The structure of control and data transfer management system for the GAMMA-400 scientific complex

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The structure of control and data transfer management system for the GAMMA-400 scientific complex

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Abstract. A description of the control and data transfer management system for scientific instrumentation involved in the GAMMA-400 space project is given. The technical capabilities of all specialized equipment to provide the functioning of the scientific instrumentation and satellite support systems are unified in a single structure. Control of the scientific instruments is maintained using one-time pulse radio commands, as well as program commands in the form of 16-bit code words, which are transmitted via onboard control system and scientific data acquisition system. Up to 100 GByte of data per day can be transferred to the ground segment of the project. The correctness of the proposed and implemented structure, engineering solutions and electronic elemental base selection has been verified by the experimental working-off of the prototype of the GAMMA-400 scientific complex in laboratory conditions.

1. Introduction

The GAMMA-400 space project [1-3] is intended for precision investigation of the cosmic gamma-emission in the energy band from ~20 MeV up to several TeV, e^-/e^+ fluxes from ~1 GeV up to ~10 TeV, cosmic-ray nuclei fluxes with energies up to ~10^{15} eV and gamma-ray bursts in the energy band of 10 keV–15 MeV. The GAMMA-400 space observatory will be launched on the NAVIGATOR service platform [4] designed by LAVOCHKIN ASSOCIATION at the beginning of the next decade on the elliptical orbit with following initial parameters: an apogee ~300000, a perigee ~500 km, a rotation period ~7 days and inclination of 51º. The expected observatory operational lifetime is more then 7 years. The planned scientific complex main technical parameters are: weight ~4100 kg, power consumption ~2000 W, total scientific downlink transmission up to 100 GByte/day.

2. The information structure of GAMMA-400 scientific instrumentation

The GAMMA-400 scientific instrumentation can be subdivided into two main parts: GAMMA-400 scientific complex and NAVIGATOR service platform systems directly providing the operation of scientific equipment. Figure 1 illustrates the structure of the integrate control and data transfer management system presented a distributed system for acquisition and pre-processing data from scientific measuring systems (SMS) and providing the control and fine tuning of their functioning.

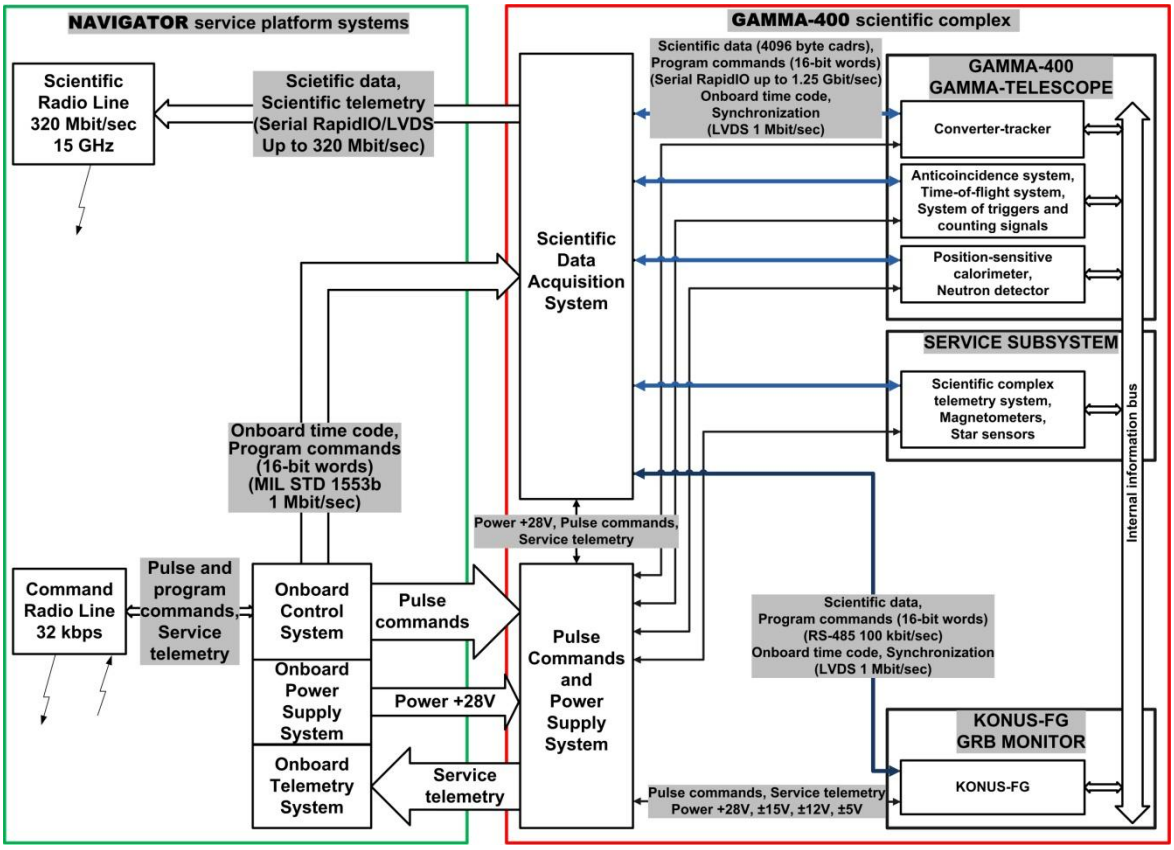

Figure 1. Functional diagram of GAMMA-400 control and data transfer management system.

The GAMMA-400 scientific complex consists of the following subsystems [5-7]:

- gamma-telescope GAMMA-400;
- gamma-ray burst monitor KONUS-FG;
- service subsystem, including two magnetometers for measuring the magnetic field along the satellite trajectory, two star sensors for determining the GAMMA-400 axes with accuracy of approximately 5" and scientific complex telemetry system for cyclic registration up to 65535 scientific complex housekeeping parameters;
- scientific data acquisition system (SDAS) [8] for acquisition and pre-processing data from SMS, storage it in non-volatile mass memory (1 TByte), scientific data and telemetry transfer into high-speed scientific radio line (up to 320 Mbit/sec) for their transmission to the ground segment of the project and control information reception from spacecraft onboard control system via multiplexed channel MIL-STD-1553B, its decoding and transfer into SMS;
- pulse commands and power supply system, providing secondary power supply for scientific complex (+28V, ±15V, ±12V, ±5V), one-time pulse radio commands sharing and their transmitting to SMS and transit of the SMS telemetry parameters to the onboard telemetry system.

The next systems of NAVIGATOR service platform are used for direct providing the functioning of scientific measuring systems:

- command radio line for receiving one-time pulse radio commands and 16-bit program control commands from control ground station and transmit them through onboard control system (OCS) to SMS. Precise timing of scientific data is maintained in SDAS by using onboard time

code from OCS, forming a 32-bit serial onboard time code transmitted to each SMS via LVDS interface along with reference synchronization signals 1 Hz, 1kHz and 1 MHz;

- scientific radio line for scientific data transmitting to the data-acquisition ground stations at a frequency of 15 GHz. The nominal data transfer rates are 160/118.8 or 320/237.6 Mbit/sec with/without coding respectively. Data encryption is used to reduce the quantity of transmission failures (level of 10^{-9} of malfunction probability in the downlink data transmission) by means of the cascade coding technique involving the Reed-Solomon and convolution codes;
- onboard telemetry system for direct (bypassing of SCTS and SDAS) monitoring of analog and digital parameters, contacts and resistance thermo sensors (up to 100 of the most important parameters for operational diagnostics of the scientific complex health);
- onboard power supply system, providing overall power supply for scientific complex (+28V).

For the control and fine tuning of scientific measuring systems functioning one can use:

- up to 100 one-time pulse radio commands in the form of either voltage pulse with duration ~0.1÷0.3 sec with amplitude equal to satellite power or "dry contacts" – switch on/switch off;
- up to 65535 programming control commands (16-bits control words) for each SMS.

The main part of the scientific data is transferred in the form of 4096 bytes length digital arrays from scientific measuring systems to the SDAS, which maintains data reception from four (three for gamma-telescope subsystems and one for service subsystem) sources of digital arrays via high-speed Serial RapidIO (1.25 Gbit/sec) channels. For data transfer from low-information (~100 kbit/sec) KONUS-FG the serial interface RS-485 is used. Data are loaded upon a request for service from SMS.

Two main operating regimes can be specified for GAMMA-400 scientific complex:

- event registration regime, corresponding to the registration of events according to the master trigger signals generated by system of triggers and counting signals formation. In this regime the data acquisition from all detecting system of the gamma-telescope is performed;
- patrol regime, realized all time independently of event registration. In this regime the periodic data acquisition from detecting system of gamma-telescope is performed. The period and set of interrogated detecting systems can be changed by the control commands.

In table 1 the information data (unpacked) requirements for GAMMA-400 scientific measurement systems for main operating regimes are presented.

Table 1. Estimated dataflow from scientific complex in the main operation regimes.

Scientific measurement system	Event regime (bytes/event)	Patrol regime (bytes/day)
Gamma-telescope GAMMA-400	325 k	800 M
GRB monitor KONUS-FG	-	200 M
Service subsystem	-	70 M
TOTAL	**325 k**	**1070 M**

Figure 2 and 3 represents the functional and timing diagram of the Serial RapidIO interface between SDAS and SMS of scientific complex. Each SMS includes uniform interface module, based on high-reliability, fault tolerance system-on-chip 1907VM038 with fast internal input-output channels [9]. Interface module includes additional DDR2 RAM (512 MB) for buffering scientific data arrays, received from SMS via 33 MHz 8-bit synchronous parallel bus and NAND FLASH memory for executable program storage.

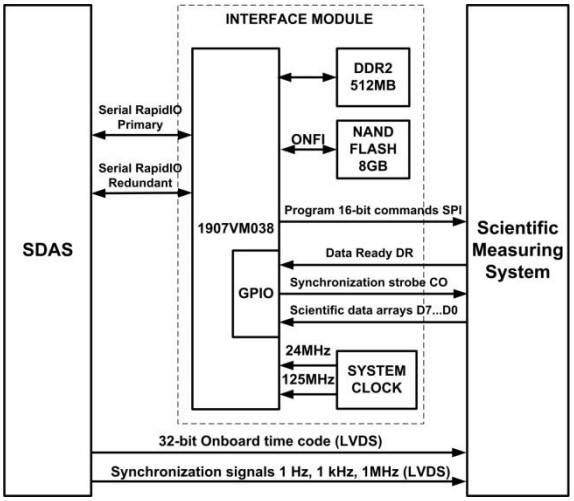

Figure 2. Functional diagram of the Serial RapidIO interface between SDAS and scientific measuring systems of scientific complex.

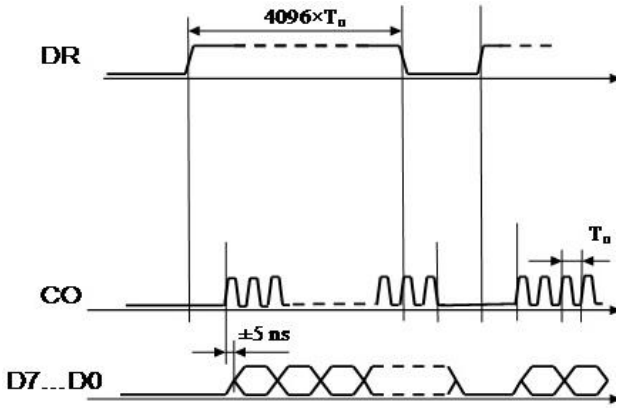

Figure 3. Timing diagram of the scientific data interchange between SDAS and SMS of scientific complex. **DR** – "data ready" request from SMS, **CO**-33 MHz synchronization strobe, **D7...D0** - 8-bit parallel scientific data (all signals are LVTTL).

3. Conclusion

During the GAMMA-400 project development, the prototype of scientific complex was created [10]. Experimental working-off of the main construction units in laboratory conditions has justified the engineering solutions and electronic elemental base selection for design of scientific complex equipment. The structure of the onboard control complex and the data transmission system from scientific instruments for the GAMMA-400 apparatus satisfies all scientific complex requirements. The use of the distributed system involving the scientific complex and service systems of the NAVIGATOR service module provides possibility for adaptive and operational management of the parameters of scientific instruments, as well as acquisition and transmission to the ground segment of the project complete streams of data and operational integrity of the scientific complex.

Acknowledgments
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