ONBOARD CONTROL COMPLEX OF KAZAKHSTANİ SCİENTİFİC NANOSATELLİTE KAZSCİSAT

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The article is devoted to the creation of an onboard control complex of a Kazakhstani scientific nanosatellite KazSciSat. The nanosatellite was developed on the basis of CubeSat 3U technology and is intended for operation in a sun-synchronous orbit with an altitude of ~600 km. The nanosatellite included a payload, an onboard control system, an attitude determination and control system, a communication system, a power supply system, a structure and mechanisms.

Key Words: Nanosatellite, Onboard Control Complex, Command and Data Handling.

1. Introduction

Scientists and specialists of the Institute of space technique and technology created and successfully launched the KazSciSat scientific spacecraft in December 2018. The main mission of the nanosatellite was to monitor the Earth's magnetic field in order to study physical processes in near space and their relationship with terrestrial processes. The KazSciSat nanosatellite was developed on the basis of CubeSat 3U technology and ECSS standards[1),2),3)]. The nanosatellite is intended for operation in a sun-synchronous orbit with an altitude of ~600 km.

One of the important subsystems of the nanosatellite is the onboard control complex (OBC), which is to collect and process data from service systems, distribute management teams between them and management board time[4)]. This article is devoted to the process of development of onboard control complex for KazSciSat.

2. Structure of onboard control complex

The structure of the onboard control complex includes a Command and Data Handling (C&DH) module providing service telemetry data processing and execute commands from Earth. There is support for real-time operating system FreeRTOS and eCos. C&DH module consists of 32-bit processor ARM7TDMI with RISC architecture and allows performing high level tasks of control as well data processing when it is necessary. C&DH module has several types of memory: flash-memory, RAM and external MicroSD card up to 2Gb for the storage of telemetry or dedicated information. MicroSD card is developed under ATP technology and have flight heritage about 1.5 years on GOMX-1 mission. Fastening of MicroSD card in C&DH slot performs using glue materials for avoiding unwarranted disconnection during vibration loads (Figure 1).

One of the main tasks of C&DH is maintain of on-board timing for the well-timed performance of flight tasks. Because of the absence of navigational equipment onboard nanosatellite which may correct onboard clocks, it is supposed to correct onboard time using commands transmitted from the ground control complex. VHF/UHV antenna system if almost omnidirectional and allows performing of the transmission of control commands “up” whenever it is needed when nanosatellite is in the zone of radio coverage.

Fig. 1. C&DH general view (GomSpace)

3. Software of onboard control complex

The GomSpace Command and Data Handling framework is a software package that implements the basic on-board software that you need to effectively implement mission specific behavior for your satellite mission. The C&DH framework significantly reduces risk in a project by focusing available resources on addressing mission specific challenges and not developing basic functionalities and by allowing integrated tests from the start of the project implementation. The C&DH package is available as a binary library distributed with development and communication tools.

The licensing plan is based on a per mission fee allowing full site access for each mission including one year of updates and support.

C&DH software is provide with C&DH module NanoMind A702/A712 and consist of following components:

- FreeRTOS oprating system;
- FreeRTOS kernel;
- filesystems;
- drivers library;

- standard C-functions library;
- CSP library.

FreeRTOS kernel includes prepared procedures for housekeeping collection from nanosatellite systems, flight planner, event logging system, data compression and encrypting procedures, semaphores, interrupt processing and initial code.

Drivers library is a package of functions for work with peripherals - I2C, SPI, USART, ADC, PWM, Flash, integrated magnetometer etc.

Ground side software is a package of software support tools for development and writing on-board software to C&DH and it's debugging.

Ground side software consists of:

- communication and commanding FTP client;
- CSP terminal (terminal interface to C&DH on satellite);
- Eclipse & GCC based tool-chain for Linux operating system.

Interaction C&DH module with other nanosatellite components performs using I2C bus according to format of command, defined for each module. Sending commands to nanosatellite systems performs by functions of driver library for peripherals, particularly by functions for I2C bus.

4. Testing of C&DH on-board software

Functional tests of C&DH on-board software are oriented for verification C&DH functions, mainly:

- gathering of housekeeping telemetry from nanosatellite systems;
- processing and execution of commands from the Earth;
- execution of flight tasks;
- preparing and sending telemetry information to the Earth;
- handling of failures.

For providing functional tests defined the preliminary list of software and electrical tools which are necessary for interacting user with C&DH module:

- client terminal. It is console-like software for data exchange via external interfaces of personal computer, connected to physical interfaces of C&DH module using communication adapter;
- communication adapter RS232-USB for conversion of serial port signals of diagnostic interface to USB signals for personal computer.

As a client terminal it is planned to use freeware for work with Telnet, SSH1 SSH2 protocols. This software works with virtual COM ports (RS232, USB) in interactive mode or in command line mode with opportunity to control session using integrated macros.

Communication adapter RS232-USB is included in delivering C&DH module package. In case of connection C&DH module to personal computer via Communication adapter RS232-USB there is power supply of C&DH module from USB port and there is no need using electrical power system of nanosatellite or some additional external power supplies.

In case of work with C&DH module using Communication adapter RS232-USB it is possible to carry out following operations:

- monitoring of C&DH module parameters. This performed by sending commands from client terminals to get interested parameters;
- sending commands on execution self-developed software functions. This possibility is awfully for verification of software procedures which is developed independently;
- starting and stopping flight planner;
- Earth commands emulation;
- testing of reaction of software on random commands, damaged data packets etc.

In accordance with the mission of nanosatellite, the consideration of accompanying processes during the interaction of nanosatellite and ground control segments was done. Since there are 3 radiochannels (VHF 156 MHz, UHF 450 MHz and S-band 2.4 GHz), next processes were found:

- communication test. This process is for the prove of presence of the communication with nanosatellite in UHF/VHF frequency range. It is supposed that this process is after the appearing of nanosatellite in radio coverage zone followed by the operation of nanosatellite;
- transmission of single control commands. This process appears periodically during communication sessions in case of necessity;
- sending of mission tasks to nanosatellite. This processing is for the upload of long-term schedule of nanosatellite operation for certain amount of time;
- download of telemetry from nanosatellite. This process is for reception of information on the nanosatellite and its subsystems statuses;
- download of dedicated information from nanosatellite. This process is for reception of dedicated information from nanosatellite payload.

Due to the fact, that different radio frequencies might be used for different processes, some of the processes might carry out simultaneously. This increases the time window for each of the processes during the communication session.

Generalized algorithms for processes of interaction of nanosatellite with ground control complex (GCC) mentioned above, which shows its behaviors, were developed.

4.1 Communication test

This process is for the check of communication presence of nanosatellite in VHF/UHF frequency range and was added as an initial phase of the appearing of nanosatellite in radio coverage zone, in order to prove the possibility of registration of command by nanosatellite from the Earth and possibility of performance of next radio contacts.

The way of performance of the process is by sending of the signal to nanosatellite, which consists of command code and ID of ground station, which is necessary for the identification of the command for nanosatellite and filtering of other possible signals on operational frequency. After the verification of received signal by spacecraft, the transmission of answer on the successful reception and recognition of signal received. This notification is a result of successful test of communication.

4.2 Transmission of single control commands

The necessity of this command is due to several factors:

- the need of operational changes in schedule of operation of nanosatellite;
- forced change of operation mode, start/stop of subsystems;
- testing of single tasks.

The logic of this process is by transmission of three times doubled command of control, verification of which on nanosatellite board is an identification of success of identification of command received. Next, the repeated transmission of control commands (also three times doubled) followed by its verification on-board, with the comparison with previous request. Next, according to the type of the command, it might be performed at once, or in a specific moment of time with higher priority amount background tasks, performing in the framework of mission schedule.

After the carrying-out of the command, nanosatellite sends corresponding notification.

5. Conclusion

The process of development of on-board control complex for KazSciSat was considered in this article. The result of this work was used for development of communication system of KazSciSat that was successfully launched in December 2018.

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References

1. ECSS-E-ST-10-06C – Technical requirements specification https://ecss.nl/standard/ecss-e-st-10-06c-technical-requirements-specification/
2. ECSS-E-ST-10-03C Rev.1 – Testing https://ecss.nl/standard/ecss-e-st-10-03c-rev-1-testing-31-may-2022/
3. ECSS-E-ST-40C – Software https://ecss.nl/standard/ecss-e-st-40c-software-general-requirements/
4. Wertz R.J., Larson W.J. Space Mission Analysis and Design, 3rd edition (1999), Springer, 996 p.