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Methods of Test Procedures' Generation on the Basis of Simulation Model's Knowledge Base

Olga Isaeva, Ludmila Nozhenkova and Andrey Koldyrev
Institute of Computational Modelling of the Siberian Branch of the Russian Academy of Sciences, Akademgorodok 50/44, 660036 Krasnoyarsk, Russia

***Abstract*—We represent a new approach to testing of spacecraft onboard equipment's functional control using simulation model's knowledge base for test procedures' generation. It allows to analyze characteristics of the objects under study using software models with further creation of real equipment's testing methods on their basis.**

***Keywords*—knowledge base; simulation modeling; spacecraft; onboard equipment; testing**

I. Introduction

A key factor of complex technical systems' science-intensive production development is automation of preparation and conduction of testing. A complex technical system is an object consisting of separate systems united in one and designed to function of all of the system in whole. The subsystems being the components of a complex system are tested both independently before they are united in one complex, and as a part of the complex system.

An example of such system is a spacecraft's onboard equipment. Quality and efficiency of testing of separate elements of the onboard equipment is a keystone of its performance during all of its active existence in space environment. Automation of such tests is one of the important mechanisms for enhancing the reliability of the produced space devices.

Methods of testing are determined by international and branch standards as well as by techniques of specific companies. For example, European Space Agency's standards are applied to spacecraft onboard equipment testing [1, 2]. Standards and methods are the basis for universal or special software-and-hardware complexes [3, 4] and also for programming languages designed for creation of the methods of test procedures' control [5].

For onboard equipment test support, methods of simulation modeling are used. For example, in documents [6, 7] we find a successful experience of simulation models' usage for design and testing of various-purpose satellites. Although the approaches to automation were thoroughly worked out, they don't cover the processes of test procedures' preparation. Stages of preparation are very cumbersome and are completed manually, demanding higher requirements to qualification of specialists.

It is necessary to find new software and technological solutions allowing not only to conduct functional control of the tested systems in different variants of usage and functional modes, but also to equip designers with tools for such tests' preparation.

In this article we present a method of test procedures' generation on the basis of simulation model's knowledge base. We have created a model [8] simulating command-and-software control of spacecraft onboard equipment and software for control-and-verification equipment designed for test automation [9]. The methods of test procedures' generation will provide automated tuning of command transmission and control of execution in accordance with the simulation model's knowledge base. For its realization, software tools of the control-and-verification equipment and the simulation model will be integrated.

The new approach will simplify the process of test procedure creation, provide its efficiency and improve the quality of the onboard equipment designer's decisions.

II. Spacecraft Onboard Equipment Simulation Model

A model of onboard equipment function contains simulators of onboard and ground devices: OCS CU – onboard control complex, CCU– command and measuring system's interface module, ODGS– onboard remote signaling equipment, GCC- Ground control complex, TRANS-Transmitter, RECIV-Receiver (Figure 1). The model demonstrates the structure of equipment and its functions at reception, processing and transmission of control commands, and also at generation and control of telemetry information. Model's function logics is described in the knowledge base.

Simulation model's knowledge base [10] consists of condition-action rules that are symbolic constructions such as «If A then B». The left part of the rule sets conditions under which it is fulfilled, and the right part is the actions causing changes in the model's condition. Knowledge base describes different features of onboard equipment's operation, ways for command execution and methods of changing the parameters of devices.

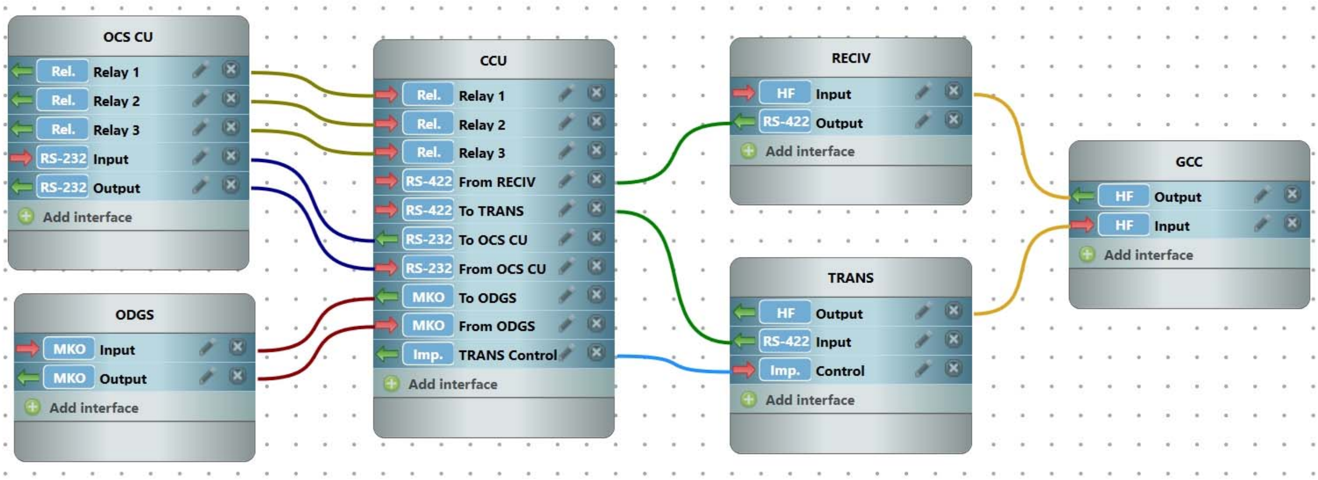

FIGURE I. ONBOARD EQUIPMENT MODEL FOR COMMAND-AND-SOFTWARE CONTROL SIMULATION

An example of a rule from the knowledge base is given in Figure 2.

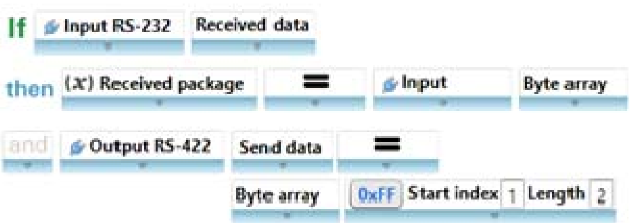

FIGURE II. AN EXAMPLE OF A RULE

The model allows to simulate functions of onboard equipment at command-and-software control of a spacecraft. A ground control complex' simulator sends commands to onboard equipment of a spacecraft. The commands are received by simulator of the command-and-measurement system which adds a receipt to telemetry and analyses the purpose of the commands. If a command is destined for the onboard control complex, the command-and-measurement system transfers it to simulator. The commands destined for the equipment of the command-and-measurement system are executed by the system itself. As soon as the command has been executed, the onboard control complex' simulator generates a response and sends it to the command-and-measurement system. Command-and-measurement system sends telemetry packages to the ground control complex containing information about the condition of the onboard systems and the results of command execution. With proper functioning, execution of commands influences the condition of the onboard systems and is represented in telemetry in a certain way. Command execution control is performed at the ground control complex in accordance with the parameters of the collected telemetry. The content and ways of data transmission in the model are regulated by the standards of the European Space Agency. Telecommands are sent from a ground mission control complex simulator to a spacecraft on the basis of the ESAPSS-04-107 standard. Telemetry is a flow of data transmitted from a spacecraft to the ground in accordance with the rules determined by the ESAPSS-04-106 standard.

In order to model different functions of the onboard equipment, a designer can create his own sequences of the condition-action rules. In the process of simulation modeling, a logical conclusion [10] is made in accordance with the developed knowledge base. Also, software chooses rules applicable to the model's current state, demonstrates command execution, simulates the processes of data package generation and transmission. Diagrams of each data transmission are provided with the animation effects.

Modeling is an interactive process. A designer can make simulation experiments changing conditions of the model's elements, conditions of signals' reception and transmission, time of waiting for responses and receipts. Simulation experiments help to thoroughly understand the methods of onboard systems' operation [11] and allow to predict reactions to external influences and emergencies. The scenarios of the onboard equipment control commands' transmission and telecommand data packages' structure and the assessment criteria of the onboard systems' function built in the simulation model can be used for autonomous test preparation [12].

III. METHOD OF TEST PROCEDURES' GENERATION

For test preparation, it is necessary to set a list of commands that will be transferred to the object of control, set up parameters of transmission and specify reference values. In this article we study spacecraft's onboard command-and-measurement equipment as an object of testing. It is designed to provide command-and-software control of the onboard systems, for transmission of telemetry information to ground systems and measurement of the current navigation parameters of the orbit. The following parameters are required for test set up: «command», «TVE (control-and-verification equipment)-CCU interface» (one of the values of RS-422 (channel 1), RS-422 (channel 2), HF), «receipt control TM», «response control CCU- OCS CU », «response control in TM», «CCU-OCS CU interface for RS232» («basic» or «backup»), « OCS CU - CCU response», «response waiting time», «attempts of transmission», «number of repetitions of transmission» and «command transmission mode» [9]. Figure 3 shows a program form for manual entry of the parameters.

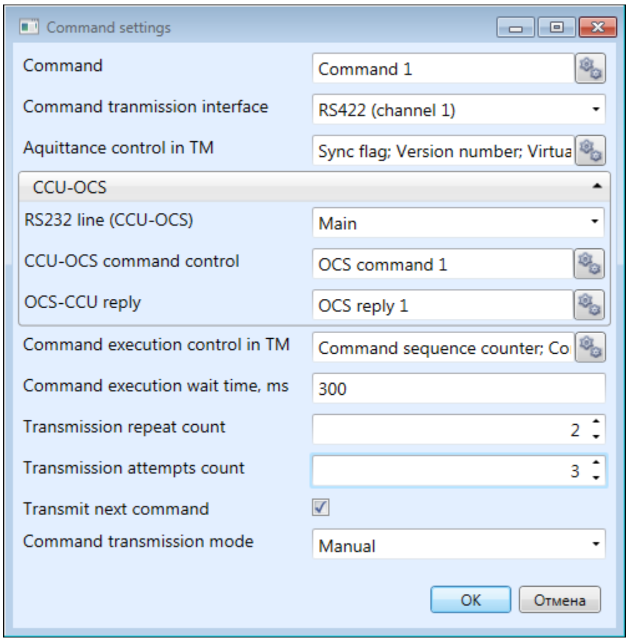

FIGURE III. PROGRAM FORM FOR TEST PARAMETERS' ENTRY

The new method of test procedures' generation allows to set basic parameters automatically. At test preparation, an onboard equipment designer can choose an arbitrary number of commands and determine the sequence of their transmission. Then the method of test procedures' generation will form a subset of rules of the knowledge base determining the order of function of the ground and onboard systems' simulators at modeling transmission of the chosen commands. Each simulator can have its own sequence of rules for completion during tests. The parameters of command transmission and execution control, acquired from the built subsets of rules, form the test methodology.

Schematically, the work of the test procedures' generation method is shown in Figure 4. With this approach, a designer needs to add parameters of tests that were not acquired from the knowledge base, and test procedures will be ready for completion.

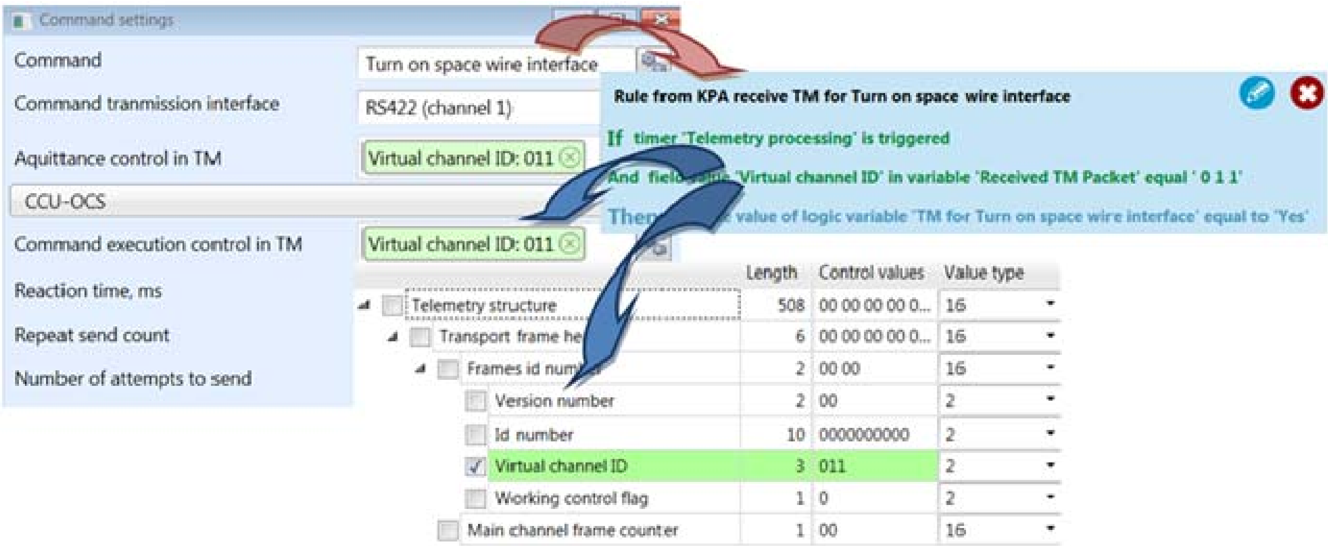

FIGURE IV. GENERATION OF TEST PROCEDURES

IV. TESTING OF THE ONBOARD EQUIPMENT'S COMMAND-AND-SOFTWARE CONTROL

In order to test command-and-software control of the onboard equipment in accordance with the set parameters, preparation and setup of software simulators are completed automatically. The software simulators performing the functions of the studied object's environment and of the virtual devices of the software-and-hardware complex of the control-and-verification equipment are automatically set up for the onboard equipment's command-and-software control testing. After preparation, the sequence of commands and analysis of the results of their execution are transferred to the object of control. Software interacts with the object of control and software simulators, performs continuous monitoring of tests and provides visualization of the telemetry received from the equipment. Software displays the list of commands with color and graphic identifiers of their progress (Figure 5).

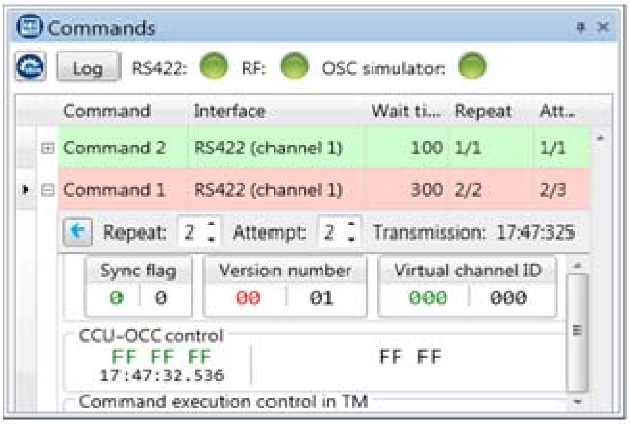

FIGURE V. MONITORING OF COMMAND-AND-SOFTWARE CONTROL'S TESTING

The monitor window displays the parameters of transmission, time of data transmission and response in telemetry, and also the control values. Visual elements of the window are constantly updated and provide the current state. Software keeps a log of actions, transmitted and received data and can make reports on all of the conducted tests. The results of tests are kept in the data storage.

A simulation model is also used for test results' analysis. Software reviews the results of tests, forms precedents and compares them with the data acquired during tests. The comparison is completed by the telemetry of the object of control in the simulation model. In case of coincidence, software visualizes the parameters of the model and the rules describing the events that caused the values of the telemetry. Using the rules, a designer can make a conclusion about the condition of the onboard systems and their actions described by the precedents of the simulation model.

The analysis of the results of simulation model's testing allow to find specifics of its function that may stay unnoticed during analysis of single parameters. The method of analysis of onboard equipment testing by simulation model's precedents is described in detail in [13].

V. CONCLUSION

Conduction of tests in highly technological production of space equipment requires significant economical and technological investments. With this respect, it is very efficient and topical to apply the methods of computer modeling for designer solutions' support at different stages of the space systems' production cycles.

Creation of a new approach that we represent in this article, simplifies the processes of preparation and functional control of the technical systems. Implementation of the methods of test procedures' generation has allowed to make analysis of characteristics of the studied objects on software models and then to form on their basis the methods of testing of real equipment.

Usage of expert knowledge implemented in simulation models, provides onboard equipment designers with the tools for test preparation for different ways of usage and different function modes of space systems' onboard equipment. Integration of simulation modeling technologies and the methods of test conduction helps higher quality of onboard equipment development and decision making.

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