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Architecture of the Simulation Modeling Infrastructure Based on the Simulation Model Portability Standard

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Abstract—**The authors are developing a subject-oriented environment of the spacecraft onboard equipment simulation modeling. This environment is basing on the Simulation Model Portability Standard, which determines the technology for compatibility and transferability of simulation models within big simulation projects of software-and-hardware complexes. We have designed a software architecture, proposed a division in software subsystems and described the main principles of their interaction. Our software extends the approaches provided by the standard with the original methods of information-graphic and intellectual modeling. Application of the simulation infrastructure allows to solve the tasks of acquisition, accumulation and diffusion of the space systems designers' experience and knowledge.**

Keywords-developing a subject-oriented software, simulation model portability; spacecraft; onboard equipment; command and measuring system

I. INTRODUCTION

There is a number of simulation infrastructures in the world space industry. They are built on the basis of the standard of the European Cooperation for Space Standardization – the Simulation Model Portability (SMP2) [1] and are designed for creation and application of the models within big simulation projects of software-and-hardware complexes. The SMP2 standard sets universal approaches to organization of the modeling systems and the technology of simulation models' compatibility and transferability in different simulation environments. The most famous simulation infrastructures are: SimTG – Astrium Satellites [2], SimSAT – European Space Agency [3], the European Mission Control Center's simulator SWARMSIM [4]. Simulation infrastructures are used in big technical projects where it is important to integrate simulation models of different purpose, including those of different manufacturers', and to use them together. For such projects it is topical to apply the SMP standard providing wide opportunities for building and application of complex multi-component simulation models.

The authors had the task to develop a subject-oriented simulation environment and to analyze the function of spacecraft onboard equipment. [5]. The task required to realize the standard's architectural requirements to software and to add the obtained infrastructure with the original methods of information-graphic and intellectual modeling [6, 7]. The standard sets the common principles of describing models' interfaces and regulates functionality of the software modules constituting the kernel of the modeling infrastructure. However, it leaves unsolved a number of the issues concerning models' construction, modeling, integration and interaction, and they are solved by software systems designers on their own. In order to create a simulation infrastructure, the authors suggest their own technological and software approaches that not only allow to provide usage of the models in different projects and on different simulators, but also consider the specifics of the tasks.

In order to achieve this, we have analyzed the requirements to onboard equipment simulation modeling, revealed basic functions of the software and developed its architecture. The architecture describes the set of the important solutions about software system's organization, choice of the structural elements, recommendations on their function and interaction. Our software architecture allows to extend the uniform approaches to models' presentation provided by the SMP2 standard, by adding of the model with the subject area's semantic constructions and the knowledge bases describing the logics of the models' function. The original tools of graphic modeling are considered in interaction both with the models' subsystems and with the simulation kernel of the infrastructure. The suggested organization of software allows to create a problem-oriented simulation modeling environment, and at the same time it guarantees compatibility of simulation models and their transferability in different simulation infrastructures.

II. SIMULATION INFRASTRUCTURE'S PURPOSE AND FUNCTIONS

Simulation infrastructure is aimed to support the work of the space systems' onboard equipment designers. Its functions are determined by the basic tasks of the designing: onboard equipment design support, generation and analysis of designer solutions at different stages of the space equipment production lifecycle. The software tools required for these tasks' solution, must be subject-oriented, visual and convenient for the work of the professionals without usage of special programming skills. An onboard equipment designer must be able to build space systems' function models applying the existing models from different manufacturers' or creating his own ones. He also should be able to integrate models and set the methods of their integration, prepare the scenarios, conduct simulation tests, and analyze the results of the modeling.

The authors have developed the methods and software of information-and-graphic modeling for visual building of the models, setting their structure and determining the links between their elements. The tools allow the designer to operate familiar semantic constructions for building of the onboard equipment function models. The methods of the model function are set in the form of the condition-action rules. The special instruments of knowledge base creation, developed by the authors, allow to describe different variants of the modeled objects' behavior. Our original instruments were tested and we built the function models of spacecraft command-and-measuring systems' onboard equipment [8]. Their implementation in the simulation modeling infrastructure will extend the possibilities of models' construction and will provide their transferability and workability in complex solutions. Infrastructure must contain software components, specifications, simulation models, the results of tests, as well as the knowledge bases consolidating knowledge and experience of the experts in creating space systems' onboard equipment.

Figure 1-2 shows the technology of building of an onboard equipment complex model which requires software support for solving of the following tasks: complex model design; realization of models on the basis of the rules; import of ready SMP-models of the third-party manufacturers'; integration of the models in a complex model; preparation of modeling; conducting of simulation experiments; analysis and visualization of the results of modeling.

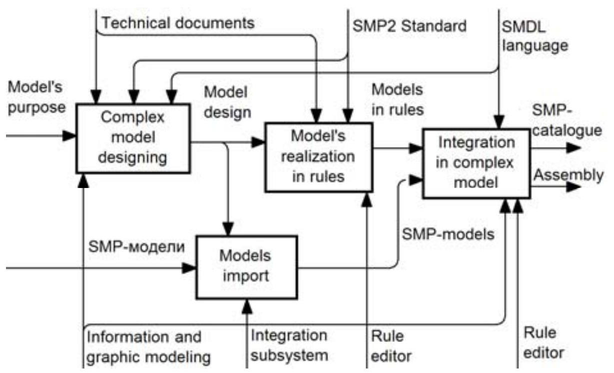

FIGURE I. TECHNOLOGY OF BUILDING MODEL: PREPARATION

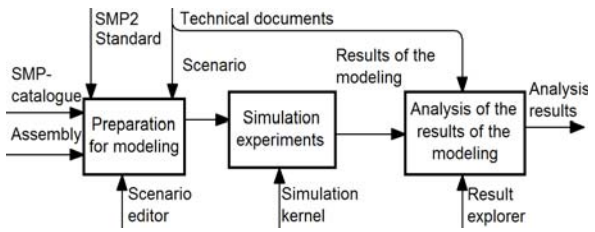

FIGURE II. TECHNOLOGY OF BUILDING MODEL: EXECUTION

Determination of the functional tasks of the onboard equipment complex model construction has allowed to define basic software modules required for their solution: information-and-graphic modeling tools, integration subsystem, rule editor, model editor and scenario editor, simulation center including the time control subsystems, event manager, logging subsystem, analysis simulation modeling and rule execution mechanisms, result explorer. Each of these unique subsystems is a special instrument providing extensive possibilities for task solution. A high level of the problem orientation is provided due to the graphical modeling instruments and the rule editor. Problem orientation will simplify usage of the existing software and the built models for the onboard equipment designers. Realization of different software subsystems in a form of unified solution is an end-to-end technology of modeling and the analysis of spacecraft onboard equipment function.

III. ONBOARD EQUIPMENT MODELING INFRASTRUCTURE'S ARCHITECTURE

We have developed an architecture of the software designed for spacecraft onboard equipment simulation modeling. The requirements to its function and design are determined by the system's purpose, the object of modeling's special features and the qualification of the subject area's specialists. We have determined the software subsystems necessary for building of the models, their integration and conduction of simulation experiments.

The schematic architecture of the software is presented in Figure 3. The kernel of simulation modeling provides the functionality of the SMP2 standard and supplies the original software tools.

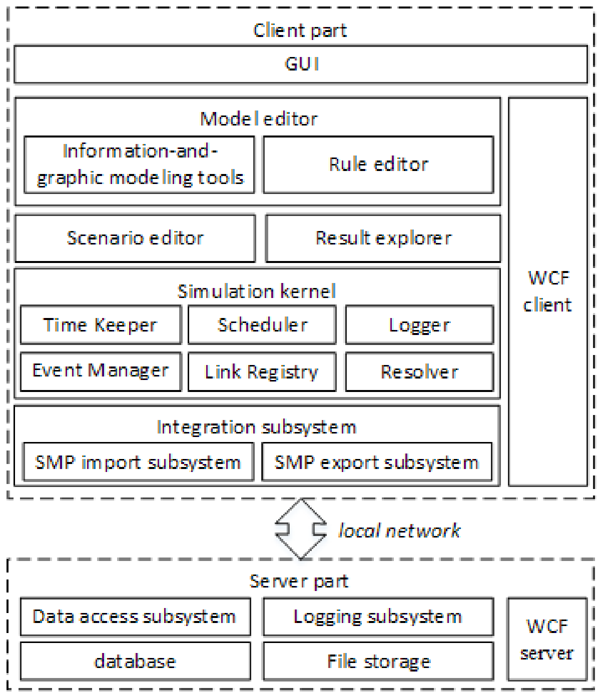

FIGURE III. INFRASTRUCTURE'S ARCHITECTURE

Simulation infrastructure's central element is the bank of models and scenarios. It provides a common information space for model building and usage, integrity and control of the versions and serves as a tool for collective development of large models of the complex technical objects. In order to support the centralized work with the model bank, the simulation infrastructure's software is divided into server and client parts.

The server part provides access to the centralized data base: the bank of the models, scenarios and the simulation tests' results. It includes the subsystems for data and logging access that provide interaction with the data base and file storage. The mechanisms of the version control and synchronization allow the onboard equipment designers to finalize the simulation models. It's most topical at big companies, where subsystems and their models are developed in different structural departments.

The client part of the software architecture is designed for the onboard equipment designer's function. It allows a designer to solve all the tasks of the modeling. He can use the models editor, rule building subsystem and the subsystem of models integration in the SMP2 standard.

The models editor includes the information-and-graphic modeling subsystem and the rule editor. The editor supplies the tools of graphical modeling for visual presentation of the modeled system's structure, subsystems' models and the links between them. The models editor includes the assembly construction subsystem that is obligatory in the SMP2 standard. The assembly subsystem allows to create complex models determining major and backup realizations of the equipment models, inputs, outputs and the links between models. Additionally, in our realization the assembly subsystem provides integration of the SMP2 format models with the models based on the rules [8]. The rule building subsystem contains the instruments for description of the model's elements behavior and their reaction to the input actions. The rule subsystem is an intellectual constructor offering the user to choose the permissible actions or operations depending on the rule's structure and elements.

Presence of a graphical model editor and the rule subsystem is a favorable difference of our infrastructure from the existing ones. Graphical and intellectual instruments allow a designer to build space systems models using the terms of the subject area, provide comfort of the work and minimize errors. Such approach helps generation and accumulation of knowledge about the methods of space systems' equipment function.

In the SMP2 standard a model is described with the Simulation Model Definition Language (SMDL) [9]. It's a formal language of model presentation that is understood by all simulation infrastructures. In our infrastructure the integration subsystem automatically interprets models in SMDL description, adding the interpretations with the structures and mechanisms supported in the simulation infrastructure. During export of a model, the subsystem creates the exit files including metamodel, modeling libraries and configuration files. In contrast with the existing infrastructures, in our case the user doesn't need to know the SMDL language or possess additional programming skills to import and export models in SMP2 format. The subsystem includes the instruments allowing to customize the model import and export parameters through graphical interface.

The scenario building subsystem is designed for simulation test preparation. Experiments can include different conditions of the modeled system's work. Any number of the simulation modeling scenarios can be built for every model. The infrastructure supports the principle of separation of knowledge about the models' function methods from their usage. This principle is realized both at the level of the logical input methods in the knowledge bases and at the level of the modeling scenarios completion. The version control system monitors compatibility of the models used in the scenario and if they are significantly changed, it saves the actual variants of the models. Such approach extends the possibilities of simulation tests' conduction and supplies flexible mechanisms of model debugging.

In order to execute third-party manufacturers' models within the original infrastructure, the kernel of the simulation modeling contains the mechanisms determined by the SMP2 standard: Time Keeper Scheduler, Logger, Event Manager Link Registry, Resolver. Besides, the kernel of the system provides all the necessary functionality for the work of the models built on the basis of the rule base. The simulation modeling kernel allows to control the speed and the course of the simulation tests. Its functions include gathering of information about the model's function during simulation tests, control of the order of message transmission between the model's blocks and of the change in their internal state. The kernel's mechanisms monitor changes of all the parameters of the model and save them at the server. The saved data allow to perform retrospective analysis of simulation tests.

Realization of these functional subsystems in the simulation infrastructure will allow to create, transfer, integrate and combine simulation models of different purpose, including those of different manufacturers.

IV. CONCLUSION

In this article we have described the simulation infrastructure architecture of spacecraft onboard equipment. The architecture contains all the necessary components for providing transferability and workability of simulation models in the simulation modeling systems built on the basis of the Simulation Model Portability Standard. The architecture's design is completed on the basis of the analysis of the purpose and goals of creating subject-oriented simulation infrastructure. The software subsystems' structure is added with the original instruments of graphical and intellectual modeling providing generation, storage and diffusion of the unique experience of space systems' onboard equipment designers. Creation of centralized banks of models and modeling scenarios allows to exchange knowledge between the specialists of different divisions and directions of the instrument making involved in space systems designing.

Application of the simulation infrastructure will provide creation of spacecraft onboard systems' models, development of modeling scenarios, conduction of simulation tests and the analysis of their results. Usage of the modeling tools increases the quality and propriety of designer solutions at different stages of the space systems' production lifecycle.

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