The automated system of telemetry data multiline reception, processing and analyzing

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Abstract. Modern automated control systems for spacecrafts are characterized by complex multicomponent architecture. The orbital group of spacecrafts is controlled from the mission control center which receives different types of office and special data. The flows of telemetry data which allow to monitor the condition of a spacecraft take a special place among various types of information circulating within an automated control system. The article contains practical recommendations regarding the improvement of special automation software for technological processes of telemetry data multiline reception, processing and analyzing. It is shown that adherence to the principles of unified systems creation provides many advantages when designing modern tools for telemetry data processing and analyzing.

1. Introduction

The modern automated control system for spacecrafts is intended for ensuring proper functioning of the spacecraft onboard systems during the whole time of its work [1, 2]. The automated control system for spacecrafts is a set of onboard and ground control facilities for technological processes equipped with the necessary software which includes [3, 4]:

- the onboard control complex, including the equipment for controlling the channels of an onboard radio complex;
- the ground control software.

In such a system there is an urgent necessity to detect violations in technological processes as quickly as only possible, from simple fuse blowing to identifying pre-failure of the onboard equipment with telemetry data analysis. However people cannot process unlimited amounts of information effectively, therefore it seems to be perspective to create complexes for automation of technological processes of telemetry data reception, processing and analyzing. High level of automation and intellectualization of the system will allow to reduce time spent on collecting necessary information and to increase the efficiency of operators` activities directed at maintaining stable functioning of the spacecraft [5].

At present, in mission control center of GLONASS they use a system of single telemetry data stream which is able to receive, process and analyze telemetry data from no more than one spacecraft at a unit moment. However 24 spacecrafts are needed in the orbital group to achieve the goal of the global navigation field creation. The total number of communication sessions reaches 40 sessions a day, simultaneous communication sessions are held with 3-5 spacecrafts at the same time. Therefore it is very important to develop new methods for ensuring automated multiline reception, processing and analyzing large amounts of telemetry data from several spacecrafts at the same time as a part of automated control system for the orbital group of spacecrafts.

The system of reception, processing and analyzing telemetry data applied today in mission control center has a number of shortcomings connected, first of all, with imperfection of the system architecture, lack of the centralized storage of telemetry archives and the procedural principles of special software creation which is focused on manual technologies and doesn't provide the necessary depth of control. All these need to be modernized.

The elements of ground control complex exchange telemetry data with specialized protocols of datalogical interaction and support each other by using allocated channels in order to exclude unauthorized access to the circulating information. In these conditions application of international standards and developments for the creation of multiline system of reception, processing and analyzing telemetry data is rather difficult. Nevertheless, foreign software solutions to the creation of telemetry systems in the form of hierarchical structure have to be considered for the modernization of the existing telemetry system.

2. Comparative analysis of foreign systems for automated control over orbital group of spacecrafts

The Global Positioning System (GPS) (US) is the only fully functioning system in the world now which is used for determining one's precise location and providing a highly accurate time reference almost anywhere on Earth. The system is owned by the Ministry of Defense and the Ministry of Transport of the United States, with the daily control fulfilled by the Air Force Space Command. The GPS constellation consists of 24 spacecrafts split into six orbital planes with four in each plane, all in circular orbits of altitude 20180 km, and inclination 56°. The number of spacecrafts in each plane can be increased up to 6 [6]. Now there are 30 spacecrafts in regular use as a part of the GPS orbital group.

The ground contour of GPS control consists of global network of the ground stations which provide measurement of orbits, monitoring and analysis of spacecraft working condition and sending control commands for the orbital group of spacecrafts. Now the ground contour of GPS control consists of the main control center, one spare control center, 12 antennas of command-measuring stations and 16 monitoring stations [7]. Their arrangement is shown in figure 1.

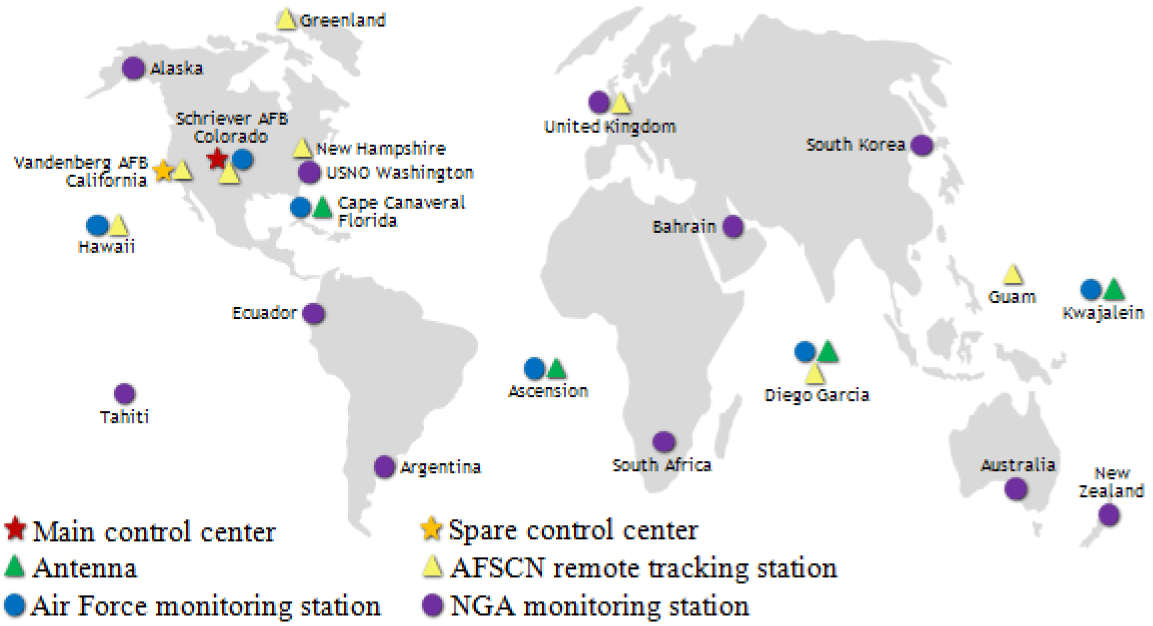

Figure 1. The ground contour of GPS control

One more navigation system which is not without interest as it uses the group of spacecrafts is the global positioning system Galileo being developed by the European Union through the European GNSS Agency (GSA) since 2003. The Galileo Space Segment will comprise a constellation of a total of 30 Medium Earth Orbit (MEO) satellites, 3 of which are operational and 3 active spares, all in circular orbits of altitude 23616 km high and an inclination 56° [8]. The inclination of an orbit is between the parameters of the American GPS system - 55° and the Russian GLONASS - 64,8°. Navigation signals of this system will provide a reliable c overage of the Earth's surface except the areas exceeding 75 latitudes. The large number of spacecrafts and the optimization of their placement in orbits guarantee high reliability of the system. The European satellite navigation system Galileo is a programme under civilian control and its data can be used for a broad range of applications.

The infrastructure of the ground contour of Galileo control system consists of sensor stations worldwide, two control centers and two launch early operations centers (LEOP centers), TT&C stations (Telemetry, Tracking and Command stations) and mission uplink stations [9, 10].

The development of the system involves several stages.

The first stage — planning and cost estimation.

The second stage consists in launching two test satellites and development of infrastructure (ground stations for them) with a total cost of 6 billion Euros.

The third stage consists in placing four Galileo IOV satellites into orbit (in-orbit validation) which constitute the first mini-constellation of Galileo. The satellites were launched on a Soyuz-STB launch vehicle from the European Spaceport in Kourou. The first four satellites were constructed by EADS Astrium and Thales Alenia Space. The satellites will be located in circular orbits of altitude 23222 km.

At the fourth stage of the project 14 more satellites were placed into orbit since 2015, the other will have been placed by 2020.

After placing, satellites will provide 90% reception of simultaneous continuous signal transmitted by four satellites in every point on the Earth, including Northern and Southern poles. An adequate signal in two frequency bands will allow Galileo clients to receive information about their precise location with an accuracy 4 m in the horizontal plane and 8 m in the vertical one with a confidential interval 0,95.

Thus, implementation of large international space projects is characterized by the use of the high-tech equipment for the solution of problems with automation in and from space. The necessity to ensure functioning of this equipment has affected the requirements imposed to ground tracking stations and space data communication systems. The telemetry system has always been aimed at safe and reliable transmission of measuring information from the onboard remote sources to the users.

The telemetry systems used in the international projects can be characterized by a number of features connected with their construction and the ways of their functioning.

1. The telemetry systems, the systems of monitoring spacecrafts are constructed as the centralized hierarchical systems based on built-in test equipment and implementation of algorithms for control and diagnostics in the onboard computer system.

2. The telemetry systems (which, in fact, are the systems of data collection and transmission) transfer diagnostic test results and information about scientific experiments using the same dedicated communication channels.

3. The reasons for rigid standardization of equipment and information transfer services are the facts, that separate elements (segments) of the project belong to different countries, space agencies and organizations which need to exchange telemetry information and provide hardware support to each other.

3. Practical recommendations to improve special automation software for technological processes of telemetry data reception, processing and analyzing

At the present moment software used in mission control centers for processing, analyzing and visualizing telemetry data does not meet modern requirements and opportunities. Therefore it can be regarded as outdated. At the same time the amount of information that needs to be processed and visualized for the control operator or the system expert grows with the development of the spacecraft platform.

To achieve the goal of global navigation field creation 24 spacecrafts are needed in the orbital group. The total number of communication sessions reaches 40 sessions a day, simultaneous communication sessions are held with 3-5 spacecrafts at the same time. Therefore it is very important to develop new methods for ensuring automated multiline reception, processing and analyzing large amounts of telemetry data from several spacecrafts at the same time.

In the existing scheme of telemetry data processing the session server provides a single-threaded mode of operation. That is, a session is possible with only one device at a time. Parallel communication session with the spacecraft requires a number of telemetry servers in various workplaces to ensure the reception of multiple telemetry streams. This situation worsens the efficiency of the telemetry sector, as in this case the time for creating a new telemetry client and setting a session increases. There occurs a problem of telemetry archives decentralized configuration created by servers for the post session analysis. As is well known decentralized data storage provokes a problem of data synchronization which is not solved in the existing system of telemetry data processing and also a problem of ensuring the authorized access to archival information.

The session operating mode of telemetry system requires the analyst to participate constantly in the organization of sessions, while with the current number of sessions, this procedure should be automated.

During reception and analyzing telemetry sessions, each telemetry client has to enter the parameters for the upcoming session manually. This, on the one hand can cause operator input errors, and, on the other - uncontrolled delays in connection to the server.

During the telemetry reception session from the ground measuring station, the signal / quality of the telemetry information may actually get worse (increase of faulty information in percentage terms) or disappear completely due to atmospheric or other kinds of disturbances in the radio signal transmitted between the spacecraft and the ground measuring station. In this case, to choose the other ground measuring station which possibly receives a better signal, the analyst has to: organize a new session with connection to the required ground measuring station, and, repeat manually the procedure of organizing a session for the telemetry client, with all that it implies.

When different hardware and software are used for telemetry data reception from various sources, their maintenance, support and operation become more difficult to perform.

Besides, the existing system of telemetry processing does not provide tools for transferring the results to the external consumers and systems, such as, for example, Regional Control Center.

One more problem which needs immediate solution is the problem of estimating a particular spacecraft operational condition before the separation contact by means of telemetry reception from the upper stage. This requires the organization of the advising datalogical interaction between the ground measuring station and the mission control center with the implementation of reasonable and appropriate technical and organizational measures and development of specialized data-sharing protocols.

In conditions of orbital group expansion it is also crucially important to provide automated reporting (week, month, etc.) on the basis of generalized telemetry data processing.

In the available system of telemetry processing there is no reliable security system designed to prevent unauthorized access, such as authorizations of telemetry clients and protection of data transmitted. This doesn't conform to safety regulations for specialized control centers.

Solution of the problems described seems to be very difficult in the available system of telemetry processing due to the used procedural methods of software development. Productivity, modularity and expansibility of the existing system are likely to be provided only by designing new multiline telemetry processing system architecture with application of the methods of system analysis and development on the basis of the object-oriented principles conforming to software quality standards.

4. Principles for the creation of a unified system for reception, processing and analyzing telemetry data

Till now the approach to the development of special software for telemetry data processing and its functional structuring was defined by the requirements imposed by specialists in the field of monitoring and controlling specific spacecrafts and hardware characteristics of the mission control center. That has resulted in a large number of different software packages for each spacecraft or their orbital group. The effective technical support of software, including its development and modernization is impossible in the current situation which is worsened with the increase in a number and types of the spacecrafts developed.

Thus, the problem of unification, i.e. creation of the unified system of telemetry data processing was defined as one of the most important as its solution will provide flexibility of functional software architecture and its independence from the spacecraft. A new technique for the creation of the unified program complex of special software for telemetry data processing was offered on the bases of results from scientific investigations. This technique assumes adherence to the following principles:

1. systematicity, which is predetermined by:

- availability of functional and data connections in the system;

- distribution of functional tasks between separate modules based on the methods of system analysis;

2. software flexibility and compatibility of its functional characteristics, due to:

- software modularity, possibility of its expansion and modification in accordance with the tasks to be solved;

- independence from the operating system;

- laying out the key tasks for the protocols of information interaction with the conjugated elements of the system;

3. automation of the system modules, which requires:

- defining the minimum necessary input information;

- maximizing the degree of system independence from human intervention;

- providing a given level of generalization of output information for its transmission to the adjacent control modules;

4. given level of the system functionality, providing:

- receiving, processing and storage of various telemetry data;
- automated control and diagnostics of the spacecraft operating condition using telemetry data;
- effective reporting of the results of telemetry data processing.

5. Conclusion

The functional scheme of the mission control center is considered on the basis of structure analyses of automated control system for the spacecraft. The tasks to be solved by control sectors as a part of the mission control center are determined. The problems of the system of telemetry data processing and analyzing are fixed. The necessity to improve special software for telemetry data processing is noted. It is shown that with placing new types of spacecrafts into orbital group, increase of computing loading and expansion of functional tasks, the existing system of telemetry processing is no longer able to provide satisfactory quality, performance, accuracy and completeness. The general principles for the creation of the unified systems of telemetry data processing are offered as a result of the research.

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