulink-Model neither the thermal dissipation was implemented nor the model directly display the subsystem operation model. So it was necessary to create another MEF block, so that, given the combinations in the input, the output would return the operation mode of the DCS.

On concluding the implementation, several simulations were performed to verify if the model implemented in Simulink was responding according to the specification and according to the SimCBERS-Model simulation results. To make the model more faithful to the specification, the outputs of "0s" and "1s" were translated to "OFF" and "ON", respectively.

For the comparison purposes, the test described in [Tominaga and Gonçalves 2015] was run on both models, i.e., in the SimCBERS-Model and the Simulink-Model. After the execution, the outputs containing the values obtained during the simulation were compared manually. It was realized that the results presented the same behavior, in this way it was possible to validate the Simulink-Model, and also, verify the functions of the DCS against requirements.

6. Conclusion

The results of the practical activity proposed during internship of Winter Introductory Course on Space Engineering and Technology were positive. The student get knowledge form the documentation related to DCS, she was able to implement the behavioral model of the subsystem and simulate it. Since the Simulink-Model behaved in the same way as the SimCBERS-Model we could show that the Technical Specification used to implement the models for SimCBERS is also valid for another type of implementation, such as as graphical languages, the Simulink.

In addition, the results also show that the MEF implementation, which is more user friendly, provides a more fluid understanding of information and rapid development (one week, by an engineering student). This can be considered as an advantage, since an inexperienced developer can easily assimilate information.

The implementation in Simulink also made possible to validate the operation of DCS without the need for a complete Operational Simulator. Thus, it is possible to use this tool for other projects or to apply the idea to subsystem verification in an isolated configuration, or when there is no available simulator and it is desired to verify and validate the subsystems model.

However, it should be noted that the use of Simulink does not replace, for the time being, the implementation of the models in the language in which the simulator is able to interpret.

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