THE AUTOMATIC SPACECRAFT *GRANAT*

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1. Cooperation

The participants in the project are:

– USSR, by developing the *Granat* spacecraft (Scientific and Production Association S.A. Lavochkin, G.N. Babakin Research Center) and the instruments in the scientific equipment packages

– ART-P, ART-S, KONUS-V, 'Podsolnukh' (Sunflower), KS-18M (IKI of the Academy of Sciences of the USSR, Leningrad Institute of Physics and Technology of the Academy of Sciences of the USSR, Nuclear Physics Science and Research Institute of the Moscow State University);

– France (CNES), by developing and delivering the gamma ray telescope SIGMA, the high energy spectrometer Phoebus, a memory device with 128 Mbit capacity, and a system for determining the current orientation of the telescope (star sensor);

– Denmark (Danish Institute for Space Research), by developing the wide-angle X-Ray telescope VOTCh;

– Bulgaria (TsLKI Bulgarian Academy of Sciences), by developing and delivering certain control instruments for the 'Podsolnukh' apparatus.

2. Purpose and Scientific Tasks

The spacecraft *Granat* with its scientific instruments package is designed to conduct detailed studies of compact and diffuse space sources in X-Rays and soft gamma rays.

The main scientific tasks to be solved by the scientific instruments package are:

– producing images of the parts of the sky and localizing sources of space radiation in the studied parts of the sky with high accuracy;

– spectral studies in time of point sources;

– measuring linear polarization of X-Ray sources;

– patrol type monitoring of the sky in order to discover and study variable sources of radiation (bursts).

The *Granat* spacecraft will be launched on December 1, 1989 from the Baikonur (Tyuratam) launch complex.

3. Ballistic Data

The launching of the spacecraft into orbit is done using a two impulse scheme. First, the launch rocket provides for the spacecraft launch into intermediate support orbit of the Earth satellite with the following nominal parameters:

– maximum altitude, 2009 km

Y. Kondo (ed.), Observatories in Earth Orbit and Beyond, 21–25.

– minimum altitude, 166 km
– inclination, 51.5 degrees
– rotation period, 107 min
– longitude of the ascending node, 9.3 degrees
– perigee argument, 119.7 degrees
– argument of the latitude of the insertion point, 119.7 degrees
– eccentricity is 0.123

The transfer of the spacecraft from the supporting orbit to the working Earth orbit is accomplished during the first revolution of the supporting orbit.

The working orbit has the following parameters:
– altitude in perigee, 2000 km
– altitude in apogee, 20,000 km
– inclination, 51.5 degrees
– rotation period, 4.05 days

The time the spacecraft spends in the Earth's shadow during the insertion part does not exceed one hour.

4. Main Characteristics of the Spacecraft

Mass of scientific equipment, 2,146 kg

Energy range of studied radiation sources, 2 – –40 MeV

Eight scientific experiments

Average power consumption by the scientific equipment on working parts of orbit, 350 Watt

Length of the scientific observation session, 24 hours

Orientation type: triaxal (constant solar-star)

Angular errors of the axes associated with the spacecraft coordinate system:

– constant error in angle, along the X-axis ca. 15 arcmin, along the Y-axis ca. 10 arcmin, along the Z-axis (toward the Sun) ca. 10 arcmin.

– maximum error in angular stabilization X: ca. 30 arcmin, Y: ca. 22 arcmin and Z: ca. 30 arcmin.

Main stars in orientation system: Sirius, Canopus, Vega, Rigel, Capella

Accuracy in determining current object orientation, 1 arcmin

Time the spacecraft is allowed to stay in the shadow, 3 hours

Total number of communication sessions with Earth: 200

Active lifespan of the spacecraft, 8 months

Observation Region: the entire sky

Capacity of the scientific equiment memory device, 128–200 Mbit

Maximum rate of transmission for scientific information, 65 kilobaud

5. Spacecraft Description

The *Granat* spacecraft consists of the orbital module and the scientific instruments package.

The base of the orbital module consists of the sequentially located toroidal instrument compartment and the support cylinder connected by a coneshaped spacer.

The toroidal instrument compartment is hermetically sealed. It contains functionally important spacecraft systems, providing the operations in Earth's orbit: radio complex, telemetry system, autonomous orientation and stabilization system, electric power system, elements of the thermal management system, blocks of electric automation. A block of star sensor is located on the outside of the toroidal compartment, on the side of the spacecraft that is constantly facing the Sun. It consists of photoelectric sensors for orientation by the Sun and stars.

The support cylinder is divided in two by an internal partition, perpendicular to its lengthwise axis. The top part constitutes a hermetically sealed compartment housing scientific equipment electronics.

The spacecraft's power source consists of three silicon solar panels. Two panels each having two folding sections, are located on trusses attached to the support cylinder and are symmetric in relation to the lengthwise axis of the spacecraft. Before insertion of the spacecraft into the working orbit, they are in a folded position and open up only after the separation of the IV stage of the rocket booster. The third solar panel is located in a fixed position on the support cylinder. The total area of solar panels is 8 square meters.

The narrow-angle transmit/receive antennas, working in decimeter and centimeter bands, provide stable radio communication with Earth regardless of the spacecraft's orientation. They are located on the orbital module.

Jet nozzles using compressed nitrogen provide angular positioning of the spacecraft during orientation and stabilization in space. The jet nozzles are located on the unfolding solar panels (which work using a momentum scheme) and on the toroidal equipment compartment (using a force scheme). Nitrogen is kept under high pressure in spherical tanks which are located outisde and in the lower part of the support cylinder.

Radiators are installed in the orbital module to sustain the necessary temperature in the hermetically sealed instrument compartments.

The radiator-heater is located on the toroidal instrument compartment, its surface constantly looking towards the Sun. The radiator-cooler is located on the support cylinder on the antisolar side. Both radiators are connected via gas pipes to the hermetically sealed instrument compartments, thus forming an active closed gas circulation system of thermal regulation.

On the outside, the spacecraft is covered by a multilayer thermal insulation of the screen-vacuum type. The insulation does not cover the windows which are for optical orientation sensors and the working surfaces of some scientific instruments that have special requirements.

The location of the instruments on the orbital module is based on the fact that functionally the majority of the instruments of the scientific equipment can be divided into two basic groups: narrow field-of-view telescopes (SIGMA, ART-P, ART-S) to observe stationary sources of cosmic radiation; and survey detectors (KONUS-V, Phoebus, VOTCh) to register and study variable cosmic radiation sources, bursts in particular.

The gamma telescope SIGMA is attached to the upper flange of the support cylinder through a coneshaped spacer. Its visor line coincides with the lengthwise axis of the spacecraft. Telescopes ART-P and ART-S are located on stationary bases on both sides of the SIGMA telescope, their axes coinciding with the axis of SIGMA. Such telescopes positioning allows simultaneous studies of cosmic radiation in an extremely wide energy range. A two-level movable platform, that contains scientific instruments of the 'Podsolnukh' experiment, is located on a base near the ART-S telescope. Its position is such that at any time it can point scientific instruments toward any location in the sky.

Survey detectors of the scientific equipment complex KONUS-V, Phoebus, and VOTCh are located on the orbital module providing for the possibility of full spherical survey of the sky without their field of view being obstructed by elements of the spacecraft. Some survey detectors are positioned on the stationary bases near ART-P and ART-S telescopes; some detectors are located on the toroidal instrument compartment. Besides the scientific instruments mentioned above, the charged particle monitor KS-18M is located on the toroidal instrument compartment.

The total length of the spacecraft is 6.5 m; the solar panel span is 8.5 m; the weight is 4.4 tons.

6. Complex of Scientific Instruments

The scientific equipment complex is subdivided into two parts. The first one includes with relatively narrow field of view, such as telescopes designed mainly to study almost stationary sources. The second part includes burst-type instruments designed for detailed studies of the sources of gamma-bursts and sources of X-Ray bursts. Splash instruments permit having the entire sky to be in the field of view.

6.1. Telescopes

Three telescopes with approximately the same information capacity form the base of the scientific instrument complex.

The French gamma telescopes SIGMA can image a 7.3 deg $\times$7.3 deg part of the sky and localize point sources of X- and soft-gamma radiation. It has a position-sensitive detector based on a NaI crystal, coding aperture, and is sensitive in the energy range from 30 to 2,000 keV. The telescope has a large effective surface of 1,024 cm^2, and, as a result, high sensitivity. The instruments spectral resolution is as close as theoretically possible for the given detector type.

The Soviet astronomical position-sensitive X-Ray telescope ART-P can image a part of the sky and localize point sources of X-Ray radiation with an accuracy of approximately one angular minute. It has position-sensitive detectors that are multiwire proportional high pressure chambers with coding aperture. The telescope is sensitive in the 3 to 100 keV range. The effective surface of the telescope is 2,400 cm^2. The instrument allows for the separation of sources that fall in its 1.8 deg $\times$1.8 deg field of view, the study of their spectra, and their behavior in time. The detector type used allows detailed spectral studies of the sources.

The Soviet astronomical spectral X-Ray telescope ART-S is equipped with detectors that are multiwire position sensitive chambers with an effective surface of 2,400 cm^2. The telescope is sensitive in the 3 to 100 keV range. Its field of view is

2 deg × 2 deg. The instrument is designed for detailed spectral and temporal behavior studies of relatively bright X-Ray sources.

These three main instruments are supposed to form an orbital observatory, sensitive in a wide spectral range from 3 keV to 2 MeV.

The on-board availability of the French memory device with 128 Mbit capacity and of the Soviet memory device with 200 Mbit capacity allows 24-hour-long observations. Together with a large detector surface area, the observatory breaks records among the implemented and currently under development space projects in sensitivity in the studied range and in the breadth of scientific tasks to be solved.

6.2. Burst Instruments

The interest in one of the most interesting and unsolved phenomena, gamma bursts, resulted in *Granat* becoming the largest goal-oriented project to study gamma bursts in the world.

The splash equipment package includes KONUS, Phoebus, Podsolnukh, and VOTCh.

The gamma burst detector KONUS consists of seven NaI(Tl) crystal-based detectors. The instrument is sensitive in 20 keV to 2 MeV range, can conduct detailed spectroscopy, study burst behavior in time, and perform rough burst localization with an accuracy of 1 deg to 2 deg.

The high energy spectrometer Phoebus consists of six detectors based on GeBi crystals and is sensitive in the range from 200 keV to 40 MeV. It has good spectral resolution in that range and is irreplacable in studying nuclear gamma lines. The opportunity to study hard tails of gamma bursts is of enormous interest.

The Podsolnukh instrument is a complex of narrov field of view telescopes conducting studies in the range from 2 to 25 keV. It is located on a turnable platform together with a block for registering video information.

The turnable platform has to support real-time automated turns and the pointing of the installed instruments towards the presumed location of the source of gamma burst. Movement is based on signals from KONUS-V. The turn speed of the platform is 90 deg/sec. Furthermore, there are plans for studying the spectral contents of the gamma burst and its temporal structure, conducting precise localization of the gamma burst source. The presence of the module for registering video information allows the source in the X-Ray band to be identified with the optical radiation from a corresponding astrophysical object.

The wide angle X-Ray telescopes VOTCh consists of 4 multilayer detectors based on CSI and NaI crystals. The detectors have rotating modulating collimators.

The sensitivity range of the instruments is from 5 to 150 keV.

The instrument complex VOTCh registers X-Ray bursts, localizes them with an accuracy of up to 10 arcmin and studies the energy spectrum of the bursts and their temporal structure. It also provides patrol type monitoring of the sky in the X-Ray band, while watching bright stationary X-Ray sources.

The charged particle monitor KS-18M is designed to measure the flows of charged protons and helium nuclei with energies of more than 1 MeV and electrons with energies of more 50 keV in interplanetary space.