Spacecraft onboard equipment testing automation technology on the basis of simulation model

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Abstract. This article presents the technology of preparation and execution of functional control of spacecraft onboard equipment on the basis of an intelligent simulation model. The technology includes implementation of the methods of test procedures' generation and analysis of the results in accordance with the simulation model's precedents. This technology allows you to analyze characteristics of the test objects on models with further analysis of the real equipment operation.

1. Introduction

Spacecraft onboard equipment is a classical example of a complex technical system. Its complexity has two important aspects. The first is determined by the complex system architecture consisting of many components combined with each other with many links of different nature. Each component includes many devices and meters with many parameters, working modes and control commands. The other aspect implies complex behavior that is difficult to predict or analytically describe. It is the second aspect that has a significant influence in cases when we talk about not mass production, but about research and development aimed at designing and creation of spacecraft onboard equipment.

The onboard equipment has high requirements to quality and reliability of operation. Verification of its consistency with the set requirements at the stages of production and assembling of different onboard systems is completed by conduction of different tests. General rules and order of tests are defined by international and industrial standards [1, 2]. On the basis of standards and methods scientists develop both universal and special software-hardware complexes of test automation [3], including those with usage of simulation models [4, 5]. However, adjustment of the existing systems to a given study area with possibilities of modeling, visual building of test procedures, control of data reception and transmission in accordance with the standards is cumbersome and often impossible.

This article presents the onboard equipment testing automation technology on the basis of intelligent simulation model of spacecraft systems' operation. Simulation modeling of command-and-software control allows more thorough preparation to tests, detection of problem areas in the object under control's function through its model. The rules set in the knowledge base of a simulation model can be used for automatic building of test procedures. The results of modeling are used for analysis of the onboard equipment's function. Our software integrates with the control-and-verification equipment in one software-and-hardware complex of spacecraft onboard equipment testing [6]. This gives a possibility to use the results of modeling for equipment control during tests. Comparison of the results of modeling and the results of tests allows to make a more thorough analysis, reveal causal relationships in the object under control's behavior in different situations during tests.

2. Command-and-software control testing technology

Testing is an experimental determination of quantity and quality characteristics of an onboard system's operation for verification of its compliance with the technical requirements. The process of testing of spacecraft onboard systems includes the stages of planning, conduction and analysis of the results. Our technology provides support for every stage with the help of software for modeling and testing. Figure 1 gives a test process diagram for one of the key tasks in organization of tests – control of reception, processing and exchange of command packages and telemetry between ground control complex and spacecraft onboard systems.

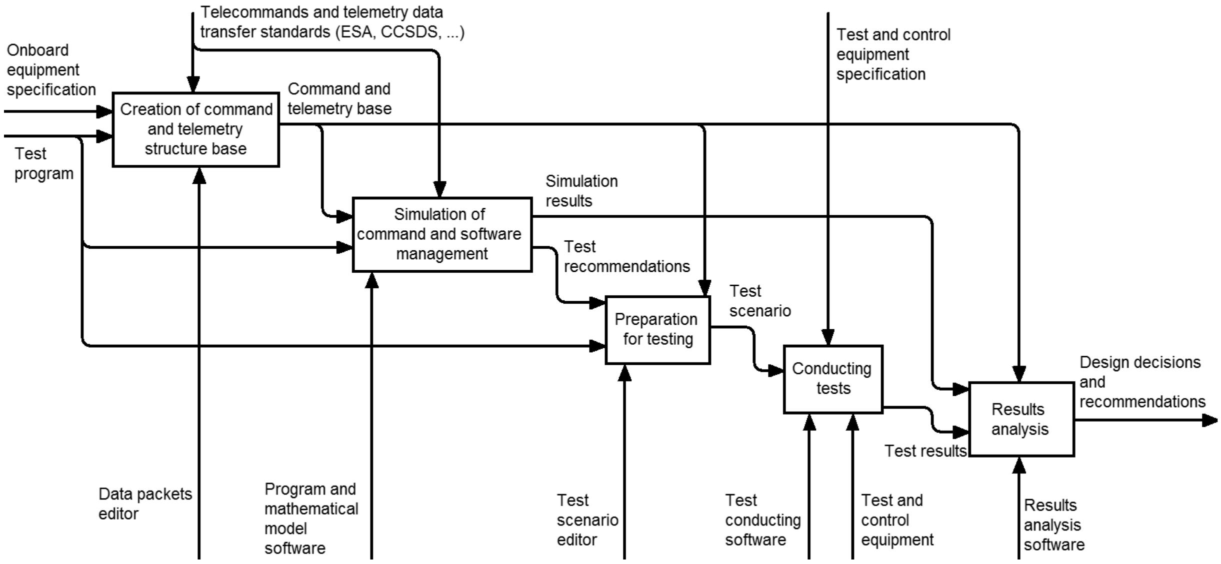

Figure 1. Test process diagram.

Preparation to command-and-software control testing starts with creation of a command base and telemetry structures. The base is created on the basis of specification of the object under control and the testing program. Specification describes the structures of the packages of data operated by the object under testing, as well as the functions of data processing and transmission and time characteristics of their execution. Command and telemetry base is created with the help of a special editor allowing to set structures of data packages, list of commands and properties of telemetry fields.

Further, modeling of the process of functioning of the systems involved in the command-and-software control of a spacecraft, particularly the command-and-measurement system, is performed. Simulation model is built in accordance with the specification of the object under control and performs all the necessary functions of data processing. For modeling, a special software complex "Software-math model of spacecraft command-and-measurement system's onboard equipment" is used [6, 7]. The model defines the parameters that allow to set different variants of configuration of onboard equipment. The methods of model's functioning are set in the knowledge base consisting of condition-action rules. The rules are constructions "If A than B". The right sides are actions changing the condition of the model and the left sides are conditions under which the actions are performed. Modeling allows to analyze functions of the systems, detect different aspects of functioning. As a result of modeling, a list of reference values for further analysis of the results of real equipment testing is formed. Modeling allows to improve understanding of how onboard equipment works and prepare more thoroughly to real equipment testing.

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On the basis of the command base and the results of modeling, scenarios of tests are preparing. Scenario is a formalized description of the process of test conduction in form of a sequence of test procedures in order to determine quantity and quality functional characteristics of the object under control. At autonomous testing of the command-and-measurement systems, ground control complex and spacecraft onboard equipment are replaced by software-and-hardware simulators. That is why scenario also describes simulators' behavior. For verification of the command-and-measurement system's operation, scenario determines criteria of data evaluation at control points with reference values obtained during modeling. Preparation of scenarios is significantly simplified by the method of test procedures' generation described below [7]. It allows to automatically set basic parameters of testing on the basis of knowledge of simulation model and make a list and order of test procedures.

In accordance with the scenario, software-and-hardware complex "Control-and-verification equipment's software" conducts testing [7]. Software interacts with the command-and-measurement system's equipment and software simulators of related systems, performs continuous monitoring of tests and visualizes telemetry received from the equipment. The results of testing are placed in a special storage.

At the stage of analysis of the results of testing, the data obtained during modeling and the results of real equipment operation are compared. Such analysis allows to discover the causes of abnormal situations. Also, there appears a possibility to run a simulation repeating the abnormal situations revealed during tests, and give reasonable recommendations for elimination of defects.

3. Test procedure generation method

For testing preparation, it is necessary to set a list of commands that will be sent to the object under testing, set parameters of transmission and reference values. In this article we regard spacecraft command-and-measurement systems' onboard equipment as the object of testing. It is designed to provide command-and-software control of the onboard systems, transmission of telemetry information to ground systems and measurement of current navigational parameters of the orbit. The method of test procedure generation [7] allows to set basic parameters of tests automatically. Schematically the work of the method is shown in figure 2.

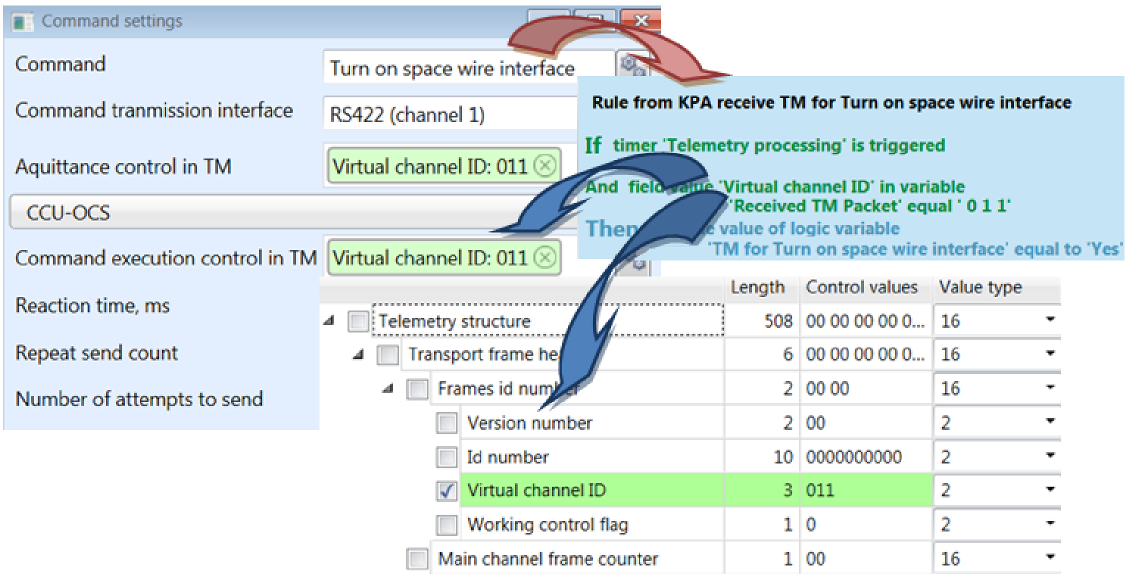

Figure 2. Test procedure generation method.

For test setting, it is necessary to set the following parameters: «Command», «Command transmission interface», «Quittance control in TM», «CCU-OSC», «Command execution control in TM», «Reaction time», «Repeat send count» and «Command issue method». An onboard equipment

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designer when preparing for testing can choose an arbitrary number of commands and define the sequence of their transmission. Then the test procedure generation method will form a subset of rules of the knowledge base determining the operating procedure of ground and onboard systems' simulators during modeling of command transmission. Each simulator may have its own sequence of rules. The parameters of command transmission and control of their execution, received from the subsets of rules, form the program of testing. An engineer can set some parameters of testing by himself if they were not acquired from the knowledge base. After that the test procedures are ready for execution. The final program of testing clearly defines the list and order of test procedures and is a ground for scenario building.

4. Testing automation method

After preparation, the object under testing receives the sequence of commands, and the results of their processing are analyzed. Software interacts with the object under testing and software simulators, performs continuous monitoring of testing and visualization of the telemetry received from the equipment. Software displays the list of commands with color and graphical identification of their execution. This is shown in figure 3.

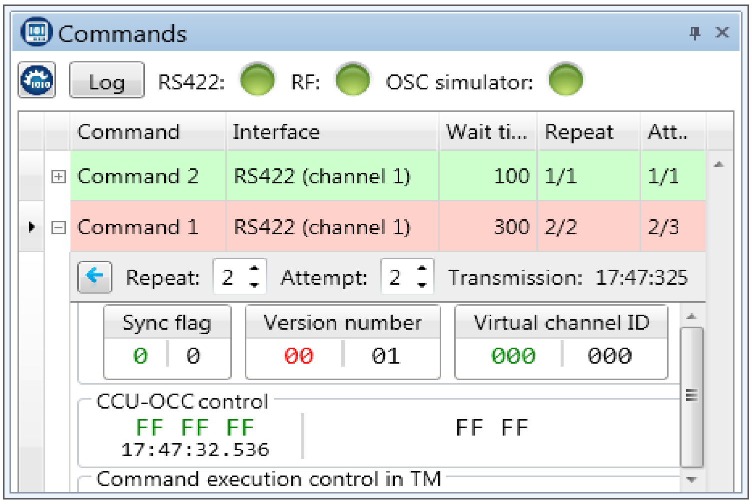

Figure 3. Monitoring of the command-and-software control testing.

The monitor window shows the parameters of sending, time of data transmission and telemetry response, as well as the reference values. Visual elements of the window are continuously updated. Software keeps a log of actions, transmitted and received data and makes a report on all conducted tests if needed. The results of tests are saved in data base.

5. Test analysis method on the basis of simulation model

For spacecraft onboard equipment tests' analysis, we suggest a method of comparison of the results of functional control with the simulation model's precedents [9].

Control-and-verification equipment's software receives, visualizes and saves all telemetry from the onboard systems and the results of measurement of physical characteristics of the operated equipment. An onboard equipment designer can study the telemetry and choose parameters for control. The new method extends the possibilities of the control-and-verification equipment's software and also allows to consider all the variants of telemetry parameters' values acquired during tests. It provides comparison of the simulation model's precedents with the telemetry package data acquired during testing of onboard equipment. If parameters match, it means that identical events happened both in simulation model and during testing of real equipment. The method is realized in the subsystem of analysis of testing by precedents. An example of visualization of the results of analysis is provided in figure 4.

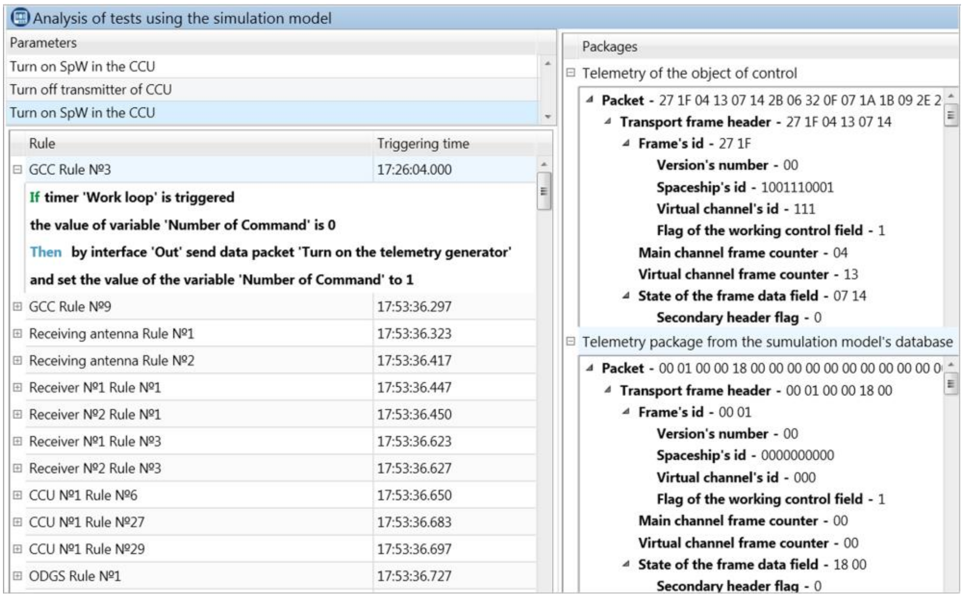

Figure 4. The results of test telemetry analysis.

Visualization of telemetry parameters and rules of simulation model allows a designer to see information about the state of the tested equipment at the moment of telemetry reception. Telemetry shows the condition of onboard detectors, settings of transmitting and receiving devices, working equipment (main/backup), etc. The rules of simulation model allow to replay the actions leading to changes of telemetry. Comparison of onboard systems' telemetry with the precedent base considers all possible changes of the parameters of simulation model, in addition to the reference points chosen by designer.

Our method can be used during testing of physical characteristics of the equipment and its work logics. Analysis can be performed in a background mode in accordance with the incoming telemetry, allowing continuous monitoring of the onboard equipment's condition.

6. Conclusion

Our automation technology of spacecraft onboard equipment's testing is designed to increase quality of testing and to build scientifically-based designer solutions.

The software realizes the methods of onboard equipment test preparation and conduction on the basis of designer's simulation models. Simulation model allows visual study of onboard equipment's work at the stage of modeling and is the base for analysis of the results of testing of the already existing equipment. The results of simulation tests are saved in the base of precedents and contain a large range of commands, rules and values of telemetry parameters describing different tasks of functioning and simulation of the command-and-software control of a spacecraft. Generation of test procedures allows automatic setting of basic parameters on the basis of the simulation model's knowledge base and determination of the list and order of test procedures. At the stage of analysis, the data acquired during modeling and the results of real equipment operation are compared. It allows to reveal the peculiarities that could have stayed unnoticed if other methods of test analysis were applied.

Acknowledgments

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