AMORE – AN ACCREDITED MODEL REPOSITORY TOWARDS THE REUSE ON AOCS PROJECTS

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ABSTRACT

In this work, we present a methodology for creating an accredited model repository to increase the level of software reuse in the development of Spacecraft Dynamics Simulators (SDS). After a brief introduction of the state-of-the-art on spacecraft simulators and their role in space engineering activities, the paper will describe our process for selecting, converting and building a catalogue of models for future reference and reuse. This is demonstrated using a set of models developed for the Attitude and Orbit Control Subsystem (AOCS) of Amazônia-1, the first mission that will be based on the Brazilian Multi-Mission Platform. Afterwards, three studies were conducted based on simulators built with models from the repository. The assessed level of software reuse encourages the adoption of the methodology for future projects of SDS.

Simulation plays an important role in the AOCS design, construction, testing, verification and validation and hence, a reliable infrastructure is crucial to achieve a successful result. Typically, the AOCS projects involve the interaction of several teams and, often, each team employs specialised tools in their activities, with little interoperability and lacking on reuse. As the demands for embedded software increases, additional verification and validations tools are required, bringing the opportunity to rationalize their use and the overall engineering process.

Nowadays, a common approach for building space systems is to adopt a model-based system engineering process, where the activities are conducted by the elaboration of domain models, which can be interchanged among teams. Such a process is often supported by simulators that execute the models in certain scenario conditions and anticipate the verification of the product. In the case of AOCS, for instance, the control engineering team designs the control law (typically using tools like Matlab/Simulink®) and in the next phase the computing team verifies and validates the on-board software, after the control algorithm has been automatically generated to a programming language for embedded systems (.e.g. Assembly, C, ADA). In both cases, the test harness is composed by infrastructures that simulate all environmental conditions to evaluate interfaces, functionalities and performance of the controller software.

Besides the complexity of the spacecraft, the construction of simulators itself demands substantial amounts of resources. Due to the particular needs of each developing phase, the features of simulation infrastructure have to be tailored (e.g. different levels of fidelity, real time constraints). Still, many software components, modelling efforts and test procedures can be available from one phase of the project to another. In this sense, it is expected that reusability and automation requirements increases on quantity and quality on ground software systems,

envisaging the optimization the project's timeline and resources. This concern is being reflected in the way the spacecraft simulation architectures are designed and in the process of building simulations as the project evolves. For instance, in the Technical Memorandum on System Modelling and Simulation (ECSS-E-TM-10-21A), the European community defines eight types of simulation facilities that support space engineering activities, identifying their communalities.

Looking in this direction, by means of building the model repository AMoRe, our work aims to reduce the lack of software reuse in attitude and orbit control projects. Our approach consists in guiding the development of models in a component-based way, which starts with the configuration of Matlab® models built in the earlier phases of algorithms design and validation activities. The candidate scripts for reuse are identified and a set of metadata is collected, such as name, description, constraints and limitations, input and output parameters, external dependences, etc. Before the model can be made available in the repository, its source code must comply with a standardised naming and coding style and be accompanied by a set of testing artefacts (harness, data, scripts and reports). It is also encouraged that all models use the same constants and reference system profiles to maximize the compatibility and consistency.

Once available in a proper catalogue, the models can be easily deployed and assembled "as is" for further Matlab® studies. However, to be practicable their use in a different environment, e.g. on-board software validation facility or real-time simulators, the software artefacts must be translated to another programming language. In the case of C/C++, this step can be automated, however usually the generated code is poor on readability or the generator tool is too expensive for the scope of our project. Thus, a semi-automated process was adopted, where the Matlab® code is translated to C++ using a common algebraic library and wrapped by a standardised interface. The detailed process is described in the paper, with examples of generated codes.

This methodology has been applied for the last three years in a training project in the field of AOCS testing, conducted at the Brazilian Institute for Space Research (INPE), taking the AOCS of Amazonia-1 satellite as a test bench. The repository provides artefacts for modelling typical equipment (Coarse Solar Sensors, Star Trackers, Magnetometers, Gyroscopes, Reaction wheels, magnetic torque rods and Thrusters) and space environment (Orbit dynamics, attitude dynamics, geomagnetic fields, celestial sphere, Earth's albedo, Sun position and dynamic perturbations).

The advantage of using AMoRe is evaluated from metrics collected from simulators constructed for recent studies at INPE. The domain of the studies were on: (i) the characterization of the inherent errors presented in the Star Track sensors of Amazônia-1 satellite and the optimisation of their positions based on the observed sky; and (ii) the assessment of propellant mass budget for SabiaMar satellite. Later, all studies and adopted models are presented in more details.

Concluding, the paper describes an effort towards the reuse of software for satellite AOCS verification and intends to be a contribution in the context of the design of an Electric Ground Support Equipment. The approach allows a well-defined rule for the design team members among problem modelling mathematics and software architecture definition. It foresees an increasing level of reuse by addition of abstract layers to the sensor and actuators models. Additionally the model accreditation process allows the introduction of a user's log book metric on the project database to be updated with real mission lessons learned.

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