Creation of the Base of a Simulation Model's Precedents for Analysis of the Spacecraft Onboard Equipment Testing Results

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Abstract—**We represent a method of analysis of the spacecraft onboard equipment testing on the basis of the simulation model precedent database. Simulation modeling allows to play all the possible versions of the onboard equipment functioning and the scenarios of spacecraft control command transmission. Usage of the results of simulation modeling extends the abilities of test software and helps to increase the quality of engineering solutions.**

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

I. INTRODUCTION

Implementation of modern technologies of the space systems' testing requires highly qualified designers with the knowledge of different features of functioning of the object of control. Onboard equipment is a high-tech product with a long life cycle. The quality of ground tests means much for the equipment's efficiency during all of its active existence in space. In course of testing, not only construction details are tested, but also the logics of work of both the devices and the complexes appearing when the object of control interacts with the adjacent systems and the periphery.

The test's rules of the different objects of control are determined by international and branch standards, for example, ISO/IEC 9646 is used for communication systems' testing [1], the European Space Agency standards apply to onboard equipment tests [2, 3]. The testing software are created on the standards and represents universal systems, special hardware-software complexes or programming languages that allow to build complex algorithms for the test procedures' control [4, 5, 6].

Automation of preparation, conduction and analysis of the onboard equipment's tests requires the methods of modeling allowing to make simulation experiments and to study the work of the equipment in different conditions. The European Space Agency standards pay much attention to the modeling technologies supporting the system design of all of the processes during transformation of the technical requirements into the system solutions. These technologies are the base for the space industry's development [7]. There are program projects in the world space industry that allow to simulate technical systems before their manufacturing and then use the built models during the equipment design and exploitation [8].

In order to increase the quality of designer solutions we suggest the method of analysis of the results of the space systems' onboard equipment testing on the basis of the simulation model's precedents. We have developed technological approaches and software tools allowing to build different models of the onboard equipment function, carry out simulation experiments, save the results of modeling in the precedent database and analyze the space equipment's testing.

II. SETTING TEST GOALS

One of the key tasks in organizing the tests is the control of the functions of reception, processing and transmission of the telecommand packages and telemetry between the ground control complex and the onboard equipment of a spacecraft.

The scheme of interaction and data transfer between the ground complex and a spacecraft is presented in Figure 1.

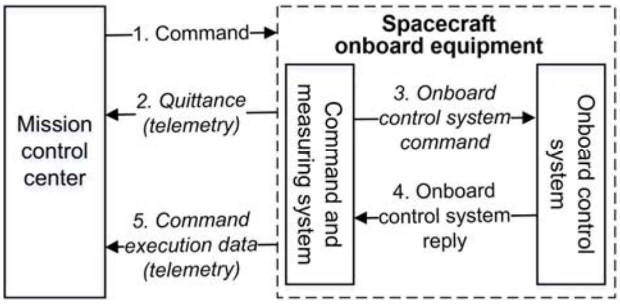

FIGURE I. DATA INTERACTION SCHEME

Ground control complex sends commands (arrow 1) that are received by the onboard equipment the commands are accepted by the command-and-measuring system that adds a quittance to the telemetry (arrow 2) and analyzes the purpose of the commands. If the command is for the onboard control complex, it is transferred there (arrow 3). The commands for the command-and-measuring system are executed by itself. When the command is completed, the onboard control complex creates a response and sends it to the command-and-measuring system (arrow 4). It sends telemetry packages containing information about the onboard systems and the results of the command execution to the ground control complex (arrow 5). If all works well, the execution of each command influences the condition of the onboard systems and has a certain reflection in the telemetry. The command execution analysis is performed by the ground control complex in accordance with the telemetry parameters.

Verification must include all possible versions and scenarios of the onboard equipment control commands' transmission. Analysis is performed by comparison of the set parameters of the telemetry packages received from the onboard systems with the reference values. A wide range of the control commands and possible variants of the telemetry parameter values makes the analysis difficult. In order to increase test efficiency we suggest the following:

1) *Build a model simulating spacecraft onboard systems' function in different variants of command reception and processing;*
2) *Conduct numerous simulation tests with the model;*
3) *Systematize different variants of the onboard equipment function and link them with the possible values of the telemetry parameters;*
4) *Create a simulation model precedent database;*
5) *Use this database for the analysis of the results of the spacecraft onboard equipment testing.*

III. Building of Simulation Model

In order to build a simulation model we have used a special software complex "Sofware-and-mathematical model of the onboard equipment of spacecraft's command-and-measuring system" [9], combining tools of simulation modeling and intellectual support of the onboard equipment design. These tools are also used in the simulation modeling infrastructure [10]. A fragment of graphical presentation of the simulation model is shown in Figure 2.

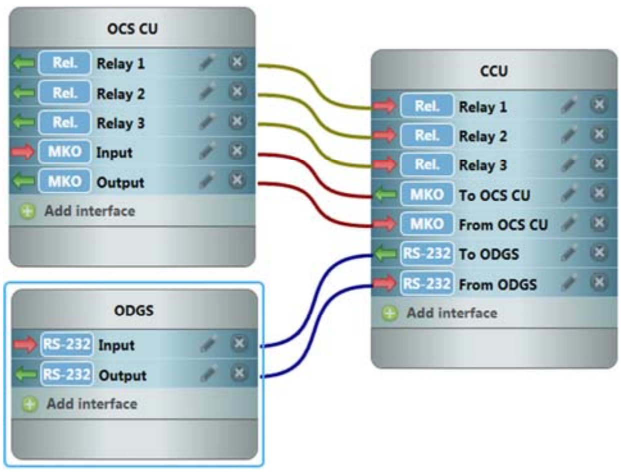

FIGURE II. A FRAGMENT OF THE MODEL'S GRAPHICAL PRESENTATION

OCS CU – onboard control complex, CCU – interface module of the command-and-measuring system, ODGS – onboard equipment of the remote indication. The links between the graphical elements of the model are directions of the informational exchange during command transmission and telemetry.

The model has a set of parameters and characteristics that can be changed in order to set different configurations of the onboard equipment. Visual building of a model with graphical elements provides sufficient advantage due to simplicity and clarity of the onboard equipment designing, as well as of the analysis and adjustment of the built solutions.

The methods of a simulation model's functioning are set in the knowledge base consisting of the condition-action rules [11]. The rules are constructions of the «If A then B» type. The right parts of the rules contain actions changing the condition of the model and the left are the conditions under which these actions are carry out. The example of the rules is given in Figure 3.

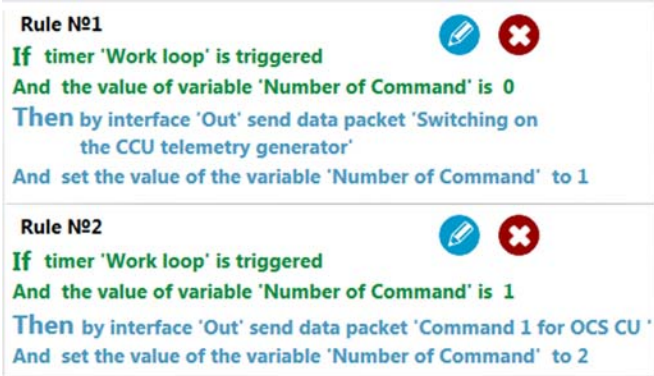

FIGURE III. EXAMPLES OF THE RULES IN THE KNOWLEDGE BASE

We have developed a database and software for storage of the results of simulation experiments. A fragment of the database structure is presented in Figure 4.

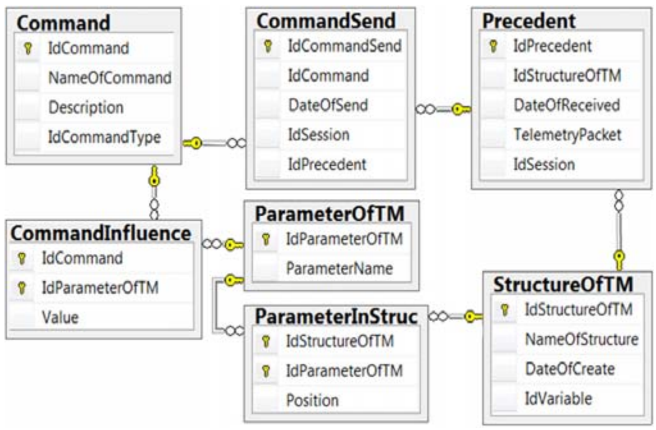

FIGURE IV. FRAGMENT OF THE PRECEDENT DATABASE STRUCTURE

The database contains structures of the tables for saving rules, their dependencies and sequences of completion, telemetry parameters, states of model elements. It also includes data structures for keeping of the arrays of bytes containing command packages and telemetry. The European Space Agency's standards are used for data transmission: ESA PSS-04-107 [12] for telecommands and ESA PSS-04-106 [13] for telemetry.

The database's structure allows to restore the sequence of the simulation model's rule completion that lead to change of the telemetry parameters. Telemetry and the actions that change it, are precedents of the simulation model. During operation, software fills in the database with the results of simulation tests.

A filled in precedent database is used for analysis of the results of the spacecraft onboard equipment testing.

IV. Test Analysis Using the Precedent Base

We have developed a method of analysis of spacecraft onboard equipment testing using the simulation model's precedent database. Control-and-verification equipment's software is used for testing [14]. During tests, software receives, visualizes and saves all the telemetry from the onboard systems and the results of changes in physical characteristics of the equipment in operation. All tests and the results can be replayed by the software [15]. Onboard equipment designer can look at the telemetry and choose certain parameters for control. The new method of analysis extends the abilities of software and allows to consider all combinations of the telemetry parameter values appearing during simulation experiments. If a simulation model describes work of the real onboard equipment well enough, then comparison of the telemetry with the precedent base allows to find out the specifics of its work that could not be detected by a designer during analysis of individual parameters.

The block diagram of the analysis algorithm using the precedent base is presented in Figure 5.

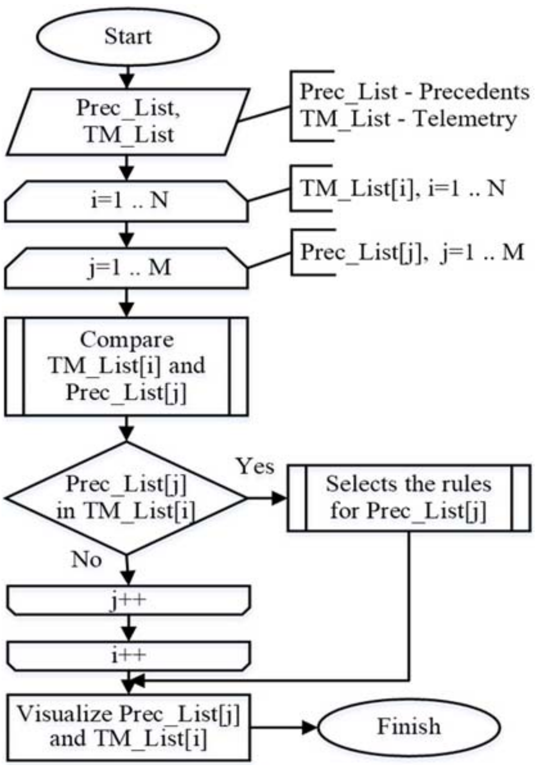

FIGURE V. ONBOARD EQUIPMENT ANALYSIS ALGORITHM

During the execution of the algorithm, software considers all the possible changes of telemetry parameters and their combinations, compares precedents with the telemetry obtained in the tests and displays the data in case of a match. The algorithm's results are the model's parameters and rules that were carried out for obtaining of this telemetry. The rules are presented in the language, close to natural, they are clear and simple. They allow to describe the events happening in the simulation model that cause changes of the telemetry values. By studying the rules, a designer can understand the condition of the onboard systems and the actions that were performed with related to the detected precedent. If necessary, the designer can replay the logical inference by performing a rule trace. Studying the process of tests preceding the received of the telemetry during testing of the real equipment, in accordance with a found precedent, a designer can compare the actions performed during tests with the simulation model's actions. For example, the simulation model's rules can show what commands caused a certain precedent, whether main or standby set of equipment is working, etc. Tests' replaying and comparison of their results with the data obtained from the simulation model allow to make conclusions about how well the equipment under test works. If the results of tests and precedents don't match, they need to be studied more thoroughly. According to the results of the analysis, the designer can decide whether to repeat tests.

V. Conclusion

We have developed a method of analysis of tests on the basis of the simulation model's precedent database. To implement the method, we have used the results of testing of spacecraft's command-and-measuring system. An example of software's work is shown in Figure 6.

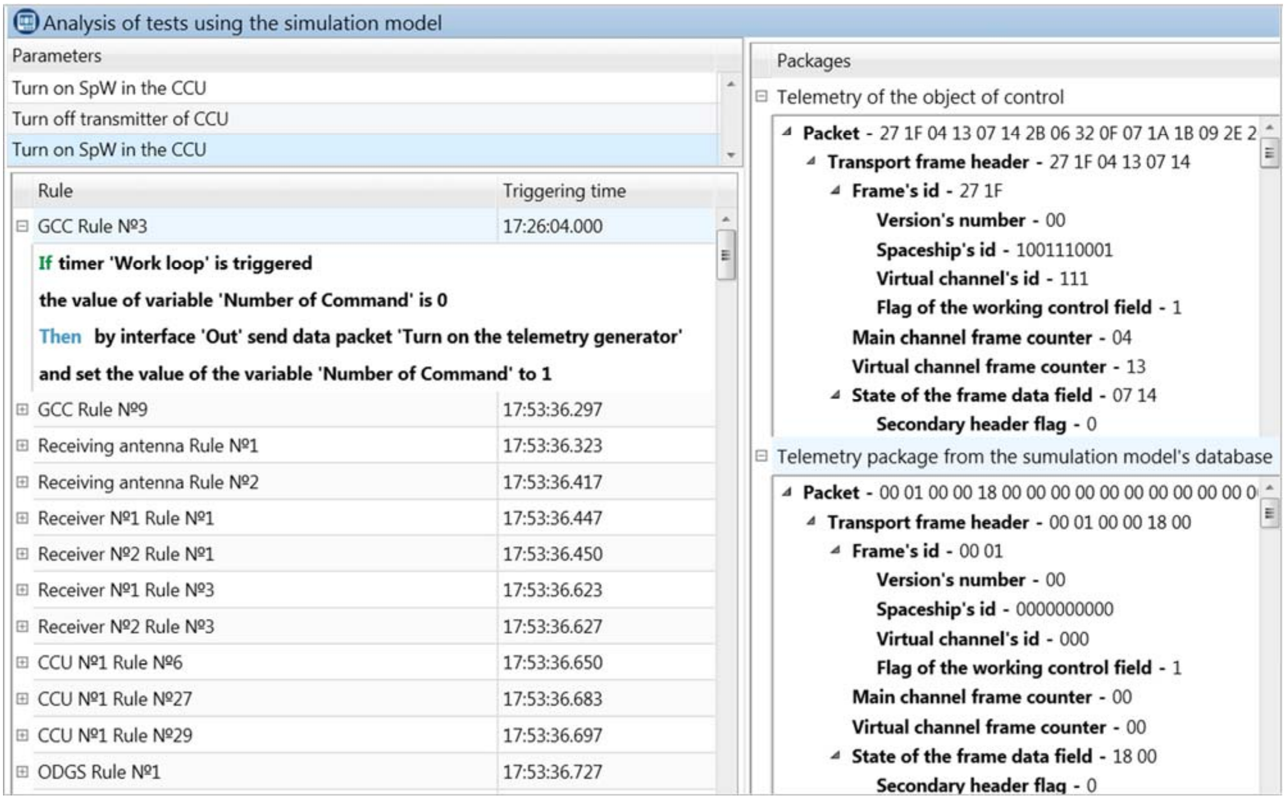

FIGURE VI. THE RESULTS OF THE TESTS' ANALYSIS USING THE SIMULATION MODEL'S PRECEDENT BASE

During analysis software generate a set of parameters complying with the precedents of the simulation model for which coincidences with the telemetry obtained in the tests spacecraft onboard equipment were found. The found rules and telemetry are visualized.

This approach allows to detect the specifics of the functioning onboard equipments that could remain unnoticed if other methods of analyzing test results are used.

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