SPECTRUM ROENTGEN GAMMA

Mission Operations Report

Edited by the Technical Implementation Committee

Version Draft 2.3

December 1994

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Editors note

The Mission Operations Report (MOR) for the Spectrum Roentgen Gamma (SRG) project is edited by the Technical Implementation Committee (TIC) - in reality by a subset of that committee.

The MOR is still in a very preliminary state. Further, some issues in the current version of the MOR are still being discussed in the TIC. The MOR should therefore currently only be seen as an estimate onhow the Mission eventually may be. The MOR will in principle be reissued every 4 months or so, in order to update the contents with the results of the newest calibrations, tests and negotiations in the TIC, the Science Operations Working Group (SOWG) and the International Science Committee (ISC).

This Draft Version 2.3 of the MOR is made from a collection of inputs from almost all instrument- and satellite groups. The forms of these inputs are very heterogeneous, which just illustrates the variety of groups contributing to the project. The editors have tried to get the inputs to converge to a more homogeneous MOR, but it should be emphasized, that there has been no attempt to edit the contents of the inputs in detail yet, and the contents therefore does not necessarely represent the current attitude of the TIC.

December 14, 1994

Allan Hornstrup
(TIC Co-Chairman).

1. Foreword

by: M. Gilfanov & E. Churazov, IKI

International orbital astrophysical observatory SPECTRUM-ROENTGEN-GAMMA (SPECTRUM-X-GAMMA, SRG, SXG) arisen from joint efforts of leading X-ray astronomy groups from more than twelve countries over the world. Scheduled for the launch in late 1995, it is fourth in the sequence of observatory class space missions, utilizing the grazing incidence optics for X-ray astronomy. The 0.2-10 keV energy range of JET-X and SODART grazing incidence telescopes is extended towards optical wavelengths by Optical Monitor and EUVITA and TAUVEX telescopes for extreme ultraviolet and towards hard X-rays - γ-rays by MART coded mask telescope, MOXE all-sky monitor and DIOGEN and SPIN γ-ray burst detectors. Large collecting area of X-ray mirrors combined with good angular (ranging from ≈20" to ≈2') and energy resolution (≈2-20% at 7 keV) will enable varied and exciting program of scientific research to be carried out.

2. SRG Program Overview.

by: M. Gilfanov & E. Churazov, IKI

The content of the SRG scientific payload has been approved by SRG International Scientific Committee (ISC) in early 1989 .The technical design of the main scientific instruments has been finished in 1992. Presently (early 1994) most of scientific instruments are passing through electrical tests. It is planned to finish complex tests of the scientific payload by the end of 1994. The total weight of scientific payload is 2,850 kg.

The scientific payload of the observatory includes:

1. Multimirror grazing incidence X-ray telescope SODART. To be deployed after the launch, it has 124 m^2 total surface area of the X-ray mirrors. Two modules of mutlimirror system will have eight changeable focal plane detectors - proportional counters, solid state and Bragg spectrometers and polarimeter. The TAUVEX ultraviolet telescope is coaligned with X-ray mirrors system.

2. JET-X multimirror grazing incidence X-ray telescope. Both of two coaligned multimirror systems have cooled CCD matrices as X-ray detectors and will provide high angular resolution imaging (20") and fine spectroscopy (2% at 7 keV).

3. MART/LIME X-ray coded mask telescope is optimized for imaging and spectroscopy in the hard X-ray range.

4. EUVITA normal incidence telescope for extreme ultraviolet.

5. MOXE all-sky X-ray monitor SPIN γ-ray burst detector.

6. DIOGEN cooled germanium detector for fine spectroscopy of γ-ray bursts.

The observatory is scheduled to fly in late 1995. Russian PROTON rocket will launch the spacecraft on to highly eccentric 4 days orbit with inclination 51.6 degrees. Initially, the apogee of the orbit will be 200,000 km, perigee - 500 km. Such orbit parameters will enable to perform X-ray observations during three days out of each four, when the spacecraft will be beyond the Earth radiation belts. In two years the orbit perigee will evolve to ~40000 km, thus giving principal possibility to perform observations during the whole orbit.

The operations with SRG spacecraft will be managed and run by russian engineers from one of the tracking stations in Moscow district. Direct contacts between satellite and ground station will be performed once per day. The capacity of fast telemetry link will be 1 Mbit/sec. The expected amount of raw scientific data from spacecraft is ≈10 Gbit per day. The capacity of on board memory is enough to store the data, accumulated by the scientific instruments of the observatory during 24 hours of observations (in nominal conditions). The spacecraft is capable to observe upto 10 different targets per day, the repointings being performed automatically without direct contact with the ground station. The health of the instruments will be monitored by instrument teams at the Quick Look Facility (QLF) located at IKI. The slow telemetry will be transmitted from ground station to QLF facility at IKI in near-real time mode.

From the point of view of scheduling of observations, the observing time of each pointed instrument is divided in to prime and non-prime time. The instrument will select the target during it's primary time while during non-prime time it will observe the target, selected by another instrument, which is prime-time instrument for this observation. (Axis of all pointed instruments are coaligned.) The allocation of prime time is:

SODART	45%
JET-X	35%
MART	10%
EUVITA	10%

From the point of view of data ownership the observing time of each instrument is divided between participating countries according to their involvement to design and manufacturing of the instrument. The 55% of observing time of each instrument belongs to Russia as a return for design of the spacecraft, launch and operations with the observatory.

The mission observations planning cycle will be half a year. The selection of proposals on the basis of scientific merit will be performed on the national levels. Each participating nation will establish it's own rules for access to the data by national astronomers. The technical job on scheduling the observations will be performed by russian Observations Planning Group (OPG), consisting of specialists of Space Research Institute (IKI) and Babakin Space Flight Center.

IKI will maintain complete archive of raw data from the observatory, though russian scientists will have access only to the part of the data from Russian share. The instrument teams will have access to the scientific data from only their national share of observing time. National archives of corresponding shares of data will be established by various participating nations.

4. Scientific objectives.

by: M. Gilfanov & E. Churazov, IKI.

One of the most exciting directions for the research are the *problems of cosmology*. The high performance multimirror X-ray telescopes JET-X and SODART will enable

- the search of high redshift quasars;
- determination of the redshifts of galaxy cluster via emission in X-ray lines of highly ionized iron;
- deep surveys and sources counts;
- fluctuations analysis;
- study of hidden mass in galaxy clusters and galaxies.

The observations of *galaxy clusters*:

- distribution of intergalactic gas and of heavy elements;
- for those clusters with microwave background diminution effect observed in radio determination of Hubble constant;
- study of cooling flows in galaxy clusters.

Study of *Galactic sources and interstellar medium*:

- black hole and neutron star binary systems;
- fine spectroscopy and polarimetry of individual objects;
- all sky monitoring, search for transient sources;
- long term monitoring of bright Galactic X-ray sources, including timing of bright pulsars;
- study of supernova remnants;
- the central part of the Galaxy - diffuse source and point sources;
- stellar astronomy - spectroscopy and polarimetry.

γ-ray burst studies:

- coarse localization of γ-ray bursts;
- fine spectroscopy;
- search for serendipitous γ-ray bursts within field of view of imaging instruments.

5. Science Instruments

5.1.1 Science Instruments - SODART - XSPECT

Instrument name: XSPECT
(Sodart Mirror Module, OXS, HEPC/LEPC)

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Instrument description

XSPECT is the general term for the Danish part of the SODART telescope. XSPECT consist of the SODART mirror modules (MM), the Bragg panel - called the Objective Crystal Spectrometer (OXS) and the 4 proportional counters HEPC/LEPC.

MM

There are two sets of mirror modules. The MM is designed as a conical approximation to the Wolter I Xray telescope geometry. The outer diameter of the MMs are 600 mm and inner radius is 82 mm. The focal length is 8000 mm. The MMs have each 143 laquered and AU-coated 0.4 mm thick Al-foils, nested to completely fill the opening. The design goal is an angular resolution of 2 arcmin HPW.

OXS

The OXS is situated in front of one of the MMs (MM no. B). The OXS concept separates the processes of energy dispersion and imaging. The large mosaic panel of flat crystals in front of the telescope acts as a narrow bandpass filter and as a mirror. Each pixel in the reflected field of view of the telescope satisfies a specific Bragg angle on the crystal and, therefore, each pixel in the detector can be identified with a particular energy. Scans which involve repositioning of the telescope axis and the angle between the crystal panel and the telescope axis (45° ±15°) yield either the spectrum of a point source or energy resolved images of an extended source. Multilayer (ML) structures will be deposited on the polished surfaces of the LiF and Si crystals to allow simultaneous measurements of the Fe L and other prominent lines in the energy range below the C K-edge.

HEPC/LEPC

The HEPC/LEPC detectors are Microstrip Proportional Counters. The MSPC is a novel approach, in which the wire grids in conventional proportional counters are replaced by narrowly spaced, conducting microstrips which are accurately deposited (±0.1 μm) on an insulating substrate. A high- and a low-energy (HEPC and LEPC) detector will be provided for each telescope.

Scientific Objectives

XSPECT is unique among the third generation Xray missions because of its large collecting area and broad energy range.
The scientific topics will at least cover:

- Normal stars
- Star-formation regions
- Neutron stars and accretion disks
- X-ray bursters
- X-ray novae
- Supernovae and their remnants
- The X-ray background and X-ray emission from galactic plane
- Galaxies, and clusters of galaxies
- AGNs

but at DSRI the emphasis will be on three major research topics:

Active Galactic Nuclei (AGN)
Temporal and spectral studies of nearby AGNs using the HEPC/LEPC (and solid state) detectors can be used to explore the detailed nature of the core of the (AGN) galaxy and its surrounding accretion disc. The size of the central core and, therefore, its energy density can be inferred from temporal variations. The nature of the emission mechanism is revealed in the shape of the broad continuum spectrum. The chemistry of the accretion disc is found in emission and absorption features that, in some favorable cases, can be obtained with high spectral resolution.

Distant AGNs can be studied to the limit of the XSPECT sensitivity above several keV where, despite the limited angular resolution, confusion is not a problem. The broad band spectra from these objects can be compare with those of the nearby objects to look for the possibility of evolution from the relatively younger distant objects to the older nearby ones.

These studies can be complemented with campaign style ground- and space-based observations using Danish as well as other national and international facilities.

Dark matter in clusters of galaxies.
XSPECT will be used to examine the distribution of the surface brightness in extended objects. In particular, the most recent studies of the surface brightness of nearby clusters of galaxies by the EINSTEIN, EXOSAT and ROSAT missions have been constrained by either or both a lack of sensitivity and a lack of spectral range. XSPECT will be able to carry out surface brightness studies to a considerably larger distance from the cluster core over a much broader energy range. These studies will have the possibility of detecting previously undetected hot dark matter. XSPECT will, in addition, be able to map the temperature and density profiles and, for sufficiently bright clusters, the Bragg spectrometer will be able to carry out detailed plasma diagnostic studies of the hot clusters gas as well as measure precise red shifts. These can then be compared with red shift distribution obtained from the individual galaxies in the cluster that has been used in the conventional way to obtain the distance to the cluster.

Cosmic X-ray background (CXRB).
At very great distances, even the collecting power of XSPECT will be insufficient to resolve the individual AGNs that are thought to be the major component of the X-ray background. Instead, the diffuse emission from all the unresolved galaxies in the XSPECT field-of-view is mapped. Two results will emerge from such observations. The spectrum of the CXRB can be obtained by eliminating the contributions from foreground objects in the field-of-view. This can be compared with the summed spectrum of nearby AGNs and differences between them can be attributed to evolutionary processes. Again, because of the high sensitivity to surface brightness, XSPECT is ideally suited for studying the fluctuations in the CXRB over a wide

range of energies. The scale height of the fluctuations is an indicator of distance: nearby populations will give large fluctuations while more distant ones will give a relative smooth distribution.

Maps of the CXRB can be correlated with surveys obtained from optical and microwave studies. The results of such correlations will have important cosmological significance.

Operating Modes

HEPC/LEPC
Each sled carries a low and high energy detector. The detectors are equal in power consumption levels. There are four levels of operation:

Level 0:	off:	27 Volt supply off
Level I:	St.by:	CPU and BIUS on
Level II:	Obs.:	Observation
Level III:	Data TX:	CPU and BUIS transmitting continuously

Mode of Operation	Levels Sled A	Sled B
1. Data transmit	III,I	I,I
2. TBD		
3. Command reception	I,I	I,I
4. One det. each sled calibration	II,I	II,I
5. One det. one sled in focus other sled background counting	II,I	II,I
6. Two det. in focus	II,I	II,I
7. Alternate det. in focus, one sled	II,II	I,I
8. One det. one sled in focus or cal.	II,0	0,0
9. Two det. in focus, two for backgr.	II,II	II,II
10. No detectors in use	0,0	0,0

Note: For each mode of operation the sleds can be interchanged. In mode 1, each detector will in turn be in level III to transmit stored data.

These modes can be time sequenced in many ways. Most of the modes will only be used rarely, if ever. Primarily, mode 9 will be the one used most often (see later section: Requirements on Operation).

Calibration Programs

ON-GROUND:
An extensive description may be found in Nørgaard-Nielsen: *Plan for the prelaunch tests of XSPECT*, jan 1994. The following is a brief summary:

MM
The total reflectivity from selected mirrorsamples will be measured extensively at low energies from 0.1 to 4.0 keV, especially around the Au M-levels. These measurements will be performed at BESSY in Berlin, Germany. The measurements will be used to estimate the effective area for the telescope at these energies. Similarly, extensive reflectivity studies will be performed around the Au L levels at the Daresbury Synchrotron Facility (UK).

The MMs will be measured in full scale at the Daresbury Synchrotron at selected energies from 6 to 12 keV. Also, the MMs will be measured at optical wavelengths at DSRI.

OXS
To minimize the prelaunch calibration of the OXS, the on-ground calibration emphasizes on examination of the possibility of the OXS to introduce artificial "emission" or "absorption" lines. The crystals will be measured in the energy range 0.1 to 5 keV at BESSY to show, that the response function is a smooth function of energy.

HEPC/LEPC
The transmission of the windows will be measured in great detail around the absorption edges of the window material. These measurements will be performed at BESSY in the energy range 0.1keV - 1.5 keV, with emphasis around the edge-energies.

The response function for the detector will for the energy range 1.5 to 5 keV be measured at BESSY. This energyrange is important since it covers the Xe 4.8 keV edge. Measurements in other energy ranges will be done at DSRI.

Energy calibration and position calibration will be performed using radioactive and conventional Xray sources at DSRI.

IN-FLIGHT

MM
To investigate in detail the off-axis behaviour of the telescope, a point source with well known spectrum will be rasterscanned through the telescope Field Of View. The source will be (TBD) and this calibration will have a duration of (TBD) seconds. The point spread function as function of energy and position of source will be found in the same way.

OXS
A detailed raster scan of the Crab source, known to contain only a faint, if any, thermal component, will be performed. The duration of this calibration will be (TBD) seconds.

HEPC/LEPC
The DSRI Proportional Counters will be calibrated both with respect to position and energy response before and after each observation when they are not in focal position. The method employs ^{55}Fe sources in the cover lid, which illuminate the full active detector area through a multiple collimator (see later).

List of on-board radioactive sources

HEPC/LEPC
The radioactive sources used are ^{55}Fe sources which illuminate the full active detector area through a multiple collimator. Source, shield and collimator are mounted in a 55 mm high, 150 mm diameter Al-tube. The source consists of 70 dots, 1 mm diam., spaced 15 mm apart. When in place above the detector, each dot will give 3 counts/sec. in a spot with 3 mm FWHM. When the detector is used for astrophysical observations, the calibration source is swung away by 90°, since it is mounted on the dust lid of each detector.

The sources are completely shielded to the environment as long as the cover lids are closed.

Up- and Downlink commands.

HEPC/LEPC

There is an ON, an OFF and one BIUS address command for each HEPC/LEPC. There may be sent up to (TBD) 128 words during ground contact. See "Command Words" in the section "Requirements on Operations" below.

Structure of Information

HEPC/LEPC

Scientific Data

All data stored and transmitted in blocks of 1024 words = 2048 bytes are called Scientific Data, although the content can also be technical. The data are collected in each instrument in 2 42Mbyte disks. The disks may be shared between the HEPC/LEPC instruments via the BIUS.

The content of the block of scientific data is :

Word	Content
1 + 2	Sync
3	Instrument identification
4	Block number 0 to 65535
5 + 6	Block type
7 + 8	Flags
9 + 10	Time, OTC number of 1/8 seconds.
11 to 1020	Data
1021+1022	Deadtime
1023 + 1024	Checksum

The content from word 9 to 1024 will be different when technical information (House keeping data) is sent. In "Data" events from the detectors are given in one of these formats :

Format	Bytes	Content
a1	7	T16-10, V, E, R, P
a2	9	T16-10, V, E, R, CG, PG, CC, PC
b1	6	T8-10, V, E, R, P.
b2	6	T8-400, V, E, R, P.
d	2	T8-10, E.
r	24	Raw data and time.

(Acronyms: V: Veto, Tx-y: time difference x bit-y µs units, E: Energy, R: Risetime, P: Position, CG: Charge Ratio Grid, PG: Position Grid, CC: Charge Ratio Cathode, PC: Postiton Cathode.)

Other formats, TBD, will be used to give images, energy and time spectra (histograms).

Note, that the HEPC/LEPC has the following names and instrument groupings:

sled A	sled B	Instrument Group
HEA	LEB	A
LEA	HEB	B

i.e. for LEPC, the Instrument Group name differs from the name of the sled. The name of the Instrument Group is reflected in the data header (in the instrument identification part).

Requirements on operations

HEPC/LEPC

Power
The HEPC/LEPC detectors have the following requirements on power (see "Operating Modes" for a description of levels):

Power	Level I	Level II	Level III
LEPC	15	25	20 W
HEPC	15	25	20 W

It is for calibration purposes required, that all 4 HEPC/LEPC detectors are operated in level II mode, even when not observing. This corresponds to a typical power consumption of 100W. The minimum requirement, when the detectors are in stand by mode (Level I), is 60 W.

Command Words
The Command Words, CCW, are used to :

a) Set the mode, or sequence of modes, which the instrument must run in the next observation period.
b) Set flags that determine which processes are allowed to run in the processor.
c) Set values of a number of hard- and software parameters.
d) In case of errors in the software to write small program sections that can be patched into the running software.

All command words are written into an EEPROM, and either used directly from there, or loaded into the RAM in which the operating program is running. The operating program is loaded from another EEPROM which is normally in read-only state.

During ground contact, a maximum of 128 words, TBC, may be sent to each instrument.

Before each observation period, a maximum of 16 words may be sent to the instruments that are used in this period. These words must obviously be stored in the BIUS system. The observation period is initiated by the SOT command.

At the end of each period one CCW may be sent to each instrument used in the period. This is sent after the FOT word.

Operational Requirements on Other Instruments.

OXS
During observations with the OXS, the source is located at an angle appr. 90° from the pointing direction of the other instruments. Furthermore, to ensure a proper θ - 2θ scan, the satellite will be moving during the observation. The current expectations are, that one OXS-observation will consist of ~10 succesive pointings separated ≤10 arcmin, each of duration ~10^4s.

HEPC/LEPC
It is for calibration purposes required, that the HEPC/LEPC detectors are switched on also when not in focal point. This has implications on the power consumption and on the duration of the telemetry session, as well as on the observation scheduling (i.e. memory capacity).

Instrument Performance

MM

The Figure 1 below shows the effective area of one of the MMs as function of energy.

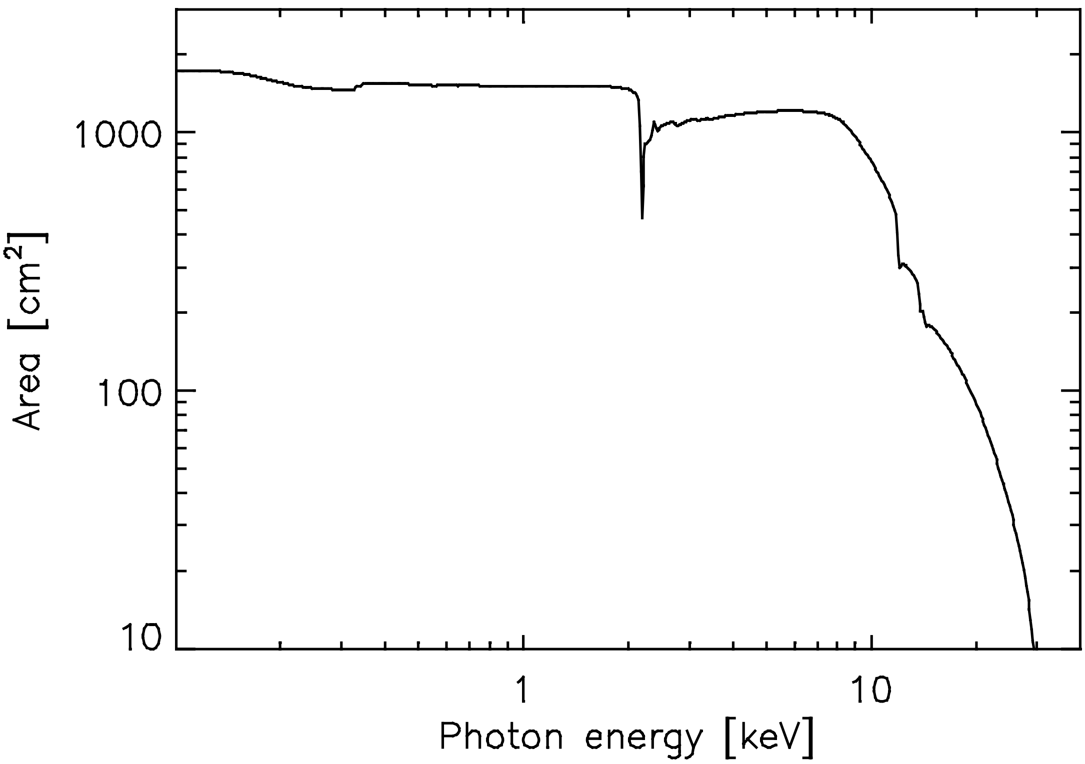

Figure 1: showing the effective area of one of the Mirror Modules of the SODART telescope.

The main parameters for the MMs are found in the table below.

TABLE. MM SPECIFICATIONS - one unit

Field of view		arcmin	60
Half power width		arcmin	< 2
Focal length		m	8
Diameter:	Inner Shell	cm	16
	Outer Shell	cm	60
Reflecting surface		Å gold	400
Effective area		cm^2@2 keV	1460
		cm^2@8 keV	1120
		cm^2@20 keV	94
Shell material		mm aluminum	0.4
Shell separation (min)		mm	0.52
Shell length		cm	20
Number of shells			143
Mass per telescope		kg	101
Total mirrored surface		m^2	62

OXS

The following table shows the main parameters for the OXS, implying the performance of the spectrometer.

TABLE. OXS CRYSTAL SPECIFICATIONS

NATURAL CRYSTALS		LiF (220)	Si (111)	RAP (001)
Lines: H- and He-like		Fe	S	O
Bragg Angle (He-like)	deg	~ 41	~ 50	~ 57
Wavelength Range	Å	1.7 - 2.5	2.7 - 5.4	15.4 - 22.6
Energy Range	keV	5.0 - 7.4	2.3 - 4.6	0.55 - 0.81
Rocking Curve Width	arcmin	~ 2.6	~ 1.6	~ 7
Resolution (point source)	$E/\Delta E$	~ 1200	~ 3200	~ 770
Peak Reflectvity	%	~ 21	~ 35	~ 2

MULTILAYER CRYSTALS		ML (001) on LiF (option only)	ML (001) on Si
Composition		Ni/C	(Ni,Cr or Co)/C
Wavelength Range	Å	56 - 83	44 - 71
Energy Range	keV	0.15 - 0.22	0.175 - 0.28
2d Spacing	Å	96	78
d Spacing (Ni)	Å	~ 15	~ 12
Number of Layers		~ 60	~ 90
Peak Reflectivity	%	~ 20	~ 15
Rocking Curve Width	arcmin	~ 45	~ 40
Resolution (point source)	$E/\Delta E$	~ 55	~ 80

A sketch showing the crystal arrangement on the OXS's will be placed here.

HEPC/LEPC

The following table shows the main parameters for the HEPC/LEPC detectors, illustrating the performance.

Table. HEPC, LEPC Scientific Specifications

Energy resolution	0.32 x (E/1 kev)^{½} kev
Background rejection	> 99 per cent
Time resolution	< 10 µs
Gas	Xe 90%, CH_4 10%

		HEPC	LEPC
Field of view	arcmin	60	30
Diameter of active area	mm	150	75
Diameter of window	mm	140	70
Position resolution	mm	<1	<2
Energy range	kev	2 - 25	0.2 - 8
Gas thickness	cm	4	4
Gas pressure	atm	1	0.5
Window : Polyimide	µm	7.5	0.85
Al	nm	52	38

5.1.2 Science Instruments - SXRP

Instrument name: **SXRP**
(Stellar X-ray Polarimeter)

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Instrument Description

SXRP consists of two separate polarization analyzers: a thin mosaic graphite crystal that makes use of the polarization dependence of Bragg reflection, and a metallic lithium target that exploits the polarization dependence of Thomson scattering. The graphite crystal and lithium target are surrounded by four imaging proportional counters that detect the Bragg reflected and the Thomson scattered x-rays (see Figure 2). The entire polarimeter assembly rotates about the optical axis of the telescope.

The Bragg polarization analyzer consists of a thin graphite crystal mounted above the lithium scattering target. A graphite crystal oriented at 45x with respect to an incoming x-ray beam will reflect only those x-rays with energies satisfying the Bragg condition and with electric vectors lying in the plane of the crystal. If the incident beam is polarized, the intensity of the reflected beam will be modulated at twice the rotation frequency of the polarimeter. The Bragg polarimeter is sensitive in two narrow bands, the first order and second order Bragg peaks at 2.6 and 5.2 keV.

The angular distribution of x-rays scattered from the lithium target depends on the polarization of the incident x-ray according to the Thomson scattering cross-section. Maximum scattering occurs when the photon is scattered through an azimuthal angle perpendicular to the photon electric vector. Therefore, the intensity of scattered radiation for a polarized beam is, again, modulated at twice the rotation frequency. The energy band pass for the lithium polarimeter extends from 5 keV, limited by photoelectric absorption, up to 15 keV, limited by the reflectivity of the SODART telescope.

The IPCs are part of the scattering polarimeter subassembly of the SXRP and are used to detect x-rays which have passed through a polarization analyzer, either reflected from a graphite crystal or scattered in a metallic lithium target. There are four IPCs, forming a box which surrounds the graphite crystal and lithium scattering target. X-rays reflected from the graphite crystal fall on a small part of one of the IPCs. There is a small thin window which is devoted to imaging x-rays reflected from the graphite crystal. The remainder of the window area on each counter is used to detect x-rays scattered from the lithium.

To match the energy band pass of the graphite and lithium polarization analyzer, the IPCs

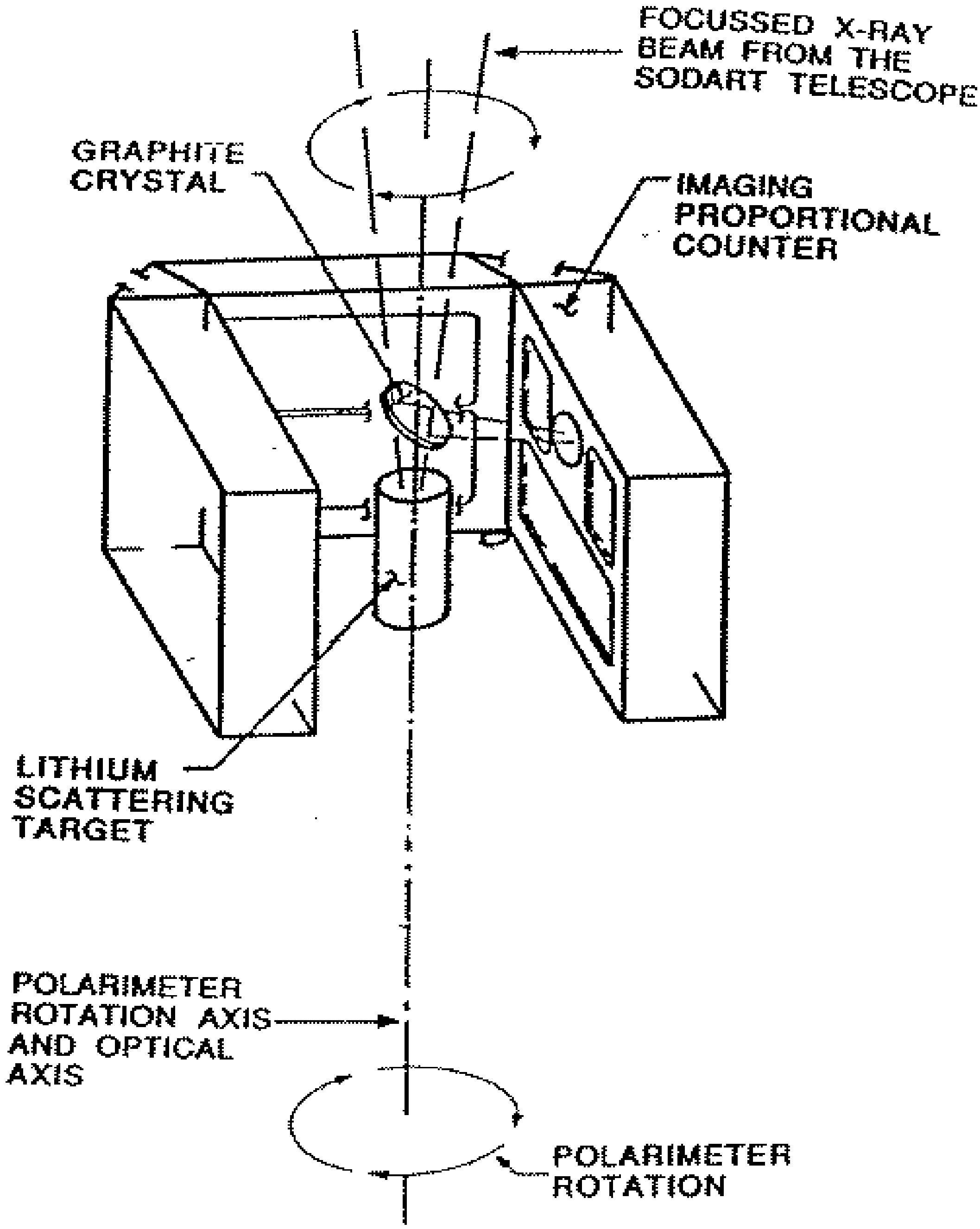

Fig. 1: Polarization analyzer. The fourth IPC is not shown for clarity.

must be efficient in an energy band extending from 2 to 15 keV. The x-ray energy is not significantly changed by Thomson scattering or Bragg reflection. Therefore, the accuracy with which we can measure the energy of incoming x-rays is determined by the energy resolution of the IPCs.

Since photons are scattered from the lithium over all angles, the detectors must intercept a large fraction of the solid angle; also, the distance from the target to the detector window must be at least 90 mm in order to reduce false polarization signatures due to spacecraft pointing errors. These two conditions lead to an active area requirement of 100 cm2 for each counter, leading to a total active area of 400 cm^2.

We have chosen to use a multiwire proportional counter with a single amplification stage, a wedge and strip cathode for position sensing, and a rear anticoincidence region. Each counter has an active area of 10 cm by 11 cm sealed with a beryllium window to eliminate the need for a gas system. The drift region is 3 cm. To have good efficiency up to 15 keV, the gas mixture contains a large fraction of xenon -- 50% Xenon - 40% Argon - 10% Methane.

Position sensing of the X-rays scattered by the lithium increases the effective modulation factor because it leads to more accurate determination of the scattering angle. Non-imaging detectors used in the same geometry would decrease the polarization sensitivity by a factor of 3. In addition, imaging allows us to continuously measure the background and its possible polarization signature.

A crucial parameter of the IPCs is their background rejection efficiency. The use of a polarization analyzer, Bragg crystal or Thomson scattering target, greatly reduces the number of detected X-rays. Low count rates imply a corresponding increase in sensitivity to background. For the lithium scattering polarimeter, the large active area required further increases the deleterious effects of the background. A low background rate is crucial for the operation of a sensitive polarimeter. The detectors employ five sided anticoincidence (rear and four sides) and anode pulse shape discrimination to reduce the background count rate.

The entire SXRP is contained in a single package with an envelope of 470 cm by 604 cm by 400 cm (not including the aperture cover) and an estimated total mass of 60 kg. The polarization analyzers and the four detectors are mounted on a rotating platform within the SXRP instrument. During normal observations, this platform under goes continuous rotation at a typical rate of 0.5 rpm. In the case of failure of a drive motor, a parafin actuator can be used to change the rotation platform drive to a redundant motor.

A functional block diagram of the rotating section of the SXRP is shown in Figure 3. All of the preamps, signal processing and digitization electronics, and high voltage power supplies are mounted on the rotating platform. Only low voltage power and digital signal are passed, via a slip ring, between the rotating and non-rotating sections of the SXRP.

The non-rotating section of the SXRP contains a 96 MB mass memory, BIUS interface and control microprocessors, the rotation drive motors, and the low voltage power supplies. The SXRP electronics is divided into two separate, but non redundant parts. Each half of the electronics processes the data from two of the four IPCs. The rotation drive can be operated from either half of the SXRP. Both halves of the SXRP must function to provide optimal performance. However, if either half fails the SXRP will still function but with reduced performance. This design greatly reduces the potential for single point failures of the entire instrument.

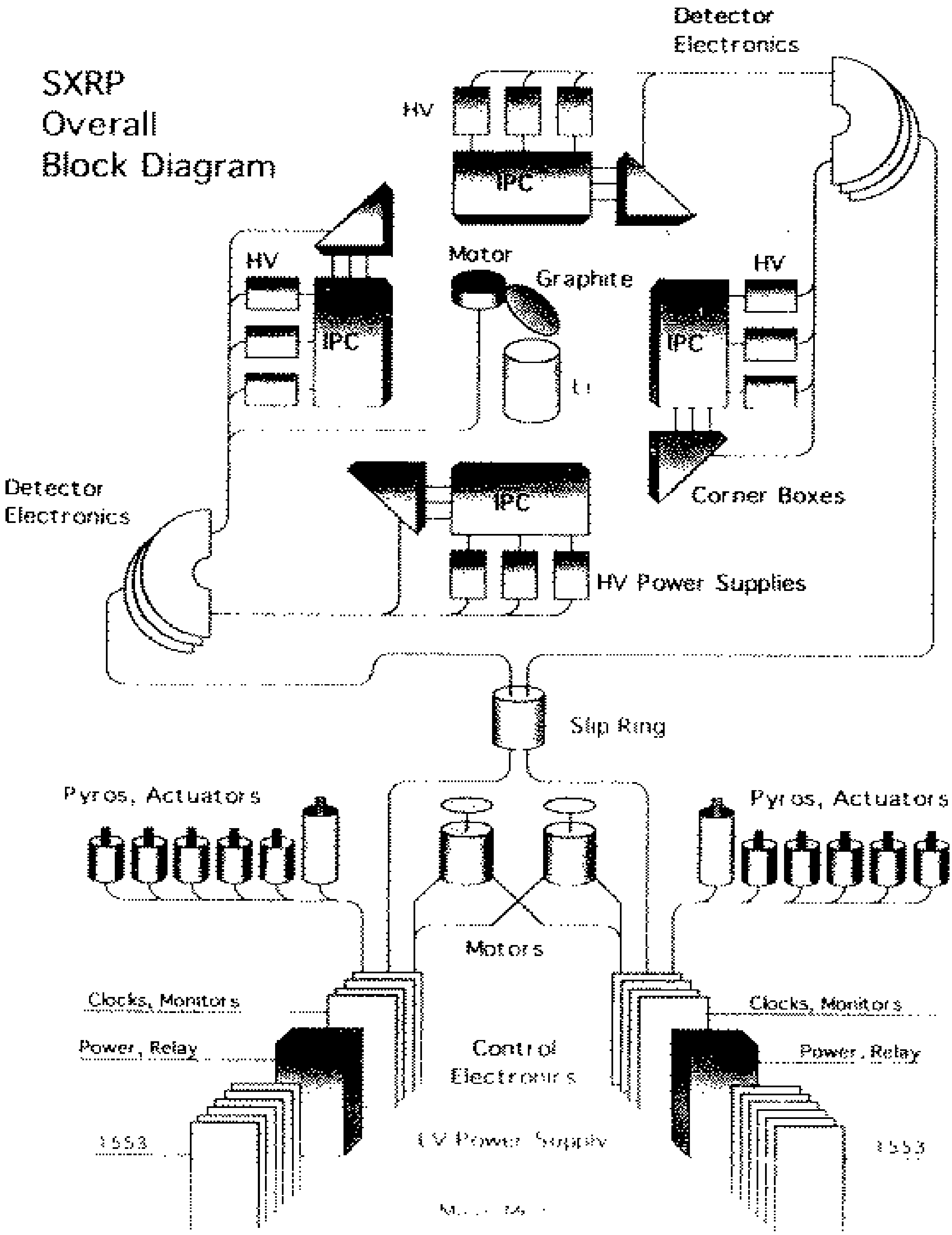

Figure 2. Functional block diagram of the SXRP.

Scientific Objectives

The Stellar X-Ray Polarimeter (SXRP) is the only orbiting X-ray polarimeter currently scheduled to be flown. It will be the only instrument available in the next decade able to extend x-ray observations to the full parameter space of the radiation. The primary processes which lead to polarized x-ray emission are non thermal radiation and electron scattering of thermal x-rays in non spherically symmetric geometries. The degree and position angle of polarization from a source is highly dependent on the geometry of some feature of the source, (the feature can be the magnetic field, the scattering disk, etc.). Thus, polarization measurements provide a direct probe of the source geometry. Because the SXRP provides unique information about x-ray emission, it will enable us to make important statements about the properties of a variety of astrophysical sources.

Binary X-ray pulsars

X-ray polarimetry will allow the study of the accretion geometry at the polar caps of magnetized neutron stars. Using the scattering polarimeter of the SXRP, we will be able to measure the x-ray polarization of Her X-1 in five pulse phase bins and three energy bins with an average minimum detectable polarization of 5% in each bin in a 2*105 second observation. This will definitively distinguish between the pencil and fan beam geometries. In addition, we will be able to measure the average polarization of a number of other X-ray binaries (Cen X-3, GX1+4, 4U1626-67, ...) to a level of a few percent in individual 105 second observations.

Supernovae remnants

The only statistically significant (19 sigma) measurement of X-ray polarization of an astrophysical object was the 19% polarization measurement of the Crab nebula by OSO-8, which verified the synchrotron nature of the emission. SXRP can extend this measurement to other supernova remnants.

Accretion disk sources

Compton scattering from an accretion disk can lead to X-ray polarization. Polarimetry can provide information on the disk geometry.

Black hole candidates

Inertial frame dragging around a rotating black hole (Lense-Thirring effect) can lead to a polarization vector that rotates with energy. Observation of such an effect could lend support the presence of a black hole and test a previously untested prediction of general relativity.

Radio pulsars

X-rays from radio pulsars are believed to be due to a synchrotron radiation. The emission mechanism for optical pulses is unknown. X-ray polarization measurements would allow a comparison with optical measurements, providing information on the optical emission mechanism.

Soft X-ray transients

A large fraction of soft X-ray transients are black hole candidates. X-ray polarization measurements could help determine the nature of these sources.

Operating Modes

There are four basic operating modes of SXRP:

1. Memory Mode - When the SXRP instrument is turned on, it comes up in the memory mode. In this mode, only the mass memory processor is operating; this processor is responsible for accepting and responding to commands on the BIUS interface and for maintaining data in mass memory (either from SXRP or from another scientific instrument on SRG). In this mode all detectors and high-voltage power supplies are turned off as are the stepper motors that operate the rotating platform. Power in this mode has been measured to be approximately 4 Watts for the engineering model (EM) SXRP. In the flight model (FM), total power should be 8 Watts.

2. Observation Mode - This is the normal operating mode of the instrument. In this mode, all normal subsystems are turned on including all detectors, all high-voltage power supplies, all processing electronics, and the motor that rotates the rotating platform. The Observation Mode is established by executing a series of BIUS commands from the Memory Mode. In the Observation Mode, detectors are operating in their normal configuration and scientific is being generated and accumulated in mass memory. Power in this mode was measured to be 20.4 Watts for EM, which contains approximately half of the electronics of the FM. The power dissipation of the FM, with one rotation drive motor operating in 0.5 rpm, is estimated to be 38 Watts.

3. Motor Transfer Mode - If one motor fails, it is possible to disengage that motor and engage a backup motor. This process involves powering a mechanical actuator based on the expansion of paraffin wax. This process is accomplished in the Motor Transfer Mode. Note that this mode is only used in case of emergency and is not a normal operating mode. In this mode, motors are operating and energy is supplied to the paraffin actuators for approximately 3 minutes. High-voltage power supplies are turned off. Power during this mode has been measured to be approximately 36.6 Watts. The power for the FM should also be 36.6 Watts.

4. Graphite Transfer Mode - Normally, the graphite crystal is oriented so that incoming X-rays are reflected to one detector. If that detector fails, a motor can be commanded to rotate the crystal to reflect to an adjacent detector. This process is accomplished in the Graphite Transfer Mode. Note that this mode is only used in the case of emergency and is not a normal operating mode. Power during this mode has been measured to be about 25.5 Watts for the EM. This number should be roughly the same for the FM.

Calibration Programs

ON-GROUND

The SXRP flight model will be calibrated at Lawrence Livermore National Laboratory, with both a polarized and unpolarized X-ray source, prior to being shipped to Moscow. Individual detectors are also calibrated at Columbia University before integration with SXRP.

IN-FLIGHT

Each detector has, imbedded in the titanium strong back of the beryllium window, a small

Fe-55 radioactive source. These sources were produced with an activity of 10 microCuries each in the autumn of 1992; by the autumn of 1995 the sources will have decayed and be producing a count rate of approximately 1 count per second in each detector. The 5.9 keV line of Fe-55 allows the gains of the detectors to be monitored throughout the flight.

List of On-board Radioactive Sources

SXRP has four on-board Fe-55 sources placed in the window of the detectors. Each source was approximately 10 microCuries in August 1992. The sources are imbedded in the detectors and emit no radiation detectable outside the SXRP.

Up- and Downlink Commands

SXRP is placed in operating mode by 4 relay commands and a short series of BIUS commands. SXRP has command tables which will be implemented to reduce the number of BIUS commands required. The command tables are stored in EEPROM and can be altered in orbit.

Structure of Information

There are 7 data block types for SXRP, 5 of which constitute actual data blocks transmitted to the ground:

1. No data/invalid
2. Disabled
3. Store for other
4. Event data
5. State of health
6. Self test results
7. Memory dump

The first two data block types should never be seen on the ground but are included here for the sake of completeness.

All the data blocks conform to the following general format:

Data Bytes	0 - 3:	Sync Words
Data Bytes	4 - 5:	Instrument Identifier
Data Bytes	6 - 7:	Block Number
Data Bytes	8 -1887:	Data
Data Bytes	1888 -1891:	Time tag of scientific data block
Data Bytes	1892 -2047:	Hamming codes (156 Hamming blocks)

Requirements on Operations

During observation mode SXRP will require 38 Watts of power. For a typical 24 hour observation, approximately 60 megabytes of data will be accumulated and stored in SXRP's mass memory.

A total pointing error (spacecraft pointing plus telescope alignment) of no more than 1 arcmin is required to reduce systematic errors in the polarization measurement to below the 1% level. Larger pointing errors will necessitate the use of detailed modeling of systematic effects to extract the polarization information.

During radiation belt passage, the HV power supplies will be shut down.

In eclipse mode, SXRP will be put into memory mode.

Operation Requirements on Other Instruments

Aspect data from Tauvex will be critical to achieve the best performance of the SXRP. Observations of bright point sources made with the HEPC or FRD in the same SODART tube as the SXRP, i.e. while the SXRP is not operating, will be needed to correlate the Tauvex aspect solution with the true SODART aspect. During the performance verification phase the SXRP will be used with the HEPC in the other SODART tube to monitor the SRG/SODART aspect.

For scientific observations, SXRP will be most effective if used in conjunction with MART and with SIXA, to monitor the complex time-dependent spectral evolution exhibited by sources like Her X-1. If required by limitations in the SODART aspect control, the SXRP will be used with the HEPC in the other SODART tube to monitor the aspect.

Instrument Performance

The performance of the SXRP is critically dependent on the effective area of the SODART telescope. Detailed evaluation of the performance of the SXRP will be presented after the SODART design is finalized.

5.1.3 Science Instruments - SIXA

Instrument name: SIXA (Silicon X-Ray Array)

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Instrument description

Detector array
SIXA is a multielement X-ray photon counting spectrometer. It consists of 19 discrete hexagonally arranged circular elements with a centreline distance of 12 mm (Figure 4)

The detector material is lithium-drifted silicon (Si(Li)). Silicon wafers of 3 mm thickness are used for the fabrication of the detector. A radiative cooler is used to bring the SIXA detector to the proper operating temperature (110-120 K). Table 1 gives a summary of the properties of SIXA, and Figure 4 shows the geometry.

Table 1: SIXA detector parameters

Diameter of active area	= 6 cm
Field of view	= 25 arc min
Number of pixels	= 19
Total/active pixel diameter	= 12/9.25 mm
Number of energy channels	= 1024
Width of each channel	= 20 eV
Energy range	= 0.5-20 keV
Quantum Efficiency	greater than 0.85 (1-20 keV)
Depletion depth	= 3 mm
Energy resolution (FWHM)	= 190-200 eV at 6 keV
Operating temperature	= 110-120 K

Entrance window
An X-ray entrance window will be placed between the telescope and the detector. The window is transparent to X-rays and opaque to the optical background, functioning at the same time as an optical filter and a part of the cooler shield. The window consists of two identical filters, both fabricated of a polyimide substrate (0.25 microns) supported by a hexagonal polyimide grid, and coated on both sides with aluminium (30 nm), where the aluminium acts as the optical filter. The total thickness of each filter is 18 microns, and the total thickness of Al for the window system is 120 nm. In addition, the transmission is affected by the thin contact layer (Au; thickness 10 nm) on the detector.

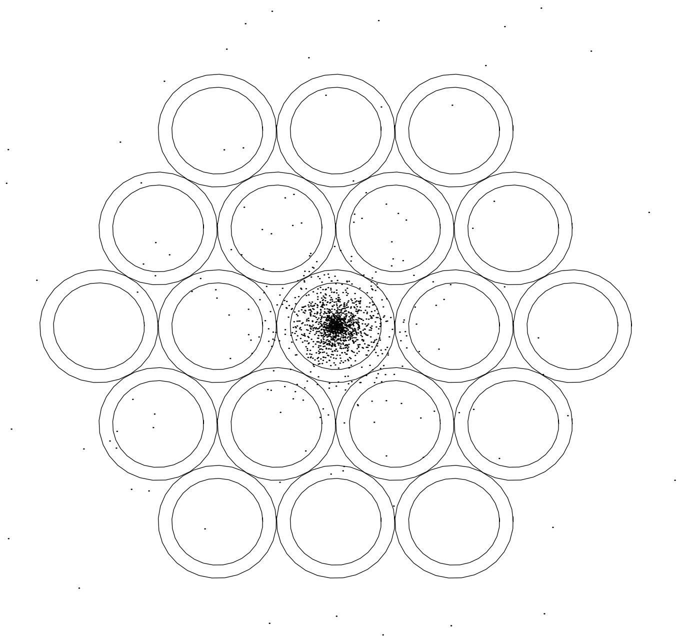

Figure 4: The SIXA detector array with the SODART point spread function. The diameter of the active area for each pixel (inner circles) is 9.2 mm (3.9 arc min), and the total diameter of each pixel is 12 mm.

The thickness of aluminium is determined so that the UV, optical and IR flux from the source and background will be reduced to a negligible level for any reasonable source brightness. The filter attenuates the flux to less than 10^{-9} from original from IR to UV; thus the noise from a fifth magnitude star would add 0.025 eV to an FWHM of 200 eV. For a zero magnitude star the respective figure would still be only about 2.4 eV.

Cooler and electronics

The detector is connected to the radiative cooler (Passive Cooling System) and to the control electronics unit. The cooler is about 1 m long tube with weight of about 100 kg, directed vertically to the optical axis. The dimensions of the electronics box are 560 * 317 * 277 mm, and the total weight of the electronics and detector system is 33 kg.

Each detector element has its own front-end electronics channel which includes a charge-sensitive preamplifier with transistor reset feedback and a linear amplifier. The first stages of the preamplifiers (JFETs) are positioned in the detector body in order to cool them and thus reduce the noise of the FETs, which will be a dominant factor determining the energy resolution. In addition to energy signal outputs, the linear amplifiers have fast timing outputs for time-interval measurements.

The front-end electronics is grouped on three cards, and one multiplexer is used for the energy outputs from each group. The multiplexers also provide anticoincidence functions and pile-up rejection. The pulse height analysers linked to each multiplexer use Gatti sliding scale construction.

The resulting digital information is processed by digital electronics including two independent processors (DPUs) that share the control of the available observing modes, which are described later in "Operating modes". The permanent programmes and parameters are stored in an EEPROM, and the system has 4 MBytes of RAM and (at least) a 40 Mbyte hard disk for the science data.

Scientific Objectives

Potential observing programmes include stellar coronae, molecular clouds, cataclysmic variables and X-ray binaries; accretion discs and coronae of neutron stars and black hole candidates; supernova remnants, active galactic nuclei, clusters of galaxies and the diffuse cosmic X-ray background.

Spectroscopy and Timing
The high sensitivity, broad energy range, and the spectral resolution of SIXA will enable observations of time-resolved X-ray spectra for a variety of astronomical objects.

The energy range of SIXA (0.5-20 keV) contains many K-shell transitions. Detailed analysis of these spectral features will permit the determination of the physical characteristics of the emitting region and its environment. The ratio of the strength of the helium-like (Fe XXV) to the hydrogen-like (Fe XXVI) lines is a measure of the plasma temperature. A temperature measure that is independent of the equilibrium assumption is the ratio of the K-alpha and K-beta line intensities. All these can be separated with SIXA.

In accretion-powered X-ray sources (X-ray binaries and AGN's) the X-ray emitting plasma is often optically thick, with FWHM almost 1 keV. With the resolution of SIXA (200 eV), line profiles can be measured, giving an opportunity to study the line broadening mechanisms and the geometry of the emitting regions.

The SIXA detector will be suitable for studies in a wide variety of time scales. Galactic sources of variable X-ray emission include accretion disks, active stars with variable X-ray emission (X-ray flares), and mass accreting compact stars in close binary systems (X-ray bursts on white dwarfs and neutron stars). These exhibit variations in timescales from fractions of a second to days.

Stars of almost all spectral types possess X-ray coronae with luminosities in the range 10^{26}-10^{34} erg/s and with mean coronal temperatures 10^{6}-10^{8} K. Spectroscopic study of stellar coronae can provide crucial information on a number of interesting physical processes, such as the generation of magnetic fields by dynamo action, the conversion of non-radiative energy into thermal energy and plasma heating, and the processes that cause mass and angular momentum loss in stars. With SIXA, a 5 sigma detection can be made in 10^4 s at distances $d = 50 * L^{0.5}$ pc for the continuum and $d = 5 * L^{0.5}$ pc for the Fe-line (where L is in units 10^{27} erg/s). Spectroscopy with a few minutes time resolution gives an opportunity to model flare dynamics of most active stars.

X-ray emission is a fundamental property of active galactic nuclei (AGN). Measurement of the X-ray time variability and spectra of these objects give us the closest look at the central energy source. X-ray active AGN's typically have strong soft excesses and canonical power-law spectra. In some cases, a broad iron line has been detected. The resolution and through-put of SIXA are sufficient for searching for e.g. the relativistic (two-horn) effects in line profiles.

Especially suitable targets for the geometry and field-of-view of SIXA are clusters of galaxies and their cooling flows. In this respect, good targets are also supernova remnants.

Operating modes

For each session between ground contacts (18-33 hours) SIXA will be programmed using a series of operation commands sent from the ground station to the satellite. If the device is not in use, it will normally be powered down (off). When switched on, the DPUs perform first a sequence of standard power-up tests. After this SIXA enters the STANDBY operating mode. All service functions are performed in the standby mode. After receiving the parameters in the standby mode, and warming up in the MEASUREMENT mode, the device is ready to start observing or calibration. When SIXA is in the measurement mode, the analog electronics is on. Other OPERATING MODES are DUMPING and DATA RETENTION modes. During, for example, reorientation it is in the data retention mode, refreshing data stored in RAM. Science data is transferred to the satellite in the dumping mode.

There will be a selection of six OBSERVING MODES available: three different SEC (single event characterization) modes, Energy-Spectrum Mode (ESM), Window-Counting Mode (WCM), and Time-Interval Mode (TIM). The control over the modes is shared between two processors, so that one DPU (SEC DPU) runs the SEC modes, and the other DPU (EGY DPU) the three other modes. The ESM, WCM and TIM can be run in parallel with one SEC mode (maximum of four modes simultaneously), and any of the modes can be switched off independently. The starting and ending times of each spectrum are stored with a 10 ms accuracy. The time resolution in SEC, ESM and WCM is about 30.5 microseconds, and in TIM it is 12.21 microseconds.

In the SEC modes the detector acts as a photon counter, and an event list is obtained. Every event is stored in a four-byte word (photon energy, arrival time, and id. of pixel). SEC 1 measures the events in all 19 elements and all energy channels. SEC 2 measures only events in the 7 central elements and within two energy windows. SEC 3 is similar to SEC 2 but the window limits are not applied. The arrival time is stored by a counter with units of about 30.5 microseconds.

In ESM an energy spectrum is obtained. The integration time (10ms, 1 s - 33 h) is specified by the user. During this interval the events in each of the 1024 channels are counted (corresponding to the energy range about 0.5-20 keV). The optimal integration time depends on the source strength. At least several thousand events have to be recorded before a useful spectrum is obtained.

In WCM an X-ray light curve is obtained in two energy bands. The user selects the sampling time (time bin) and the two energy bands within which the events are summed in each of the seven central elements separately. Typically, the energy bands could be 0.5-2 keV (soft), 2-10 keV (medium), 10-20 keV (hard) and 6-7.5 keV (the iron line). For hardware requirements, ESM and WCM are coupled, so that the time bin is a fixed (1/1024, 2/1024, 4/1024, ..., 1) fraction of the integration time in ESM.

In TIM a time interval spectrum is obtained. The seven central elements act as one, and the time intervals between every other event (i.e. t2-tl, t4-t3, ...) caught by them is stored. The time unit for the intervals is 12.21 microseconds, and there are 8192 channels, each corresponding to one time interval (n * 12.21 microseconds, n=1,2,3,...,8192). When a time interval matching an interval in the range 12.21 - (4096 * 12.21) microseconds is registered, the corresponding counter is incremented. TIM mode is therefore suitable for searching short time periodicities in astronomical objects.

WCM and SEC 2 modes use common energy windows defined in the measurement programme for each target separately. TIM has a lower energy threshold which can be redefined with a separate parameter command.

Calibration Programs

ON-GROUND:
There is a GSE system for on-ground testing and calibration of the instrument. Before the GSE system is connected to SIXA E-box, signals from the GSE must be calibrated following the instructions in the SIXA GSE System User Manual.

Each detector element has, as a good approximation, a linear relationship between the measured energy channel number and the absorbed photon energy. The slope of this relation will be about 20 eV/channel and the offset about 0 eV. Each element is calibrated indepe-ndently by observing a well-known source. On-ground calibration is done using a radioisotopic source (Fe-55 with a Ti filter) that emits X-rays at two distinct energies. The obtained calibration parameters (slope and offset) are then written into the SIXA EEPROM in order to determine energy windows for the SEC 2 and WCM correctly.

IN-FLIGHT
A standard radioisotopic calibration source (Fe-55 with a titanium filter) is installed on the protective lid of SIXA. A calibration measurement programme is stored in SIXA EEPROM and is started with the SCAL ground command. The standard calibration is made in proper time intervals to determine the energy scale for the detector elements. Calibration is made when SIXA is not observing. The power consumption and telemetry requirements during calibration are, however, the same as during normal observations.

The long-term stability of the system has to be checked in proper time intervals also by observing well-known celestial targets:
1) Empty sky for background checking
2) A bright point source with known energy spectrum characteristics (Crab Nebula, whose spectrum slope as well as time variations are known to a high accuracy)
3) A diffuse source (Perseus Cluster of Galaxies, which has well above measurable count rates simultaneously for all detector elements of SIXA)

Using the results of this programme and combining these to the results of the standard calibration, the response of SIXA can be determined and the EEPROM calibration parameters updated.

The parameters for the following programme are based on the spatial, temporal and spectral distributions of the target radiation estimated using previous observations of the Einstein and the EXOSAT satellites.

A. Point source = Crab Nebula (Taurus XR-1)

Expected average count rate with SIXA (0.5-20 keV): 6000 cts/s

The most important calibration target is the Crab Nebula (Taurus XR-1). The spatial extent of the X-ray emitting region in this supernova remnant is below 2 arcmin, which makes it a point source for SIXA (one detector element is about 5 arc minutes in diameter). The spectral slope of this target is well determined and the average flux rate is also known with high accuracy. Also, the timing capabilities of SIXA can be checked with the Crab Nebula, since the X-ray pulsar in the center has very well determined period, the pulses in X-rays are short and their period (about 33 milliseconds) can be predicted with very high accuracy. The observations of this target should be made in the raster scan mode controlled by the satellite to obtain spectra of the source for all 19 detector elements.

The observing time needed is not long, since the source is very strong. Sufficient number of high quality spectra can be obtained easily in 3 hours, and the whole data memory capacity (44 MBytes) will thus be used.

B. Diffuse source = Perseus Cluster of Galaxies (Perseus XR-1)

Expected count rate/element with SIXA (0.5-20 keV):
 2.4 cts/s for the center element
 1.4 cts/s for each of the 6 inner circle elements
 0.5 cts/s for each of the 12 outer circle elements

The total area of the X-ray emitting region is more than 30 arcmin in diameter, and therefore all SIXA elements will simultaneously receive measurable flux from this object. The spectral distribution is not well known for the object, but the total intensity is temporally stable, and high enough for all SIXA elements. The purpose is also to compare the results with simultaneous measurements of the PSPC counters in the other SODART telescope (cross calibration).

Since the source is not very strong the observation of a full day (18 hours) will result in mass memory consumption of only 6 MBytes (4 MBytes for EGY spectra and 2 MBytes for SEC data).

List of on-board radioactive sources

There is one radiation source with SIXA for calibration purposes. The source is mounted inside a collimator at a distance of 240 mm from the detector array. The active material is Fe-55 coated by a titanium filter. The emitted radiation is X-rays between 4.5 and 6.4 keV with a 2-pi (solid angle) radiation of the order of 10^5 1/s (May, 1992).

Up- and Downlink commands.

Group 1 (regular flight operation):
- ANA_ON (switch on analog electronics) is to be sent to SIXA always before start of observation or calibration. After a delay (analog warm-up time, 15 minutes) the system is ready to start measurement when it receives a SOT or SCAL command.
- PARAM (receive measurement parameters) is to be sent during each GC after which SIXA will do observations. One command can contain measurement programmes up to 6 targets. Up to 15 targets can be observed using multiple PARAM commands.
- COORD (receive target coordinates) to send preplanned coordinates from the ground station.
- SCAL (start calibration)

Group 2 (service commands):
- SDIAG (start diagnostics): The DPU('s) addressed by this command start(s) performing selected self-tests. A test report will be given as HK data.
- CPAR (change parameter) to rewrite parameters stored in SIXA EEPROM.
- WMEM (write memory) to reprogram any locations in SIXA EEPROM.
- RMEM (read memory) to dump the contents of SIXA EEPROM and some RAM areas. The

generated file has to be downloaded before starting any measurements.
- SDISK (set disk full) enables dumping of hard disk contents after a total failure of operation during OT (e.g. due to a SEU in the DPU).

Group 3:
- FORCE (force high voltage on) is to be used only if the detector temperature measurement circuits have become faulty, preventing SIXA from switching on the HV in the normal way.

Structure of information

The ground interface consists of three logical data flows: science data, ground commands and housekeeping data. A science data file can be an SEC data file, an ESM data file or an RMEM data file. An SEC/ESM data file consists of a file header of a fixed length (424 words) and of data of variable length for each target. An RMEM data file includes contents of 1-6 memory areas. Ground commands are sent via the SRG bus in the data words of a CCW block. The length of a housekeeping data record is 15 words. Data structure varies for different HK report types (ordinary, power up, SIU RAM test, HD diagnostics).

Requirements on operations

When the external DC/DC converter is used, the standby power consumption is about 22 W and the observation mode power consumption about 45 W. The power consumption increases during data dumping (from the standby value) but has a minor effect on average values. SIXA is in the observation mode during most of the observation time (all the time between the ANA_ON and FOT commands) and also when it is performing the calibration programme with the radioisotopic source. SIXA is in the standby mode during the traverse through the radiation belts, during GC's before dumping, and during telescope reorientation. SIXA can be powered off during GC after dumping and during OT when it is not observing and has no data to refresh. The passive cooler has a continuous power consumption of 7.5 W.

During normal operation a status word is sent once a minute and housekeeping records (15 words by each DPU) every 15 minutes. Data dumping during GC takes about 8 minutes when the whole memory (4 MB RAM plus 40 MB hard disk) is dumped.

The commands used in a typical observation sequence are:

During GC:
- if SIXA is powered off, the power-up sequence consisting of relay commands and housekeeping requests
- CPAR and RMEM, if some parameters (e.g. calibration) are to be changed
- any other applicable service commands (e.g. some diagnostics)
- 1-3 PARAM commands (max. 16 words each)

During OT repeat for each target:
- (orientation)
- ANA_ON
- SOT
- (observing)
- FOT

During GC:

- BGC
- TVW
- dump data from the EGY DPU
- TVW
- dump data from the SEC DPU
- possible shut-down sequence (relay commands)

All commands are duplicated by BIUS and sent to both DPU's (on buses A and B).

Operational requirements on other instruments.

Cross calibration with the PSPC counters is desirable when in-flight calibration of SIXA with the diffuse source is performed. That is, we propose that the diffuse calibration source (Perseus Cluster of Galaxies, Perseus XR-1) be observed simultaneously by the PSPC counters in the other SODART telescope when SIXA is observing the source for calibration purposes.

Instrument performance

The numerical values of spectral and spatial resolution were already given in Table 1.

The total response of the SIXA/SODART system is demonstrated in Figure 5.

The time resolution for the system is 30.5 microseconds for event characterization (SEC, ESM, WCM), and 12.21 microseconds for time interval (TIM) spectra. The maximum continuous count rate is 5000-10000 cts/s, which limit is determined by the capacity of the DPUs with the actual load by various software tasks. The upper limit is close to one Crab (about 6000 cts/s with SIXA). A source is effectively a point source, if its extent does not exceed 5 arc minutes (the total diameter of one detector element).

The analog electronics part of the system can separate events with a much higher time resolution than indicated above, which property is used by hardware for coincidence and pile-up rejection. X-ray bursts caused by, for example, cosmic radiation hitting the satellite will thus be filtered out effectively before they enter the digital counters. Direct hits of high energy cosmic rays will also be rejected because they exceed the energy range of SIXA.

The following simulations with sources of known count rates demonstrate the performance of SIXA.

To have a detection of a spectrum, one would like to have 10 counts per energy channel on the average. In this way a spectrum can be recorded in 10^5 s integration for a 1 DSF (DSF = the Einstein Deep Survey Limit) source (NGC 4151 at 400 Mpc). Sources as weak as 50 DSF can be observed in 30 minutes. An example would be NGC4151 at a distance of 60 Mpc (the actual distance of NGC4151 = 11 Mpc).

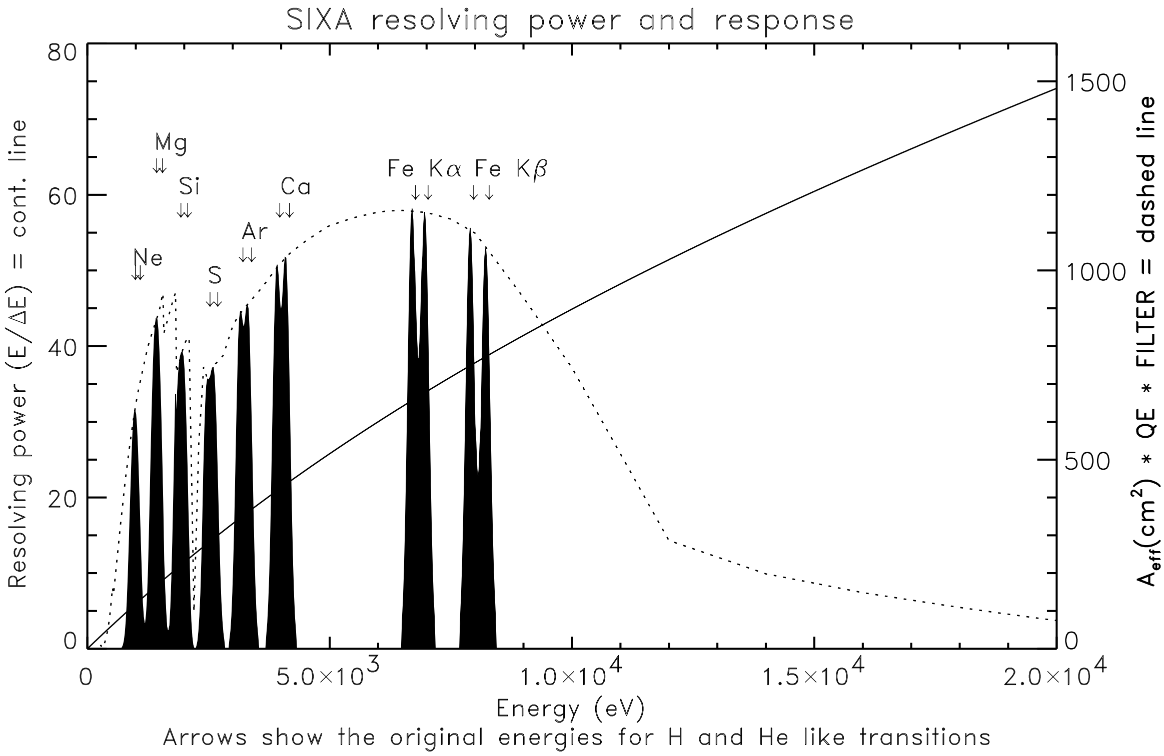

Figure 5: The resolving power (cont. line, scale at left), and the efficiency (dashed line, scale at right) of SIXA accounting for the SODART telescope effective area. The resolution is also demonstrated with spectral lines at various energies. The effect of SODART point spread function is not included. For ideal pointing it attenuates the flux for one pixel approximately by a factor 0.9.

The strongest galactic X-ray sources have continuum levels of 0.01-0.1 cts/s/cm^2/keV at the iron line (with EW = 100-200 eV), and integration times of 10-100 s can give the detection of the line.

For physically significant line profile studies of XRB's and AGN's, a good signal to noise ratio is needed. Since the lines are broad and the equivalent widths small, S/N ratios around 100 are necessary. With the above constraint, a good line profile can be observed in 20 minutes for Cyg X-l, while for the weaker source NGC4151, only a few iron line profiles can be registered during one day of observing time.

To test the power of SIXA to observe extragalactic sources, we have simulated about 100 clusters of galaxies. For a relatively close-by cluster, the Coma cluster (A1656) at distance 50 Mpc, our simulations show that the 6.7 keV iron line detection requires about 10 minutes of integration, while the continuum detection could be made already with about only 2 minutes of integration time. A very accurate measurement of the line profile can be made with an integration of approximately 30 hours (S/N at the continuum about 100).

The above estimates apply for one detector element (pixel). With 19 pixels, either a coarse spectral image of a part of the Coma cluster could be obtained with the same observation, or the integration time could be reduced to about 7 hours to obtain an equally accurate spectrum by summing up the counts in all 19 pixels. The whole cluster can be covered with about 5 pointings. These observations would then yield the temperature, iron abundance, ionisation equilibrium across the whole cluster and the cooling flow.

Since the scientific data will be transmitted to the ground station during a short session once per 17-33 hours (the ground contact interval), the memory restrictions will put constraints on the number of events and/or spectra depending on the selected observing mode. Current plans include a 40 Mbyte hard disk for the SEC mode data, and 4 Mbytes of RAM for the combinations of ESM, WCM and TIM. With the SEC mode, about 10 million events can be observed during one ground contact interval. For example, all events from a 100 counts/s source in a 10^5 s observation could be stored. In addition to this, for example, 100 spectra from all 19 elements in the ESM, or $2.8 * 10^5$ time bins in the WCM could be stored. The counter sizes for each channel in ESM (65535), WCM (255) and TIM (65535) set the upper limits for reasonable observing time per spectrum (SEC and TIM) and time bin (WCM). In ESM and TIM, a saturated counter will remain in the value 65535, while in WCM it will restart from 0 after reaching 255.

Pointing and tracking are important factors due to the pixel geometry of SIXA (there is dead area between the pixels). Pointing accuracy of 2 arc min and the size of the tracking circle smaller than 2.5 arc sec would cause less than 10 percent loss of photons and smaller than 2 percent variability in count rate due to pointing and tracking errors, respectively.

5.1.4 Science Instruments - KFRD

Instrument name: KFRD

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Russia

Instrument Description

Complex of focal x-ray detectors (KFRD) is placed on the movable carriages of SODART telescope (Figure 6).

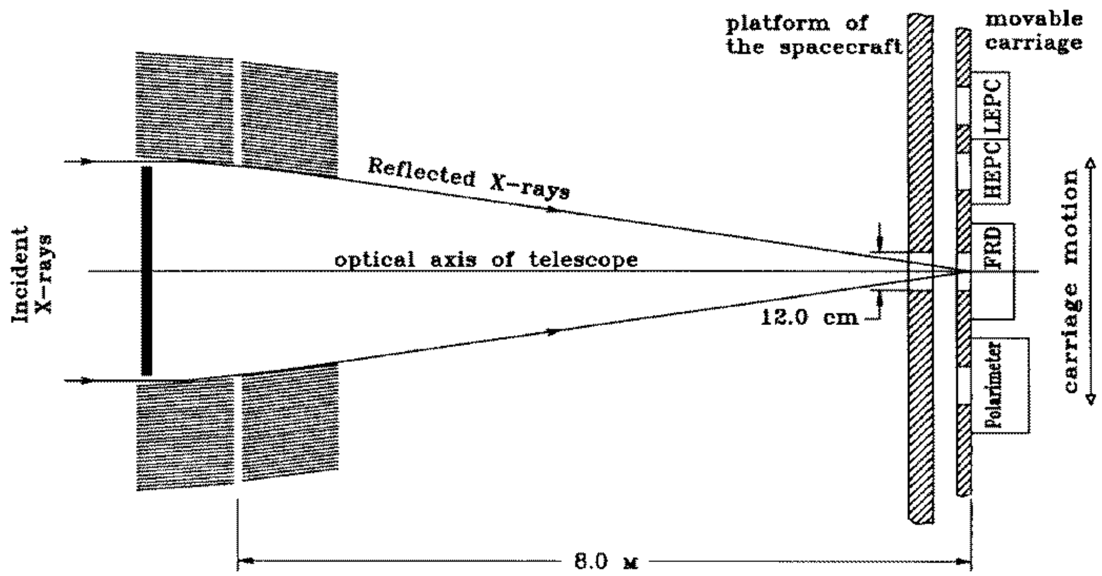

Figure 6 Telescope SODART layout.

KFRD consists of two instruments FRD-A (carriage A) and FRD-B (carriage B). Instruments FRD-A and -B are fully identical. They are two independent position sensitive x-ray spectrometers.

Instrument structure

FRD consists of following systems (Figure 7):

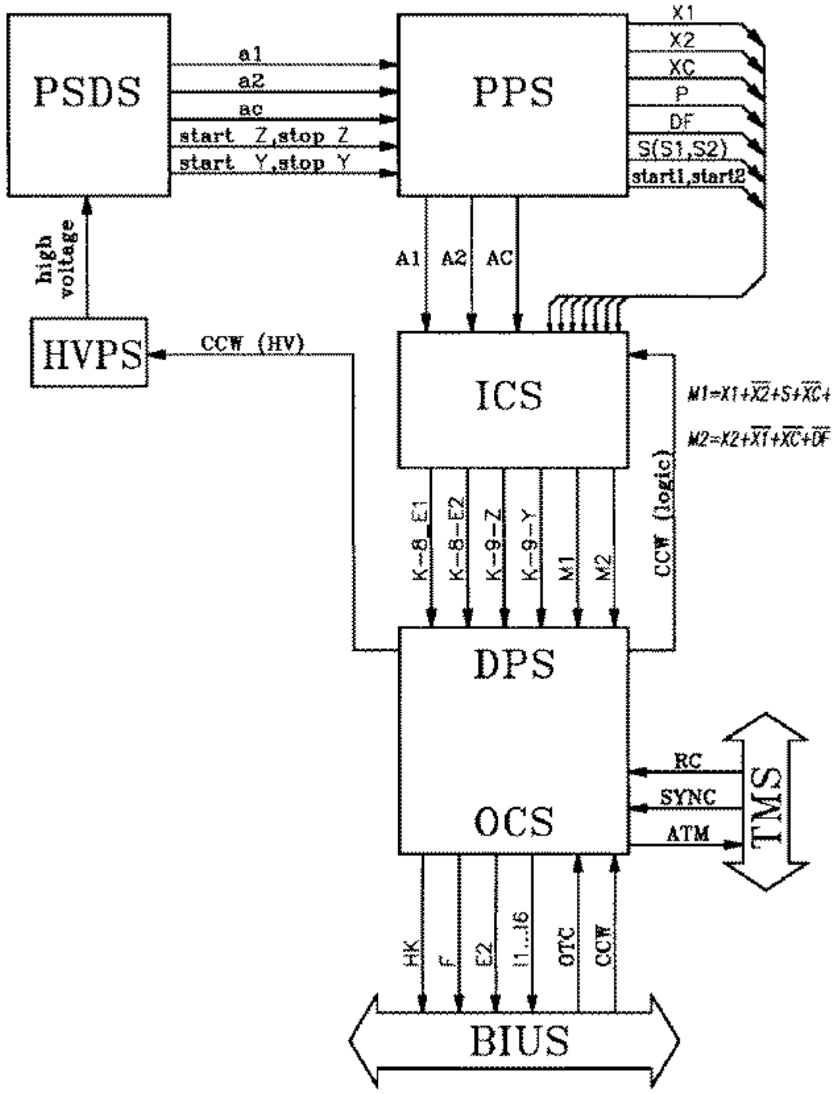

Figure 7 Block diagram of the FRD.

Position Sensitive Detector System (PSDS) includes MWPC;
Pulse Processing System (PPS) includes front-end electronics, discriminators and pulse shaping amplifiers, produces control pulses;
Secondary Power Supply and High Voltage Supply (SPS-HVS) provide necessary voltage for PSDS and PPS;
Information Conversion System (ICS) transforms analogous pulses into digital code;
Data Processing System (DPS) forms arrays of scientific and housekeeping information in the shape suitable for transmitting in the channels linking with *onboard information system* (BIUS), receives and decodes commands, clock and synchropulses coming to KFRD;
Output Channels System (OCS) maintains link with BIUS and telemetry systems of the spacecraft (receiving relay commands and transmitting of the analog information).

Design of the MWPC

Internal volume of the MWPC is a cylinder 55 mm in height and 340 mm in diameter. Size of the position sensitive area of the MWPC is - 150x150 mm. Diameter of the entrance Be window is 120 mm. Support frame is installed on the window for compensation of internal gas pressure. Three calibration x-ray sources Fe^{55} (5.89 keV) and one source Cd^{109} (22.1 keV) are integrated into the Ti body of the chamber beyond the entrance window zone over the sensitive area. The chamber has 7 high voltage throughput.

The schematic layout of the MWPC is shown on the Figure 8.

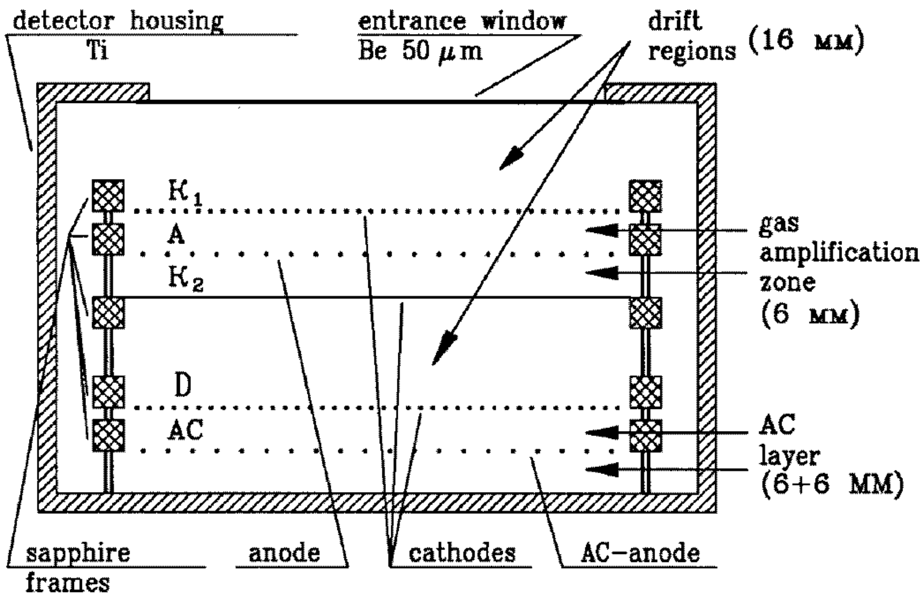

Figure 8 Schematic diagram of the FRD MWPC..

The system of electrode planes forms two layers. The first layer is position sensitive and spectrometric, the second one - only spectrometric. The second layer is also used for anticoincidence system with the aim to reduce the charge particle background in the MWPC. All electrode planes are mounted on the ceramics frames.

The first layer includes amplification zone of 12 mm depth formed by anode plane A and cathode planes K_1 and K_2 and two drift zones of 16 mm depth placed above and under the amplification zone. Second layer of 6 mm depth formed by anticoincidence plane AC and grounded plane D. The second cathode of the AC-layer is the bottom of the camber. AC-layer has only an amplification zone.

The tungsten-rhenium golden wire is used for anode planes with diameter 20 mm. Wire pitch in both layers is 3 mm. Anode wires of each layers combined in two groups and connected with its preamplifiers. The guard wires with diameter 100, 150 and 200 mm are placed on the edge of electrode planes for smoothing edge plane influence.

Cathodes K_1 and K_2 and drift D planes are made of wire with diameter 100 mm, pitch - 1 mm, material - Be bronze. The delay line on discrete elements is used for determination of coordinate x-ray photon detection.

Mechanical interfaces

Each instrument FRD (A and B) consists of three boxes interconnected by electrical cables (Figure 9)

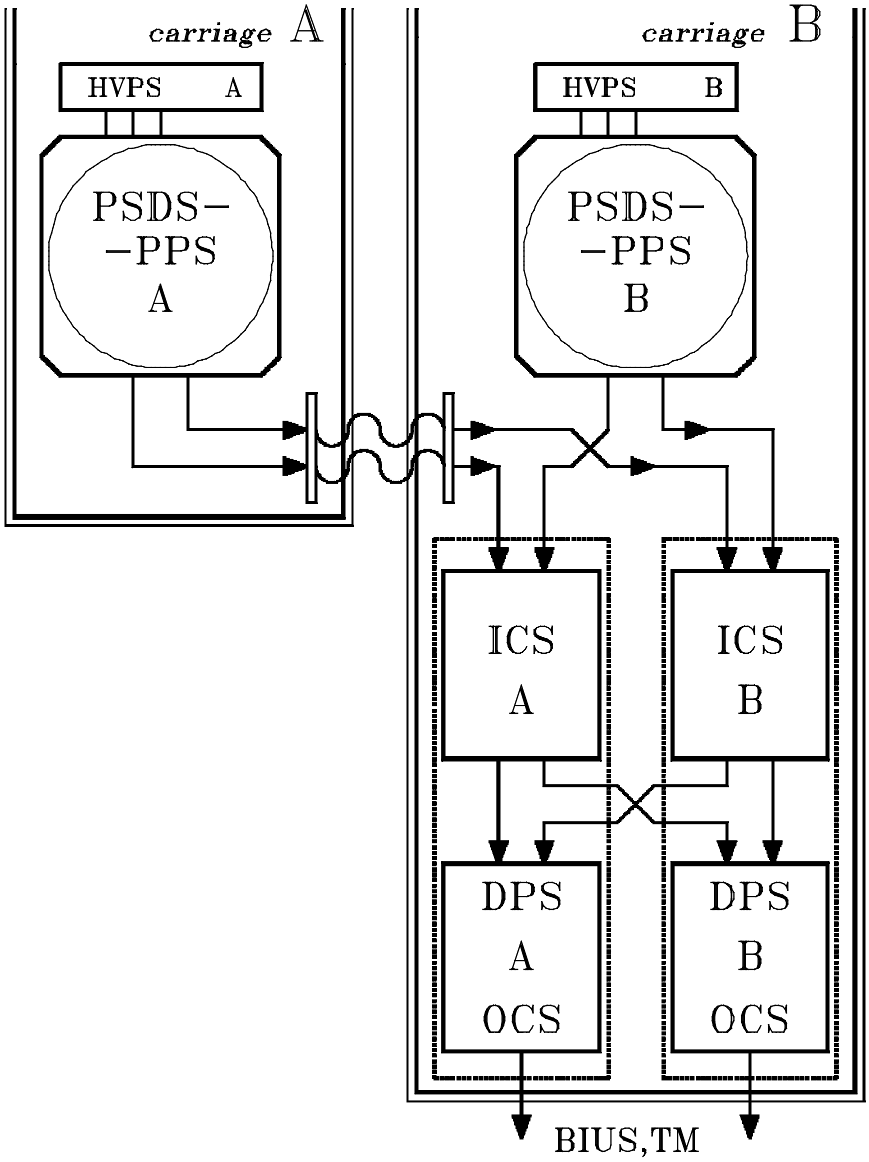

Figure 9 Deposition of the KFRD blocks on the SODART carriages.. Masses of the boxes are presented in table 1.

Table 1

1. Detector box (PSDS-PPS)	PSDS, PPS	13.9

2. Electronics box (EB)	ICS, DPS, OCS	20.5
3. Secondary power supply and high voltage supply	SPS, HVS	3.7

Boxes PSDS-PPS(A) and SPS-HVS(A) are accommodated on carriage A (overall weight - 18.1 kg).

Box EB(A) and all the three boxes of the FRD(B) are accommodated on the carriage B (overall weight - 59.1 kg).

Weight of the cable approximately. 14 kg.

Total mass of KFRD on both carriages is 90.2 kg (without cables - 76.2 kg).

Scientific Objectives

Operating Modes

To increase the reliability of the instruments FRD-A and -B were subdivided into three levels:
- PSDS-PPS,
- ICS,
- DPS, OCS.

Each level may work with its levels as well as with strange ones. As a result KFRD has 8 possible operation modes besides the on-duty mode.

There are 10 different modes of KFRD from the power consumption point of view:

Table 2

N	MODE	POWER , Watt		
		total	carria-ge A	carria-ge B
1	(PSDS-PPS)(A) + (ICS)(A) + (DPS,OCS)(A)	50...60	20	30...40
2	(PSDS-PPS)(B) + (ICS)(B) + (DPS,OCS)(B)	50...60	0...2	50...58
3	(PSDS-PPS)(A) + (ICS)(B) + (DPS,OCS)(A)	50...52	20	30...32
4	(PSDS-PPS)(A) + (ICS)(A) + (DPS,OCS)(B)	50...52	20	30...32
5	(PSDS-PPS)(A) + (ICS)(B) + (DPS,OCS)(B)	50...52	20	30...32
6	(PSDS-PPS)(B) + (ICS)(A) + (DPS,OCS)(B)	50...52	0...2	50
7	(PSDS-PPS)(B) + (ICS)(B) + (DPS,OCS)(A)	50...52	0...2	50

8	(PSDS-PPS)(B) + (ICS)(A) + (DPS,OCS)(A)	50...52	0...2	50
9	- - -	0	0	0
10	on-duty systems A and B	18...20	2	18

Operation Modes at the beginning if the mission

After the launch the instrument must be switched on in surviving mode (_ 10).
Relay command 10 "ON DUTY A,B" switch in on-duty system FRD A and B (30 after detaching of accelerating platform)
CCW: not requested
Memory (SMM): not requested
Power consumption: 18...20 Watts
ATM: usual (every 10 minutes)

Test of the instrument performance

1. Turning on during Ground Session for short time for every mode under operator control.
Turning on KFRD consecutively in 8 (eight) various modes out of focus on Normal cyclogram. Duration of the each mode 25 (5+3+15+2) minutes. Total test duration - 4 hours.
ATM: every 10 seconds
Other instruments: BIUS
SMM or SXRP (in data receiving mode)

2. Turning on during Observation Session for long time for every mode.
Turning on KFRD consecutively in modes A and B in focus on Normal cyclogram. Duration of the each mode 4 hours. Total test duration - 8 hours.
ATM: every 10 minutes
Other instruments: BIUS
SMM or SXRP (in data receiving mode)
Source: any stellar x-ray source of the order 50 mCrab.

Calibration Programs

In-flight calibrations

All calibration will be carried out for FRD-A and FRD-B (mode 1 and 2) on Normal cyclogram (for both detectors).

1. Crab Nebula
45 point covering the area with 120 mm in "serpent"-shape for 100 sec observation per point plus 5 minutes for s/c manoeuvre.
Time Duration: 4 hours
Aim: efficiency calibration
Data Collected Amount: 45-50 Mbyte

2. Point Source of the order 50 mCrab (type TBD)
45 point covering the area with 120 mm in "serpent"-shape for 100 sec observation per point plus 5 minutes for s/c manoeuvre.
Time Duration: 4 hours
Aim: PSF calibration

Data Collected Amount: 10-15 Mbyte

3. Source of the order 50 mCrab (type LMC, SMC)
   - Time Duration: 4 hours
   - Aim: efficiency calibration
   - Data Collected Amount: 10-15 Mbyte

4. Source of the order 2 mCrab (type 3C273, 3C390.3, M82)
   - Time Duration: 4 hours
   - Aim: efficiency calibration
   - Data Collected Amount: 1-2 Mbyte

5. Field without known sources
   - Time Duration: 4 hours
   - Aim: efficiency calibration and background determination
   - Data Collected Amount: 1-2 Mbyte

6. Out of the focus
   - Time Duration: 4 hours
   - Aim: background determination
   - Data Collected Amount: 1-2 Mbyte
   - Other Instrument: nearest Danish (for FRD-A)
SXRP (for FRD-B)

List of on-board radioactive sources

Three calibration x-ray sources Fe^{55} (5.89 keV) and one source Cd^{109} (22.1 keV) are integrated into the Ti body of the chamber beyond the entrance window zone over the sensitive area.

Up- and Downlink commands

12 relay commands are available for choosing different operation modes of KFRD:

Table 3

N	Denomination	Function
1	ON A	switch in FRD on carriage A
2	ON B	switch in FRD on carriage B
3	ON 1	switch in FRD in reserve combination N 1
4	ON 2	switch in FRD in reserve combination N 2
5	ON 3	switch in FRD in reserve combination N 3
6	ON 4	switch in FRD in reserve combination N 4
7	ON 5	switch in FRD in reserve combination N 5
8	ON 6	switch in FRD in reserve combination N 6

9	OFF A,B	switch off FRD in any mode
10	ON DUTY A,B	switch in on-duty system FRD A and B
11	OFF DUTY A	switch off on-duty system FRD A
12	OFF DUTY B	switch off on-duty system FRD B

Only one of 8 different mode is allowed during observation session. Any mode changing must be performed only via command "OFF A,B" (N 9).

Different modes of ICS and DPS operation, various temperature limits for thermosystem may be chosen by means of 13 control words (CW) received from BIUS.

BIUS provides on-board time code (OTC) for FRD.

The spacecraft telemetry system provides for FRD the following frequency: 1 Hz and 65536 Hz.

FRD sends into the analog telemetry spacecraft system a housekeeping information about the performance of instrument subsystem and execution of coming commands. The number of analog parametric channels is equal to 5, analog generator channels - 20.

Structure of Information

Information about each X-ray photon detected in the first layer packed in 5 bytes:
- 9 bit - code of Y-coordinate;
- 9 bit - code of Z-coordinate;
- 8 bit - code of energy E1;
- 12 bit - code of time (least significant bit = 1/4096 s).

For x-ray photons detected in the AC-volume only the code of energy is produced.

The output information of the FRD coming to the telemetry system includes:
- data flux of each x-ray photon (F);
- mean intensity spectra of 6 counters (I1...I6);
- energy spectrum (E2);
- housekeeping (HK).

Maximum data flux after logical rejection and data processing is 3300 photon/s.

Arrays of data accumulated are transmitted to BIUS periodically each 8 s on request from BIUS block by block. Maximum of the array size is 128 kword.

Data flux from celestial x-ray source with Crab-like spectrum is 1.5 Mbyte/day/mCrab besides counts from background 8 Mbyte/day.

Requirements on operations

Normal cycloam

According this cyclogram instrument will be operated during Observation, Calibration (in and out of the SODART focus) and testing at the first stages of SRG mission.

(for power consumption see fig.6 in TD)

(turning on - switching from ON DUTY mode to NORMAL)

Relay Command 10 (ON DUTY A,B) switch in on-duty system FRD A and B

Relay Command 1 (ON A) switch in FRD on carriage A
(ATM requests every 10 minutes in Observation mode and every 10 seconds during Ground Control)
(Waiting 5 minutes for Initialization procedure)
(BIUS starts to send TVW every 8 seconds)
FRD sends 1 frame to SMM with flag "Load OBS from SMM (y/n)"
If (fLoadOBS==Y) then SMM sends and FRD recieves OBS (max - 8 kByte or 4 frames)
Send CCWs from BIUS memory to configure instrument (max. number - 13 CCW)
(Wait 3 minutes to settle HV)
SOT
Collect data from build-in r/a sources for 15 minutes (count rate 20 p/sec + background)
(BIUS sends TVW every 8 seconds)
(BIUS sends SHK every 5 minutes)
...
...
FOT
(turning off - switching from NORMAL mode to ON DUTY)
Relay Command 9 (OFF A,B) switch off KFRD in any mode
(the gap no more than 10 minutes)
Relay Command 10 (ON DUTY A,B) switch in on-duty system FRD A and B

Emergency Cases

On Board Emergency Cases

In the cases of emergency situations (ECO, BAT) and for ERB instrument must be switch to ON DUTY mode (_ 10).

(turning off - switching from NORMAL mode to ON DUTY)
Relay Command 9 (OFF A,B) switch off KFRD in any mode
(the gap no more than 10 minutes)
Relay Command 10 (ON DUTY A,B) switch in on-duty system FRD A and B

Instrument Emergency Cases

1. There aren't x-ray events in data blocks

Possible causes	*What Should Be Done*
- PDS-PPS doesn't work	switch to another mode
- HVPS doesn't work	switch to another HVPS

2. Spectra are distorted

Possible causes	*What Should Be Done*
- PDS-PPS doesn't work	switch to another mode
- ICS doesn't work	switch to another mode
- HVPS doesn't work	switch to another HVPS

3. There isn't communication with BIUS

Possible causes	*What Should Be Done*
- PDS-COs doesn't work	switch to another mode

For switching to another mode in any case is necessary to send two Relay Commands:

(turning off - switching from NORMAL mode to ON DUTY)
Relay Command 9 (OFF A,B) switch off KFRD in any mode

(the gap no more than 10 minutes)
Relay Command &COMMAND switch in KFRD

Where &COMMAND is any of the commands with number from #1 to #8.

Operational Requirements on Other Instruments.

General notes

Instrument has not in-built mass memory. Scientific and housekeeping information collected during the operation must be transmitted every 8 seconds via BIUS to SMM or to another instrument which is able and ready to get the information from BIUS bus.

Instrument must be in ON DUTY mode (_ 10) all time except observation or calibration out of the focus of telescope to maintain its normal operating temperature .

Full switching off (mode _ 9) of the instrument is not acceptable for period longer 10 minutes.

Instrument Performance

As a detector of x-ray radiation position the position sensitive *multiwire proportional chamber* (MWPC) is used in FRD. MWPC exhibits high efficiency over the whole energy band of SODART telescope up to 20-25 keV region (Figure 10)

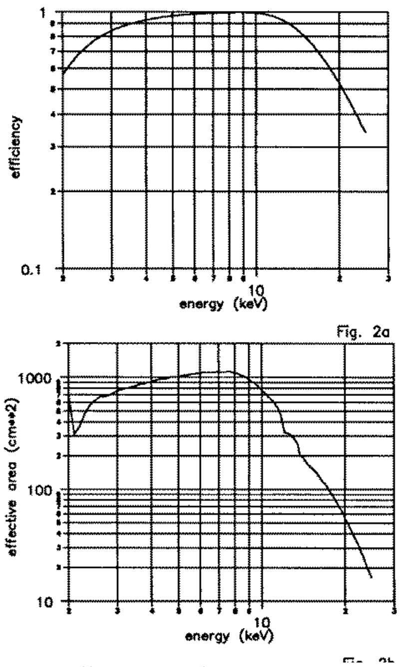

Figure 10 Efficiency of the FRD MWPC (a) and effective area of SODART with FRD (b).

Table 4

Detector	MWPC filled with 85%Xe+10%Ar+-5%CO_2 at pressure 1.3 atm
Energy band	2 ÷ 25 keV
Entrance window	50 mm Be ∅ 120 mm

Efficiency/effective area	0.98/1100 cm^2 at E=5.9 keV 0.44/ 35 cm^2 at E=22.1 keV
Energy resolution	17% at E=5.9 keV, 9% at E=22.1 keV
Spatial resolution	0.5 mm at E=5.9 keV (10 arc sec in focal plane)
Angular resolution	2 arc min (limited by mirrors)
Timing	1/4096 ~ 250 µs
Dead time -	50 µs

5.1.5 Science Instruments - TAUVEX

Instrument name: TAUVEX

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Instrument description

TAUVEX consists of a three-telescope array mounted on a single bezel and enclosed in a common envelope. Each telescope is a reflecting Ritchey-Chretien design, with field-flattener corrector lenses. The clear aperture of each telescope is 20 cm.

The systems are designed for imaging the same 0.9 degree field in the space-UV spectral band from 140 nm to 300 nm. Therefore the corrector optics are manufactured from high quality CaF_2, as well as the filter substrates and detector windows. The CaF_2 elements are kept at a temperature high enough to eliminate the Lyman alpha line at zero redshift. The image quality is 6-8 arcsec (FWHM), depending on the spectral band of observation.

Each telescope is equipped with an internal light source that is capable of illuminating the cathode of each detector through any of the filters and with the experiment cover closed. This option is named "the BIT (built-in-test) lamp".

The filter complement consists of a broad-band filter (BBF), which provides a blue cutoff for wavelengths shorter than 200 nm, three intermediate band filters (SF-1, SF-2 and SF-3) with central wavelengths near 160, 210 and 260 nm respectively, and bandpasses of about 40 nm, and two narrow band filters centered at 150 and 210 nm, with bandpasses of about 10 nm.

The detectors are photon-counting imaging devices, made of a CsTe cathode on the inner surface of the entrance window, a stack of three multi-channel plates (MCP), and a multi-electrode anode of the wedge-and-strip type. The photons detected by the instrument are treated by an elkectronic chain that calculates their arrival positions on the anode plate. A process of internal tracking compensates the calculated position for platform drift (but not jitter) and keeps the quality of images within the nominal 10" FWHM, which corresponds to three pixels on the anode surface.

Images are constructed for typical integration times of one hour in a solid state buffer memory. At the completion of the observation the three images and the fast photometry streams (see below) are stored onto hard disks, together with the engineering data pertaining to the session and the communication log of TAUVEX. These data comprise the 160MByte of telemetry allowed for in the downlink budget.

Within the SRG program, TAUVEX has no right for target assignment but observes whenever any of the prime science instruments is observing.

TAUVEX is constructed for Tel Aviv University and the Israel Space Agency by El-Op, Electro-Optical Industries, Ltd., of Rehovoth, Israel.

Scientific Objectives

TAUVEX has as its primary aim the task of imaging the sky region observed by the principal SRG instruments (SODART, JET-X, MART and EUVITA). Its secondary task is fast photometry of selected sources in its field-of-view. Its service role consists of providing tracking corrections to the guidance system of the SRG spacecraft.

The major science objectives of TAUVEX are (a) searches for QSOs and AGNs based on their UV properties, (b) surface photometry of galaxies in the UV, (c) studies of stars and nebulae within the Galaxy, (d) the nature of the UV background, and (d) simultaneous studies of variable sources in the UV and X-ray domains.

The TAUVEX data serves for post-observation aspect derivation for SODART. It is also transmitted during observation to the SRG acquisition and control system to be used for fine stabilization of the spacecraft line of sight.

Operating modes

The main operating mode of TAUVEX is "observation", in which the three telescopes acquire image data. Secondary modes are "fast photometry" explained above and "tracking", which coexist with the main mode and with each other. The information provided during the main mode is a set of three images each of 2MByte data. The photometric mode provides a much smaller (up to 0.5 MByte long) vector of values. The "tracking" process provides offset data of the tracking star relative to the "aiming location" in TAUVEX pixel coordinates, every 2 sec, if required.

Calibration Programs

ON-GROUND:

The ground calibration consists of response matrices for various detector and filter combinations, maps of dark pattern, distortion matrices, and measurements of stray light rejection.

IN-FLIGHT

This will consist of targets acquired serendipitously while another instrument is looking at a target in the neighborhood. It is possible that modes of using the BIT lamp may also serve for calibration, although this has not yet been decided.

List of on-board radioactive sources

No radioactive materials are used in TAUVEX

Up- and Downlink commands

The TAUVEX Book of Commands has been submitted to IKI. As it is a substantial document, it cannot be included here.

Structure of information

A detailed document describing the data structure of TAUVEX was submitted to IKI. As it is quite extensive, it cannot be included here.

Requirements on operations

TAUVEX requires up to 60W to operate and about 32W during survival. Its downlink telemetry budget is 160MByte per session, which includes science data files, internal engineering telemetry information, communication log, etc. The uplink command budget is typically 160--190 data words for observations, for star map uplink and for tracking purposes. It is envisaged that typically every three months there may be a software update session, when TAUVEX will require an uplink of a few hundred words.

Operational requirements on other instruments.

The most important requirement has to do with line-of-sight retention between TAUVEX and SODART. This has implications on the accuracy of the SODART attitude reconstruction as well as on the actual meaning of the attitude corrections sent to the SRG ACS.

Other requirements have to do with general timing with respect to other SRG instruments, in order to synchronize UV fast photometry with information collected in other spectral bands.

Instrument performance

TAUVEX will be able to detect point sources with monochromatic UV magnitude of 21 in the BBF in a typical one-hour observing session. The limiting magnitude for other bands ranges from 20 to 18, depending on the filter bandpass.

The performance of TAUVEX is reduced with the Sun in the forward position, because of scattered light within the instrument. The worst-case degradation is the reduction of the limiting brightness by one or two magnitudes.

The fast photometry mode allows measurement of the UV brightness of up to two sources in one band for times from 10 msec and longer.

5.2 Science Instruments - JetX

Instrument name: **JETX**
(Joint European X-ray Telescope)

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Instrument description

System Design
JETX consists of two identical, co-aligned, imaging telescopes, each with an angular resolution of 20 arcseconds or better over the energy band 0.3 - 10 keV. Focal plane imaging is provided by passively cooled CCD detectors which match the spatial resolution of the telescopes and provide high spectral resolution, particularly around the 7 keV Fe-line complex.

The x-ray mirrors are 0.3m in diameter with a focal length of 3.5m and consist of a nested array of 12 mirror shells with combined on-axis effective area for two telescopes of 360 cm^2 at 1.5 keV and 140 cm^2 at 8.0 keV. the field of view is 20 arcmin radius and the 20 arcsec angular resolution corresponds to a spatial resolution in the focal plane of 0.340 mm (HPW).

The spatial resolution of the CCD detector in the focal plane depends on the pixel size of 27 x 27 μm^2, which oversamples the focussed image of a point source. Spectroscopic capability is provided by using the CCD to detect individual photons, whose energy is determined from the deposited charge. In silicon the release energy per hole-electron pair is 3.65 eV.

A large area three-phase MOS frame transfer CCD fabricated on high resistivity silicon and operated with deep depletion has been developed for JETX. Front illumination has been chosen, with one electrode fabricated with a wide but thin polysilicon layer to minimise the reduction in low energy response caused by photon absorption in the electrode structure. The combined response of the CCD and the x-ray mirror covers a bandpass from 0.3 to 10 keV.

Spacecraft drift and thermal distortion over long, 10^5 sec, observations would lead to image blurring and loss of sensitivity. However, JETX has an attitude monitor (plus a second in cold redundancy) to measure the instrument pointing direction to 5 arcsec, at 1 sec intervals, and thereby allow drift in pointing between successive CCD frame images (integration time 2.5 sec) to be corrected in the data analysis. The attitude monitor detects and monitors positions of up to four stars in its 4 deg x 5.5 deg field of view, and a post facto attitude solution for JETX to 30 arcsec precision can be established through data processing on the ground.

A silicon radiation monitor detector measures the ambient cosmic particle radiation levels, so that the X-ray telescopes can be switched off during solar flares and passages through the

Earth's radiation belts.

Sub-Systems
JETX operates as a stand-alone instrument with simple interfaces to the spacecraft.

The JETX structure is constructed from three carbon fibre tubular sections. The structure contains the instruments and acts as an optical bench, with which to maintain focus and stable alignment of the x-ray mirrors relative to the focal plane detectors and accurate co-alignment between the x-ray telescopes and the attitude monitor. A telescope alignment monitor (TAM) measures the thermal mis-alignments and angular distortion between the mirror and focal plane bulkheads to 5 arcsec accuracy. The structure is under active thermal control by means of a distributed array of heaters and temperature sensors. Heat flows to and from space are controlled by multilayer insulation, and by thermal baffles in front of the x-ray mirrors, and stray light baffles in front of the attitude monitor.

The forward section of the structure has a deployable door, which remains closed until the satellite has reached orbit. A pyrotechnic cutter releases the door latch on command and the door is opened by spring-loaded hinges with dampers. The function of the door is to protect sensitive optical surfaces from contamination and moisture for ground operations and during launch.

The x-ray mirrors are mounted on a bulkhead in the forward section of the structure. The CCD detectors, together with a shutter and a filter wheel mechanism, are mounted on the focal plane bulkhead, which is part of the rear section of the structure. Each CCD is cooled by a passive radiator which is mounted on the outside of the structure and connected to the CCD cryostat by a thermal link. The thermal link is rigidly clamped for ground handling and launch activities and released in orbit to create thermal isolation between the CCD/thermal link assembly and the cryostat structure. Signal processing electronics for the CCDs are also mounted on the focal plane bulkhead.

The instrument incorporates an on-board command and data management electronics with a 60 Mbyte mass memory sufficient to store 24 hours-worth of scientific data. The command and data management system (CDMS) electronics, the 60 Mbyte mass memory and the power converters and power distribution unit are housed in the electronics compartment, which is mounted on the side of the aft section. The CDMS is designed around four identical microprocessors, one for control and data formatting, two for processing events - one for each x-ray telescope, and the fourth in redundancy. All spacecraft and internal interfaces are redundant. On-board software is held in PROMs. All electrical interfaces to the spacecraft, including spacecraft power, timing and commands are in the electronics compartment. Power and commands are routed through the power distribution unit and CDMS, respectively, to the other sub-systems. Heat from electronics units is radiated directly to space via a high emissivity surface on the electronics compartment.

The attitude monitor is mounted on the outside of the forward section, together with a stray light baffle, whose aperture is kept closed prior to launch, by an extension on the JETX door. The drive electronics are integral with the attitude monitor; signals are transferred to the CDMS unit for processing and transfer to the Spectrum-X telemetry.

Spacecraft Interfaces
The Spectrum-X data handling system (the BIUS) communicates with the JETX instrument over multiple MIL-STD-1553 buses, both for sending commands, and for transferring science data to the telemetry. Telemetry is provided via a low speed link for command verification and housekeeping and a high speed link for science data.

JETX has 14 relay commands from the spacecraft, which are used mainly for power switching. The MIL-STD-1553 bus with the BIUS spacecraft computer includes provision for block commands containing up to 16 data words. Science data is tranferred to the BIUS at an effective data rate of approx. 800 kbit/sec, requiring approx. 10 min for dumping the 60 Mbyte JETX memory during ground contacts. The slow telemetry JETX interface with the spacecraft operates at 16 kbit/sec and is used to transfer blocks of 120 bytes of housekeeping data at intervals between 4 and 60 sec. In addition there are a number of direct monitors of voltages, thermistors and relay contacts within JETX.

The mass of JETX is 545 Kg and the operational power consumption is approx. 260 W, approximately half of which is used for thermal control.

Scientific Objectives

The scientific potential of JETX derives from its high spatial and good energy resolution, the advantageous orbit of Spectrum-X-Gamma and its timeliness in relation to later, larger X-ray missions, such as AXAF and XMM.

The low intrinsic noise of the system allows long, photon limited exposures, yielding a sensitivity limit near 3×10^{-15} erg/cm^2/s, ten times fainter than the Einstein deep Survey limit, and similar to the ROSAT Deep Survey limit. This sensitivity will remain un-confused (at 40 beams per source) provided JETX achieves an angular resolution of better than 30 arcsec HEW. Also the higher energy response makes JETX a valuable extension to ROSAT, for example in determining temperature structures in clusters of galaxies and detecting the important Fe K-features in active galaxies.

The major scientific goal of JETX is a study of faint X-ray sources, by spectroscopy, imaging and timing. The high resolution optics, low noise detectors and 4-day orbit, combine to emphasise the value of long exposures for JETX.

The key scientific objectives of JETX are:

Deep Fields
Direct measurement of source counts, to a level corresponding to approx. 0.5 of the X-ray background flux, hence identifying the major constituent(s) of the XRB in the 2-10 keV band (and possibly revealing an entirely new class of faint, strongly evolving sources).

Medium Survey
Broad-band spectroscopy of many X-ray sources detected in the ROSAT survey, yielding information on the possible evolution of the X-ray emission and absorption in AGN, etc.

Extended Source Spectra
Imaging and spectroscopy of rich clusters, elliptical galaxies, SNRs, etc. to determine their temperature, density and chemical abundance distributions; hence their mass and evolution.

Bright Source Observations
To study, in particular, the variability in flux and spectrum and hence the geometry of individual emission and absorption features.

Operating modes

The primary scientific tasks for the JETX x-ray telescopes will be to measure the spectra of x-ray images with the focal plane CCDs. For this purpose, the CCDs are used in frame transfer, imaging mode with full spectral resolution. The x-ray images are integrated in the image section of the CCD and then transferred rapidly (approx. 6 msec) into the shielded store section. Then, whilst the image in the store section is read out, through two read-out nodes, the next image is integrated in the image section. The time resolution of the frame transfer mode is 2.5 seconds, which is the time required to read out the image from the store section.

The maximum count rate in which the frame transfer mode can operate is determined by the need to avoid coincidence of two events in any pixel during an integration interval. The criterion has been adopted that the event rate should be below 0.025 counts/pixel/integration period, which leads to a flux limit of 2 counts/sec/point source and corresponds to a source brightness of 2 mCrab.

As a backup to frame transfer mode there is a full-frame mode in which an image is integrated in the image section of the CCD and is then read out directly through the two adjacent nodes without transfer to the store section. This mode could be used in the event of a failure developing in the CCD frame store or its readout chain.

A Bright Object mode is provided in order to allow imaging of sources with fluxes between one and two orders of magnitude higher than the baseline 2 mCrab level. In this mode there are two image to store section transfers in the 2.5 second cycle, each of 6 msec duration. The information in the second transfer is discarded and the length of the first integration period may be varied down to approx 0.1 sec.

An option, available in imaging and bright object modes, permits combining charge from 2 x 2 (or larger) arrays of pixels on-chip and thereby recovering spectral resolution and efficiency that would otherwise be lost due to charge division between pixels.

A timing mode is provided for observing bright point sources. One CCD in one telescope is read out continuously at a fast clocking rate. Position information is not preserved but events are time binned to 24 μs resolution at full energy resolution. Only one telescope can be operated in timing mode because of data rate limitations, but the second telescope can continue to operate in imaging mode.

Calibration Programs

The calibration of JETX consists of two main programmes - ground (ie laboratory and test facility) measurements prior to launch, and in-orbit measurements derived from observations of specific targets. The in-orbit measurements will complement the ground measurements in the following ways

- By determining instrumental parameters not measurable on the ground
- By improving calibration parameters whose ground measurement is restricted
- By verifying ground calibration parameters
- By monitoring changes in instrumental parameters (especially as a function of time)

ON-GROUND

The X-ray telescopes
Ground measurements will be performed at the unit level (eg detector responses, filter transmissions, mirror properties etc.) and then combined into an integrated calibration model of the full system. This model will then be compared with an integrated telescope calibration obtained at the Panter test facility.

In the integrated calibration the focal plane detectors will be illuminated with monochromatic x-rays focussed by the mirrors. It is planned to perform three such calibrations as follows -

- Comparison of the CCD and filter performance with and without a single mirror shell. The focal length of the system will be measured together with the on and off axis responses. In addition dead-time effects caused by focussed event pile-up will be investigated and the on-axis filter transmission and CCD efficiencies measured.

- An end-to-end test of the system will repeat the earlier tests to provide a preliminary flight calibration using the QM mirror nest. In addition an accurate focal length determination will be performed and an all up vignetting function for the focal plane obtained.

- The final calibration, using the flight model mirrors, will form the integerated calibration of the system. Spot checks of all previous calibrations will be made, including focal position and throughput measurements.

The Attitude Monitor
Ground calibration will be used to check the relative alignment of the AM field of view with that of the x-ray telescopes and to check the pixel centroiding algorithm.

The alignment will be checked during the JETX telescope tests at the Panter facility. This will be done by using the AM to monitor a set of point sources located at known angular displacements from the x-ray sources simultaneously viewed by the x-ray telescopes.

Characterisation of the CCD and centroiding algorithms will be performed using the optical head of the AM on its own. This will be mounted horizontally on a surface table and aligned with a collimated beam of light from a pinhole. This beam will be driven in small steps across the face of the detector in order to allow calibration of the effect of small movements across single pixels and derivation of the centroiding relationship. It will also allow calibration of effects due to optical distortions across the field of view.

IN-FLIGHT

The X-ray Telescopes
An on board ^{55}Fe source will provide two lines at 5.9 keV and 6.5 keV. The radioactive source will be periodically commanded into the field of view in order to perform calibration checks. An aluminium fluorescence target will provide a line at 1.48 keV. These lines will be used to perform in-flight checks of CCD spectral linearity, quantum efficiency, energy resolution and some measure of in orbit radiation damage through charge transfer efficiency measurements.

An in-orbit science calibration programme will be performed in order to measure the following telescope parameters:

Point spread function as a function of off-axis angle. This requires a stable point source with no diffuse emission and a flux ideally less than approx 2 mCrab and an angular extent less than the telescope response.

Boresighting of the telescope and detectors. This requires sources with optical counterparts whose positions are accurately known. In practice these measurements will be combined with those of the point response described above.

The on-axis effective area across the spectrum. This requires a time stable point source with no diffuse emission.

The off-axis effective area. These measurements will be obtained from offset pointings during the derivation of the point response and could use the same candidate sources.

Image quality versus thermal effects. For this calibration, JETX should be able to observe a known point source whilst thermal engineering tests are performed both on Spectrum-X and on JETX.

Optical, UV and EUV light leakage. These will be measured by observing a number of stars which cover the required spectral range.

Timing accuracy. This will be checked using candidates with extremely well established periods and their derivatives.

Flat fielding. A post-facto method for deriving the detector flat field map is to simply integrate photons in the field of view throughout the mission. In this way the effect of the point like nature of the target sources becomes time averaged.

Some of the above calibrations will need to be repeated for the various JETX internal observation modes on both telescopes. This will be done by varying the internal observation mode during any given calibration pointing.

These calibrations will be followed by some performance verification which would include deep survey and studies of known objects.

In order to track the telescope response over the lifetime of the mission a minimum set of calibrations will be required periodically throughout the duration of the mission.

Candidate sources for the calibration targets have yet to be selected. Selection is complicated by the count rate limitation of the JETX X-ray telescopes. Analysis of data from ASCA and ROSAT should help to form a reasonable selection of targets.

During initial switch-on, Calibration and Performance Verification background rates and effects will be measured and modelled against key parameters.

<u>The Attitude Monitor</u>
A series of star images obtained for small displacements of the pointing direction will be produced in order to check the spatial calibration of the system. This will be accomplished through a series of slow raster scans of approximately 1 or 2 degrees amplitude and duration approximately 20 minutes interspersed with periods of a few minutes stable pointing.

Any field containing stars of visual magnitude greater than approximately 6 will be suitable for this purpose.

A diagnostic readout obtained during a stable pointing will be used to determine the sensitivity threshold of the system and will also allow periodical updates to the pixel defects tables by comparison of the observed field with a Star Catalogue of the relevant sky field.

List of On-board Radioactive Sources

There are two ^{55}Fe radioactive sources, one associated with each filter wheel forward of the CCD detectors at the focus of each of the two X-ray telescopes. The source strengths are 0.1 millicurie at the nominal start of life (April '94) and each has a 70 to 80 µm Al foil both for attenuation and in order to provide Al fluorescence photons.

Up- and Downlink Commands

The prime JETX command words (16 bits per word) are listed below. Some have up to 13 accompanying data words. Command word bit allocations are only fixed for relay commands, others are specifiable.

Command	Action
RLPSAON	RL02: Power System A ON
RLPSBON	RL02: Power System B ON
RLPSSEP	RL03: Power Systems Separate
RLCPU1	RL04: CPU 1 select
RLCPU2	RL05: CPU 2 select
RLCPU3	RL06: CPU 3 select
RLCPU4	RL07: CPU 4 select
RLBIUS1	RL08: Norm 1553 buses select
RLBIUS2	RL09: Red 1553 buses select
RLTCSAON	RL10: TCS A ON
RLTCSBON	RL11: TCS B ON
RLPOWOFF	RL14: Power OFF
RLRECON	RL15: Reconfigure
RLTCSOFF	RL16: TCS OFF
MCSTATUS	Transmit status word
MCCONTAC	Begin contact
MCSTAOBS	Start observation time
MCFINOBS	Finish observation time
MCCUTOFF	Emergency power cut-off
MCRADPAS	Prepare for rad belt passage
MCLOSSOR	Loss of fine orientation
MCBATDIS	Spacecraft battery discharge
MCVECTOR	Transmit vector word
TEFILREG	Fill register with value
TPCONFIG	Update curr TP config table
TCOPYFSC	Copy f/s table to current
TCOPYFFC	Copy f/f table to current
TCOPYTMC	Copy t/m table to current
TCOPYCFS	Copy curr to f/s table
TCOPYCFF	Copy current to f/f table
TCOPYCTM	Copy current to t/m table
TOBS	Start obs with curr settings
TSET	Set up TP/TE
TFSCOBS	Copy f/s - curr, start obs
TFFCOBS	Copy f/f - curr, start obs
TTMCOBS	Copy t/m - curr, start obs
TCFSOBS	Copy curr - f/s, start obs
TCFFOBS	Copy curr - f/f, start obs

TCTMOBS	Copy curr - t/m, start obs
TPCOLUP	Bad column update
TPPIXUP	Bad pixel update
TPCOPCP	Copy CP and patch TP memory
TPCOPTP	Copy TP and patch TP memory
TPTEIF	Select TE serial i/f
TPSETDFW	Set filter wheel def #steps
TPMOVEFW	Move filter wheel def #steps
TPFWOPM1	Move FW (mech 1) to op posn
TPFWOPM2	Move FW (mech 2) to op posn
TPCONTFW	Step FW continuously
AMMODE	AM operating mode
AMLENS	AM lens heater set level
AMDEICE	AM deice heater set level
AMCOLUP	AM update bad column table
AMPIXUP	AM update bad pixel table
AMSTART	AM update s/m start amplit
AMSTARS	AM search for n/2 stars
AMSMRED	AM update s/m red factor
AMLEAST	Min # stars for SM success
CPCOPTRS	Copy N bytes to TRS
CPPATTRS	Patch N bytes to TRS
CPCOPNTR	Copy N bytes to non TRS
CPPATNTR	Patch N bytes to non TRS
CPSTWORD	Set the CP status word
BMTHON	Modify sw/on c/rate thresh
BMTHOFF	Modify sw/off c/rate thresh
MMEDAC	Enable/disable EDAC
MMMODID	Modify ID of 1st mod in seq
MMFLAGSL	Modify mod dis flags (LSB's)
MMFLAGSM	Modify mod dis flags (MSB's)
MMMASK	Modify data r/mask for XRTn
MMSCIDAT	Modify max no data pkts/obs
MMTYPE	Select MM data type
LRMODL	Modify reg LSB's/hardware
LRMODM	Modify reg MSB's/hardware
LRRAM	Assert RAM relay config
NLRONT	Switch on NLR's for spec t
NLRON	Switch on NLR n for def t
NLROFF	Switch off NLR n

Structure of Information

The telemetered data consists of science and housekeeping data accumulated into blocks and read out from mass memory. All the data are assembled into blocks of 136 bytes, which contain 2 bytes of ident/sync code, 131 bytes of data and 3 bytes of error-correcting code (ECC). Every 2 seconds a header block is inserted which contains attitude monitor star data and housekeeping data. Between header blocks are a variable number of XRT data blocks.

A mass memory error detection and correction, which is additional to the block ECC, can be turned ON or OFF. If it is ON then every 4 bytes of data in the memory have a 1 byte ECC added, this does not affect the data formats, only the memory capacity.

The telemetry format uses 2048 byte frames with 8 sync/header bytes and 2040 data bytes. If the memory EDAC is disabled, there are 15 JETX blocks to each telemetry frame; if the EDAC is enabled, there are 12. The JETX block boundaries will normally be aligned with the telemetry frame boundaries.

Requirements on Operations

JETX will normally be observing except during radiation belt passages, ground contacts and when the satellite is in solar eclipse. JETX operations will continue in parallel to any other prime instrument. During normal operations power consumption will be approx. 260 W. During radiation belt passages, ground contacts or any other periods when the instrument is on but not observing it will be approx. 230 W. In eclipse mode, which will only occur once or twice per year, the main electronic systems will be switched off and the power consumption will fall to approx. 140 W.

JETX stores its science data internally in a solid state mass memory which has a capacity of up to 60 Mbytes. This mass memory will be dumped at every ground contact and will require 650 secs of dump time assuming the memory is full. Slow Housekeeping data will be provided to the spacecraft at the rate of 120 bytes every 60 secs during normal operations out of ground contact. During Ground contact the housekeeping data rate will increase to 120 bytes every 4 secs.

JETX will be operated primarily using spacecraft mode-change commands. A "Start of Observation" and "End of Observation" command will be required for each observation. There may be a multiple of observation setups between ground contacts. Typically this will not exceed 4 setups. To change between the various internal JETX observation modes (normal, bright object and timing) a small number of reconfiguration commands will require to be stored in the BIUS to reconfigure JETX. Typically between 2 and 9 16 bit command words will be required to perform these reconfigurations. If a totally new configuration is required which is not standard then more than 100 commands may be required.

During ground contact data will be dumped via the spacecraft standard command sequence of "Begin Ground Contact" and "Transmit Vector Word".

Configuration of JETX into radiation belt mode can occur via one of two methods. Firstly through use of the spacecraft mode change command and secondly via JETX background monitor detectors. (These same detectors are used to provide the spacecraft broadcast signals for all the SRG instruments on radiation belt entry and exit). JETX is reconfigured to its previous observation mode following a radiation belt passage via the "Start of Observation" command. Note that if a different internal observation mode is required then additional configuration commands will need to be stored on board in the BIUS.

JETX will automatically safe itself upon receipt of either the "Emergency Cutoff" command or "Loss of Attitude" command. Following safeing and recovery of the spacecraft JETX can be repowered and resume operations. In addition JETX can be manually safed at any time by use of real time commands.

A survival mode is used during launch and in the event of a spacecraft emergency. In this mode power is supplied directly from the spacecraft systems to the JETX base heaters. The heater power supplied in this mode is approx. 190 W.

Operational Requirements on Other Instruments

It is highly desirable that simultaneous observations with other instruments are available for calibration and internal self consistency checking. These measurements should not only overlap the JETX energy range but also include broad band measurements at other wavelengths for consistency checking eg to verify that transient effects are not instrumentally generated.

Instrument Performance

The performance of JETX may be summarised in terms of the expected scientific yield from observations as follows :

i) Imaging with 20 arcsec resolution with a limiting sensitivity of approx 3 x 10^{-15} ergs/cm^2/sec.

ii) Medium resolution spectroscopy (E/dE >10) in the 1-10 keV band with emphasis on high sensitivity and spectral resolution (E/dE > 50) around the 7 keV Fe-line complex.

iii) Time variability of x-ray spectra on timescales ranging from milliseconds to months.

5.3 Science Instruments - MART-LIME

Instrument name: MART-LIME

Contact person:

Institute:

5.4 Science Instruments - EUVITA

Instrument name: EUVITA

Contact person: Dr. A. Zehnder
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Institute: Paul Scherrer Institute
Würenlingen and Villingen
CH-5232 Villingen PSI
tel. +41 56 99 36 15 fax. +41 56 99 32 94

Instrument description

EUVITA is a set of 8 extreme UV and soft X-ray normal incidence imaging telescopes, each of them sensitive in a narrow band ($\lambda/\Delta\lambda$ = 15 to 80), centred at wavelengths between 50 and 175 Å. Each telescope has an effective area of a few cm^2, a field of view of 1.2° and an angular resolution of 10 arc seconds.

The 8 EUVITA imaging telescopes (the number of telescopes is still in discussion) will be placed along the principal axis of Spectrum-X-G. All EUVITA telescopes will be operated simultaneo-usly so that the variability of sources will be monitored continuously. Each telescope has a normal incidence multi-layer coated parabolic mirror. The diameter of the mirrors is 20 cm with a focal length of 140 cm. The relative thickness of the individual layers of mirror coating defines the reflectivity as a function of the wavelength. It is possible to produce multi-layers for the EUV with peak reflectivities of 10 to 45 % and a bandwidth smaller than 10 % FWHM. The useful geometric mirror area is 221 cm^2 on-axis, taking into account the shadow of the detector and support.

The EUVITA-detector will be mounted on-axis at the prime focus of the mirror in the detector electronic box supported by a spider arrangement. The detector box will also contain the front-end detector electronics. It consists of a micro-channel plate stack (MCP) in zigzag configuration and a wedge and strip position sensitive readout anode. The ion grid prevents positive ions from reaching the detector. A broad band metallic filter is mounted close to the front of the MCP stack so as to block off photons with energies lower than the bandpass peaks of the mirrors, in particular in the far UV region where the mirror reflectivity increases.

In order to enhance the quantum efficiency a photocathode layer is deposited directly onto the top MCP. Further quantum efficiency enhancement is obtained by applying a negative bias to the filter mesh mounted in front of the MCP. In this way electrons emitted from the MCP surface are forced back into the MCP channels without any loss of spatial resolution. The front-end electronics are mounted directly behind the detector. This design ensures low noise levels.

The designs of the individual telescopes are identical. The telescopes differ only in the multi-layer coatings of the mirrors, in the filters and in the photocathode materials. These three elements define the bandpass of each telescope and are chosen in such a way as to optimise the overall sensitivities.

Scientific Objectives

Late-type stars are the main population in the solar neighbourhood. Almost all late-type cool dwarf stars are soft X-ray emitters. EUV observations of plasmas with temperatures up to several 10^6 are necessary in constraining theoretical models for the processes heating the coronal plasma.EUVITA will measure the flux from groups of strong lines and will permit a better knowledge of coronal temperature structure.

Hot O-B stars emit most of their radiation in the FUV and EUV but are not abundant in the solar neighbourhood. The heating mechanism of their coronae is not fully understood.

Single compact stellar objects also can be EUV emitters. The hydrogen-dominated atmospheres of isolated hot white dwarfs are transparent to soft X-ray radiation originating from thermal emission in their photospheres. The EUV and soft X-ray observation of white dwarfs is necessary for understanding the evolutionary link between the final stages of low mass stars and the beginning of the WD phase. The effective temperature of hot white dwarfs is lower than the temperature range in which EUVITA is the most sensitive ($T \$= 3 \text{ x } 10^5$ to 10^6), however we expect nearby sources to be well detected in the lower energy wave-bands. Moreover, white dwarfs are numerous.

Another type of source is thermal emission from the hot surface of *single neutron stars*. Surface temperatures of cooling neutron stars are expected to be in the range $10^5 \leq T \leq 10^{6.5}$ for ages between 10^3 to 10^6 years. Sufficiently nearby and un-absorbed neutron stars could be observed in soft X-rays.

Accretion driven stellar sources are among the brightest soft X-ray sources. Cataclysmic variables (CVs) are a large group of interacting binary systems containing a white dwarf accreting matter from a normal stellar companion by way of an accretion disk. The accretion disk and the boundary layer of this disk are predicted to emit substantially in the EUV and soft X-rays.

Active Galactic Nuclei (AGN) are still another class of extragalactic EUV sources. Observation of EUV and soft X-ray emission from AGN is essential in constraining theoretical models of AGN accretion disks. In particular, the EUVITA wavebands will detect radiation from the poorly known, high energy end of the UV continuum excess (or 'blue bump') characteristic for quasars and Seyfert galaxies, where this excess component is expected to decrease and join the high energy power law spectrum. The blue bump has often been associated with thermal emission from the surface of an accretion disk.

Operating modes

This is a very tentative description of the various modes. The number of modes and their characteristics should be clarified. A special mode during solar flares could be necessary.

Russian input in this section is mandatory

Mode	description
normal	normal data acquisition
scan	raster scan over small field (max 5°x5°)
radiation belt	sensitive electronics off, no data in
safe mode	all powers off in abnormal situation
data dump	no data acquisition during data dump
initialisation	checkup before first HV on
background mode	shutter closed to measure background noise

Table 1: *Description of the various modes of operation*

Mode	HV	LVDEB	LVCDP	shutter	TC	SMM	Only once
normal	ON	ON	ON	open	ON	ON	
scan	ON	ON	ON	open	ON	ON	
radiation belt	no	no	ON	open	ON	off	
safe mode	no	no	no	closed	ON	no	
data dump	no	no	ON	open	?	ON	
initialisation	no	ON	ON	closed	ON	ON	
background	ON	ON	ON	closed	ON	ON	ON

Table 2: Main characteristics of the different modes of operation during flight

Calibration Programs

ON-GROUND:

* instrument sensitivity (SMMP,...)
* parameter file loading/reloading
* test of commands
* test of temperature control
* test of CDP
* test of SMM

All these tests should be conducted as late as possible before launch.

IN-FLIGHT CALIBRATION:

* background measurement with and without telescope shutter
* absolute sensitivity by pointing to bright source
* raster scan to measure image distortions

List of on-board radioactive sources

None

Up- and Downlink commands.

To be filed by Russians

Structure of information

To be filed by Russians

Requirements on operations

To be filed by Russians

Operational requirements on other instruments.

To be filed by Russians

Instrument performance

Preliminary description of expectations to instrument performance.

The EUVITA band-passes are described in table 3. The various components listed in this table are not yet definitively optimised. Table 4 gives the minimal detectable fluxes for an observation time of 10^5 seconds.

telescope number	1	2	3	4	5	6	7	8
field of view (FOV) [°]	1.2							
angular resolution [arc-sec]	≈ 10							
mirror	normal incidence multi-layer mirror							
useful mirror area [cm^2]	221							
central wavelength λ_0 [Å]	175	149	132	102	83	70	59	49
resolution $\lambda_0/\Delta\lambda$	15	20	30	50	60	60	60	80
max. refl. [%]	30	45	40	10	10	10	10	10
filter	AL/C	Lex-/Be	Lex-/Be	Lex/-Ti/B	Lex-/Sn	Lex-/Sn	Lex-/Sn	Lex-/Sn
grid transmissivity	0.64							
maximum effective areas [cm^2] with different photocathodes:								
MgF_2	4.3	4	5	0.8	1	1.6	1.2	0.7
CsI	4.6	5.3	8.4	1.3	0.8	1	0.9	1
KBr	3.9	4.1	5.8	1.5	1.9	3	2.4	1.9
NaBr	7.5	7.7	10.4	1.8	2.1	3.2	2.8	2.5
grasp (I) [Å] with different photocathodes:								
MgF_2	2.8 10^{-1}	2.0 10^{-1}	1.5 10^{-1}	1.7 10^{-2}	9.1 10^{-3}	1.2 10^{-2}	8.5 10^{-3}	3.2 10^{-3}
CsI	3.0 10^{-1}	2.8 10^{-1}	2.5 10^{-1}	2.7 10^{-2}	7.5 10^{-3}	7.5 10^{-3}	6.4 10^{-3}	4.4 10^{-3}
KBr	2.7 10^{-1}	2.1 10^{-1}	1.8 10^{-1}	2.8 10^{-2}	1.8 10^{-2}	2.3 10^{-2}	1.7 10^{-2}	9.0 10^{-3}
NaBr	4.9 10^{-1}	3.9 10^{-1}	3.2 10^{-1}	3.7 10^{-2}	1.9 10^{-2}	2.5 10^{-2}	2.0 10^{-2}	1.1 10^{-2}

Table 3: *Parameters describing the EUVITA band-passes: the central wavelength of the peak, bandwidth of the peaks with $\Delta\lambda$ = FWHM, the peak reflectivities, and the filters used for each telescope. The maximum effective areas and the "grasp" I (integral over all wavelengths of the product of the mirror reflectivity, the filter and the mesh transmissivity and the photocathode efficiency) are given for different filters.*

Telescope number	1	2	3	4	5	6	7	8
Min. det. flux	1.5	1.9	2.3	20	39	29	37	65

Table 4: *Minimal detectable fluxes F_{min} [10^6 photons/cm^2 sec Å] for a NaBr photocathode and an observation time of 10^5 seconds.*

5.5 Science Instruments - MOXE

Instrument name: MOXE

Contact person:

Institute:

5.7 Science Instruments - DIOGENE

Instrument name: DIOGENE

Contact person: F. ALBERNHE
email: CESRVB::ALBERNHE

Institute: C.E.S.R
9 Avenue du Colonel Roche
TOULOUSE
FRANCE

Instrument description

The instrument is made of :
- a sealed capsule with two Germanium detectors, a planar (diam.58 x 12 mm.) and a coaxial one (diam.58 x 12 mm.). These detectors are cooled by a passive cooling system with an amovible cap to avoid earth albedo near perigee. The PCS will achieve a temperature of about 100K.
- a front head electronics box (preamplifier, H.V>)
- a main electronics box with analog and digital electronics, the calculator, and bius interface.

Scientific Objectives

The main objective is the high energy resolution spectroscopy of gamma ray bursts in the range 20 keV - 8 MeV. One other objective is the spectroscopy of solar gamma rays lines emission. There is also a technological objective wich is the in-flight study of radiation degradation of detectors and their regeneration by annealing at 100 Centigrades.

Operating modes

We have two modes.

The normal mode with continuous acquisition of gamma spectra with the two detectors and during times of 67 sec.,1 hour and 4 hours depending of the energy range.

The burst mode : a continuous monitoring trigger the burst mode. During this mode the photons energy is transmitted individually with the time. We have a capacity of two bursts with 23000 photons for planar detector and 34000 for coax detector. We have also pre burst spectra.

Calibration Programs

ON-GROUND:
We have two kinds of tests :

- "cold" tests on the detector alone cooled by liquid nitrogen
- "hot" tests with the detector mounted on the PCS and the satellite (i.e. without possibility to achieve the working temperature). This test is made with an internal electrical generator.

IN-FLIGHT
We have two kinds of tests :
- energy calibration and energy resolution control with parasitic gamma ray lines
- electrical tests with the internal generator.

List of on-board radioactive sources

No radioactive sources.

Up- and Downlink commands.

The configuration of experiment is made by BIUS after switch-on with a context of 10 commands stored by BIUS. This context may be updated from ground when necessary (i.e.to change levels or threshold values during the mission).

Structure of information

Scientific telemetry

109 x 1024 16 bits words for normal mode (222 kbytes for 1 day)

64 x 1024 16 bits words for one burst (131 kbytes) with a maximum of 2 bursts a day (262 kbytes).

A complete description is given in "Diogene. Informations transmises a la telemesure." 92-05-v1.

Requirements on operations

Power requirements: 7 watts normal, 10.5 watts with heaters, 3.5 watts survival mode.
Telemetry : 222 (min) to 484 (max) kbytes depending onthe presence of bursts.

Operational requirements on other instruments.

None

Instrument performance

Preliminary description of expectations to instrument performance:

The critical instrument performance is the energy resolution of the detectors we expect ~2.5 keV for Co60 line. We expect a working temperature below 100K wich is also a critical parameter for the degradation of detectors.

6. Spacecraft Description

Editors: Dr. A. Ryzhenko, Dr. A. Uliashin, Dr. S. Gavrilin,
Lavochkin Association

Main Radio Complex

1. The Main Radio Complex

(MRC) performs the following major function:

* receives control commands from the ground and transmit them to on-board systems (OS)
* receives, stores and outputs control commands time line from TPS to OS
* retransmits radio signal to make ephemeris determinations (measurement of radial velocity and/or range)
* acquires, converts, stores and down-links telemetry and scientific data in the following modes:
  - direct transmission
  - recording in memory
  - memory dump
  - direct transmission with simultaneous memory dump
* generates and delivers synchronizing frames and frequencies to on-board systems
* records on-board time

2.

The following systems are incorporated into the MRC:

* main radio system (MRS)
* time program system (TPS)
* telemetry system (TS)

2.1 Main Radio System

The MRS provide spacecraft radio support and includes:

* two L-band command receivers (0.770 GHz) - to receive commands from ground (CRP)
* two L-band and two C-band (5.008 GHz) receivers - to receive commands and retransmit signal to ground for ephemeris determinations (CMRP, CMRC)
* two C-band transmitters (TC) - 5.884 GHz

(power of transmitter 50/3 W)

* two L-band transmitters (TP) - 0.930 GHz
  (power of transmitter 10 W)

* master oscillator, decoder, coder, logic units and so on

The L- and C-band signals are transmitted via omni directional (ODA) and highly directional antennae (HDA).

The MRS can operate in the following modes:

* reception of commands from the ground in the L or C-bands with amplitude or phase modulation

* measurement of range and range rate (L and C-band)

* transmission of telemetry in the direct transmission (in real time) or in the memory dump mode at rate of up to 16 kilobaud (L and C -band)

* transmission of scientific data at rate 1 Mbaud (L and C band)

Commands sent to the spacecraft may be of two kinds:

* relay command (RC), number of bits: 9

* serial commands (SC), number of bits: 36
  6 bit - address
  30 bit - Control Command Word

  Command uplink rate - 10 bit/s

Minimum time tag between commands:

* delivery from ground:
  - RC - 3s
  - SC - 6s

* delivery from TPS:
  - RC - 0.375s
  - SC - 0.125s

Number of RC relay commands - 512.

2.2 Telemetry System (TS)

The TS provides for:

* maximum admissible number of sensors connected to the TS - 2304 (of which 256 are temperature sensors) in each message acquisition subsystem

* number of quantisation levels - 2850.

* number of sources of digital arrays that can be transmitted in the TM frame structure - 15

* maximum number of receivable " external signals" (TM ES)- 7

* maximum number of transmitted " synchropulse" (SP) - 128

* delayed transmission telemetry to on-board memory

* direct transmission of telemetry to MRS

* direct transmission of telemetry to MRS and to memory simultaneously

The TS includes:

* message acquisition subsystem (<u>MAS</u>- 2 units)

* telemetry computer (<u>TC</u> - 2 units)

* telemetry recording and memory dump system (<u>TRS</u>) that consist of:
  - TRS
  - memory

The <u>MAS</u> provides for:

* time-sequential reception of sensor messages

* processing of these messages

* output of processing results in the form of a sequential binary code

The <u>TC</u> provides for:

* MAS control with sequential scanning of sensors

* delivery to MRS of real time telemetry.

* recording to memory

* delivery to MRS and recording to memory of real time telemetry with other or the same programs simultaneously

* delivery to MRS telemetry from memory

The <u>TRS</u> provides for:

* memory control

* selection of the rate of information output to the MRS

On-board memory capacity is about 40 MB.

Telemetry parameters are sequentially scanned by the TS in accordance with telemetry frame descriptions stored in the TC.

The required frame (frame group) i.e. the number of the program for sequential scanning of telemetry programs, is assigned by CCW sent from the TPS or from the ground.

Different telemetry programs can be generated simultaneously in different telemetry streams.

During the mission, the TC can be partly reprogrammed with regard to correction or on-board installation of new telemetry programs.

2.3 Time-Program System

The TPS performs the following major functions:

* dispatcher of on-board systems
* generate and deliver clock frequencies to on-board systems
* receives, stores and outputs to on-board systems CCW
* executing fixed (stored in ROM) or flexible (stored in RAM) programs with delivery RC and CCW to on-board systems
* recording on-board time and delivery time code to on-board systems

The TPS incorporates:

* a thermo stabilised clock-oscillator
* a timer and input/output (I/O) unit
* a processor and I/O matching unit

Fixed programs and constants are stored in TPS ROM and can always be used without modification.

Flexible programs and constants are stored in TPS RAM and can always be modified from the ground.

TPS programs may be started and stopped by RC and CCW transmitted from ground or other TPS programs, with respect to time reckoned by on-board time count program of the TPS, and by signals from other on-board systems: called by EXTERNAL SIGNALS.

There is a total of 64 ES, each of which may initiate a certain TPS program. In case of necessity, commands from ground are used to "reinterpret" ES in flight in order to initiate other programs.

The entire memory of the TPS is 10k 16-bit words (2k-ROM, 8k- RAM).

ANTENNA SUPPLY SYSTEM (ASS)

1. The following antennae are incorporated in ASS:

* two low directionality DM (L) range

* two low directionality SM (C) range

* high directionality (diameter 0.9)

2. General characteristics

Low directionality	Amplification	Polarization
DM antenna (receipt.)	0.1(angl. of 80)	right
(transm.)	0.2(angl. of 80)	right
SM antenna (receipt.)	0.1(angl. of 80)	right
(transm.)	0.1(angl. of 80)	left
Highly directionality		
(receipt.)	20 (angl.of 0.05)	right
(transm.)	500(angl of 0.05)	left

ON-BOARD CONTROL SYSTEM (OBCS)

1. OBCS performs the following major functions:

The system was designed about a stable gyroscopic reference frame with low frequency stellar updates from star sensors and solar sensors. Selection of necessary sensors are defined by mission program.

The mode of the stabilization is carried out by reaction whells. Reorientation of the spacecraft are executed by Control Moment Gyros. Unloading of momentum actuatores are provided by gas reaction engines. The main purpose of ACS is the following:

* Damping of space craft body rate after separation with booster, sun acquisition and providing the space craft necessary attitude relative to the sun.

* holding attitude reference of space craft Safe-Hold mode;

* targetting the payload to the sky source and stabilization of the space craft in that direction with necessary accuracy;

* reorientation of space craft from source to source;

* guiding High-Directionality Antenna to the Tracking Station;

* correction of the spacecraft orbit;

* passive space craft gyro stabilization by its spin up about axis with maximum moment of inertia.

2. The main performance of ACS

* Star Tracker

Accuracy	± 30 arcsec
Stability during 30 Hour	± 5 arcsec
NEA	< 1 arcsec

Readout time	1 sec
LSB	1 arcsec

* Sun and Star sensors

Accuracy	± 3 arcmin
Stability during 30 Hours	± 30 arcsec
NEA	± 20 arcsec

* Rate Gyros Assembly

Rate range	0.1 & 0.5 deg/sec
Instability of scale factor	0.02 %
Random noise	0.15/0.04 arcsec
LSB	0.02/0.007 arcsec
Drift	0.01 arcsec/sec
Readout time	0.1 sec

* Pointing parameters

Pointing accuracy

- with Star Tracker	< 3.5 arcmin
- with Sun and Star Sensor	< 4.5 arcmin
Stabilization accuracy	< 2.5 arcsec
Rate	< 0.0001 deg/sec

Pointing accuracy after calibration of misalignment

- with Star Tracker	< 2 arcmin
- with Sun and Star Sensors	< 4 arcmin

* The maximum angular rate of reorientation	0.35 degree/sec

THE SODART TELESCOPE'S SERVICE COMPLEX

STRUCTURAL DIAGRAM FOR THE SODART TELESCOPE'S SERVICE COMPLEX

The SODART Telescope's Service Complex is intended to service the scientific instruments mounted on the Telescope, and to organize scientific experiments according to the cyclogram generated by the sequencer of the SPEKTR-RENTGEN-GAMMA Spacecraft.

The Service Complex includes the following subsystems:

1. BUSS (Subsystems Control Unit) provides control of the operations of the Service Complex' subsystems, their interactions, as well as preparation of the telemetry data from the Telescope's Service Complex. BUSS communication channels to the Service Complex subsystems are based on the modified low-level series-type interface MIL-STD-1533B.

2. BIMRK (Interface Unit with Main Radio Channel) provides link from the Service Complex subsystems to the sequencer and the telemetry systems of the SPEKTR-RENTGEN-GAMMA

Spacecraft.

3. BIUTR (Thermal Measurements and Control Unit) is a system to maintain the preselected thermal fields on the Bragg spectrometer panel and on the mirror systems by sampling temperature and control sensors according to the established algorithm and by supplying power to the electric heaters. If necessary, BIUTR can convey the status of the maintained temperature fields to the telemetry system.

4. SUMSP-A, SUMSP-B (Focal Instruments Replacement Mechanism Control System) controls the mechanism of Telescope deployment during Telescope's preparation for operation (once after insertion into orbit) and the focal instruments' slide displacement mechanisms while the focal instruments' detectors that are located in the Telescope's focal points are being changed.

5. BU SAJ-A, BU SAJ-B (Active Adjustment System's Control Unit) provides precise mounting of the focal instrument detector into the Telescope's focal point; the system makes, for such purpose, optical measurements of the magnitude of misalignment between the focal instrument's detector position and the Telescope's focal point. The misalignment signal is transferred through BUSS to the respective SUMSP and is followed by the slide displacement mechanism.

6. BU CU (Control Unit for Bragg Spectrometer Panel Displacement Mechanism) controls displacements of the Bragg spectrometer panel; the value of the panel's positioning angle is generated by BUSS.

7. BUK-A, BUK-B (Cover Control Unit) controls the drives for the covers of focal instruments mounted on the respective slides of the focal instruments.

8. BUK-S (Cover Control Unit) controls the drives for the covers of the Telescope's Optical Unit.

Power Supply System

Power Supply System (PSS) provides electric power to on-board system. For this purpose, the PSS provides:

* power supply buses
* control of charging and discharging of storage batteries
* telemetry monitoring of power supply parameters

The PSS incorporates:

* two solar panels (SP)
* three storage batteries (StB)
* power distribution and stabilization complex (PDSC)

The PSS is constructed on the generator-accumulator principle. The generator is a solar battery. The SP consists of two panels of silicon photovoltic cells (three leaves in each). The

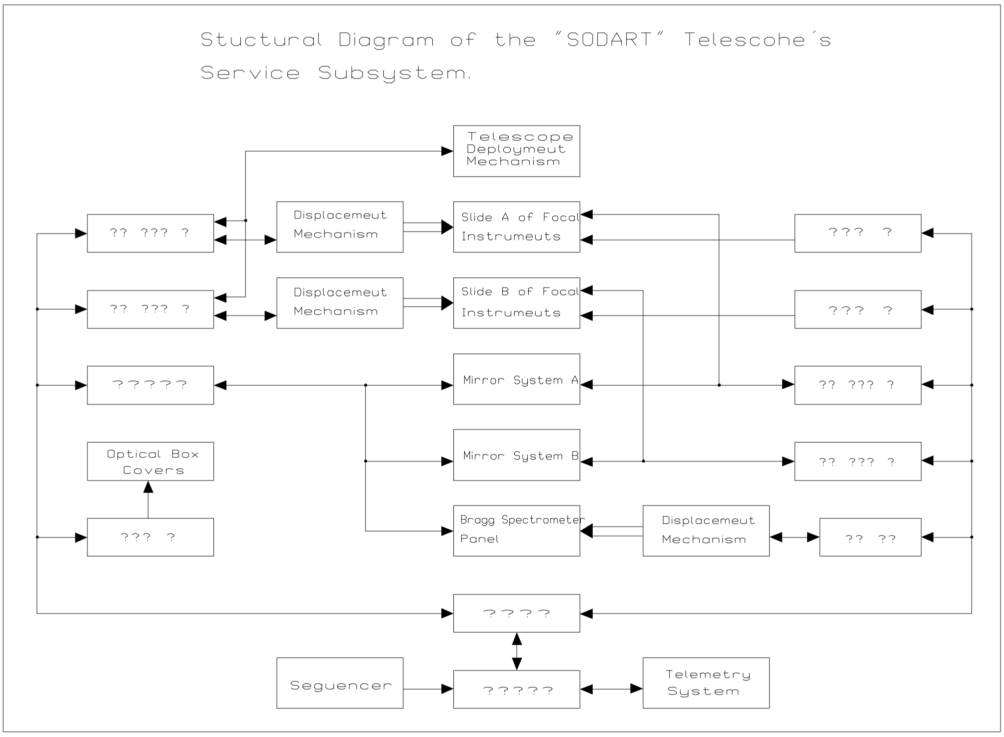


Figure 11 Block diagram of the SODART service System (Zakharchenko).

solar batteries are sectionalized.

The StB is provided to power on-board systems when spacecraft passes solar shadow or when consumption current surpasses the solar batteries current. Two StB are used simultaneously, third - reserve.

The StB is made up of series-connected sealed nickel-hydrogen cells. The StB are equipped with sensors to control charging and discharging.

The PDSC provides for:

* combined operations of storage and solar batteries
* stabilization of voltage
* protects the StB from excessive discharging and overcharging
* monitors parameters of the PSS
* PSS control in emergency situations

In the emergency situation (ES) when voltage on the supply buses decrease to 25 V or voltage across one of the cells falls to 0.5 V then PDSC automatically:

* disconnects active StB and connects reserve StB
* outputs to TPS external signal DISCHARGE BATTERY

General characteristics SSP:

* supply buses voltage -27+1.35V
  27-0.35V
* guarantee capacity StB - 35 A/h
* guarantee solar battery current during 3 years - 66 A
* maximum total power consumption - 2600 W

SPACECRAFT THERMAL CONTROL SYSTEM

The principles of the spacecraft thermal maintenance system (STCS) are based on the use of:

* passive facilities (vacuum-shield heat insulation, thermal conductors and thermistors)
* electric heaters for thermal stabilization of external devices
* gas circulation system for temperature control of the instrument package

Heater operation is controlled by relay commands or signals of sensing elements.

The active gas-circulation regulating system (TRS) maintains temperature conditions inside the container by regulated supply of cooling gas. The gas is supplied by a fan unit with cold redundant fan motors. Fan is activated after separating spacecraft from booster by command from TPS. Choice of combinations can be either automatic or from command from the ground.

Gas temperature is regulated by changing the ratio of gas flow through radiator to total flow. The ratio of gas is changed by changing position of the multi position shutter with an electric drive.

The TRS operates in an automatic mode formed by the control module in accordance with the signals from temperature sensors or commands from ground.

SOLAR PANEL ORIENTATION SYSTEM (SPOS)

SPOS is intended for:

* bringing the solar battery panels into the working state
* guiding the active side of the panels towards the Sun
* subsequent tracking of the Sun

For panels control independent subsystems are used.

Subsystems includes:

* solar sensor, mounted on the ends of solar battery panel
* drive unit, mounted on the axis of panel
* control unit

General characteristics:

* in guidance mode, the active side of solar battery panels is guided towards the Sun with variation of the azimuth of the Sun by ±180, altitude of the Sun from -75° to +75° and rate of change of azimuth not greater than 0.21°/s; rate of guidance of the panels is up to 0.3°/s.

* in tracking mode, tracking of the Sun is effectuated with variation of the azimuth of the Sun in the range ±360° N (N =1,2,...n), altitude of the Sun from -75° to +75° and rate of change of azimuth up to 0.01°/s.

PROPULSION SYSTEM

The propulsion system performs the following major function:

* damping the space craft after separation from the booster

* correcting the parameters of the space craft orbit

* stabilization of the space craft when conducting the unloading of the powered gyroscopes

* stabilization of the space craft when effecting orbit corrections

* controlling the motion relative to the centre of mass during re-orientation

The propulsion system includes next subsystems:

* pressurization

* fuel

* system for gas generation and cooling of decomposition products of hydrozine

* electric heaters

* telemetry sensors

Propulsion system control is ensured by on-board control systems and radio commands.

7. Launch Vehicle

1. The SPECTRUM-X-GAMMA automatic space vehicle incorporate:

* launcher Proton-2
* booster
* spacecraft Spectrum-X-Gamma

Launcher and booster launching mass of 700,000 kg.

Three stages Proton transfers the combination of booster and space craft to an Earth-satellite reference orbit and separates.

Booster transfers this orbiting unit:

* after separation, by means a first switch-on of sustained to an elliptical orbit
* at the epicentre of the transfer orbit, by a second switch-on of spacecraft from the transfer to the working orbit; then spacecraft separates from booster and begins to function in independent flight.

2.Mass properties

Spacecraft		6000 kg
-	astrophysical module	2570 (+235) kg
-	platform with scientific equipment	415 (+35) kg
-	scientific equipment complement	2500 (+250) kg

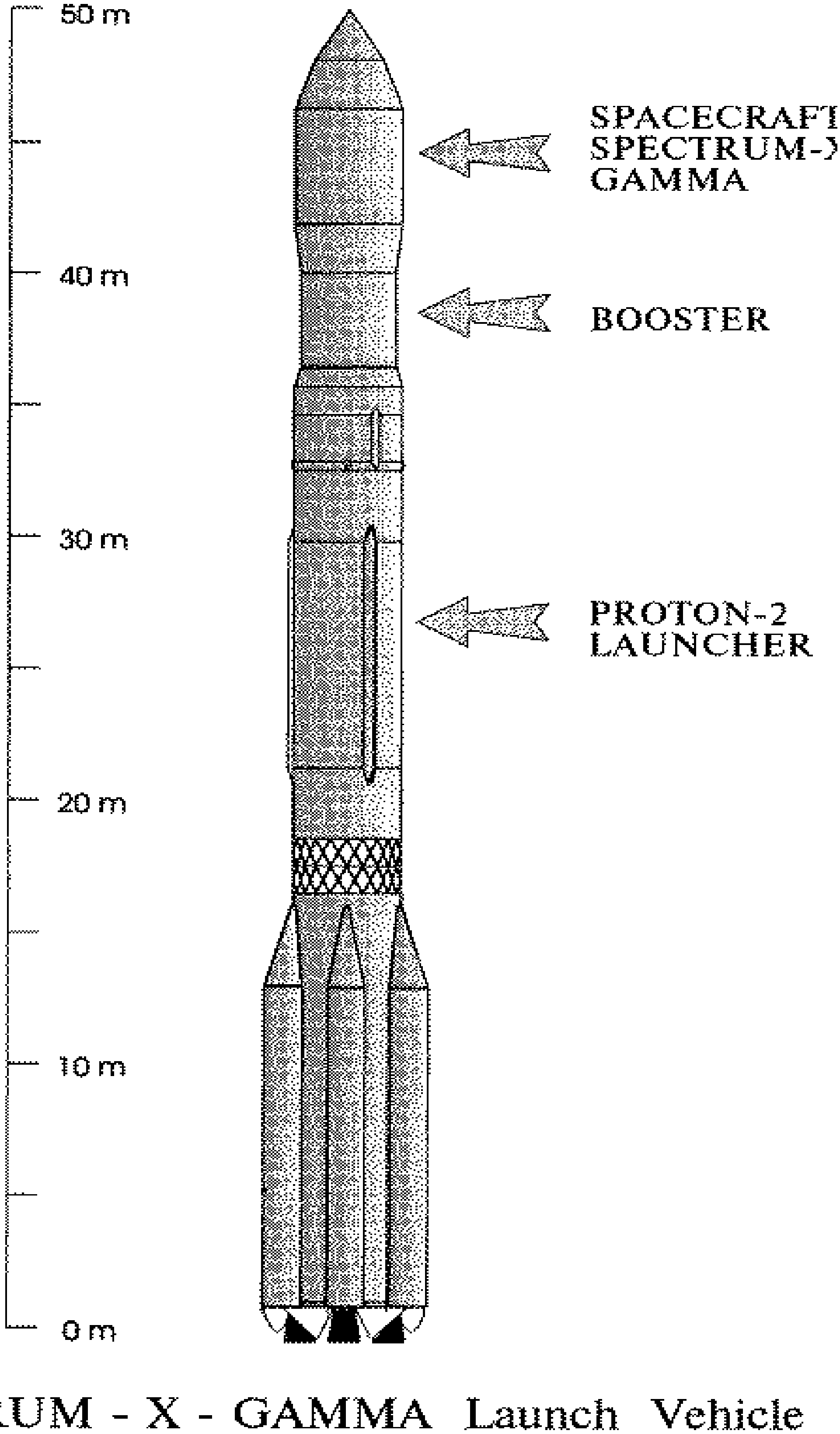
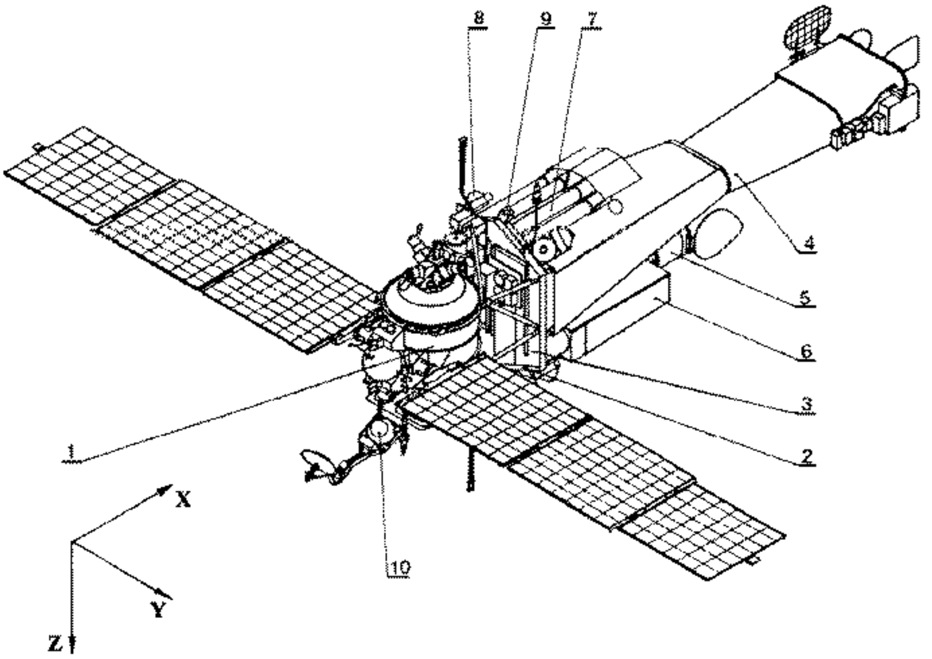


Figure 12 The SXG Launch Vehicle.



1. Astrophysical module
2. Adapter truss structure
3. Scientific equipment platform
4. SODART X-ray telescope
5. JET-X X-ray telescope
6. MART X-ray telescope
7. EUVITA UV telescope
8. MOXE X-ray survey monitor
9. SPIN gamma burst spektrometer
10. DIOGEN gamma burst spektrometer

Figure 13 The SXG satellite

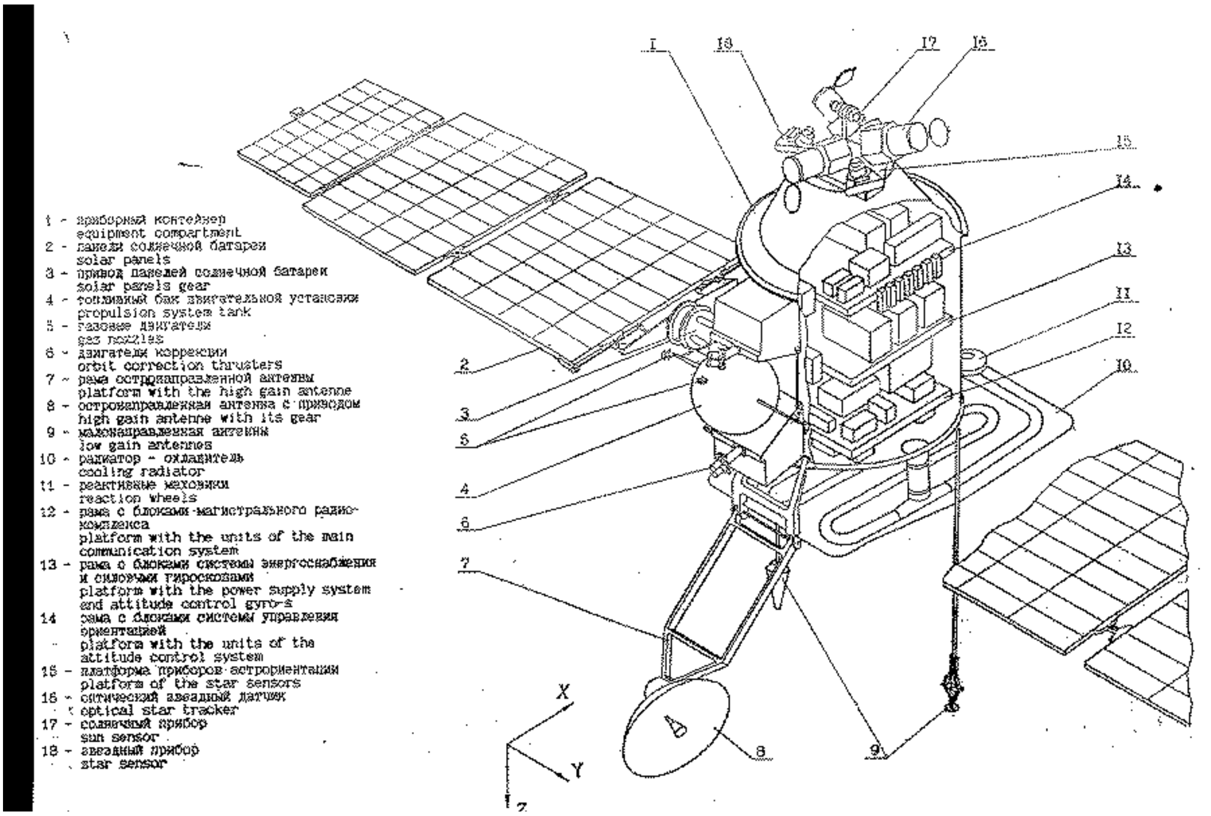


Figure 14 The SXG bus.

8. Mission Sequence

Editor: Dr. A. Ryzhenko, BSFC

MISSION CONTROL
IN-ORBIT CHECKOUT STAGE (ISSUE 1)

INTRODUCTION

In-orbit checkout stage includes the two phases:

-tests of the on-board and Ground Station systems
-tests of the experiments

This document is devoted to the preliminary program of the FIRST CONTROL SESSION (FCS) and the FIRST PHASE IN-ORBIT CHECKOUT STAGE (FPCS).

Duration of this stage is about 15 days
All time tagging will be specified in the future

1. FIRST CONTROL SESSION

FCS is automatically started after satellite separation 1.5 hour after launch.

Control systems realized by Time Program System (TPS) and Ground Station (GS) uplink.

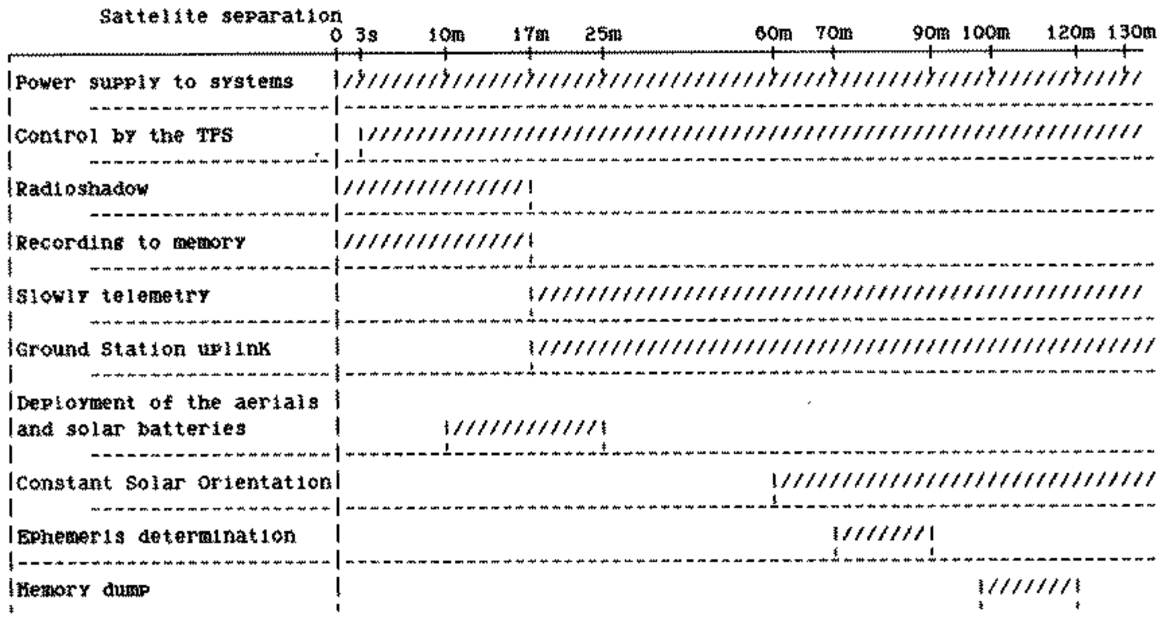


Figure 15 First Control Session Program

The FCS program is presented on Figure 15.

The experiment procedure operating at the FCS are presented on Figure 16.

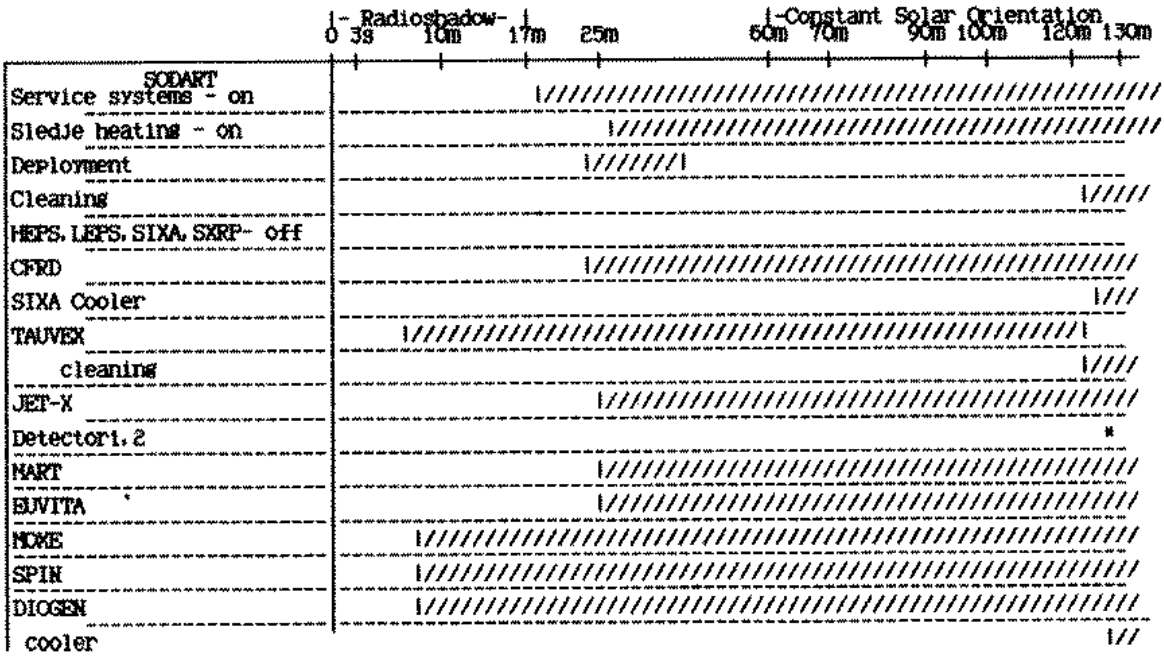


Figure 16 Experiments Procedure Operations

The admissible experiments power during the first year after launch is 1400 W.

2. PROCEDURE OPERATING

The FPCS procedure operating is presented on Figure 17.

MISSION CONTROL
IN - ORBIT CHECKOUT STAGE (ISSUE 2)

INTRODUCTION

This document describes the procedure required for the in-orbit test and verification of instruments. Realisation of this procedure begins after completing tests and verifications of the on-board and ground service systems i.e. (preliminary) during 15 days after launch (see ISSUE 1).

The procedures in this document assume nominal operation.

In - orbit fault conditions and emergency situations will be described in a separate document.

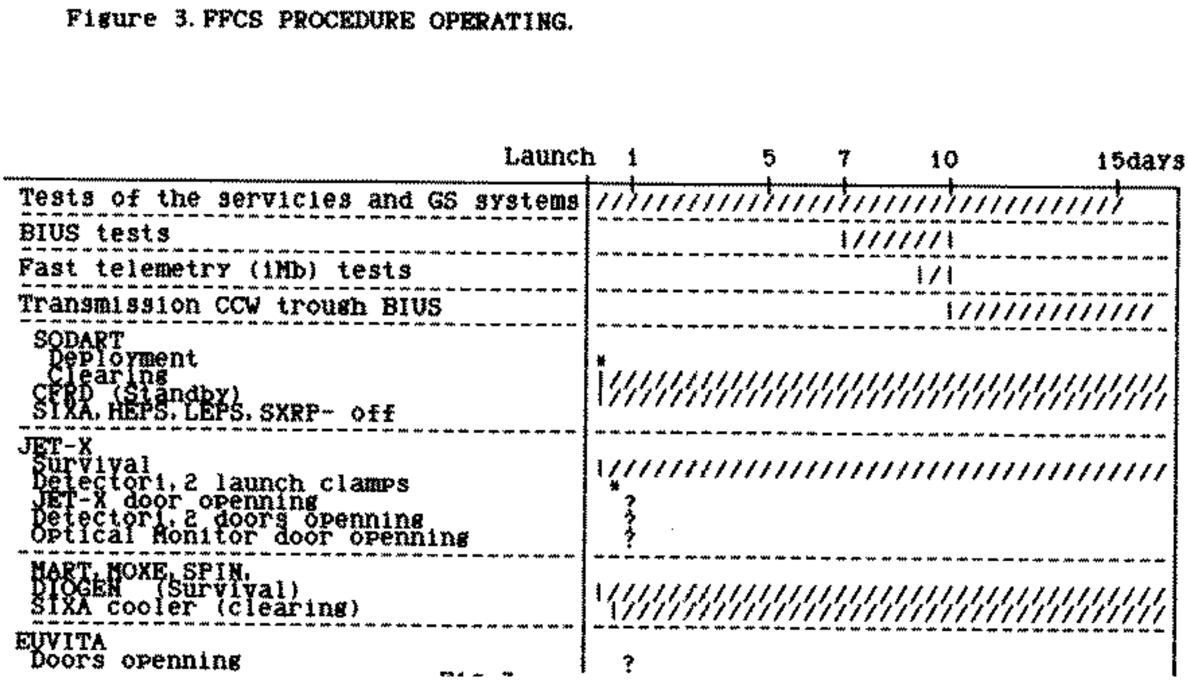


Figure 17 FFCS Procedure Operating

1. Preliminary test and verification procedure (PTVP)

PTV may be separated on the two periods:

* qualification tests
* calibration, adjustment and other special operations

Preliminary qualification tests schedule presented on Figure 18

For preparation of the calibration tests schedule is required a list of the calibration sources. Since this list is unknown by now it is currently impossible to prepare the calibration tests schedule.

2. Requirements on PTVP

Considering, that the Spectrum-X mission includes many experiments, the tests schedule may be complicated.

It is possible to use Module principle to solve this problem. Plan must be structured into test modules.

Module must consist of:

* commands time line
* autonomous modes duration (max and min)

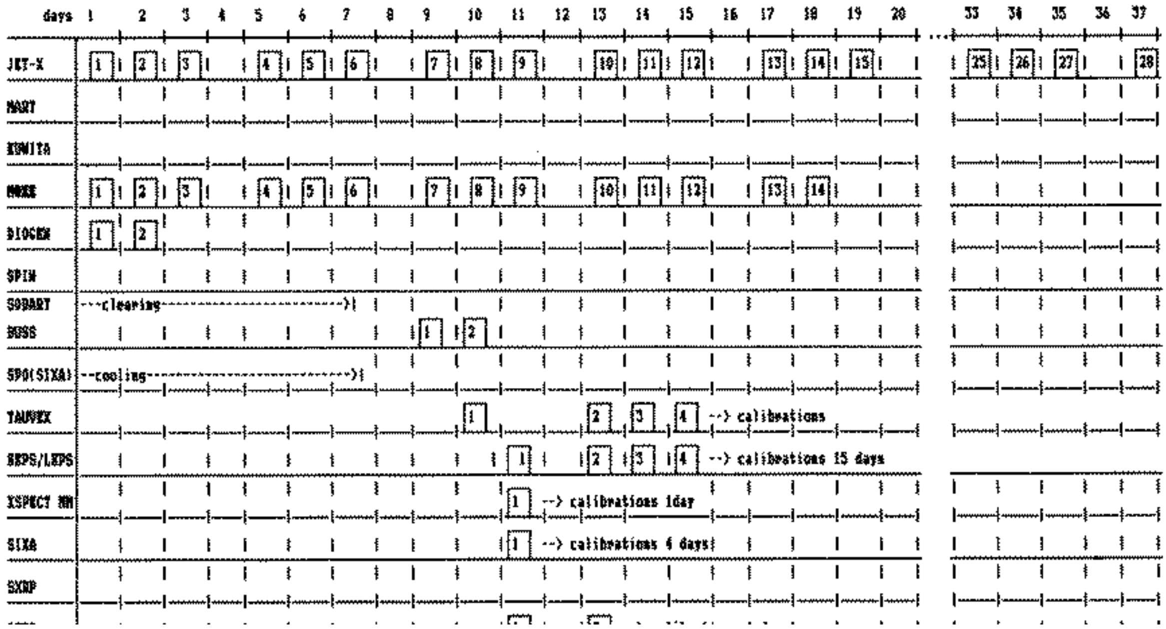


Figure 18

* mass memory budget
* special requirements for other systems

Module structure requires:

* commands time line must be implemented during one Ground Contact
* autonomous mode duration must be chosen considering next conditions
- GC duration - up to 6 hours
- GC usually carried out once per day
- there are 3 GC carried out during each orbit
* module must consist of only one memory dump

In special cases after agreement with space craft planning group this structure may be changed.

Mission Control
Observation Time Stage (Issue 1)

INTRODUCTION

This document is devoted to the preliminary program of the OBSERVATION TIME STAGE (OTS).

OTS included the next stages:

- GROUND CONTACT (GC)
- OBSERVATION TIME (OT)

OTS is started after completion of the IN-ORBIT CHECKOUT STAGE (OCS) procedure. If it is necessary to provide realization check operation on the OTS (which cannot be done during GC), the OTS is stopped and OCS is started. OCS consists of one or many CHECK SESSIONS (CS).

All time tagging will be specified in the future.

1. GROUND CONTACT

1.1. GC intended for:

- radio connection with the space craft
- memory dump
- express analysis of the on-board systems status
- up-link commands for the GC and the next OT
- ephemeris determination
- check of operation

GC are usually carried out once a day.

As example possible GC and OT arrangement are presented on Figure 20.

1.2. Space craft control is on the uplink and on the TIME PROGRAM SYSTEM's (TPS) programs (Figure 19) .

Command uplink rate - 10 bit/s.

There are two types of commands utilized on GC:

- relay command (RC), number of bits: 9
- serial command (SC), number of bits: 36

SC consists of:

- address, number of bits: 6

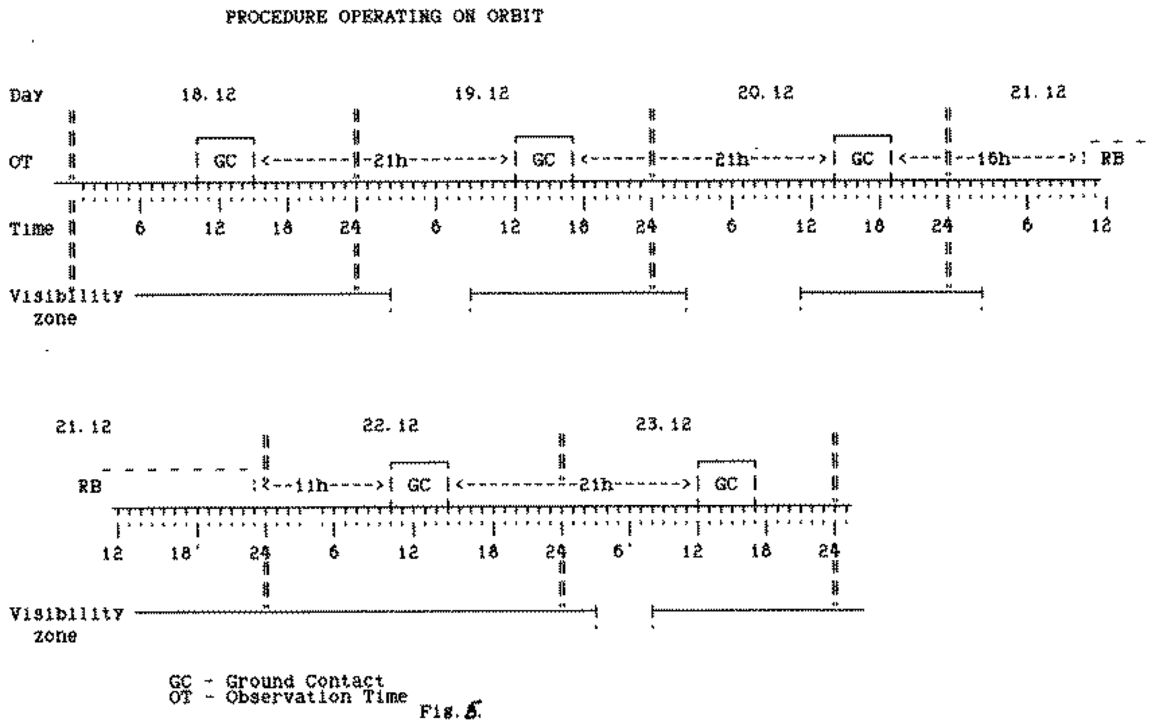


Figure 19 Procedure Operating On Orbit

- Control Command Word (CCW), number of bits: 30

Minimum time tag between commands from TPS:

- for RC - 0.375s
- for CCW -0.125s

GC procedure is prepared during preparation of ACTIVITY PLAN by CONTROL GROUP (CG). ACTIVITY PLAN is prepared for one month.

1.3. Downlink rates:

- telemetry rate 1 - 16 kbaud
- space craft memory dump 1 - 16 kbaud
- data dump (through BIUS) -1 Mbaud

After completion of the express analysis of the telemetry and data all team present reports to GC:

- about execution of the last OT
- about experiments status
- confirm the command uplink procedure

```
                         PROCEDURE OF THE GROUND CONTACT.
                          BGC
                           |<------GROUND CONTACT-( 5h 20m )--------->|
                   FOT     |                                      SOT |
---------------------------+------------------------------------------|-
Time (m)          |:       |10 : 15  :<------4h--------->:20 :15 : 20 |
------------------+--------|------------------------------------------|-
Telemetry to      |        |  :    :         :     :   :   :  :  |
S/C memory        |XXXXX   |  :    :         :     :   :   :  :  |
------------------+--------|------------------------------------------|-
Slow telemetry    |        |                                          |
 down link        |:       |XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|
------------------+--------|------------------------------------------|-
S/C memory dump   |:       |   :XXXXX:                                |
------------------+--------|------------------------------------------|-
Experiments       |        |        :                  :              |
memory dump       |:       |        :XXXXXXXXXXXXXXXXXXX:             |
------------------+--------|------------------------------------------|-
Commands uplink   |        |                 :                        |
for next OT       |:       |                 :*******:                |
------------------+--------|------------------------------------------|-
Ephemeris         |        |                          :   :           |
determination     |:       |                          :XXX:           |
------------------+--------|------------------------------------------|-
Reorientantion    |:       |                               XXX        |
------------------+--------|------------------------------------------|-
Observation       |:       |                                        : |
time              |X       |                                        :X|X
------------------+--------|------------------------------------------|-
Express analysis           |                                          |
of the experiments         |                                          |
status            |        |XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX:        |
------------------+--------|------------------------------------------|-
Reports to GOCG   |        |                                          |
about experiments          |                                          |
status            |        |                     -------->:           |

        OT - Observation Time             BGC - Begin Ground Contact
        SOT - Start Observation Time
        FOT - Finish Observation Time

                             Fig. 6.
```

Figure 20 Procedure of the Ground Contact

Operation performance monitoring during the uplink:

- monitoring of the distribution of the commands from the Ground Station
- monitoring of the receipt of the commands by radio system, BIUS, BUSS, experiments.

Operations carried out after uplink ending:

- all team present report to GC about preparation for next OT
- reorientation to the next target
- distribution of the START OBSERVATION command to experiments
- distribution of the END of the GROUND CONTACT command to space craft

2. OBSERVATION TIME

2.1

OT intended for:

- research
- recording telemetry and data to space craft and experiments memory
- reorientation (number up to 10)

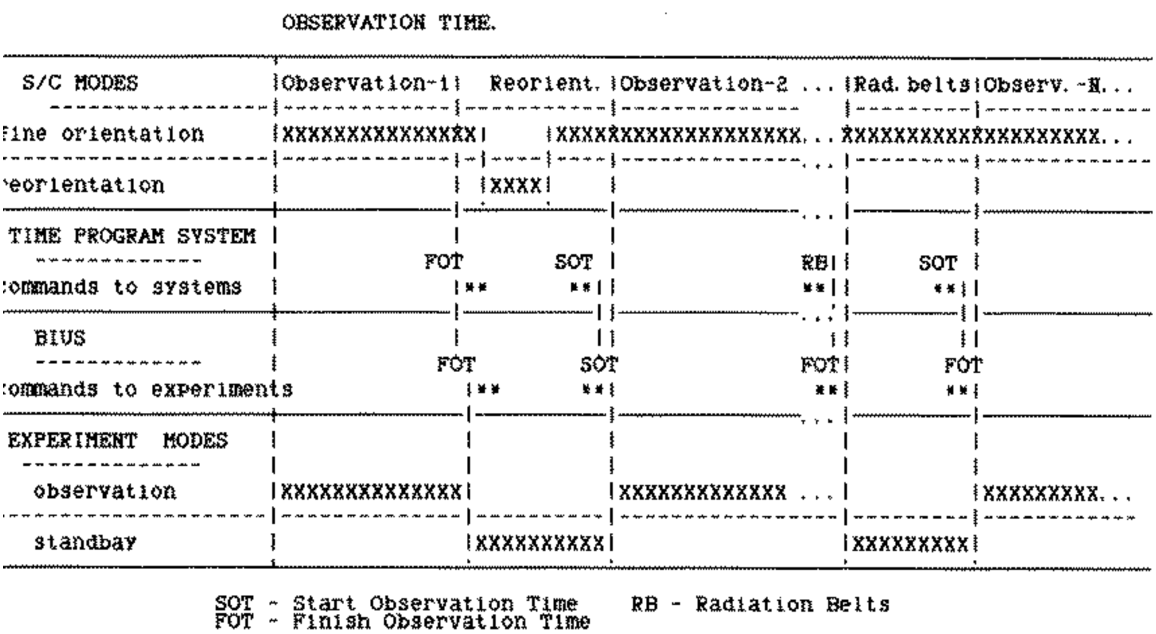


Figure 21 Observation Time

- execution of the experiments procedure (Figure 21)

Space craft control is performed automatical during OT.

TPS ensures:

- controlling of the systems for execution of the OT procedure
- controlling space craft under ES and transmission space craft into the SAVE HOLD mode
- distribution of the on-board time

BIUS ensures:

- storage and distribution of the CCW to experiments
- transmission of the total CCW from TPS to experiments
- transmission of the telemetry from experiments to radio system
- transmission of the information from OPTICAL MONITOR JET-X or TAUVEX to on-board Control System

BUSS ensures:

- storage and distribution of the CCW to SODART service systems (SSS)
- transmission of the total CCW from TPS to SSS
- transmission of the telemetry from SSS to radio system
- controlling of the SSS reserve

2.2

List of the total CCW is present on table 2

Table 2

CCW name	Function
START OBSERVATION TIME (SOT)	Execute preloaded OT procedure
FINISH OBSERVATION TIME (FOT)	Stop the OT procedure
BEGIN GROUND CONTACT (BG)	Begin the GC
RADIATION BELTS (RB)	Indicates travelling Radiation Belts
DISCHARGED BATTERY (DB)	Indicates infringement of the power balance or start of the Long ECLIPSE (> 1 hour)

2.3 SOLAR ECLIPSE MODE

If the duration of the ECLIPSE is less than 1 hour then space craft mode does not change and OT does not stop.

If the duration of the ECLIPSE is more than 1 hour then the following are ensured:

- before travel into ECLIPSE a GC is carried out during the visibility zone of the Ground Station.

- memory dump

- experiments are put to SAVE HOLD mode

- on-board Control System is put to SPIN mode

- before ECLIPSE TPS distribution to systems CCW DISCHARGED BATTERY and

```
                                  ECLIPSE ( duration > 1 h ).

S/C modes            |Gr. Cont. |Save Hold  | Eclipse|Save Hold | Gr. Cont.|Observation Time
Telemetry down link  |XXXXXXXXXX|           |        |          |XXXXXXXXX|
Telemetry to memory  |          |XXXXXXXXXXXXXXXXXXXXXXXXXXXXXXX|         |XXXXXXXXXXXXXXXXXXXXX
Memory dump (1 Mbod) | XXXXX    |           |        |          |         |
Commands to BIUS/BUSS| *    *   |          *|        |*         |    *    |
Orientation modes    |          |           |        |          |         |
   --------------    |          |           |        |          |         |
  fine               |XXXXXXXX| |           |        |          |    |XXXXXXXXXXXXXXXXXXXXXXXXXX
  spin               |        |XXXXXXXXXXXXXXXXXXXXXXX|<----- 8 h -->|   |
  constant solar     |          |           |        ||XXXXXXXXXXXXXX|:   |
BIUS                 |          |           |        |          |     |   |
commands to experim. | *     '* |          *|        |*         |   '*    |
Experiments modes    |          |           |        |          |         |
  standby            |X|      |XXXXXXXXXXXX|         ||XXXXXXXXXXXXXXXX|   |
  memory dump        | |XXXXX|  |           |        |          |         |
  exlipse            |          |         |XXXXXXXXXX|          |         |
  observation        |          |           |        |          |         |XXXXXXXXXXXXXXXXXXXXXX
                                      Fig. 9.
```

Figure 22 Eclipse (duration > 1 hour).

experiments are put to the SURVIVAL mode (Figure 22).

2.4

General OT's emergency situations are presented in table 3

MISSION CONTROL
EMERGENCY SITUATIONS (ES) (Issue 1)

1.Classification of the ES

Type	Possible consequences
ES1	Endanger the health of the space craft
ES2	Endanger fulfilment of the Observing Time
ES3	Endanger normal course of the Ground Contact
ES4	Changes in the operating program
ES5	Endanger the experiments

2. General

In case of ES1 or ES2, the space craft is automatically being transferred into Safe-Hold Mode (SH). Definition and removal of the causes, which have caused ES, take place after analysis of telemetry data during next GC.

SH of the space craft ensures:

* support of the power balance
* support of the thermal balance
* possibility of carrying out GC at any time

In case of ES3 CG will use radio line in order to recover the space craft and analyse of the status of the space craft. If removal of the causes of ES are impossible, then space craft automatically is being transferred into the SH.

3. Emergency situations which endanger the space craft health (ES1)

ES1 results from any of the following:

* total fault of any service system
* infringement of the power balance and discharge accumulator battery more than allowable

3.1 Total fault of the service system

Spacecraft reliability are achieved through two forms of redundancy: Hot and Cold. The cold redundant systems may be enabled automatically or by radio - line (RL). Table 1 presents types of space craft service systems reserve.

Table 1.

System	Type of reserve	Type of the contraol of the reserve
Radio system receiver part tramsitter part	cool	by radio line
Power Supply	cool	automatically or by RL
Thermal Contraol	cool	automatically or by RL
On-Board Control	hot cool	automatically or by RL
TIme Program	hot	
Control Solar Battery Panel	cool	by RL

3.2. Infringement of the power balance

Infringement of the power balance may be in the cases:

* Loss of suntracking by Sun-panels.
* Infringement of the power balance and discharge storage battery more than allowable

Control Solar Battery System consists of the two panels controlled by independent systems. The power of either panel is enough for SH.

Power Supply System includes three storage batteries. One is reserve. If current requirement excesses above current SB long-duration then Power Supply System turn-on the reserve battery and space craft service system automatically transfer into the SH and experiments into Survival mode.

4. Emergency situations which endanger normal course of the OT (ES2)

ES2 results from any of the following:

* when Attitude Control System can't carry out fine orientation
* ES with SODART Service Systems
* ES with experiments

Analysis of the normal course operation is carried out with Attitude Control System automatically. In the case of an emergency, the Control System outputs to TPS an external signal and then TPS provides:

* transfer service systems to Safe-Hold mode
* transfer experiments to Standby mode

SODART BUSS Unit carries out analysis of the SODART service systems status. In emergency situations:

* BUSS Unit outputs to TPS an external signal which indicates failure on a given sled

* TPS transfers experiments placed on the failed sled (or all SODART experiments if this emergency is total) to Standby mode

* TPS outputs to BUSS Unit command for transferring Sodart Service System to Local Standby mode (one sled) or Total Standby mode if the situation is total.

5. Emergency situations which endanger normal course of Ground Contact (ES3)

ES3 results from any of the following:

* Radio System fault

* Space craft Operation Ground Support Facilities fault

In the receiver part of the Main Radio System the use of ES3 generally initiates the hot reserve. Constantly turned ON:

* two command receivers combined to different antennae

* command-measurement receiver

* three command decoders

One command receiver is on cool reserve.

Each command - measurement receiver includes two halves.
One half is turn ON.

If the ES occurs in the MRS, the reserve turns on and GC occurs

All Control Centre systems have reserve parts

There are GC in "zone of visibility" of two tracking stations with UP-LINK and DOWN-LINK reserve

If the GC does not finish on the limit time Time Program System automatically transfer space craft into SH.

6. Rescheduling Observation Time (ES4)

General case of rescheduling OT may include new interesting sources into OT schedule.

General principles for this procedure:

* need to insert a new source in the program must be confirmed by special scientist group

* new observation carried out instead of the planned observation shall not disturb next OT Schedule

* Implementation of rescheduling procedure may require 3-5 days

The possibility of uplinking "unplanned commands" to the experiments during the same Ground Contact will be provided but with constraints. These constraints depend from the necessary and very accurately carried out Observation Times Schedules in order to ensure all time shares for each national committees and instruments.

7. Emergency situations with experiment (ES5)

Operating program in the ES5 is developed by the control team of the experiment and must be agreed with CG.

There may be two ways out from emergency:

* express analysis of telemetry and uplink of "unplanned commands" for correction of experiment status during the same GC

* transfer experiment into standby mode; correction of experiment status into future GC

The requirements are:

* list of the emergency commands must be prepared on beforehand (document EMERGENCY SITUATIONS AND RECOVERY PROCEDURES)

* EMERGENCY SITUATIONS AND RECOVERY PROCEDURES (ESRP) must be prepared before launch and agreed with SPACECRAFT CONTROL GROUP (CG)

* ESRP items can be added during flight

If the emergency situation is unknown to ESRP then:

* experiment transfers into SAFE HOLD MODE

* analysis of the experiments status is carried out

* preparation of recommendations for the experiments future program and agree these with the CONTROL GROUP

* the transfer procedure must be described in ESRP

* operations from ES must consist of commands time line and time to its realization and monitoring

If these recommendations are impossible to perform during the same OT Schedule (i.e. too many commands or need to carry out special tests), then after ISC decision and agreement with Perspective Planning Group:

* preparation of Checkout Stage Procedure (CSP)

* Stop the OT schedule

* carry out the CSP instead of planned observation, without disturbing next OT Schedule

Correction of the Perspective Plan may only be done by the Perspective Planning Group after special decision of the ISC.

Adopting only preprepared emergency procedures with known time line and execution times will minimize:

* mistakes arising from express analysis, and allow rapid feasibility checks from execution during the same GC.

9. Mission Support

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DATA PROCESSING CENTER

Data Processing Center (DPC) is located in Lavochkin Association, Moscow, Khimki. It was created for testing spacecraft during integration test in Lavockin Associtiоn and for spacecraf t flight control. The main tasks of the DPC are:

- communications with ground stations for telemetry data reception and telecomand sending
- telemetry data processing to access spacecraft health status, displaying
- archive and retrieval data
- telecommand data planning and verification
- spacecraft control
- communications with Scientific Instruments Control Group (SICG)

DPC is Ethernet based local area network with PC compatible computers (AT/386 and AT/486). Software architecture include:

- DOS 6.0
- IPX and TCP/IP (Novell Netware 3.11, PC TCP)
- Telemetry and telecommand data processing s/w
- Auxiliary s/w

DPC LAN is connected to INTERNET, so TM and TC data is available in Space Research Institute and other sites in the world where are Internet connected computers.

SPACECRAFT CONTROL GROUP

is located in DPC, Lavochkin Association and its main tasks are the following:

- s/c housekeeping telemetry analysis to obtain s/c systems health status
- telecommand data files preparing and verification
- organization all groups activity to control s/c

SCIENTIFIC INSTRUMENT CONTROL GROUP

is located in Space Research Institute (IKI). Main tasks of SICG are:

- checking of the scientific instruments programm accomplishment
- preparing telecommand data files for scientific instruments
  for S/C Control Group

10. Acronyms

(still very incomplete)

List of some of the acronyms used in the Mission Operations Report:

AGN	Acitive Galactic Nuclei
CCD	Charged Coupled Device
CXRB	Cosmic X-Ray Background
DIOGENE	
DSRI	Danish Space Research Institute
EGSE	Electrical Ground Support Equipment
EUVITA	
EXOSAT	European X-Ray Satellite.
GSE	Ground System Equipment
HEPC	High Energy Proportional Counter (on SODART)
IKI	Space Research Institute, Moscow
IR	InfraRed
ISC	International Science Committee
JetX	Joint European Telescope for X-rays.
KFRD	Complex of Focal X-ray Detectors (on SODART)
LEPC	Low Energy Proportional Counter (on SODART)
MART/LIME	Mask Astronomical Roentgen Telescope - Large-area Imaging Mwpc Experiment
MM	Mirror Modules (on SODART telescopes)
MOR	Mission Operations Report
MOXE	
MRC	Main Radio Complex
MRS	Main Radio System
MSPC	Micro Strip Proportional Counter
MWPC	Multi Wire Proportional Counter
OPG	Observations Planning Group
OXS	Objective Crystal Spectrometer
QLF	Quick Look Facility
SIXA	Silicon X-ray Array (on SODART)
SODART	Soviet Danish Roentgen Telescope
SRG	Spectrum Roentgen Gamma
SXG	Spectrum X-Gamma - the same as SRG.

TAUVEX	Tel Aviv University Ultraviolet Explorer
TIC	Technical Implementation Committee
TPS	Time Program Systems
TS	Telemetry System
UV	UltraViolet
XSPECT	Xray Spectral and Timing mission (Danish share of SODART).