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NASA-MIR: Development, Integration and Operation of Systems of the Priroda Module of the Mir Orbital Station

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Development, Integration and Operation of Systems of the Priroda Module

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ABSTRACT
The Priroda module was the last of six principal modules that comprised the Mir space station. Launched in April, 1996, it was added to the Mir base block, Kvant, Kvant II, Kristall, and Spektr, each launched between 1986 and 1995. Together with Soyuz and Progress transport vehicles, the system operated in orbit for more than fifteen years, though Priroda was a presence for only five of those years.

In 1990, the U.S. and Russia began a joint program of scientific and manned space flight studies in response to agreements reached by the Bush Administration. Initial activities included the conduct of medical experiments studying the effects of long-duration space flight on board Mir. Provisions were made for the flight of a Russian cosmonaut on Space Shuttle, and of an American astronaut on board Mir.

After an initial period of activity of approximately one year, the program was expanded, through a contractual agreement, to include the docking of up to ten Space Shuttle missions to Mir, the addition of several American astronauts on Mir and of Russian cosmonauts being brought to and from Mir on the Shuttle. In addition, approximately 2000 kilograms of scientific hardware and support systems were flown to the Mir.

Both the Spektr and Priroda modules were designed in the mid to late 1980s and the flight systems constructed and assembled from 1989 to 1991. Priroda was to have been launched by 1991 as a component of Mir 1.5, a second Mir-type station that woul be launched in place of the much larger Energiya booster-launched Mir 2 which had to be cancelled when the Energia program was cancelled.. As the U.S./Russian contract was implemented, the modules were reconfigured and retrofitted to house U.S. science hardware. This resulted in the elimination of some Russian scientific systems, and the addition of module secondary structure and other modifications.

In May, 1995, the Spektr module was launched to the Mir station. It carried approximately 700 kilograms of U.S. scientific payload, principally in the medical and biological science fields. The launch, docking, and subsequent activation of Spektr occurred during the same period that the American astronaut, Dr. Norman Thaggard, was completing a four month endurance mission on Mir.

The U.S. Priroda effort, coming after a period of intense work to meet the Spektr integration activity schedule, was structured and organized in such a way as to establish long-term working relationships and to develop an infrastructure for the integration and operation of future spacecraft systems. In addition to the spacecraft systems and experiments integrated on Priroda, several significant integration processes were established. These included prototypes for the definition of systems requirements, integration documentation, and system resources, including manifest and integration/interface control documentation and certification processes. Also, new concepts and hardware were introduced for the housing of hardware on Mir and Space Shuttle and would later be adopted for use on the International Space Station. This included the system used for the logistics transfer of most hardware and consumables.

Perhaps one of the greatest benefits of the NASA/Mir program was the ability and necessity of the Russian and American program's engineering and management staffs to work together, gaining mutual experience, trust and respect.

THE PRIRODA MODULE

Priroda, at the time of the signing of the initial U.S./Russian contract, was due to be launched in 1991, though a more realistic launch date was probably in early 1992. As a result of additional efforts required to implement the NASA/Mir contract, delays in work on the Spektr, and other difficulties, including internal Russian funding, manpower, and contractual problems, the Priroda launch was repeatedly delayed. By late 1995, the launch was scheduled for its actual date, in April, 1996.

Priroda's total mass was 19.5 metric tons, of which 3400 kg was scientific hardware, most of which was Russian and Russian affiliated earth resources observation equipment. Of the total, the U.S. provided 850 kg of materials processing, life sciences, earth observation and support systems at launch. Approximately another 2000 kg was delivered by STS- 76,79, 81, 84, 86, 89 and 91 for integration into Priroda and Mir during the remainder of the NASA/Mir program. Many of the major science facilities were returned on missions STS-89 and 91.

The Priroda module was capable of autonomous flight prior to its docking with Mir, and included significant new service systems that enhanced Mir's earth observation and telemetry capabilities.

A representation of the major Priroda features is included as figure 1. The Priroda module was approximately 2.9 m in diameter over most of its length, with five bulkhead rings, a spherical base to which an unpressurized instrumentation structure is mated, and a conical base (at launch) in which the docking system and hatch for crew intravehicular transfers was located. The Priroda module included a payload shroud, the instrument/payload compartment, and an instrument module. The shroud protected the module and external equipment from aerodynamic effects during the launch sequence. The instrument compartment was the main portion of the module and housed spacecraft systems, experiments, and the pressurized area for crew operations. The unpressurized section of the instrument module housed spacecraft systems.

The instrument / payload compartment was divided lengthwise into three sections. The first compartment principally housed module systems hardware while the later two housed primarilypayload systems. All of the U.S. designed hardware was installed in the instrument/payload compartment. The instrument / payload compartment was divided into an inner habitation and work compartment and an outer instrumentation compartment. The two were divided by aluminum-magnesium coated plastic panels. The panels provide a fire break and formed a significant portion of the module's environmental control system, allowing conditioned air to flow through the crew compartment before returning through the instrumentation compartment.

The instrument module, aft of, and partially surrounding, the instrument/ payload compartment, carried propulsion system components, EVA restraints, and scientific equipment.

In order to accommodate U.S. systems and scientific hardware the Russians modified the Priroda module to include additional structural, load bearing elements and the addition of additional openings and internal compartments for containment of U.S. systems. Several Russian experiment systems, some in the biotechnological area, had to be eliminated in order to meet contractual obligations with the U.S.

THE U.S. PRIRODA EFFORT

Phase 1A of the NASA-Mir program was oriented around the integration of the Spektr module.

At that time a major period of development and integration of medical science hardware in support of Spacelab missions was in progress. Spacelab, a versatile space laboratory designed to fit in the payload bay of the Space Shuttle, was developed for NASA by the European Space Agency (ESA) The NASA-Mir effort was placed under the auspices of the Johnson Space Center. Consequently, Spacelab hardware, such as the Standard Interface Assembly (SIA) Rack and MIPS data management system hardware were adopted for use in outfitting Mir. These resources were invaluable in saving the development effort the resources of time and dollars, especially as the Phase 1A started principally as a medical research effort using many of Spacelab's existing experiment systems.

In planning for Phase 1 B, efforts were being made to expand the Mir research program into the areas of materials processing, biotechnology, and earth resources research. Many of the systems in use or in development in these areas were being developed for later use on the International Space Station, but many had been based on systems developed for use in the Space Shuttle middeck.

In the period from 1993 through early 1994, a significant effort was being directed by NASA Headquarters to reduce the resource requirements associated with flying Shuttle missions. Included in the cost reduction efforts would be an effort to reduce the costs associated with payloads and science implementation. SPACEHAB, Incorporated had recently flown the first successful Spacehab commercial module on STS-57, and put forward an unsolicited proposal to support the Mir missions. Spacehab was built to support the NASA commercialization effort under the Commercial Middeck Augmentation Module Project, specifically to expand the capability to fly payloads developed for use in the Shuttle middeck.

By the late spring of 1994, it appeared likely that NASA would shift its Mir efforts away from Spacelab and towards Spacehab. The availability of experiment systems developed for use in the Shuttle middeck, combined with the potential for use of the Spacehab module for the Mir missions, led to the adoption of middeck compatible systems and resources on board Priroda.

Although a new design for use in Priroda, single lockers were designed specifically for commonality in dimensions and utility routing with similar lockers on board the Shuttle middeck and Spachab. In order to expedite the logistics of hardware transfers between Space Shuttle and Mir, a family of soft stowage bags designed for fit into the lockers was designed and developed. Initially, versions of the bags would be called Priroda Bags, but later modifications were built under the name Cargo Transfer Bags (CTB). Payload Utility Panels were based upon the Middeck Utility Panel on Shuttle, and designed specifically as an interface between the Priroda power system and middeck-class experiments provided power resources. The centralized PUPS also limited the number of interfaces directly between the U.S. experiments and the Mir power system, thereby simplifying the developing of electrical interface drawings and affording some protection to both Mir systems and U.S. payloads.

In order to meet Russian schedules imposed for a launch by early summer of 1995, one of the largest Government Furnished Equipment crash development programs since the Apollo era was put in place by July, 1994. After a preliminary design review in August, 1994, and a preliminary ICD issued concurrently, flight-ready systems hardware was in hand beginning in September, 1994.

Fabrication of all mounting panels, adapter plates, and single and double lockers was completed by December, 1994, and racks, and the U.S. power distribution system were completed by February, 1995.

During the same time period, major experiment systems were being adopted and in some cases, modified for use in Priroda. These included the Microgravity Glovebox, a system designed originally for use in Spacelab, adopted for use in the middeck, and modified to meet Priroda requirements.

Accommodations for Shuttle Thermal Enclosure System (STES) units, which had been in extensive use for a variety of commercial and scientific efforts, such as the Protein Crystal Growth series of missions, were included in the Priroda planning. The Bioreactor, a system for the 3-D development of living cells and which had a near term requirement for long duration missions, was adopted for use on Priroda in the form of the Bio-Technology System (BTS). An agreement between NASA an the Canadian Space Agency brought a third nation's experiments into the U.S. Priroda effort in the form of the Microgravity Isolation Mount (MIM) and experiments designed for use with it. Other systems included the Enhanced Dynamic Load Sensor (EDLS), for making anthropometric measurements, the Commercial Generic Bioprocessing Apparatus, video and photographic equipment, and several experiments in combustion, fluid dynamics, and biology. A data management system, the Mir Interface to Payload Systems (MIPS), developed initially for use on Shuttle and adapted for use on Spektr, was also included.

INTEGRATION PROCESSES

With the beginning of Phase 1 B of the NASA/Mir program, a contract for the integration of U.S. hardware was established between the Russian Space Agency and NASA. In response, the Russians began to centralize their integration organization.

The Rocket and Space Company (RSC) Energia, as the prime contractor for defining integration requirements and vehicle configuration for the Russian Space Agency, had been responsible for the development of all of the Russian, and previously Soviet, manned space vehicles. The company was organized into several major groups responsible for

- vehicle definition, development and integration
- systems design and integration
- science and applications
- testing

An organization chart based upon the author's observations is included as figure 2.

As the NASA/Mir program developed, responsibility for integration of U.S. hardware was delegated to the science and applications group. This group had been responsible for the definition and development of technological, biotechnological, and medical experiment systems for Energia. Though the group had been responsible for preparing integration documentation for their own systems and also had a science program management and integration department.

At the beginning of the U.S. effort to develop systems for use on Priroda, NASA already had over a year and a half of experience with the Spektr activities. The Spektr effort was not without difficulty. Spektr comprised most of Phase 1A of the program. The Phase 1A portion of the NASA/Mir program was done without the benefit of a formal contract and therefore firm guidelines, processes, and programmatic or technical requirements were not established and a formal, centralized configuration control system was not in place.

A programmatic requirements document, the US/R-001, was initiated by the Russianmedical research/integration group, but the document was never completed and never formally signed. Consequently no schedules, programmatic requirements, or documentation requirements were ever firmly established.

Integration documentation, in the form of '100 Series' documents, equivalent to the Space Shuttle program's Payload Integration Plan, Annexes, and ICDs, were not consistently required or applied. Individual Russian engineers from the science and applications group were responsible for guiding the development of the integration documents, but content of the documents was largely up to each individual engineer's personal definitions. Similarly, hardware testing requirements were not uniformly applied. In some cases, the Energia integration group was bypassed by NASA investigators working directly with other Russian science organizations such as the Institute for Biomedical Problems (IBMP).

Though a systems and environmental requirements document was developed and signed during Phase 1A, it was incomplete and inadequate. Without a defined configuration control mechanism; new requirements were being established continuously. By mid-1994, no fewer than six, sometimes conflicting, versions of the US/R-002 Systems Requirements Documents were in use.

The process for integrating hardware and preparing documentation was largely ad hoc, with the integration groups, hardware test engineers, principal investigators and experiment engineers, and hardware coming together for meetings at which the U.S. side presented the experiment hardware and set about preparing and reviewing integration documentation. Frequently hardware had been tested and certified prior to the test and certification requirements having been defined.

Early in the Priroda effort, meetings were held between the principal NASA and contractor engineers and their Russian counterparts in Russia. A plan was developed for the definition of design and test requirements and for the development of draft integration documentation.

This would occur in two phases; the initial would occur in Russia approximately six months prior to hardware turnover. A second review of documentation in the U.S. would occur two months prior to hardware certification testing. Although the design of many of the support and experiment systems was already well along by the time either of the reviews would occur, the reviews would allow the definition of an acceptable hardware testing program far enough in advance to permit the program to be planned and scheduled accordingly.

Initially, requirement reviews and documentation reviews were scheduled according to hardware development plans. This proved to be unworkable as there were frequently overlapping activities occurring in both the U.S. and Russia. Therefore a phased approach was introduced in which reviews would be planned so that the center of activity would shift approximately every one to two months. The schedule of meetings carried out was:

1994	August	Moscow
	Requirements definition for support systems	
	November	Houston
	Final documentation preparation and test activities for support systems	
1995	Feb-March	Moscow
	Requirements definition for experiment systems and support system hardware turnover	
	May-June	Houston/Huntsville, Al
	Final documentation preparation and test activities for experiment systems	
	July	Moscow
	Requirements definition for experiment systems and experiment system hardware turnover	
	August	Houston
	Final documentation preparation for stowed hardware and test activities for experiment systems	
	Nov-December	Moscow
	Integrated testing of active hardware in the Priroda module and turnover of stowed hardware	
1996	Jan-February	Baikonur
	Integration of experiment systems and stowed hardware for flight	
	March	Baikonur
	Final active flight hardware integration and end-to-end testing	
	April	Baikonur
	Launch	

Periodically, the schedule became compressed and U.S. and Russian engineers would find themselves flying back and forth between the U.S. and Russia, together, as the center of activity shifted. But generally the approach always permitted the full understanding of hardware test requirements early enough that changes could be introduced, sometimes to the hardware design, and frequently to the hardware test program. The approach permitted time for developing document translations and also permitted hardware developers to plan for a second opportunity for hardware acceptance testing in the case that the first opportunity had to be aborted for technical problems.

Typically, an overview of the hardware, its operational procedures, and the test plans and requirements were defined first (100, 101, 102, 105 and 108 documents). Test results and safety documentation (106, 107) were submitted approximately at the time of hardware testing. Russian engineers responsible for hardware integration frequently had the opportunity to participate in and observe the hardware testing, and they concentrated their documentation reviews on all but crew training and safety documentation.

After the initial phase of documentation generation for support systems was completed (August, 1994), both sides agreed that it would be of mutual benefit to develop a set of guidelines or 'blank books' for experiment developers to use in preparing their integration documentation. The documentation being developed until this time was frequently inconsistent owing to different Russian engineer's opinions on the appropriate document contents. It was also anticipated that standardizing the content and structure would simplify the job of translation, also reducing the cost for this considerable effort. The U.S. side led this effort, reorganizing some of the document outlines so that redundancies could be eliminated. Blank books were formally approved by both sides in March, 1995. Unfortunately the late distribution did not permit their full use by the major experiment developers for the Priroda as their documentation was already well along in development. They would however be applied for later systems delivered by Space Shuttles. Stowed systems and later Space Shuttle launched payload systems going to Mir would find the documents of value.

Also during this period a new 001 document was prepared, identifying major milestones to be met by experiment developers; the 002 document was expanded and the multiple versions consolidated into a single consistent set of requirements; and the format and contents of an 004 manifesting document were defined in order to maintain a comprehensive resources definition of all systems, interfaces, and requirements. An integrated management information system database, called the Payload Integrated Planning System was subsequently developed to maintain and automate the maintenance of the manifest and resources definition.

A schedule of activities covering all documentation and hardware testing was published approximately every six weeks, and when managers and engineers were not attending meetings or reviews in one another's country, telecons were being held frequently, typically once a week. Communications was maintained either through telecons or faxes initially, though by the conclusion of the program, email had been established between key managers.

PROBLEM AREAS

Difficulties arose most frequently when organizations external to those responsible for U.S. experiment integration or for science were required to support activities. These incidents were most notable in the areas of training, operations and safety.

Training was conducted not by the Energia organization but by the Russian military at the Gagarin Cosmonaut Training Center in Star City, Russia. Energia science 'curators' were responsible, however, for on-orbit experiment operations.

Although Star City trainers came to the U.S. to support some documentation and hardware reviews, training documents (108) were almost never reviewed or ultimately used. Energia curators almost never attended training sessions in the U.S. or in Russia. And other Energia operations personnel from the Russian Center for the Control of Space Flight, otherwise known as TsUP (pronounced "soup") appeared totally unaware of U.S. experiment systems, their operations or requirements, until after the systems arrived in orbit.

Safety reviews of experiment or other systems were not regularly conducted by the Russian safety organization. Safety approvals were a major difficulty at the outset, though by later in the program as processes were established, the difficulties eased.

Russian primary emphasis was in the materials area, though even there the organization and individuals responsible for the review, and who did not represent the safety organization, did not appear to go through a rigorous review process. Few detailed safety requirements were defined and no 'standard practices" guidelines, such as are available for the U.S. Shuttle program, were provided. Russian materials engineers failed to attend many hardware reviews and test sessions and safety engineers were never in attendance.

Frequently inconsistencies arose in the handling of potential issues between different experiments, or even on the same system or experiment, from one review to another. One of the best examples occurred in the area of stowage provisions. After encountering serious materials concerns and issues with stowage foam provided by the U.S. for Spektr, the use of new acceptable materials was given a high priority early in the Priroda activity. Materials, processes and requirements were defined early with the full support of the Russian materials organization. But after hardware had been completed and submitted for final review prior to flight, new requirements were imposed, ultimately resulting in a total rebuilding of the stowage system.

Although safety associated documentation was required to be provided early, the information was not reviewed as it was being provided. Feedback on the results of the Russian reviews was so late that little remedial action could be taken because hardware had already been delivered and installed for flight.

The Russian organizational structure was a hindrance in efficiently carrying out the overall Priroda effort. For instance, considerable flight-like training hardware was provided for outfitting a trainer at the Star City training facility. But, since the trainers came under the responsibility of the military rather than the Energia hardware integration group, much of the U.S. training hardware was never used.

Maintaining the schedule was a principal difficulty in the integration effort. Part of this problem was a result of inaccurate schedules provided by the Russians early in the program. For instance, the design, development, production, and testing of the U.S. support systems was expedited at some expense in man-hours and dollars, in order to meet the initial spacecraft integration schedule requirements. Hardware such as the lockers and electrical system was ready for the initial Russian review in late September of 1994, but the Russian's first trip to the U.S. to review the Priroda hardware was delayed until November as a result of bureaucratic problems. Hardware which the U.S. was required to deliver in early 1995 was never used until late in the year.

Early in the program, delays to the Russian's travel in turn delayed several of the hardware test activities until complete joint approval was gained and until Russians were physically present to observe some testing. The decision was reached, mutually, at the time of this November meeting, that in the future, test activities would be conducted according to the schedule jointly agreed to at the previous meeting, regardless of whether all appropriate engineers would be in place by the required time. Such agreements, including schedule details, were included in joint meeting 'protocols'.

Another schedule challenge faced in late 1994 and early 1995, was shipping and customs.

Lockers, some four dozen of which completed testing activities by early December, 1994, were shipped immediately from the U.S. Shipping delays initially occurred as a result of common carrier problems. Then, when the hardware reached Russia, it was immediately confiscated in Russian Customs storage facilities. It remained there through April, 1995. After a thorough series of investigations, including researching the shipping policies for overseas airlines and several visits to the Russian Customs house, it was determined that delays resulted from two principal difficulties. The first was related to the size of the hardware shipping container. The larger the container, the more likely hardware would miss overseas flights. The second problem was due principally to delays by the Energia organization. These investigations led to discussions between the NASA shipping organization, U.S. Customs, and the NASA Headquarters international officeon how to package items in the future, using required shipping documentation and external markings., Ultimately, the decision was made to attempt to hand-carry most hardware with U.S. engineers attending reviews in Russia. The concerted effort resulted in the reduction of typical transportation time to two days for hand-carried items and to approximately two weeks for typical shipped items.

The lack of a single Russian authority to control all components of a space mission to the same degree that NASA does for the U.S. frequently created inefficiency and confusion that thwarted the best efforts of the individuals and individual organizations. Separate entities were responsible for integration and integration requirements (Energia), physical integration (Krunechev), training and training facilities (military-Star City), and for launch processing (military Space command). Within Energia, different organizations were responsible for pre-flight integration and operations planning than for in-flight operations.

HARDWARE INTEGRATION

After several delays to the Priroda module schedule, the module was ready for the integration of U.S. hardware in December, 1995. Testing at the KIS test facility in Korolev (Kaliningrad at the time) proceeded according to plan with a single serious technical problem, fully the responsibility of the U.S. side. The problem points out the significance of standardizing engineering practices and maintaining communications. A data cable connecting the MIPS data system to the MIM (Microgravity Isolation Mount) experiment, was miswired, causing a blown fuse in the MIM. The failure resulted from a combination of problems. The MIPS system utilized a non-mil-spec connector which had not been wired in accordance with mil-spec requirements. The data cable was improperly designed, and miscommunication between the MIPS, MIM and a Star City training group resulted in no test having been conducted between training hardware units, even though it was believed that a successful test had been performed. Next, Russian engineers failed to follow jointly approved test requirements for an interface and functional test external to the Priroda module, prior to integration.

In January, 1996, a new MIM unit, already in preparation, was shipped to Moscow and then to the Russian launch facility at the Baikonur Cosmodrome in Kazakhstan. It was the last major piece of U.S. hardware accepted for integration.

U.S. engineers worked together with their Russian counterparts to integrate and test U.S. hardware at Baikonur. This activity occurred over a ten day period without significant difficulties. Those which did arise came about mainly because the physical integration of hardware was the responsibility of the Krunechev Manufacturing company, rather than the Energia company which had responsibility for defining systems and integration requirements.

SUMMARY

Priroda provided an excellent challenge and an opportunity for the NASA to demonstrate that it still has the capacity to develop in-house, space hardware for flight according to compressed schedules-something not done routinely in recent years.

Perhaps more significantly, Priroda permitted Russian and U.S. personnel to gain insight into the processes and operations, frequently very different, in use by one another in order to prepare and fly their spacecraft, and perhaps most importantly, it created new friendships and developed confidence in one another's technical abilities.

SUMMARY

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ABOUT THE AUTHOR.

Gary H. Kitmacher has been at the NASA Johnson Space Center since 1981. Mr. Kitmacher serves as the Space and Life Sciences manager for space flight safety and supports Space Station and Shutte missions and commercialization initiatives.

Mr. Kitmacher has served in several capacities since coming to the space center in 1981.

- During the Shuttle-Mir program; he was the US manager responsible for the last Mir module, Priroda, and directed integration and operations on Mir. He led US efforts to develop, certify and integrate systems and payloads on Mir. One of the systems developed at his direction is the logistics system now in use for International Space \ Station.
- Previously he worked in the commercial Spacehab program and managed the STS-60/Spacehab 2 mission.
- During the design and definition stage of the Space Station, he was the Man-Systems system architectural control agent and later applied this experience to the design of manned moon and Mars habitats, rovers and landers.
- In 1985-86 he served as the subsytem manager for Space Shuttle Crew Equipment and Stowage.

Mr. Kitmacher has masters and bachelors degrees in Management, Geology, Astronomy and Education and is an Adjunct Professor in the University of Houston School of Business teaching a course in the commercialization of space technology.

Mr. Kitmacher is married. He resides with his wife and daughters in Houston, Texas.

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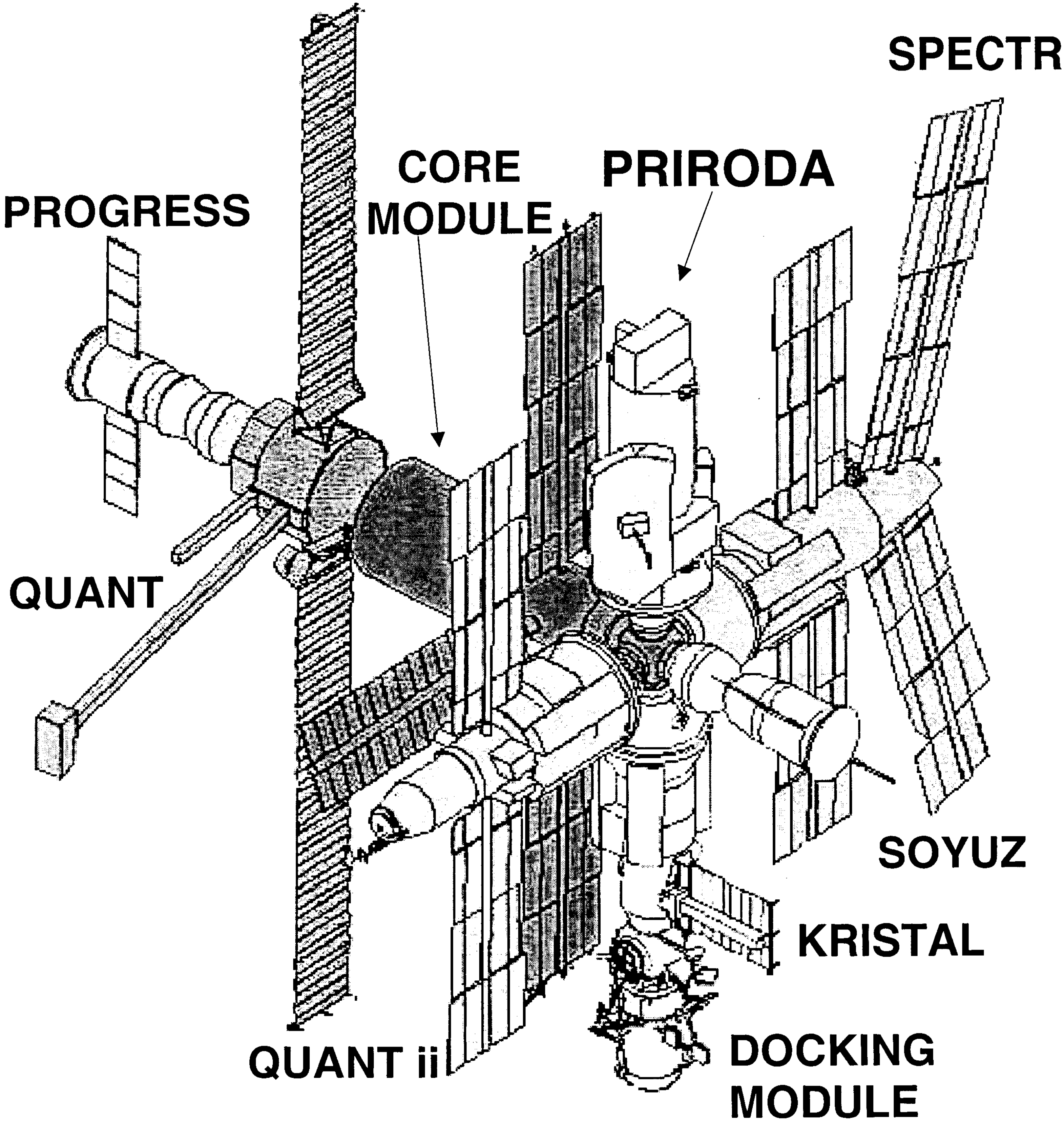
SYSTEMS USED DURING NASA/ MIR LATER USED FOR INTERNATIONAL SPACE STATION

Developed for use on NASA/Mir, now in routine use on ISS

Crew On Orbit Support System (COSS)
Payload Lockers
Soft Stowage and Cargo Transfer Bags (CTBs)
Payload Utility Panel (PUP) Electrical Systems used subsequently as the basis for ISS PEAK

Prototypes Flown on Mir as a Test for ISS
Crew On Orbit Support System II (COSS II)
Personal Computer System (PCS)
Astroculture (ASC)
Biotechnolgy System (BTS)
Commercial Generic Bioprocessing Apparatus (CGBA)
Commercial Generic Bioprocessing Apparatus II (CGBA II)
Enhanced Dynamic Load Sensor (EDLS)
Micro-Gravity Glovebox (MGBx)
Micro-Gravity Isolation Mount System (MIM)
Wireless Network Experiment (WNE)
Optical Properties Monitor (OPM)
Crew Medical Restraint System (CMRS)
Volatile Organics Analyzer (VOA)
Protein Crystal Growth (PCG)
Defibrillator
Mir Sample Return Experiment (MSRE)


SPECTR
CORE
MODULE
PRIRODA
PROGRESS
QUANT
SOYUZ
KRISTAL
QUANT ii
DOCKING
MODULE

Disc	Investigation	Experiment type	Investigator/affiliation
ADV	ASTROCULTURE (ASC)	science	Bula, Raymond, Ph.D. / University of Wisconsin / Madison
ADV	Commercial Generic Bioprocessing Apparatus (CGBA)	science	Stodieck, Louis, Ph.D. / University of Colorado-Boulder
ADV	Commercial Generic Bioprocessing Apparatus (CGBA-02)	science	Stodieck, Louis, Ph.D. / University of Colorado-Boulder
ADV	Commercial Protein Crystal Growth (CPCG)	science precursor	DeLucas, Larry, Ph.D. / University of Alabama / Birmingham
ADV	High Temperature Liquid Phase Sintering (LPS)	science	Smith, James, Ph.D. / University of Alabama at Huntsville
ADV	Liquid Motion Experiment (LME)	engineering	Dodge, Frank T., Ph.D. / Southwest Research Institute, San Antonio, TX
ADV	Materials in Devices as Superconductors (MIDAS)	science	Wise, Stephaine / NASA / LARC
ADV	Optizon Liquid Phase Sintering Experiments	science	Smith, James, Ph.D. / University of Alabama at Huntsville
ADV	X-Ray Detector Test	science precursor	DeLucas, Larry, Ph.D. / University of Alabama / Birmingham
ES	Calibration & Validation of Priroda Microwave Sensors	science	Shiue, James C. / NASA / Goddard Space Flight Center
ES	Comparison of Atmospheric Chemistry Sensors on Priroda & American Satellites	science	Kaye, Jack A. / NASA / Goddard Space Flight Center
ES	Regional & Temporal Variability of Primary Productivity in Ocean Shelf Waters	science	Muller-Karger, F. E. / University of South Florida
ES	Test Site Monitoring	science	Evans, Cynthia, Ph.D. / Lockheed-Martin / Houston; Lulla, Kamlesh, Ph.D. / NASA / JSC
ES	Validation of Biosphere-Atmosphere Interchange Model for Northern Prairies	science	England, A.W. / University of Michigan
ES	Validation of Priroda Rain Observations	science	Thiele, Otto W. / NASA / Goddard Space Flight Center
ES	Visual Earth Observations	science	Evans, Cynthia, Ph.D. / Lockheed-Martin / Houston; Lulla, Kamlesh, Ph.D. / NASA / JSC
ES	Visual Observations	science	Lulla, Kamlesh, Ph.D. / NASA / JSC; Saganti, Premkumar / Lockheed-Martin / Houston
ES	Watershed Hydrologic Studies	science	Jackson, Thomas J. / United States Department of Agriculture

FB	Active Dosimetry of Charged Particles	science	Schott, Jobst Ulrich / Institute for Aerospace Medicine
FB	Cellular Mechanisms of Spaceflight Specific Stress to Plants	science	Krikorian, Abraham D., Ph.D. / SUNY / Stoney Brook
FB	Developmental Analysis of Seeds Grown on Mir	science	Musgrave, Mary, Ph.D. / Louisiana State University
FB	Effective Dose Measurement at EVA	science	Deme, Sandor, Ph.D. / Atomic Energy Research Institute / Hungary
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FB	Environmental Radiation Measurements on Mir Space Station		Benton, Eugene V., Ph.D. / University of San Francisco
FB	Greenhouse-Integrated Plant Experiments on Mir	science	Salisbury, Frank, Ph.D. / Utah State University
FB	Incubator - Integrated Quail Experiments on Mir	science	Fermin, Cesar, Ph.D. / Tulane University School of Medicine
FB	Standard Interface Glovebox Operations	engineering	Savage, Paul / NASA / ARC
HLS	Analysis of Volatile Organic Compounds on Mir Station	science	Palmer, Peter T., Ph.D. / San Francisco State University
HLS	Anticipatory Postural Activity (POSA)	science	Bloomberg, Jacob, Ph.D. / NASA / JSC
HLS	Assessment of Humoral Immune Function During Long Duration Spaceflight	science	Sams, Clarence F., Ph.D. / NASA / JSC
HLS	Bone Mineral Loss and Recovery after Shuttle/Mir Flights	science	Shackelford, Linda C., M.D. / NASA / JSC
HLS	Cardiovascular Investigations (712/709)	science	Blomqvist, C. Gunnar / University of Texas Southwestern Medical Center; Eckberg, Dwain / McGuire Research Institute
HLS	Collecting Mir Source and Reclaimed Waters for Postflight Analysis	science	Sauer, Richard L., P.E. / NASA / JSC
HLS	Crewmember and Crew-Ground Interactions During NASA-Mir	science	Kanas, Nick A., M.D. / VA Medical Center, San Francisco
HLS	Evaluation of Skeletal Muscle Performance and Characteristics	science	Siconolfi, S.F., Ph.D. / NASA / JSC
HLS	Eye-Head Coordination During Target Acquisition (Phase 1A)	science	Reschke, M., Ph.D./ NASA / JSC

HLS	Frames of Reference for Sensori-motor Transformations	science	Berthoz, Alain, M.D. / CNRS / Paris, France
HLS	GASMAP Facility Operations	engineering	Booker, Floyd, Ph.D. / NASA / JSC
HLS	Humoral Immunity (Phase 1A)	science	Sams, Clarence F., Ph.D. / NASA / JSC
HLS	In-flight Radiation Measurements	risk mitigation	Badhwar, Gautam, Ph.D. / NASA / JSC
HLS	Magnetic Resonance Imaging (MRI) After Exposure to Microgravity	science	LeBlanc, Adrian D., Ph.D. / Baylor College of Medicine
HLS	Microbiological Investigations (E590 and E703)	risk mitigation	Pierson, Duane L., Ph.D. / NASA / JSC and G. Weinstock, Ph.D. / University of Texas Medical School / Houston
HLS	Microbiological Investigations of the Mir and Flight Crew (Phase 1A)	risk mitigation	Pierson, Duane L., Ph.D. / NASA / JSC
HLS	Posture and Locomotion (Phase 1A)	science	Paloski, William, Ph.D. / NASA / JSC
HLS	Protein Metabolism During Long Term Space Flights	science	Stein, T. Peter, Ph.D. / University of New Jersey / Medical and Dental College
HLS	Renal Stone Risk Assessment During Long Duration Space Flight	science	Whitson, Peggy Ph.D. / NASA / JSC
HLS	Renal Stone Risk Assessment: Dried Urine Chemistry	science	Whitson, Peggy Ph.D. / NASA / JSC
HLS	Sleep Investigations (639/663/710)	science	Monk, Timothy, Ph.D / University of Pittsburgh
HLS	The Effects of Long-Duration Space Flight on Eye, Head, and Trunk Coordination During Locomotion	science	Bloomberg, Jacob J., Ph.D. / NASA / JSC
HLS	The Effects of Long Duration Space Flight on Gaze Control	science	Reschke, M., Ph.D./ NASA / JSC
HLS	Trace Chemical Contamination (Phase 1A)	risk mitigation	Sauer, Richard, P.E. / NASA / JSC
HLS	Viral Reactivation (Phase 1A)	science	Pierson, Duane L., Ph.D. / NASA / JSC
ISS	Cosmic Radiation and Effects Activation Monitor (CREAM)	science	Truscott, Peter / Defense Research and Evaluation Agency / UK
ISS	Enhanced Dynamic Load Sensors (EDLS) on Mir	risk mitigation	Beck, Sherwin / NASA / LaRC

ISS	Mir Audible Noise Measurement	risk mitigation	Parsons, C. / NASA / JSC
ISS	Mir Electric Field Characterization (MEFC)	risk mitigation	Chavez, Mark / NASA / JSC
ISS	Mir Environmental Effects Payload (MEEP)	risk mitigation	Gay, Buck / NASA / JSC
ISS	Mir Structural Dynamics Experiment (MiSDE)	risk mitigation	Kim, Hyoung-Man, Ph.D. / McDonnell Douglas Corp.
ISS	Mir Wireless Network Experiment	risk mitigation	Gawdiak, Yuri / NASA / ARC
ISS	Optical Properties Monitor (OPM)	risk mitigation	Wilkes, Don / AZ Tech
ISS	Orbital Debris Collector (ODC)	risk mitigation	Horz, Friedrich / NASA / JSC
ISS	Passive Optical Sample Assembly (POSA) #1	risk mitigation	Zwiener, Jim / NASA / MSFC
ISS	Passive Optical Sample Assembly (POSA) #2	risk mitigation	Pippin, G. / Boeing
ISS	Polish Plate Micrometeoroid Debris (PPMD) Collector	risk mitigation	Kinard, W. / NASA / LaRC
ISS	Radiation Monitoring Equipment - III	risk mitigation	Golightly, Mike / NASA / JSC
ISS	Shuttle/Mir Alignment Stability Experiment	risk mitigation	Yates, Russel / NASA / JSC
ISS	Space Portable Spectroreflectometer (SPSR)	risk mitigation	Carruth, Ralph / NASA / MSFC
ISS	Spektr Recovery - Optical Properties Monitor (OPM)	risk mitigation	Wilkes, Don / AZ Tech
ISS	Test of PCS Hardware	engineering	Lofton, Rod / NASA / JSC
ISS	Water Microbiological Monitoring (WMM)	risk mitigation	Pierson, Duane L., Ph.D. / NASA / JSC
LSR	Crew Medical Restraint System (CMRS)	risk mitigation	Billica, Roger / NASA / JSC

LSR	Volatile Organics Analyzer (VOA)	risk mitigation	James, John, Ph.D. / NASA / JSC
LSR	Water Quality Monitor (WQM)	risk mitigation	Sauer, Richard, P.E. / NASA / JSC
MG	Ambient Diffusion Controlled Protein Crystal Growth	science	Carter, D., Ph.D. / NASA / MSFC
MG	Angular Liquid Bridge Experiment - MGBX	science	Concus, Paul / University of California at Berkley
MG	Binary Colloidal Alloy Tests (BCAT 2)-MGBX	science	Weitz, Dave, Ph.D. / University of Pennsylvania
MG	Binary Colloidal Alloy Tests (BCAT) - MGBX	science	Weitz, Dave, Ph.D. / University of Pennsylvania
MG	Biochemistry of 3-D Tissue Engineering - BTS	science	Lelkes, Peter, Ph.D. / University of Wisconsin School of MedicineHammond, Timothy, Ph.D. / Louisiana State University
MG	Biotechnology System (BTS) Diagnostic Experiment Reflight	engineering	Gonda, Steve, Ph.D. / NASA / JSC
MG	Biotechnology System (BTS) Facility Operations	engineering	Gonda, Steve, Ph.D. / NASA / JSC
MG	Canadian Protein Crystallization Experiment - MIM	science	Sygusch, Jurgen, Ph.D. / University of Montreal
MG	Candle Flame in Microgravity (CFM) - MGBX	science	Deitrich, Dan, Ph.D. / NASA / LeRC
MG	Cartilage in Space - BTS	science	Freed, Lisa, Ph.D. / Mass. Institute of Technology
MG	Colloidal Gelation	science	Weitz, Dave, Ph.D. / University of Pennsylvania
MG	Forced Flow Flamespread Test (FFFT) - MGBx	science	Sacksteder, Kurt / NASA / LeRC
MG	Interface Configuration Experiment (ICE) - MGBx	science	Concus, Paul / University of California at Berkeley
MG	Interferometer Protein Crystal Growth - MGBX	science	McPherson, Alex / University of California, Irvine
MG	Liquid Metal Diffusion Experiment (LMD) - MIM	science	Rosenberger, Franz / University of Alabama / Huntsville
MG	Mechanics of Granular Materials (MGM)	science	Sture, Stein, Ph.D. / University of Colorado
MG	Microgravity Glovebox (MGBX) Facility Operations	engineering	Reiss, Don, Ph.D. / NASA / MSFC
MG	Microgravity Isolation Mount (MIM) Facility Operations	engineering	Trygvasson, Bjarni, Ph.D. / Canadian Space Agency

MG	Opposed Flame Flow Spread on Cylindrical Surfaces - MGBX	science	Altenkirch, R.A. / University of Washington / Pullman
MG	Passive Accelerometer System (PAS)	science	Alexander, Iwan / University of Alabama in Huntsville
MG	Protein Crystal Growth (PCG) GN2 Dewar	science	McPherson, Alex / University of California, Irvine
MG	Protein Crystal Growth (PCG) GN2 Dewar (Phase 1A)	science	Koszelak, Stan / University of California / Riverside
MG	QUELD Furnace Experiment - MIM	science	Smith, Reginald, Ph.D. / Queen's University / Canada
MG	Space Acceleration Measurement System (SAMS) Operations	engineering	DeLombard, R. / NASA /LeRC
MG	STES VDA-2	science	DeLucas, Lawrence / University of Alabama / Birmingham
MG	Technological Evaluation of MIM # 2 (TEM2)	science precursor	Allen, Jeff / University of Dayton, Ohio
MG	Technological Evaluation of MIM (TEM)	science precursor	Allen, Jeff / University of Dayton, Ohio
OPS	Mir Module Photo Survey	operations	WG-6
SMP	Acoustic Noise Measurement of the Mir Environment	risk mitigation	WG-8
SMP	Analysis of Mir Archival Water Samples	risk mitigation	WG-8
SMP	Crew Microbiological Assessment	risk mitigation	WG-8
SMP	Enhanced Tilt Test	risk mitigation	WG-8
SMP	Formaldehyde Active Sampling Comparison	risk mitigation	WG-8
SMP	Functional Neurological Assessment	risk mitigation	WG-8
SMP	In Flight Stand Test (LBNP)	risk mitigation	WG-8
SMP	Mir Defibrillator and Crew Medical Restraint System (CMRS)	risk mitigation	WG-8
SMP	Mir Microbiological Assessment	risk mitigation	WG-8

SMP	Monitoring Orthostatic Function During Entry, Landing, & Egress	risk mitigation	WG-8
SMP	Nutritional Status Assessment	risk mitigation	WG-8
SMP	Photodocumentation of Skin Injuries and Allergic Reactions	risk mitigation	WG-8
SMP	Physical Fitness Assessment	risk mitigation	WG-8
SMP	Space Medicine Program - Joint Medical Operations	risk mitigation	WG-8
SMP	Special Environmental Assessment of Mir	risk mitigation	WG-8
SMP	Spektr Recovery - Space Medicine Program - Joint Medical Operations	risk mitigation	WG-8
SMP	Toxicological Assessment of Airborne Volatile Organic Compounds	risk mitigation	WG-8
SS	Mir Sample Return Experiment (MSRE)	ISS support	Tsou, Peter, Ph.D. / Jet Propulsion Lab
SS	Particle Impact Experiment (PIE)	ISS support	Maag, Carl, Ph.D. / T&M Engineering

Модуль дистанционного зондирования Земли "Природа" для орбитальной станции "Мир".

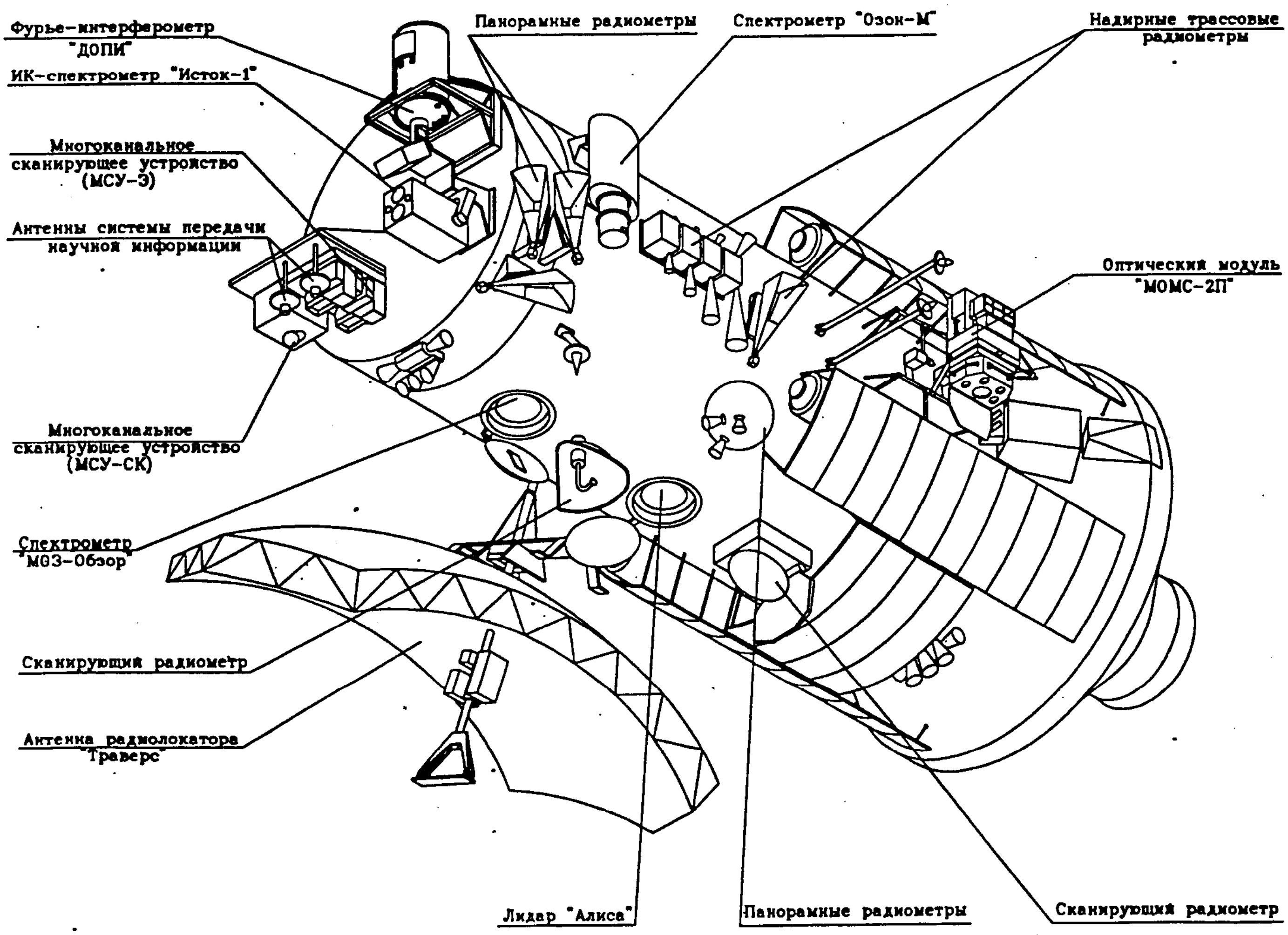

FIGURE 1A: MAJOR EXTERNAL FEATURES OF PRIRODA

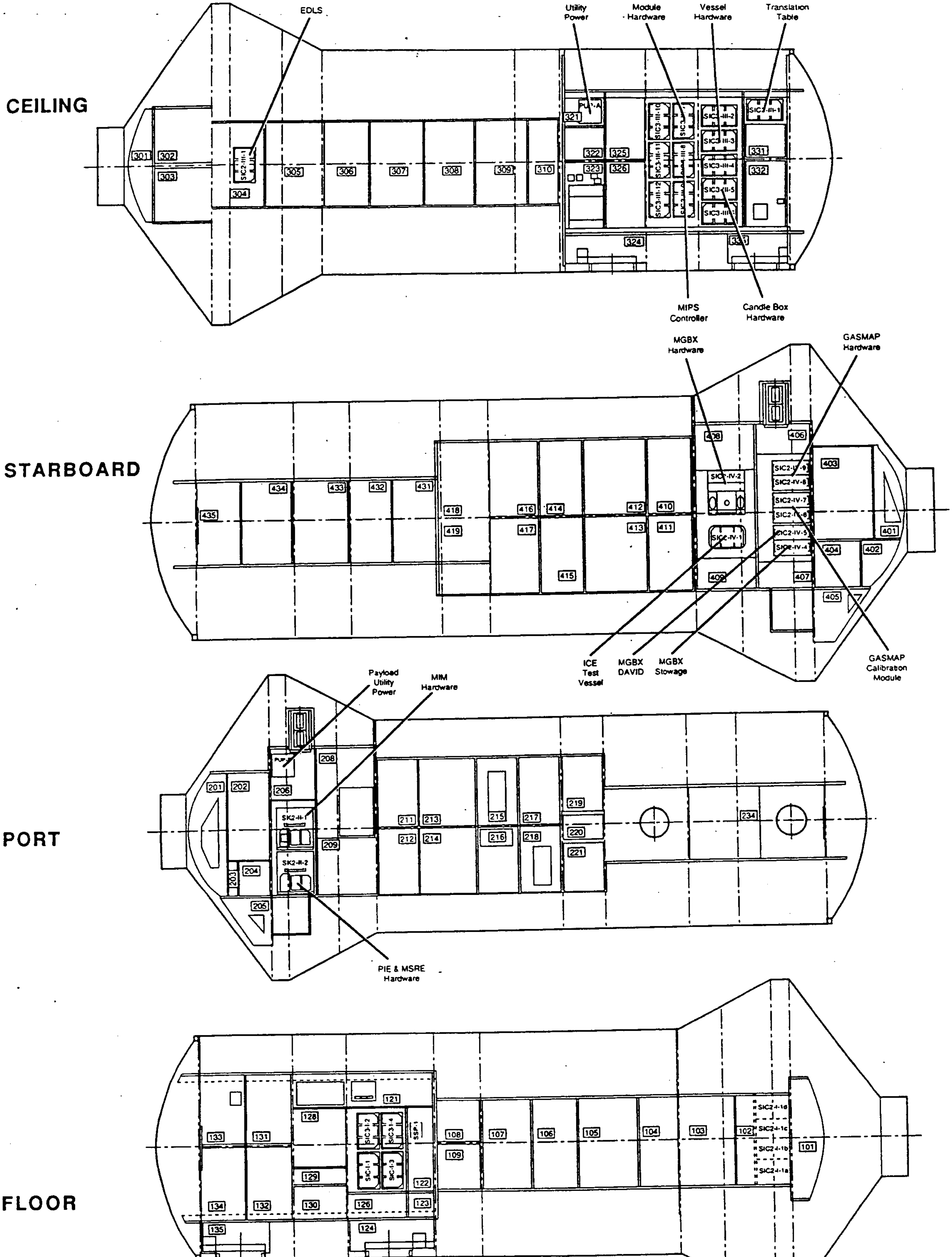

FIGURE 1B: U.S. SYSTEMS INTERNAL TO PRIRODA

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