

# Section 11 - Science Program

**Authors:**

Victor Dmitriyevich Blagov, Deputy Co-Chair, Flight Operations and Systems Integration Working Group (WG) (Operations)

Oleg Nikolayevich Lebedev, Co-Chair, Mission Science WG (MSWG)

John Uri, Co-Chair, MSWG

Tonya Sivils, MSWG

## 11.1 Introduction

### 11.1.1 Rules and Responsibilities

#### 11.1.1.1 U.S. and Russian

The relationship between the parties for the purposes of research program implementation was governed by US/R-001.

The primary document describing the scope of the team's work within each increment was the Increment Payloads Requirements Document (IPRD) developed by the MSWG-4.

Based on the above documents the U.S. party undertook:

- to develop the flight, training, and test hardware as well as the relevant operating and test documents;
- to formulate the program and the requirements as to the performance of each of the experiments;
- to ensure hardware testing;
- to develop drawings and electrical diagrams;
- to train the crew at NASA centers;
- to develop the experiment procedures;
- to secure concurrence as to the flight data files;
- to participate in the testing of the hardware in Russia;
- to participate in the experiment planning;
- to deliver the hardware to the station aboard the Orbiter.

The Russian party provided for:

- a feasibility assessment of the proposed program;
- the concurrence of hardware documents;
- hardware integration to the station systems;
- participation in acceptance testing (AT) and the incoming inspection of the hardware in the United States;
- the logistics of the AT and incoming inspection in Russia;
- the development of the flight data files;
- crew training in Russia;
- the collection of pre- and postflight data in Russia;
- experiment planning and in-flight implementation;
- data acquisition aboard and transmission from the station;
- the delivery of the hardware to the station using the Progress and Soyuz vehicles.

The schedules for the data exchange and hardware deliveries were defined in Document US/R-002.

The Russian party's primary task was to evaluate the safety of the U.S. hardware with regard to its utilization aboard the *Mir* station.

Considering the commercial nature of the project, Russian experts were not involved in setting experiment objectives, experiment result analysis, or validity evaluations except as regards experiments to assess *Mir* parameters and those where Russian researchers were invited to participate by the U.S. party.

In addition, Russian experts performed pre- and postflight data collection in Russia.

#### 11.1.1.2 WG-4 and WG-6

Science program activities were supported by two WGs:

- WG-4: Mission Science WG;
- WG-6; *Mir* Operations and Integration WG.

WG-4 concentrated on developing the science program and processing the results while WG-6 dealt with developing the hardware, the documentation, crew training, hardware testing and integration on board the station, in-flight research, and data acquisition.

Normally, all issues were discussed at joint team meetings held 4 times a year.

#### 11.1.2 Resources

An extensive research program has been implemented in the course of 6 missions performed under Contract NAS15-10110.

To support the program the Russian party was to allocate considerable resources to accommodate the mass of U.S. cargoes (up to 2,360 kg aboard the station at any one time), the power requirement (up to 2 kW average per day), and crew time (up to 70% of the U.S. astronaut's duty time and 30% of the Russian cosmonaut's duty time).

The actual program proposed by the U.S. party required less power (up to an average of 1.5 kW) and cosmonaut time (up to 17%) but exceeded the agreed-to mass limitations. In addition, the Russian party provided for the delivery of U.S. cargoes by Soyuz and Progress vehicles, which had not been a contract provision.

At the program development and implementation stages the parties worked together in the spirit of mutual understanding without resorting to undue formality, thereby promoting overall activity success.

### 11.1.3 Program Overview

On the whole the program has been completed, although there was a shortfall with regard to NASA-5 because of the accident on the Spektr module, postponement of NASA-6 experiments, and cancellation of a number of sessions for medical reasons. Nonetheless, results have been obtained in virtually all the planned experiments.

A number of steps taken by the parties to achieve a consensus on issues of experiment setup and implementation aboard a space vehicle were conducive to program completion.

It was early in the course of flights under the *Mir*-Shuttle program that the U.S. party recognized that it was impossible to run a rigid replanned timeline to cover the entire duration of a long spaceflight and adopted the Russian method of design (preflight) and real-time (in-flight) planning.

This approach allowed the introduction of new sessions for the purposes of hardware repairs and recovery, adjustment of experiment procedures, change in operation times, etc.

In its own turn because of time constraints, the Russian party agreed to depart from the principle of having experiment procedures developed by Russian experts, which saved some time but reduced the scope of documentation monitoring by principal investigators.

Russian researchers that had an active role in experiment preparation and result assessment have obtained new data in space medicine, biology, and developed a number of systems to evaluate the station's operating parameters.

## 11.2 Mission Science Working Group (WG-4)

### 11.2.1 WG-4 History

The Mission Science Working Group (MSWG) was established in July 1992 as WG-4 in the overall joint Shuttle/*Mir* WG structure, following the U.S.-Russian agreement for expanded cooperation in human spaceflight. The initial agreement called for the

flight of a Russian cosmonaut aboard the U.S. Space Shuttle, the flight of a U.S. astronaut aboard the Russian Space Station *Mir*, and the docking of the U.S. Space Shuttle with the Russian Space Station *Mir*. WG-4 was tasked to develop a cooperative science program, primarily in the Life Sciences, as part of these joint missions. The scope of the joint activities was expanded in November 1993 with the addition of four more long-duration flights of U.S. astronauts aboard *Mir* and up to nine additional Shuttle dockings with *Mir*. The U.S. would also provide life and microgravity science hardware to be installed in the Spektr and Priroda modules. The research program was expanded to include other science disciplines. In December 1995, two additional long-duration missions of U.S. astronauts aboard *Mir* were agreed to. WG-4 was given responsibility for developing and managing the science requirements of this expanded research program.

#### 11.2.2 WG-4 Responsibilities

The MSWG had the primary overall responsibility for managing the research requirements in the Phase 1 program. Throughout preflight planning, in-flight operations, and postflight closeout, the MSWG was the intermediary interface between the experiment disciplines representing the requirements of the Principal Investigators (PIs) and the various experiment implementation organizations and processes. These included NASA Headquarters and the Program Office Management; Configuration Control Boards; the Training, Integration, and Operations groups; and the science discipline groups made up of payload developers. During the Phase 1 program, approximately 150 PIs were represented by seven research disciplines: Advanced Technology, Earth Sciences, Fundamental Biology, Human Life Science, International Space Station (ISS) Risk Mitigation, Microgravity, and Space Sciences. (See Attachment 11.2 for the list of PIs and associated investigations.)

As part of this process, the MSWG was responsible for ensuring science requirements are clearly defined and documented for implementation. This involved the development and management of requirements documents, such as the jointly agreed IPRD used during Phase 1B and the STS-71/Spacelab-*Mir* Mission Science Requirements Document, a U.S.-only document. Due to frequent changes in mission resource allocations and operational constraints, these documents were updated as appropriate through configuration controlled changes to the baselined science requirements. Mission Science had the responsibility to resolve any resource conflicts among the various disciplines and investigations, and during flight operations to actively participate in the replanning process.

The MSWG was also involved in various WG meetings and flight readiness activities. Periodic joint meetings with the investigator teams, including as appropriate, international partners in the mission research, were held to review the science requirements and their proposed implementation as defined in operations products, address mission critical issues, and establish working protocols. At the start of each mission, readiness reviews were held to discuss and resolve any science or operations problems that would potentially delay or impact the success of the mission.

In support of mission preparation and implementation, the MSWG also developed informational packages for release to the public through the NASA Public Affairs Office, press briefings, brochures, web sites, and symposia.

After flight, Mission Science had the responsibility for assessing the operational and science success of each mission and ensuring that the PIs reported on the results of the experiments. The science results were tracked through direct reporting from the PIs, at science symposia and through tracking the PIs' publications and public presentations.

#### 11.2.3 WG-4 Structures and Processes

Throughout each increment, and across the Phase 1 program, Mission Science coordinated with the Discipline Leads to ensure successful implementation of the research objectives of the Phase 1 program and the objectives of each individual PI.

For each increment, a set of science requirements were entered into a computerized database, the Payload Integration Planning System (PIPS), and established through baselining of its product, the IPRD, at the *Mir* Operations and Integration Working Group (MOIWG) configuration control board. The U.S. requirements were then reviewed with Russian counterparts of both MSWG and MOIWG to assure that they were within resource constraints. Periodic revisions were distributed based on updates agreed upon during these joint meetings. The Final IPRD, usually released three months prior to the start of each increment, was then used as the guiding document for operations planning and real-time implementation.

The MOIWG also used the PIPS database for hardware management and used the IPRD in developing operations products for mission implementation. Whereas the MOIWG had increment specific teams dedicated to premission planning, real-time operations, and postmission closeout, the MSWG maintained a core team that worked throughout all aspects of the Phase 1 research program, both at the management and research discipline level. Mission Science coordinated with the MOIWG and supported mission implementation functions as part of the Houston Mission Control Center (MCC-H) Payload Operations Support Area (POSA) and the *Mir* Operations Support Team (MOST) or U.S. Consultants Group in the TsUP (Russian Mission Control Center) in Korolyov.

During real-time science implementation, replan requests (RR), generated by the discipline teams or operations implementation members, were written to document requested changes. Specialists in the POSA, composed of a science and operations team, evaluated the RRs for implementation feasibility. If these changes were outside the scope of the requirements documented in the Final IPRD, the RR was attached to a change request for disposition through the MOIWG configuration control board. The PIPS database was updated with approved change requests throughout the course of the mission. Approved changes were sent over to the TsUP and negotiated with the Russian side as changes to the Russian Final IPRD. Once successfully negotiated, the Form 24 (Russian Timeline) was updated with the requested inputs. At the end of the mission, the Final IPRD represented what was planned for implementation. The RR attachments plus the Final IPRD represented what was actually implemented.

#### 11.2.4 Results Processing

The goal of work in research of the *Mir*-NASA Project scientific program was to perform operations to support and supply the American scientific research of the *Mir*-NASA Project.

The operational objectives were:

1. A scientific methodological examination of American research, including biomedical ethics issues.
2. Ground preparation and certification of equipment and hardware for flight research.
3. Pre- and postflight data collection as part of the biomedical research program.
4. Training and ground following of the flight portion of experiments.
5. Participation in the preparation and performance of fundamental biological research.
6. Supporting ground following of experiments by Russian specialists at MCC.

In contrast to the previous stage of Russian-American scientific cooperation under the *Mir*-Shuttle program, the microgravity, biomedical, and fundamental biological research programs included suggestions which had been selected by an independent U.S. peer review panel, and the Russian side became familiar with them after the selection.

The American proposals which had passed a scientific review were presented to the Russian side in the form of a list of experiments and brief information about the research process, the equipment used, and crew time requirements. During the course of discussions between the Russian and American specialists, the feasibility of conducting the experiments in space was evaluated and the possibilities for pre- and postflight examinations of Russian cosmonauts and American astronauts were agreed to. The Russian specialists suggested combining a number of research projects into a single procedure, which would allow resources and time to be saved and would simplify crew member training.

As a result of the discussions, the Russian and American sides came to the agreement that for each of the experiments co-executors would be appointed from the Russian side who would ensure following the experiments in all stages of their preparation and implementation. The co-executors would integrate the requirements of the Russian national science program with the American research to avoid duplication and obtain valid scientific results which might be used by the partners in accordance with the special agreements for each separately performed experiment.

The joint work of the Russian and American scientists frequently led to significant modification of the American proposals. It made the proposal more realistic and adaptable to crew activity conditions during extended spaceflight. On a number of the proposals, the American scientists backed away from their initial requirements or simplified them.

The Russian co-executors prepared and presented materials for the Russian Academy of Sciences Biomedical Ethics Commission. Members of the Commission performed a great deal of preliminary work in standardizing the techniques for evaluating the risk of conducting the research with the help of people from the American Biomedical Ethics Commission. A single form of informed consent for performing research involving humans was developed and agreed to, which is used when preparing materials for cosmonauts of both sides. As a result of the commission's work, biomedical and fundamental biological research programs for the *Mir*-NASA project missions were approved.

The results of the agreements were outlined in the IPRD, which was really almost the implementation plan for the science documents. The IPRD addressed the issues of training astronauts and cosmonauts, performing pre- and postflight sessions, and the plan for transferring hardware from the Shuttle to *Mir* and returning hardware and experiments materials. Flight sessions were also addressed in the IPRD.



The Russian specialists took part in training the Russian crew members during the familiarization sessions at Johnson Space Center (JSC), as well as at Star City. The Russian specialists took part in preparing the procedures for performing the experiment, which were the prototype for the documentation for teaching cosmonauts and implementing the experiments during flight. Participation in preparing the flight data files also included:

- writing instructions for operating hardware;
- making corrections to preliminary versions of the flight data files;
- confirming the flight-ready version of the flight data files.

Long-term and detailed planning of the research took place with the participation of the Russian specialists who were responsible for performing individual experiments and the members of the MCC medical group. In addition, they prepared radiograms on experiment procedures, held radio conversations with the crew before and during the experiment, and held consultations on repairing hardware (if necessary).

At this stage of performing the research, the Russian specialists interacted with the American specialists in the Consulting Group at MCC. During this interaction, the procedures for performing the experiments were refined and the programs were corrected if necessary. Reasons for decreasing the quantity of research while it was being performed were:

- hardware malfunctions;
- medical restrictions;
- Spektr module depressurization;
- rescheduling of *Mir* service operations.

Problems that arose were regularly discussed in teleconferences between the American and Russian specialists, with management and leading project specialists participating.

The involvement of Russian specialists in the pre- and postflight observations in various experiments was not uniform, as some of them participated in the materials analysis and processing of results obtained.

The Russian scientists took part in gathering background data. In a number of cases they fulfilled service functions, and in other experiments they took on the role of co-executors, taking part in processing and analyzing data obtained.

The observations of Russian cosmonauts were called for by experiments with identical procedures in the American and Russian science programs, and were performed by Russian specialists per the agreed-upon protocols.

The degree of participation by Russian scientists was determined by preliminary agreements reached at meetings of the Joint Working Group. The partners exchanged data on the research in accordance with agreements reached at meetings of Russian and American specialists.

The problems which arose during the course of the experiments were resolved quickly by the scientists with the cooperation of the MCC Consulting Group and Russian specialists responsible for planning.

#### 11.2.5 WG-4 Accomplishments

The challenges to the successful completion of the Phase 1 research program during its relatively brief history are too numerous to list in this report. Among a few major ones are: the compressed development schedule; the two sides learning to work together; overcoming language barriers; the U.S. team learning the “culture” of long-duration spaceflight; and replanning of the research program in the face of significant and ever-changing operational constraints. With the representation of accomplishments listed in this section, it is clear that the Phase 1 research program has overcome these challenges, yielding a wealth of new information and, as always in scientific endeavors, raising many new questions. It will be several more years before the full scope of what was accomplished and learned can be fully appreciated.

The 10 long-duration *Mir* missions and 7 long-duration NASA missions, as well as the 9 Shuttle-*Mir* docking Shuttle missions, resulted in a wealth of station research experience, samples, data, and science return for the approximately 100 unique *Mir*-based investigations, representing approximately 150 investigators, that were conducted during the NASA-*Mir* Research Program. Seven U.S. astronauts and 17 Russian cosmonauts, three of whom were involved in two Phase 1 missions, participated in the long-duration research program. The actual number of investigations per research discipline is supplied in Table 11.1, some of which were flown over multiple increments.

**Number of Long-Duration Investigations per Discipline**

**Table 11.1**

Research Discipline	Research Increment						
	1	2	3	4	5	6	7
Advanced Technology		1	2			1	3
Earth Sciences		2	2	2	3	3	3
Fundamental Biology	1	3	2	4	5	1	
Human Life Sciences	26	11	12	8	6	5	6
ISS Risk Mitigation		5	7	8	7	6	2
Microgravity	1	12	10	11	9	9	8
Space Sciences		2	2	2			
<b>Total Investigations</b>	<b>28</b>	<b>26</b>	<b>37</b>	<b>35</b>	<b>30</b>	<b>25</b>	<b>22</b>

Reference Attach. 11.3 for the table of investigations flown on each Phase 1 increment.

The *Mir* station provided many U.S. investigators, whose previous experiences included only short-duration Shuttle missions, their first experience with a long-duration platform as a test bed for facilities and experiment protocols planned for use on ISS. International participation in the Phase 1 research program included investigators from the United States, Russia, Canada, the United Kingdom, Japan, Germany, France, and Hungary.

Advanced Technology investigators used the weightless environment of *Mir* to study basic physical processes and generate better quality and new alloys, with multiple industrial and scientific applications.

The three-year near-continuous observations of Earth phenomena by trained crew members has added tens of thousands of images to the exciting database of Earth imagery and to researchers' understanding of long-term changes, both ephemeral natural and human induced, and for the first time documented global baseline conditions leading up to and through the 1997 El Niño.

Documentation during this timeframe on *Mir* demonstrated for the first time the northwestward drift of the South Atlantic Anomaly through comparison between Skylab and *Mir* data.

Fundamental Biology investigations yielded highly successful plant growth experiments resulting in the most biomass ever grown in space and the first plants grown from seeds developed entirely in space.

The Human Life Sciences study of crew members before, during, and after long-duration flight has led to a better understanding of the physiological and psychological effects of long-duration spaceflight. The NASA-*Mir* program has seen the documentation of space-induced changes in human body systems such as the immune system, cardiac functions, circadian rhythms, renal functions, and bone and mineral metabolism.

*Mir* operations and risk mitigation experiments have contributed significantly to our understanding of long-duration spaceflight and resulted in modifications to ISS planning, design, and operations. The structural dynamics and micrometeoroid impact experiments are two examples of demonstrations of crew and vehicle microgravity disturbances and interactions as well as how materials and structures respond to long exposures to the low Earth orbit environment.

Microgravity discipline supported science has extended the duration of tissue culture experiments from 14 days to 4 months in orbit developing 3-dimensional tissue cultures. Tissue constructs such as these are difficult to generate on Earth and have great potential for applications in orthopedic and cosmetic surgery. In addition, new techniques for growing protein crystals in space have been established with qualitative and quantitative improvements over ground-based activities. Analyses of these high-quality crystals are leading to advances in pharmacology and molecular biology.

The discovery of extraterrestrial particulates in the aerogels contained in the Space Sciences experiment collector trays clearly demonstrates that many cosmic dust particles can be returned to Earth for physical and chemical analysis.

Following each Phase 1 mission, each U.S. PI was required to submit to Mission Science a postflight Operational Accomplishments Report (R+30 days), a Preliminary Research Report (R+180 days), and a Final Research Report (R+1 year), outlining their research status and preliminary conclusions. To date, a total of 237 postflight research reports have been received, archived, and distributed by Mission Science. Attachment 11.4 contains the table of contents for each document published to date of these reports. Also, many PIs have published their Phase 1 research findings in peer-reviewed publications, and these are listed in Attachment 11.5.

The MSWG has also organized Research Results Symposia in which investigators have participated by sharing data between similar research areas and presentation of results to date. These types of forums have supplied NASA management, the Phase 1 crew members, and the participants of the Phase 1 research program with the results and successes of the numerous experiments conducted during the program. The first symposium, held at JSC in August 1997, focused primarily on experiments from the NASA-2 and NASA-3 missions. The second meeting, held in April 1998 at Ames Research Center, focused mainly on the NASA-4 and -5 missions. A third symposium targeted for November 1998, at Marshall Space Flight Center, will close out those experiments conducted throughout the program and will focus on the NASA-6 and -7 missions. Two symposia proceedings packages, a compilation of 82 Phase 1 experiment presentations, have been distributed and the table of contents of these can be found in Attachment 11.6.

#### 11.2.6 Lessons Learned

The 10 most important lessons learned from the Phase 1 Research Program are listed below. Clearly, many if not all will have application in the successful conduct of the research program on ISS.

**1. Develop and implement a realistic schedule from experiment solicitation to flight.**

The 2-year experiment solicitation-to-flight schedule for Phase 1 was inadequate to ensure proper definition and implementation of all selected experiments without significant challenges. The lack of early definition of the research had multiple impacts to proper implementation of the experiments.

**2. Plan for a realistic complement of experiments for each long-duration mission to achieve specific scientific objectives.**

Provide a narrower focus for each increment and plan the research program accordingly (quality vs. quantity).

**3. Maintain clear distinction between science requirements (PI-generated) and science operations (guided by operational constraints).**

Science “requirements” were often changed to accommodate operational constraints; in truth, the requirements did not change, only their implementation.

**4. Ensure full coordination between experiments and facilities, hardware and software interfaces, in ground testing, training, etc.**

There were instances where incompatibilities were uncovered only in flight; this was usually due to inadequate time for preflight preparation.

**5. Ensure that training is performed in full-up configuration, with all experiment components.**

There were instances where the first time a crew member did an end-to-end experiment session was on orbit.

**6. In scheduling science activities, all overhead must be accounted for.**

Performing a science session usually requires additional time that initially was not accounted for, potentially leading to crew overwork. These ancillary activities include, but are not limited to, on-orbit refresher training; search for and identification of all required hardware items; evolving crew familiarity with the experiment; experiment setup; experiment stow.

**7. Develop a single hardware manifest.**

There were multiple manifests maintained by different organizations, with different purposes and authorities, often leading to confusion.

**8. Develop a single hardware/safety documentation system for all payload carriers.**

Hardware developers were often swamped in submitting essentially the same information to different organizations in different formats.

**9. With limited voice communication with the crew, rely more on E-mail.**

In many cases, use of E-mail allows for more thorough communication between the crew member and the ground support team.

**10. Understand the cultural differences between short-duration and long-duration flight and their interactions.**

These are in the areas of training, operations, manifesting, etc. Many of these factors are not unique to *Mir*, but are a reflection of operating in a long-duration environment, regardless of the specific platform.

**11. During selection of experiment, the management team should pay special attention to reviewing of biomedical studies to maximize crew member acceptability.**

11.2.7 WG-4 Summary

The Phase 1 Research Program offered many U.S. investigators their first opportunity to conduct research in a long-duration environment. This invaluable experience gained not only by the investigators but also by the U.S. and Russian ground support teams, in addition to the actual scientific return from the program, will be a tremendous aid in conducting similar research on ISS. From a research perspective, Phase 1 was clearly a worthwhile endeavor.

## List of Phase 1 Principal Investigators and Their Experiments

Attach. 11.2

### Phase 1A

#### **Metabolic Research:**

Fluid and Electrolyte Homeostasis and its Regulation  
Dynamics of Calcium Metabolism and Bone Tissue

#### **U.S. Investigator(s)**

Helen Lane, Ph.D.  
Helen Lane, Ph.D.

#### **Russian Investigator(s)**

Anatoly Grigoriev, M.D.  
V. Ogonov, M.D., Ph.D.  
Irina Popova, Ph.D.

Renal Stone Risk Assessment

Peggy Whitson, Ph.D.

German Arzamozov, M.D.  
Sergey Kreavoy, M.D.

Metabolic Response to Exercise

Helen Lane, Ph.D.

Irina Popova, Ph.D.

Metabolism of Red Blood Cells

Helen Lane, Ph.D.

Svetlana Ivanova, Ph.D.

Red Blood Cell Mass and Survival

Helen Lane, Ph.D.

Svetlana Ivanova, Ph.D.

Physiologic Alterations and Pharmacokinetic Changes

During Spaceflight

Lakshmi Putcha, Ph.D.

I. Goncharov, Ph.D.

Humoral Immunity

Clarence Sams, Ph.D.

Irina Konstantinova, M.D.

Viral Reactivation

Duane Pierson, Ph.D.

Irina Konstantinova, M.D.

Peripheral Mononuclear Cells

Clarence Sams, Ph.D.

Irina Konstantinova, M.D.

#### **Cardiovascular and Pulmonary Research:**

Studies on Orthostatic Tolerance With the Use of LBNP  
Studies of Mechanisms Underlying Orthostatic Intolerance

John Charles, Ph.D.

Valeriy Mikhaylov, M.D.

Using Ambulatory Monitoring Baroflex Testing  
and Valsalva Maneuver

Janice Yelle, M.S.  
John Charles, Ph.D.

Valeriy Mikhaylov, M.D.

Maximal Aerobic Capacity Using Graded Bicycle Ergometry

Steven Siconolfi, Ph.D.  
Suzanne Fortney, Ph.D.

Valeriy Mikhaylov, M.D.  
Alexander Kotov, M.D.

Evaluation of Thermoregulation During Spaceflight

Suzanne Fortney, Ph.D.

Valeriy Mikhaylov, M.D.

Physiological Response During Descent of Space Shuttle

John Charles, Ph.D.

Valeriy Mikhaylov, M.D.

#### **Neurosensory Research:**

Evaluation of Skeletal Muscle Performance & Characteristics

Steven Siconolfi, Ph.D.  
John McCarthy, Ph.D.

Inessa Kozlovskaya, M.D.  
Yury Koryak, Ph.D.  
N.M. Kharitonov, Ph.D.

Morphological, Histochemical & Ultrastructural

Characteristics of Skeletal Muscle

Daniel Feedback, Ph.D.  
M. Reschke, Ph.D.  
J. Bloomberg, Ph.D.  
W. Paloski, Ph.D.

Boris Shenkman, Ph.D.  
I. Kozlovskaya, M.D.  
L. Kornilova, M.D.  
V. Barmin, M.D.  
A. Sokolov, M.D.  
B. Babayev, M.D.

Eye-Head Coordination During Target Acquisition

Posture and Locomotion

J. Bloomberg, Ph.D.  
W. Paloski, Ph.D.  
M. Reschke, Ph.D.  
D. Harm, Ph.D.

I. Kozlovskaya, M.D.  
A. Voronov, Ph.D.  
I. Tchekirda, M.D.  
M. Borisov

#### **Hygiene, Sanitation, and Radiation Research:**

Microbiology

Duane L. Pierson, Ph.D.  
Richard Sauer, P.E.  
G.D. Badwhar, Ph.D.  
T.C. Yang, Ph.D.  
John James, Ph.D.  
Richard Sauer, P.E.

Natalia Novokova, Ph.D.  
Vladimir Skuratov, M.D.  
Vladislav Petrov, Ph.D.  
B. Fedorenko, Ph.D.  
L. Mukhamedieva, M.D.  
Yuri Sinyak, Ph.D.

In-Flight Radiation Measurements

Measurement of Cytogenetic Effects of Space Radiation

Trace Chemical Contamination

## List of Phase 1 Principal Investigators and Their Experiments (continued)

### Phase 1A continued

#### **Behavior and Performance Research:**

The Effectiveness of Manual Control During Simulation of Flight Tasks (PILOT)      Deborah L. Harm, Ph.D.      V.P. Salnitskiy, Ph.D.

#### **Fundamental Biology Research:**

	<u>U.S. Investigators</u>	<u>Russian Investigator</u>
Incubator	Biospeciman Sharing Program	T.S. Guryeva, Ph.D. Olga Dadasheva, Ph.D.
Greenhouse	Frank Salisbury, Ph.D. Gail Bingham, Ph.D.	M. A. Levinskikh, Ph.D.
<b>Microgravity Research:</b>		
Space Acceleration Measurement System (SAMS)	Richard DeLombard Stan Koszelac, Ph.D.	S. Ryaboukha, Ph.D. O. Mitichkin, Ph.D.
Protein Crystallization Methods	Alexander Malkin, Ph.D.	

### Phase 1B

#### **Advanced Technology:**

	<u>U.S. Investigator(s)</u>	<u>Russian Investigator(s)</u>
Optizone Liquid Phase Sintering Materials in Devices and Superconductors	James Smith, Ph.D. Stephanie Wise Ruth Amundsen	Yuri Grigorashvili Svyatoslav Volkov Eugene Vasilyev Vladimir Koshelev
Commercial Protein Crystal Growth Commercial Generic Bioprocessing Apparatus Liquid Motion Experiment ASTROCULTURE X-Ray Detector Test	Larry DeLucas Louis Stodieck Richard Knoll Raymond Bula Larry DeLucas	

#### **Earth Sciences:**

Calibration & Validation of Priroda Microwave Sensors Comparison of Atmospheric Chemistry Sensors on Priroda and American Satellites	James Shiue, Ph.D. Jack Kaye	Neon Armand, Ph.D.
Regional & Temperature Variability of Primary Productivity in Ocean Shelf Waters Test Site Monitoring & Visual Earth Observations	F.E. Muller-Karger O. Kopelevich Kamlesh Lulla, Ph.D. Cynthia Evans, Ph.D.	Lev Desinov, Ph.D.
Validation of Biosphere-Atmosphere Interchange Model for Northern Prairies Validation of Priroda Rain Observations	A. W. England Anatoly Shutko Otto Thiele	

#### **Fundamental Biology:**

Incubator-Integrated Quail Experiments on <i>Mir</i>	Gary W. Conrad, Ph.D. Cesar D. Fermin, Ph.D. Stephen B. Doty, Ph.D. Bernd Fritzsich, Ph.D. Patricia Y. Hester, Ph.D. Peter I. Lelkes, Ph.D. Page A. W. Anderson, M.D. Bernard C. Wentworth, Ph.D. Toru Shimizu, Ph.D.	Olga Dadasheva, Ph.D. Tamara Gurieva, Ph.D.
--	---	--



## List of Phase 1 Principal Investigators and Their Experiments (continued)

### Phase 1B continued

#### **Fundamental Biology Continued:**

Environmental Radiation Measurements  
Greenhouse-Integrated Plant Experiment

Effective Dose Measurements  
Cellular Mechanisms of Spaceflight Specific to Plants  
Standard Interface Glovebox  
Developmental Analysis of Seeds Grown on *Mir*  
Effects of Gravity on Insect Circadian Rhythmicity  
Active Dosimetry of Charged Particles

#### **Human Life Sciences:**

Analysis of Volatile Organic Compounds on *Mir*  
Anticipatory Postural Activity  
Assessment of Humoral Immune Function  
Bone Mineral Loss & Recovery  
Collecting *Mir* Source & Reclaimed Waters  
Crew Member & Crew-Ground Interactions  
Evaluation of Skeletal Muscle Performance & Characteristics  
Gas Analyzer System Metabolic Analysis Physiology  
Magnetic Resonance Imaging After Exposure to Microgravity  
Microbiological Interaction in the *Mir* Space Environment  
Protein Metabolism  
Renal Stone Risk Assessment

Renal Stone Risk Assessment: Dried Urine Chemistry  
Sleep Investigations

Effects of Long-Duration Spaceflight on Eye, Head, &  
Trunk Coordination During Locomotion  
Effects of Spaceflight on Gaze Control  
Frames of Reference for Sensorimotor Transformation  
Cardiovascular Investigations

#### **International Space Station Risk Mitigation:**

Enhanced Dynamic Load Sensors on *Mir*  
*Mir* Audible Noise Measurement  
*Mir* Electric Field Characterization  
*Mir* Environmental Effects payload  
*Mir* Wireless Network  
Orbital Debris Collector  
Passive Optical Sample Assembly #1 and #2  
  
Polish Plate Micrometeoroid Debris Collector

#### **U.S. Investigators**

Eugene Benton, Ph.D.  
Frank Salisbury, Ph.D.  
Gail Bingham, Ph.D.  
John Carman, Ph.D.  
William Campbell, Ph.D.  
David Bubenheim, Ph.D.  
Boris Yendler, Ph.D.  
Sandor Derne, Ph.D.  
Abraham. D. Krikorian  
Paul D. Savage  
Mary Musgrave, Ph.D.  
T. Hoban-Higgins, Ph.D.  
Jobst Ulrich Schott

Peter Palmer, Ph.D.  
Jacob Bloomberg, Ph.D.  
Clarence Sams, Ph.D.  
Linda Shackelford, M.D.  
Richard L. Sauer, P.E.  
Nick A. Kanas, Ph.D.  
S. F. Siconolfi, Ph.D.  
Floyd Booker  
Adrian LeBlanc, Ph.D.  
George M. Weinstock  
T. Peter Stein, Ph.D.  
Peggy Whitson, Ph.D.

Peggy Whitson, Ph.D.  
Allan Hobson, M.D.  
Timothy H. Monk, Ph.D.  
Harvey Moldofsky, M.D.  
Jacob Bloomberg, Ph.D.

Mill Reschke, Ph.D.  
Alan Berthoz, Ph.D.  
C. Gunnar Blomqvist, M.D.  
Dwain Eckberg, M.D.

Sherwin Beck  
C. Parsons  
Phong Ngo  
Buck Gay  
Yuri Gawdiak  
Freidrich Horz  
G. Pippin  
Jim Zwiener  
W. Kinard

#### **Russian Investigators**

M. Levinskikh, Ph.D.  
  
  
  
  
  
  
Yuri Akatov  
  
Margartia Levinskikh  
Alexei Alpatov

Valentina Savina, M.D.  
Inessa Kozlovskaya, M.D.  
A. T. Lesnyak  
V. Oganov, M.D., Ph.D.  
Yuri Sinyak, Ph.D.  
Vyacheslav Salnitskiy  
Inessa Kozlovskaya, M.D.  
  
Inessa Kozlovskaya, M.D.  
A. Viktorov, Ph.D.  
Irina Larina, Ph.D.  
Sergey Kreavoy, M.D.  
German Arzamazov, M.D.  
Sergey Kreavoy, M.D.  
Irina Ponomareva, M.D.  
  
Inessa Kozlovskaya, M.D.

Inessa Kozlovskaya, M.D.  
Victor Gurfinkel

**List of Phase 1 Principal Investigators and Their Experiments (continued)**

**Phase 1B Continued**

**International Space Station Continued:**

Shuttle/*Mir* Alignment Stability Experiment  
 Water Microbiological Monitor  
*Mir* Structural Dynamics Experiment  
 Optical Properties Monitor

Cosmic Radiation and Effects Activation Monitor  
 Test of PCS Hardware  
 Space Portable Spectroreflectometer  
 Radiation Monitoring Equipment

**Microgravity:**

Biotechnology System Facility Operations  
 Binary Colloidal Alloy Test  
 Cartilage in Space

Biotechnology Diagnostic Experiment  
 Biotechnology Co-Culture

Biochemistry of 3D Tissue Engineering

Candle Flame in Microgravity  
 Forced Flow Flamespread Test  
 Opposed Flow Flamespread on Cylindrical Surfaces  
 Interface Configuration Experiment  
 Liquid Metal Diffusion  
 Mechanics of Granular Materials

Microgravity Glovebox Facility Operations  
 Angular Liquid Bridge Experiment  
 Microgravity Isolation Mount Facility Operations  
 Queen's University Experiment in Liquid Diffusion  
 Passive Accelerometer System  
 Protein Crystal Growth GN2 Experiment

Diffusion Controlled Crystallization Apparatus  
 Space Acceleration Measurement System  
 Technological Evaluation of Microgravity Isolation Mount (MIM)  
 Colloidal Gelation  
 Canadian Protein Crystallization Experiment  
 Interferometer Protein Crystal Growth

**Space Sciences:**

*Mir* Sample Return  
 Particle Impact Experiment

**U.S. Investigators**

Russel Yates  
 Duane L. Pierson, Ph.D.  
 Hyoung-Man Kim, Ph.D.  
 Don Wilkes

Peter Truscott  
 Rod Lofton  
 Ralph Carruth  
 Mike Golightly  
 Francis Afinidad

Steve Gonda, Ph.D.  
 David A. Weitz, Ph.D.  
 Lisa Freed, M.D., Ph.D.  
 Steve Gonda, Ph.D.  
 Steve Gonda, Ph.D.  
 Elliot Levine, Ph.D.  
 Thomas Goodwin  
 Timothy Hammond, Ph.D.  
 Peter Lelkes, Ph.D.

Dan Deitrich  
 Kurt Sacksteder, Ph.D.  
 Robert A. Altenkirch  
 Mark Weislogel  
 Franz Rosenberger  
 Stein Sture, Ph.D.  
 Nicholas Costes, Ph.D.  
 Don Reiss, Ph.D.  
 Paul Concus, Ph.D.  
 Bjarni Trygvasson, Ph.D.  
 Reginald Smith, Ph.D.  
 Iwan Alexander, Ph.D.  
 Alexander McPherson, Ph.D.  
 Stan Koszelak, Ph.D.

Dan Carter, Ph.D.  
 Richard DeLombard  
 Jeff Allen  
 David Weitz, Ph.D.  
 Phillip Gregory  
 Alexander McPherson, Ph.D.

**Russian Investigators**

S. Shitov, Ph.D.

Vyacheslav Mezhin  
 S. Naumov  
 Sergey Demidov

Stanislov Naumov, Ph.D.  
 Vladislav Petrov

Stanislav Ryaboukha

**Attachment 11.3: Table of Phase 1 Investigations per Mission Increment**

**Phase 1A**

	<u>Mir 18/NASA 1</u>	<u>STS-71</u>	<u>Mir 19</u>
<b>Metabolic Research:</b>			
Fluid and Electrolyte Homeostasis and its Regulation	X	X	
Dynamics of Calcium Metabolism and Bone Tissue	X	X	
Renal Stone Risk Assessment	X	X	
Metabolic Response to Exercise	X		
Metabolism of Red Blood Cells	X		
Red Blood Cell Mass and Survival	X		
Physiologic Alterations and Pharmacokinetic Changes			
During Spaceflight	X		
Humoral Immunity		X	X
Viral Reactivation	X		
Peripheral Mononuclear Cells		X	
<b>Cardiovascular and Pulmonary Research:</b>			
Studies on Orthostatic Tolerance With the Use of LBNP	X	X	
Studies of Mechanisms Underlying Orthostatic Intolerance Using		X	
Ambulatory Monitoring Baroflex Testing and			
Valsalva Maneuver	X	X	
Maximal Aerobic Capacity Using Graded Bicycle Ergometry	X	X	
Evaluation of Thermoregulation During Spaceflight	X		
Physiological Response During Descent of Space Shuttle		X	
<b>Neurosensory Research:</b>			
Evaluation of Skeletal Muscle Performance and Characteristics	X	X	
Morphological, Histochemical & Ultrastructural Characteristics			
of Skeletal Muscle	X		X
Eye-Head Coordination During Target Acquisition	X	X	X
Posture and Locomotion	X		X
<b>Hygiene, Sanitation, and Radiation Research:</b>			
Microbiology	X	X	X
In-flight Radiation Measurements	X	X	X
Measurement of Cytogenetic Effects of Space Radiation	X		
Trace Chemical Contamination	X	X	X
<b>Behavior and Performance Research:</b>			
The Effectiveness of Manual Control During Simulation			
of Flight Tasks (PILOT)	X		
<b>Fundamental Biology Research:</b>			
Incubator	X		X
Greenhouse			X
<b>Microgravity Research</b>			
Space Acceleration Measurement System (SAMS)			X
Protein Crystallization Methods		X	X

**Attachment 11.3: Table of Phase 1 Investigations per Mission Increment (continued)**

**Phase 1B**

	<b>Research Increment</b>					
	<b><u>2</u></b>	<b><u>3</u></b>	<b><u>4</u></b>	<b><u>5</u></b>	<b><u>6</u></b>	<b><u>7</u></b>
<b>Advanced Technology:</b>						
Optizone Liquid Phase Sintering	X					X
Materials in Devices as Superconductors		X				
Commercial Protein Crystal Growth		X				
Commercial Generic Bioprocessing Apparatus		X			X	
Liquid Motion Experiment				X		
ASTROCULTURE						X
X-Ray Detector Test						X
<b>Earth Sciences:</b>						
Calibration & Validation of Priroda Microwave Sensors	X*	X*	X*	X*	X*	X*
Comparison of Atmospheric Chemistry Sensors on Priroda and American Satellites	X*	X*	X*	X*	X*	X*
Regional & Temperature Variability of Primary Productivity in Ocean Shelf Waters	X*	X*	X*	X*	X*	X*
Test Site Monitoring & Visual Earth Observations	X	X	X	X	X	X
Validation of Biosphere-Atmosphere Interchange Model for Northern Prairies	X*	X*	X*	X*	X*	X*
Validation of Priroda Rain Observations	X*	X*	X*	X*	X*	X*
<i>Mir</i> Window Documentation				X	X	
* - Priroda sensors used to support these experiments were only partially activated						
<b>Fundamental Biology:</b>						
Environmental Radiation Measurements	X	X	X	X		
Incubator-Integrated Quail Experiments on <i>Mir</i>	X					
Greenhouse - Integrated Plant Experiments		X				
Effective Dose Measurement at EVA			X	X		
Cellular Mechanisms of Spaceflight Specific to Plants			X			
Standard Interface Glovebox			X			
Developmental Analysis of Seeds Grown on <i>Mir</i>				X		
Effects of Gravity on Insect Circadian Rhythmicity				X		
Active Dosimetry of Charged Particles					X	
<b>Human Life Sciences:</b>						
Effects of Spaceflight on Gaze Control	X					
Anticipatory Postural Activity	X					
Evaluation of Skeletal Muscle Performance & Characteristics		X				
Effects of Long-Duration Spaceflight on Eye, Head, & Trunk Coordination During Locomotion	X	X				
Assessment of Humoral Immune Function	X	X	X		X	X
Bone Mineral Loss & Recovery	X	X	X	X	X	X
Collecting <i>Mir</i> Source & Reclaimed Waters	X	X	X*	X*	X*	X*
Analysis of Volatile Organic Compounds on <i>Mir</i>	X	X	X*	X*	X*	X*
Microbiological Investigations of the <i>Mir</i> Crew		X	X*	X*	X*	X*
Gas Analyzer System Metabolic Analysis Physiology	X	X	X	X		
Magnetic Resonance Imaging After Exposure to Microgravity	X	X	X	X	X	X
Protein Metabolism	X	X				
Renal Stone Risk Assessment	X	X			X	X
Crew Member & Crew-Ground Interactions		X	X	X	X	X

**Attachment 11.3: Table of Phase 1 Investigations per Mission Increment (continued)**

**Phase 1B Continued**

<b>Human Life Sciences Continued:</b>	<b>Research Increment</b>					
	<b><u>2</u></b>	<b><u>3</u></b>	<b><u>4</u></b>	<b><u>5</u></b>	<b><u>6</u></b>	<b><u>7</u></b>
Sleep Investigations			X	X	X	
Frames of Reference for Sensorimotor Transformations			X	X		
Cardiovascular Investigations					X	X
* - performed under the Space Medicine Program (SMP)						
<b>International Space Station Risk Mitigation:</b>						
<i>Mir</i> Audible Noise Measurement	X					
Shuttle/ <i>Mir</i> Alignment Stability Experiment	X	X				
Enhanced Dynamic Load Sensors on <i>Mir</i>	X		X		X	
<i>Mir</i> Electric Field Characterization	X	X	X			
Orbital Debris Collector	X	X	X	X	X	
Passive Optical Sample Assembly #1 and #2	X	X	X	X	X	
Polish Plate Micrometeoroid Debris Collector	X	X	X	X	X	
Water Microbiological Monitor		X	X	X*	X*	
<i>Mir</i> Structural Dynamics Experiment		X	X	X	X	
Optical Properties Monitor			X	X	X	
Cosmic Radiation and Effects Activation Monitor					X	X
Test of PCS Hardware					X	X
Space Portable Spectroreflectometer					X	
Radiation Monitoring Equipment					X	X
* - performed under the SMP						
<b>Microgravity:</b>						
Interface Configuration Experiment	X					
Candle Flame in Microgravity	X					
Forced Flow Flamespread Test	X					
Angular Liquid Bridge			X			
Opposed Flow Flamespread on Cylindrical Surfaces			X			
Binary Colloidal Alloy Test		X			X	
Passive Accelerometer System		X				
Biotechnology System Facility Operations	X	X	X	X	X	X
Biotechnology Diagnostic Experiment			X	X	X	
Cartilage in Space		X				
Biochemistry of 3D Tissue Engineering					X	
Biotechnology CoCulture						X
Mechanics of Granular Materials	X				X	
Microgravity Glovebox Facility Operations	X	X	X	X	X	
Microgravity Isolation Mount Facility Operations	X		X		X	X
Technological Evaluation of MIM	X					
Liquid Metal Diffusion			X			
Queen's University Experiment in Liquid Diffusion			X		X	X
Protein Crystal Growth GN2 Experiment	X	X	X	X		X
Diffusion Controlled Crystallization Apparatus	X	X	X	X		X
Space Acceleration Measurement System	X	X	X	X	X	X
Colloidal Gelation				X		
Canadian Protein Crystallization Experiment					X	
Interferometer Protein Crystal Growth					X	

Attachment 11.3: Table of Phase 1 Investigations per Mission Increment (continued)

**Phase 1B Continued**

	<b>Research Increment</b>					
<b>Space Sciences:</b>	<b><u>2</u></b>	<b><u>3</u></b>	<b><u>4</u></b>	<b><u>5</u></b>	<b><u>6</u></b>	<b><u>7</u></b>
<i>Mir</i> Sample Return Experiment	X	X	X			
Particle Impact Experiment	X	X	X			

# Attachment 11.4: Phase 1 Postflight Reports

## PHASE 1 A

PUBLISHED MARCH 1998

<b>INTRODUCTION.....</b>	<b>v</b>
<b>Section 1: Metabolism Reports .....</b>	<b>1-1</b>
2.1.1 Fluid and Electrolyte Homeostasis, Dynamics of Calcium Metabolism and Bone Tissue, Red Blood Cell Mass and Survival ( <i>Mir</i> 18 Final Science Report).....	1-3
2.1.3 Renal Stone Risk Assessment During Long-Duration Spaceflight ( <i>Mir</i> 18 Final Science Report).....	1-9
2.2.3 Metabolic Response to Exercise ( <i>Mir</i> 18 Final Science Report).....	1-19
2.3.1 Physiologic Alterations and Pharmacokinetic Changes During Spaceflight ( <i>Mir</i> 18 Final Science Report).....	1-25
2.4.2 Assessment of Humoral Immune Function During Long-Duration Spaceflight (STS-71 Final Science Report) .....	1-35
2.4.3 Reactivation of Latent Viral Infections in the <i>Mir</i> Crew ( <i>Mir</i> 18 Final Science Report).....	1-41
2.4.3 Reactivation of Latent Viral Infections in the <i>Mir</i> Crew ( <i>Mir</i> 19 Final Science Report).....	1-49
2.4.4 Phenotypic and Functional Analysis of Peripheral Mononuclear Cells During Long-Duration Spaceflight (STS-71 Final Science Report).....	1-55
<b>Section 2: Cardiovascular and Cardiopulmonary Reports .....</b>	<b>2-1</b>
3.1.1 Studies of Orthostatic Intolerance With the Use of Lower Body Negative Pressure (LBNP) ( <i>Mir</i> 18 Final Science Report)....	2-3
3.1.2 Studies of Mechanisms Underlying Orthostatic Intolerance Using Ambulatory Monitoring, Baroreflex Testing and the Valsalva Maneuver (STS-71 Final Science Report).....	2-11
3.2.1 Aerobic Capacity Using Graded Bicycle Ergometry ( <i>Mir</i> 18 Final Science Report).....	2-19
3.2.2 Evaluation of Thermoregulation During Long-Duration Spaceflight ( <i>Mir</i> 18 Final Science Report).....	2-31
3.3.1 Physiological Responses to Descent on the Space Shuttle (STS-71 Final Science Report).....	2-43
<b>Section 3: Neuroscience Reports.....</b>	<b>3-1</b>
4.1.1 Skeletal Muscle Performance and Characteristics ( <i>Mir</i> 18 Final Science Report).....	3-3
4.1.2 Morphological, Histochemical, and Ultrastructural Characteristics of Skeletal Muscle ( <i>Mir</i> 18 Final Science Report) .....	3-13
4.2.1 Eye-Head Coordination During Target Acquisition ( <i>Mir</i> 18/19 Final Science Report).....	3-25
4.2.4 Biomechanics of Movement During Locomotion ( <i>Mir</i> 18 Final Science Report) .....	3-53
4.2.4 Biomechanics of Movement During Locomotion ( <i>Mir</i> 19 Final Science Report) .....	3-69
4.2.4 Alterations in Postural Equilibrium Control Associated With Long-Duration Spaceflight ( <i>Mir</i> 18 Final Science Report).....	3-79
4.2.4 Alterations in Postural Equilibrium Control Associated With Long-Duration Spaceflight ( <i>Mir</i> 19 Final Science Report).....	3-91
4.2.4 Anticipatory Postural Activity (POSA) ( <i>Mir</i> 18 Final Science Report) .....	3-103
4.2.4 Anticipatory Postural Activity (POSA) ( <i>Mir</i> 19 Final Science Report) .....	3-109
<b>Section 4: Hygiene, Sanitation and Radiation Reports.....</b>	<b>4-1</b>

5.1	Microbiological Investigations of the <i>Mir</i> Space Station and Flight Crew ( <i>Mir</i> 18 Final Science Report).....	4-3
5.1	Microbiological Investigations of the <i>Mir</i> Space Station and Flight Crew ( <i>Mir</i> 19 Final Science Report).....	4-61
5.2.1	In-Flight Radiation Measurements ( <i>Mir</i> 18 Final Science Report).....	4-93
5.2.6	Cytogenetic Effects of Space Radiation in Human Lymphocytes ( <i>Mir</i> 18 Final Science Report) .....	4-103
5.3	Toxicological Assessment of Air Contaminants ( <i>Mir</i> 18 Final Science Report) .....	4-111
5.3	Toxicological Assessment of Air Contaminants ( <i>Mir</i> 19 Final Science Report) .....	4-125
5.3	Trace Chemical Contamination: Water Quality ( <i>Mir</i> 18 Final Science Report).....	4-153
5.3	Trace Chemical Contamination: Water Quality ( <i>Mir</i> 19 Final Science Report).....	4-167
<b>Section 5:</b>	<b>Behavior and Performance Reports.....</b>	<b>5-1</b>
6.2.2	The Effectiveness of Manual Control During Simulation of Flight Tasks (Pilot) ( <i>Mir</i> 18 Final Science Report).....	5-3
<b>Section 6:</b>	<b>Fundamental Biology Reports .....</b>	<b>6-1</b>
7.1.1	Incubator Experiment ( <i>Mir</i> 18/19 Final Science Report).....	6-3
7.1.2	Greenhouse - Integrated Plant Experiments on <i>Mir</i> ( <i>Mir</i> 19 Final Science Report) .....	6-7
<b>Section 7:</b>	<b>Microgravity .....</b>	<b>7-1</b>
8.1.1	Space Acceleration Measurement System (SAMS) on <i>Mir</i> ( <i>Mir</i> 19 Final Science Report) .....	7-3



## Attachment 11.4: Phase 1 Postflight Reports Continued

### PHASE 1B QUARTERLY 1 PUBLISHED MAY 1997

<b>INTRODUCTION</b> .....	<b>xii</b>
<b>SECTION 1:    ADVANCED TECHNOLOGY</b> .....	<b>1-1</b>
CGBA       Commercial Generic Bioprocessing Apparatus (NASA 3 Operational Accomplishment Report).....	1-3
LPS         Optizone Liquid Phase Sintering Experiment (OLiPSE-01) (NASA 2 Operational Accomplishment Report) .....	1-5
<b>SECTION 2:    EARTH SCIENCES</b> .....	<b>2-1</b>
OBS        Visual Earth Observations (NASA 2 Operational Accomplishment Report).....	2-3
OBS        Visual Earth Observations (NASA 3 Operational Accomplishment Report).....	2-21
<b>SECTION 3:    FUNDAMENTAL BIOLOGY</b> .....	<b>3-1</b>
Radiation   Environmental Radiation Measurements on <i>Mir</i> Station (NASA 2 Operational Accomplishment Report) .....	3-3
Radiation   Environmental Radiation Measurements on <i>Mir</i> Station (NASA 3 Operational Accomplishment Report) .....	3-5
Svet        Greenhouse - Integrated Plant Experiments on <i>Mir</i> (NASA 3 Operational Accomplishment Report) .....	3-8
Incubator   Incubator Experiment (NASA 2 Operational Accomplishment Report) .....	3-11
<b>SECTION 4:    HUMAN LIFE SCIENCES</b> .....	<b>4-1</b>
SSAS        Analysis of Volatile Organic Compounds on <i>Mir</i> Station (NASA 2 Operational Accomplishment Report).....	4-5
SSAS        Analysis of Volatile Organic Compounds on <i>Mir</i> Station (NASA 3 Operational Accomplishment Report).....	4-9
Posa        Anticipatory Postural Activity (NASA 2 Operational Accomplishment Report).....	4-13
Immunity    Assessment of Humoral Immune Function During Long-Duration Spaceflight (NASA 2 Operational Accomplishment Report)- .....	4-21
Immunity    Assessment of Humoral Immune Function During Long-Duration Spaceflight (NASA 3 Operational Accomplishment Report).....	4-23
Bone        Bone Mineral Loss and Recovery after Shuttle/ <i>Mir</i> Flights (NASA 2 Operational Accomplishment Report).....	4-25
Bone        Bone Mineral Loss and Recovery after Shuttle/ <i>Mir</i> Flights (NASA 3 Operational Accomplishment Report).....	4-27
Water       Collecting <i>Mir</i> Source and Reclaimed Water for Postflight Analysis (NASA 2 Operational Accomplishment Report).....	4-29
Water       Collecting <i>Mir</i> Source and Reclaimed Water for Postflight Analysis (NASA 3 Operational Accomplishment Report).....	4-33
Interaction   Crew Member and Crew-Ground Interactions During NASA/ <i>Mir</i> (NASA 3 Operational Accomplishment Report).....	4-37
Posture     The Effects of Long Duration Spaceflight on Eye, Head, and Trunk Coordination During Locomotion (NASA 2 Operational Accomplishment Report).....	4-39

Posture	The Effects of Long Duration Spaceflight on Eye, Head, and Trunk Coordination During Locomotion (NASA 3 Operational Accomplishment Report).....	4-47
Gaze	The Effects of Long-Duration Spaceflight on Gaze Control (NASA 2 Operational Accomplishment Report).....	4-55
Exercise	Evaluation of Skeletal Muscle Performance and Characteristics (NASA 3 Operational Accomplishment Report).....	4-67
GASMAP	Gas Analyzer System for Metabolic Analysis Physiology (NASA 2 Operational Accomplishment Report).....	4-69
MRI	Magnetic Resonance Imaging After Exposure to Microgravity (NASA 2 Operational Accomplishment Report).....	4-71
MRI	Magnetic Resonance Imaging After Exposure to Microgravity (NASA 3 Operational Accomplishment Report).....	4-73
Micro	Microbiological Investigations of the <i>Mir</i> Space Station and Flight Crew (NASA 3 Operational Accomplishment Report)..	4-75
Protein	Protein Metabolism During Long-Term Spaceflights (NASA 2 Operational Accomplishment Report).....	4-85
Protein	Protein Metabolism During Long-Term Spaceflights (NASA 3 Operational Accomplishment Report).....	4-87
Renal	Renal Stone Risk Assessment During Long-Duration Spaceflight (NASA 2 Operational Accomplishment Report).....	4-89
Renal	Renal Stone Risk Assessment During Long-Duration Spaceflight (NASA 3 Operational Accomplishment Report).....	4-93
<b>SECTION 5:</b>	<b>MICROGRAVITY</b> .....	<b>5-1</b>
DCAM	Ambient Diffusion Controlled Protein Crystal Growth (NASA 2 Operational Accomplishment Report) .....	5-3
DCAM	Ambient Diffusion Controlled Protein Crystal Growth (NASA 3 Operational Accomplishment Report) .....	5-5
BCAT	Binary Colloidal Alloy Tests (NASA 3 Operational Accomplishment Report) .....	5-7
CFM	Candle Flame in Microgravity (NASA 2 Operational Accomplishment Report) .....	5-9
Cartilage	Cartilage in Space (NASA 3 Operational Accomplishment Report) .....	5-11
FFFT	Forced Flow Flame Spreading Test (NASA 2 Operational Accomplishment Report).....	5-13
ICE	Interface Configuration Experiment for the <i>Mir</i> Glovebox (NASA 2 Operational Accomplishment Report).....	5-15
MGM	Mechanics of Granular Materials (STS-79 Operational Accomplishment Report).....	5-17
Glovebox	Microgravity Glovebox Facility (MGBX) (NASA 2 Operational Accomplishment Report) .....	5-21
Glovebox	Microgravity Glovebox Facility (MGBX) (NASA 3 Operational Accomplishment Report) .....	5-23
MIM	Microgravity Isolation Mount (NASA 2 Operational Accomplishment Report).....	5-25
PCG-Dewar	Protein Crystal Growth (PCG) GN <sub>2</sub> Dewar Experiment (NASA 2 Operational Accomplishment Report).....	5-27
PCG-Dewar	Protein Crystal Growth (PCG) GN <sub>2</sub> Dewar Experiment (NASA 3 Operational Accomplishment Report).....	5-29
QUELD	Queen's University Experiment in Liquid Diffusion (NASA 2 Operational Accomplishment Report) .....	5-31
SAMS	Space Acceleration Measurement System on <i>Mir</i> (NASA 2 Operational Accomplishment Report).....	5-33
SAMS	Space Acceleration Measurement System on <i>Mir</i> (NASA 3 Operational Accomplishment Report).....	5-35
TEM	Technological Evaluation of the MIM (NASA 2 Operational Accomplishment Report).....	5-37
<b>SECTION 6:</b>	<b>SPACE SCIENCES</b> .....	<b>6-1</b>
MSRE	<i>Mir</i> Sample Return Experiment (NASA 2 Operational Accomplishment Report) .....	6-3
PIE	Particle Impact Experiment (NASA 2 Operational Accomplishment Report).....	6-5

# Attachment 11.4: Phase 1 Postflight Reports Continued

## Phase 1B Quarterly 2

PUBLISHED AUGUST 1997

<b>INTRODUCTION</b>	.....	<b>vii</b>
<b>SECTION 1: ADVANCED TECHNOLOGY</b>	.....	<b>1-1</b>
LPS	Optizone Liquid Phase Sintering Experiment (OLiPSE-01) (NASA 2 Preliminary Research Report).....	1-2
<b>SECTION 2: EARTH SCIENCES</b>	.....	<b>2-1</b>
OBS	Visual Earth Observations (OBS) (NASA 2 Preliminary Research Report) .....	2-3
<b>SECTION 3: FUNDAMENTAL BIOLOGY</b>	.....	<b>3-1</b>
Radiation	Environmental Radiation Measurements on <i>Mir</i> Station (NASA 2 Preliminary Research Report) .....	3-5
Incubator	Incubator Experiment (NASA 2 Preliminary Research Report).....	3-8
<b>SECTION 4: HUMAN LIFE SCIENCES</b>	.....	<b>4-1</b>
SSAS	Analysis of Volatile Organic Compounds on <i>Mir</i> Station (NASA 2 Preliminary Research Report) .....	4-3
Posa	Anticipatory Postural Activity (Posa) (NASA 2 Preliminary Research Report) .....	4-19
Immunity	Assessment of Humoral Immune Function During Long-Duration Spaceflight (NASA 2 Preliminary Research Report) .....	4-27
Bone	Bone Mineral Loss and Recovery After Shuttle- <i>Mir</i> Flights (NASA 2 Preliminary Research Report) .....	4-29
Water	Collecting <i>Mir</i> Source and Reclaimed Water for Postflight Analysis (NASA 2 Preliminary Research Report).....	4-35
Coordination	The Effects of Long-Duration Spaceflight on Eye, Head, and Trunk Coordination During Locomotion (NASA 2 Preliminary Research Report).....	4-59
Gaze	The Effects of Long-Duration Spaceflight on Gaze Control (NASA 2 Preliminary Research Report).....	4-77
MRI	Magnetic Resonance Imaging (MRI) After Exposure to Microgravity (NASA 2 Preliminary Research Report).....	4-89
Protein	Protein Metabolism During Long-Term Spaceflights (NASA 2 Preliminary Research Report) .....	4-95
Renal	Renal Stone Risk Assessment During Long-Duration Spaceflight (NASA 2 Preliminary Research Report) .....	4-101
<b>SECTION 5: MICROGRAVITY</b>	.....	<b>5-1</b>
BTS	Biotechnology System (BTS) Facility Operations (NASA 2 Operational Accomplishment Report) .....	5-3
BTS	Biotechnology System (BTS) Facility Operations (NASA 2 Preliminary Research Report) .....	5-7
CFM	Candle Flame in Microgravity (CFM) (NASA 2 Preliminary Research Report) .....	5-19
CPCG	Commercial Protein Crystal Growth (CPCG) (NASA 2 Preliminary Research Report) .....	5-29
FFFT	Forced Flow Flame Spreading Test (FFFT) (NASA 2 Preliminary Research Report) .....	5-33
ICE	Interface Configuration Experiment (ICE) for the <i>Mir</i> Glovebox (NASA 2 Preliminary Research Report).....	5-37

MGM	Mechanics of Granular Materials (MGM) (NASA 2 Preliminary Research Report) .....	5-49
MGBX	Microgravity Glovebox Facility (MGBX) (NASA 2 Preliminary Research Report) .....	5-59
MIM	Microgravity Isolation Mount (MIM) (NASA 3 Operational Accomplishment Report) .....	5-61
PAS	Passive Accelerometer System (PAS) (NASA 3 Operational Accomplishment Report) .....	5-63
QUELD	Queen's University Experiment in Liquid Diffusion (QUELD) (NASA 2 Preliminary Research Report) .....	5-65
TEM	Technological Evaluation of the MIM (TEM) (NASA 2 Preliminary Research Report) .....	5-71

# Attachment 11.4: Phase 1 Postflight Reports Continued

## Phase 1B Quarterly 3

PUBLISHED JANUARY 1998

<b>INTRODUCTION</b> .....	<b>i</b>
<b>SECTION 1: ADVANCED TECHNOLOGY</b> .....	<b>1-1</b>
CGBA Commercial Generic Bioprocessing Apparatus (CGBA) (NASA 3 Preliminary Research Report) .....	1-3
<b>SECTION 2: EARTH SCIENCES</b> .....	<b>2</b>
OBS Visual Earth Observations (OBS) (NASA 3 Preliminary Research Report) .....	36
OBS Visual Earth Observations (OBS) (NASA 4 Operational Accomplishments Report) .....	48
<b>SECTION 3: FUNDAMENTAL BIOLOGY</b> .....	<b>55</b>
BRIC Cellular Mechanisms of Spaceflight Specific Stress to Plants Experiment (NASA 4 Operational Accomplishments Report) ...	59
Dose Effective Dose Measurement During EVA Experiment (NASA 4 Operational Accomplishments Report) .....	63
Radiation Environmental Radiation Measurements on <i>Mir</i> Station (NASA 3 Preliminary Research Report) .....	65
Radiation Environmental Radiation Measurements on <i>Mir</i> Station (NASA 4 Operational Accomplishments Report) .....	71
Svet Greenhouse - Integrated Plant Experiments on <i>Mir</i> (NASA 3 Preliminary Research Report) .....	73
SIGB Standard Interface Glovebox Hardware Verification (NASA 4 Operational Accomplishments Report) .....	111
<b>SECTION 4: HUMAN LIFE SCIENCES</b> .....	<b>113</b>
Water Analysis of <i>Mir</i> Archival Water Samples (NASA 4 Operational Accomplishments Report) .....	117
SSAS Analysis of Volatile Organic Compounds on <i>Mir</i> Station (NASA 3 Preliminary Research Report) .....	121
Immunity Assessment of Humoral Immune Function During Long-Duration Spaceflight (NASA 3 Preliminary Research Report) .....	135
Immunity Assessment of Humoral Immune Function During Long-Duration Spaceflight (NASA 4 Operational Accomplishments Report) .....	137
Bone Bone Mineral Loss and Recovery After Shuttle- <i>Mir</i> Flights (NASA 3 Preliminary Research Report) .....	139
Bone Bone Mineral Loss and Recovery After Shuttle- <i>Mir</i> Flights (NASA 4 Operational Accomplishments Report) .....	145
Water Collecting <i>Mir</i> Source and Reclaimed Water for Postflight Analysis (NASA 3 Preliminary Research Report) .....	147
Interaction Crew Member and Crew-Ground Interactions During NASA- <i>Mir</i> (NASA 3 Preliminary Research Report) .....	173
Interaction Crew Member and Crew-Ground Interactions During NASA- <i>Mir</i> (NASA 4 Operational Accomplishments Report) .....	177
Coordination The Effects of Long-Duration Spaceflight on Eye, Head, and Trunk Coordination During Locomotion (NASA 3 Preliminary Research Report) .....	179
Coordination The Effects of Long-Duration Spaceflight on Eye, Head, and Trunk Coordination During Locomotion (NASA 4 Operational Accomplishments Report) .....	189
Exercise Evaluation of Skeletal Muscle Performance and Characteristics (NASA 3 Preliminary Research Report) .....	197
Orientation Frames of Reference for Sensorimotor Transformations (NASA 4 Operational Accomplishments Report) .....	199

MRI	Magnetic Resonance Imaging (MRI) After Exposure to Microgravity (NASA 3 Preliminary Research Report) .....	203
MRI	Magnetic Resonance Imaging (MRI) After Exposure to Microgravity (NASA 4 Operational Accomplishments Report) .....	207
Micro	Microbiological Investigations of the <i>Mir</i> Space Station and Flight Crew (NASA 3 Preliminary Research Report) .....	209
Micro	Microbiological Investigations of the <i>Mir</i> Space Station and Flight Crew (NASA 4 Operational Accomplishments Report).....	219
Protein	Protein Metabolism During Long-Term Spaceflights (NASA 3 Preliminary Research Report).....	229
Renal	Renal Stone Risk Assessment During Long-Duration Spaceflight (NASA 3 Preliminary Research Report).....	235
Sleep	Sleep Investigations (NASA 4 Operational Accomplishments Report).....	243
SSAS/GSC	Toxicological Assessment of Airborne Volatile Organic Compounds (NASA 4 Operational Accomplishments Report).....	247
<b>SECTION 5:</b>	<b>MICROGRAVITY .....</b>	<b>251</b>
ALB	Angular Liquid Bridge Experiment - MGBX (NASA 4 Operational Accomplishments Report).....	253
BCAT	Binary Colloid Alloy Test (BCAT) (NASA 3 Preliminary Research Report) .....	257
LMD	Liquid Metal Diffusion (LMD) - MIM (NASA 4 Operational Accomplishments Report).....	265
MIDAS	Materials in Devices as Superconductors (MIDAS) (NASA 3 Preliminary Research Report).....	267
MGBX	Microgravity Glovebox Facility (MGBX) (NASA 4 Operational Accomplishments Report).....	273
OFFS	Opposed Flow Flame Spreading Over Cylindrical Surfaces (OFFS) (NASA 4 Operational Accomplishments Report) .....	277
QUELD	Queen's University Experiment in Liquid Diffusion (QUELD) (NASA 4 Operational Accomplishments Report).....	281
SAMS	Space Acceleration Measurement System (SAMS) on <i>Mir</i> (NASA 4 Operational Accomplishments Report).....	285

# Attachment 11.4: Phase 1 Postflight Reports Continued

## Phase 1B Quarterly 4

PUBLISHED MARCH 1998

<b>INTRODUCTION</b> .....	<b>i</b>
<b>SECTION 1: EARTH SCIENCES</b> .....	<b>1-1</b>
Window <i>Mir</i> Window Survey (NASA 5 Operational Accomplishments Report).....	1-3
OBS          Visual Earth Observations (OBS) (NASA 2 Final Research Report).....	1-15
OBS          Visual Earth Observations (OBS) (NASA 4 Preliminary Research Report) .....	1-21
OBS          Visual Earth Observations (OBS) (NASA 5 Operational Accomplishments Report) .....	1-25
<b>SECTION 2: FUNDAMENTAL BIOLOGY</b> .....	<b>2-1</b>
BRIC         Cellular Mechanisms of Spaceflight-Specific Stress to Plants Experiment (NASA 4 Preliminary Research Report) .....	2-3
Dose         Effective Dose Measurement During EVA Experiment (NASA 4 Preliminary Research Report).....	2-9
Beetle       Effects of Gravity on Insect Circadian Rhythmicity Experiment (NASA 5 Operational Accomplishments Report) .....	2-15
Radiation    Environmental Radiation Measurements on <i>Mir</i> Station (NASA 4 Preliminary Research Report) .....	2-17
Radiation    Environmental Radiation Measurements on <i>Mir</i> Station (NASA 5 Operational Accomplishments Report).....	2-23
Greenhouse   Developmental Analysis of Seeds Grown on <i>Mir</i> (NASA 5 Operational Accomplishments Report).....	2-25
<b>SECTION 3: HUMAN LIFE SCIENCES</b> .....	<b>3-1</b>
SSAS         Analysis of Volatile Organic Compounds on <i>Mir</i> Station (NASA 2 Final Research Report).....	3-3
SSAS         Toxicological Assessment of Airborne Volatile Organic Compounds (NASA 4 Preliminary Research Report) .....	3-19
Immunity     Assessment of Humoral Immune Function During Long-Duration Spaceflight (NASA 2 Final Research Report).....	3-47
Bone         Bone Mineral Loss and Recovery After Shuttle- <i>Mir</i> Flights (NASA 5 Operational Accomplishments Report) .....	3-49
Water        Collecting <i>Mir</i> Source and Reclaimed Water for Postflight Analysis (NASA 2 Final Research Report) .....	3-51
Water        Analysis of <i>Mir</i> Archival Water Samples (NASA 4 Preliminary Research Report).....	3-81
Water        Analysis of <i>Mir</i> Archival Water Samples (NASA 5 Operational Accomplishments Report) .....	3-101
Interaction   Crew Member and Crew-Ground Interactions During NASA- <i>Mir</i> (NASA 4 Preliminary Research Report) .....	3-105
Interaction   Crew Member and Crew-Ground Interactions During NASA- <i>Mir</i> (NASA 5 Operational Accomplishments Report).....	3-109
Orientation   Frames of Reference for Sensorimotor Transformations (NASA 4 Preliminary Research Report).....	3-111
MRI          Magnetic Resonance Imaging (MRI) After Exposure to Microgravity (NASA 2 Final Research Report) .....	3-117
MRI          Magnetic Resonance Imaging (MRI) After Exposure to Microgravity (NASA 4 Preliminary Research Report).....	3-125
Micro        Microbiological Investigations of the <i>Mir</i> Space Station and Flight Crew (NASA 5 Operational Accomplishments Report) .....	3-129
Protein       Protein Metabolism During Long-Term Spaceflights (NASA 2 Final Research Report).....	3-133
Renal        Renal Stone Risk Assessment During Long-Duration Spaceflight (NASA 2 Final Research Report).....	3-139
Sleep (E639)  Sleep Investigations: Human Circadian Rhythms and Sleep in Space (NASA 4 Preliminary Research Report).....	3-145

<b>SECTION 4:</b>	<b>MICROGRAVITY .....</b>	<b>4-1</b>
DCAM	Ambient Diffusion Controlled Protein Crystal Growth (DCAM) (NASA 2 Final Research Report) .....	4-3
DCAM	Ambient Diffusion Controlled Protein Crystal Growth (DCAM) (NASA 5 Operational Accomplishments Report).....	4-7
CFM	Candle Flame in Microgravity (CFM) (NASA 2 Final Research Report).....	4-9
CGEL	Colloidal Gelatin (CGEL) (NASA 5 Operational Accomplishments Report).....	4-19
CPCG	Commercial Protein Crystal Growth (CPCG) (STS-79 Final Research Report).....	4-21
CPCG	Commercial Protein Crystal Growth (CPCG) (STS-86 Operational Accomplishments Report) .....	4-29
ICE	Interface Configuration Experiment (ICE) for the <i>Mir</i> Glovebox (NASA 2 Final Research Report).....	4-33
PCG-VDA	Protein Crystal Growth (PCG) VDA-2 Experiment (STS-84 Preliminary Research Report) .....	4-41
SAMS	Space Acceleration Measurement System (SAMS) on <i>Mir</i> (NASA 2 Final Research Report).....	4-47
SAMS	Space Acceleration Measurement System (SAMS) on <i>Mir</i> (NASA 3 Preliminary Research Report) .....	4-59
SAMS	Space Acceleration Measurement System (SAMS) on <i>Mir</i> (NASA 5 Operational Accomplishments Report).....	4-61
TEM	Technological Evaluation of the MIM (TEM) (NASA 2 Final Research Report) .....	4-65
<b>SECTION 5:</b>	<b>SPACE SCIENCES .....</b>	<b>5-1</b>
PIE	Particle Impact Experiment (PIE) (NASA 4 Preliminary Research Report) .....	5-3



## Attachment 11.4: Phase 1 Postflight Reports Continued

### PHASE 1B QUARTERLY 5

PUBLISHED JUNE 1998

<b>INTRODUCTION</b> .....	<b>xii</b>
<b>SECTION 1: ADVANCED TECHNOLOGY</b> .....	<b>1-1</b>
CGBA Commercial Generic Bioprocessing Apparatus (CGBA) (NASA 3 Final Research Report) .....	1-3
CGBA Commercial Generic Bioprocessing Apparatus (CGBA) (NASA 6 Operational Accomplishments Report).....	1-8
MIDAS Materials in Devices as Superconductors (MIDAS) (NASA 3 Final Research Report) .....	1-11
<b>SECTION 2: EARTH SCIENCES</b> .....	<b>2-1</b>
Window <i>Mir</i> Window Survey (NASA 5 Preliminary Research Report).....	2-3
Window <i>Mir</i> Window Survey (NASA 6 Operational Accomplishments Report).....	2-8
OBS Visual Earth Observations (OBS) (NASA 3 Final Research Report).....	2-28
OBS Visual Earth Observations (OBS) (NASA 6 Operational Accomplishments Report) .....	2-31
<b>SECTION 3: FUNDAMENTAL BIOLOGY</b> .....	<b>3-1</b>
Dosimetry Active Dosimetry of Charged Particles (NASA 6 Operational Accomplishments Report).....	3-3
Beetle Effects of Gravity on Insect Circadian Rhythmicity (NASA 5 Preliminary Research Report) .....	3-5
Greenhouse Greenhouse - Integrated Plant Experiments on <i>Mir</i> (NASA 3 Final Research Report).....	3-13
Greenhouse Developmental Analysis of Seeds Grown on <i>Mir</i> (NASA 5 Preliminary Research Report).....	3-63
Incubator Incubator Experiment (NASA 2 Final Research Report) .....	3-73
<b>SECTION 4: HUMAN LIFE SCIENCES</b> .....	<b>4-1</b>
Water Analysis of <i>Mir</i> Archival Water Samples (NASA 5 Preliminary Research Report).....	4-3
Water Analysis of <i>Mir</i> Archival Water Samples (NASA 6 Operational Accomplishments Report) .....	4-13
SSAS Analysis of Volatile Organic Compounds on <i>Mir</i> Station (NASA 3 Final Research Report).....	4-19
Immunity Assessment of Humoral Immune Function During Long-Duration Spaceflight (NASA 6 Operational Accomplishments Report).....	4-41
Bone Bone Mineral Loss and Recovery After Shuttle- <i>Mir</i> Flights (NASA 3 Final Research Report).....	4-43
Bone Bone Mineral Loss and Recovery After Shuttle- <i>Mir</i> Flights (NASA 5 Preliminary Research Report) .....	4-49
Bone Bone Mineral Loss and Recovery After Shuttle- <i>Mir</i> Flights (NASA 6 Operational Accomplishments Report).....	4-55
Interaction Crew Member and Crew-Ground Interactions During NASA- <i>Mir</i> (NASA 3 Final Research Report).....	4-57
Interaction Crew Member and Crew-Ground Interactions During NASA- <i>Mir</i> (NASA 6 Operational Accomplishments Report).....	4-61
MRI Magnetic Resonance Imaging (MRI) After Exposure to Microgravity (NASA 3 Final Research Report) .....	4-63
MRI Magnetic Resonance Imaging (MRI) After Exposure to Microgravity (NASA 5 Preliminary Research Report).....	4-75

MRI	Magnetic Resonance Imaging (MRI) After Exposure to Microgravity (NASA 6 Operational Accomplishments Report) .....	4-79
Protein	Protein Metabolism During Long-Term Spaceflights (NASA 3 Final Research Report) .....	4-81
Renal	Renal Stone Risk Assessment During Long-Duration Spaceflight (NASA 3 Final Research Report) .....	4-87
Renal	Renal Stone Risk Assessment During Long-Duration Spaceflight (NASA 6 Operational Accomplishments Report).....	4-93
<b>SECTION 5:</b>	<b>MICROGRAVITY .....</b>	<b>5-1</b>
DCAM	Ambient Diffusion Controlled Protein Crystal Growth (DCAM) (NASA 2 Preliminary Research Report).....	5-5
DCAM	Ambient Diffusion Controlled Protein Crystal Growth (DCAM) (NASA 3 Preliminary Research Report).....	5-11
DCAM	Ambient Diffusion Controlled Protein Crystal Growth (DCAM) (NASA 4 Operational Accomplishments Report).....	5-17
ALB	Angular Liquid Bridge Experiment - MGBX (NASA 4 Preliminary Research Report) .....	5-21
BTS	Biotechnology System (BTS) Facility Operations (NASA 4 Operational Accomplishments Report) .....	5-25
BTS	Biotechnology System (BTS) Facility Operations (NASA 5 Operational Accomplishments Report) .....	5-31
Cartilage	Cartilage in Space-BTS (NASA 3 Preliminary Research Report).....	5-35
MGM	Mechanics of Granular Materials (MGM) (STS-79 Final Research Report) .....	5-41
MGM	Mechanics of Granular Materials (MGM) (STS-89 Operational Accomplishments Report).....	5-51
MGBX	Microgravity Glovebox (MGBX) Facility Operations (NASA 5 Operational Accomplishments Report) .....	5-55
PAS	Passive Accelerometer System (PAS) (NASA 3 Final Research Report) .....	5-57
PCG-Dewar	Protein Crystal Growth (PCG) GN <sub>2</sub> Dewar Experiment (NASA 2 Preliminary Research Report) .....	5-67
PCG-Dewar	Protein Crystal Growth (PCG) GN <sub>2</sub> Dewar Experiment (NASA 2 Final Research Report).....	5-71
PCG-Dewar	Protein Crystal Growth (PCG) GN <sub>2</sub> Dewar Experiment (NASA 3 Preliminary Research Report).....	5-75
PCG-Dewar	Protein Crystal Growth (PCG) GN <sub>2</sub> Dewar Experiment (NASA 3 Final Research Report).....	5-79
PCG-Dewar	Protein Crystal Growth (PCG) GN <sub>2</sub> Dewar Experiment (NASA 4 Operational Accomplishments Report).....	5-83
SAMS	Space Acceleration Measurement System (SAMS) on <i>Mir</i> (NASA 2 Preliminary Research Report) .....	5-85
SAMS	Space Acceleration Measurement System (SAMS) on <i>Mir</i> (NASA 4 Preliminary Research Report) .....	5-87
SAMS	Space Acceleration Measurement System (SAMS) on <i>Mir</i> (NASA 6 Operational Accomplishments Report).....	5-99

## Attachment 11.5: List of Phase 1 Peer-Reviewed Publications

- Arzamazov, G. S., Whitson, P. A., Larina, O. N., Pastushkova, L. Kh., Pak, C. Y. C. "Assessment of the Risk Factors for Urolithiasis in Cosmonauts During Long Flights." *Aviakosmicheskaja I Ekologicheskaja Meditsina* 30(3): 24-32, (1996).
- Badhwar, G.D. "Drift rate of the South Atlantic Anomaly." *J. Geophys. Res.*, Vol. 102, pp. 2343-2349, (Feb. 1997).
- Badhwar, G.D. "The Radiation Environment in Low Earth Orbit." *Radiation Research*, 148 (5 Suppl): S3-10, (1997).
- Badhwar, G.D., Atwell, W., Cash, B., Petrov, V.M., Akatov, Y.A., Tchernykh, I.V., Shurshakov, V.A., and Arkhangelsky, V.A. "Radiation environment on the *Mir* orbital station during solar minimum." *Adv. Space Res.*, (1997) (accepted for publication).
- Badhwar, G.D., Cucinotta, F. A. "Depth Dependence of Absorbed Dose, Dose Equivalent and Linear energy Transfer Spectra of Galactic and Trapped Particles in Polyethylene and comparison with Calculations of Models." *Radiation Research*, 149: 209-218, (1998).
- Badhwar, V.A., Shurshakov, V.A., and Tsetlin, V.V. "Solar modulation of dose rate onboard the *Mir* station." *IEEE Nucl. Science*, 1997 (submitted for publication).
- Bingham, G.E., Salisbury, F.B., Campbell, W.F., and Carman, J.G. "The Spacelab- and *Mir*-1 'Greenhouse-2' experiment." *Microgravity Science and Technology*, 18(3):58-65, (1994).
- Bingham, G.E., Salisbury, F.B., Campbell, W.F., Carman, J.G., Yendler, B.Y., Sytchev, V.S., Berkovich, Y.B., Levinskikh, M.A., and Podolsky, I. "The Spacelab-*Mir*-1 'Greenhouse-2' Experiment." *Adv. Space Res.* 18:225-232, (1996).
- Fortney, S.M., Mikhaylov, V., Lee, S.M.C., Kobzsev, Y., Gonzalez, R.R., and Greenleaf, J.E. "Body Temperature and Thermoregulation After 115-Day Space Flight." *Aviat. Space Environ. Med.* (In Press).
- Freed, L.E., Langer, R., Martin, I., Pellis, N., and Vunjak-Novakovic, G. "Tissue Engineering of Cartilage in Space." *Proc. Natl. Acad. Sci. USA*, Vol. 94, pp 13885-13890, (1997).

### Attachment 11.5: List of Phase 1 Peer-Reviewed Publications (Continued)

- Fritsch-Yelle, J. M., Leuenberger, U. A., D'Aunno, D. S., Rossum, A. C., Brown, T. E., Wood, M. D., Josephson, M. E., Goldberger, A. L. "An Episode of Ventricular Tachycardia During Long-Duration Spaceflight." *American Journal of Cardiology*, **in press** (1998).
- Jones, S. B. and Or, Dani. "Microgravity Effects on Water Flow and Distribution in Unsaturated Porous Media: Analysis of Flight Experiments." *Soil Science*, In press.
- Koszelak, S., Leja, C., and McPherson, A. "Crystallization of Biological Macromolecules from Flash Frozen Samples on the Russian Space Station *Mir*." *Biotech. and Bioeng.*, Vol. 52, pp. 449-458, (1996).
- Layne, C.S., Lange, G.W., Pruett, C.J., McDonald, P.V., Merkle, L.A., Smith, S.L., Kozlovskaya, I.B. and Bloomberg, J.J., "Adaptation of neuromuscular activation patterns during locomotion after long-duration space flight." *Acta Astronautica*, **in press**, 1998.
- Layne, C.S., Mulavara, A.P., McDonald, P.V., Kozlovskaya, I.B., Pruett, C.J., and Bloomberg, J.J. "The effect of Foot Pressure on Neuromuscular Activation Patterns Generated During Space Flight." *J. Neurophys.*, **In Press** (revision), (1997).
- Salisbury, F.B., Bingham, G.E., Campbell, W.F., Carman, J.G., Bubenheim, D.L., Yendler, B., Jahns, G. "Growing Super-Dwarf Wheat in Svet on *Mir*." *Life Support and Biosphere Science*, 2:31-39, (1995).
- Sture, S., Costes, N. C., Batiste, S., Lankton, M., AlShibli, K., Jeremic, B., Swanson, R. and Franc, M. "Mechanics of Granular Materials at Low Effective Stresses." **Accepted** for publication in *J Aerospace Engineering* July 1998.
- Yang, T. C., George, K., Johnson, A. S., Durante, M., Fedorenko, B. S. "Biodosemity results from Space Flight *Mir-18*." *Radiation Research*, 148 (5 Suppl): S17-S23, (1997).

## Attachment 11.6: Phase 1 Symposia Presentations

### Presentations From August 5 - 7, 1997 Symposium

<b>List of Attendees</b> .....	<b>i</b>
<b>Section 1: Environmental Monitoring</b> .....	<b>1-1</b>
Analysis of Volatile Organic Compounds on <i>Mir</i> (SSAS/GRAB).....	
Collecting <i>Mir</i> Source and Reclaimed Water for Postflight Analysis (Water).....	
Water Quality Monitor (WQM) .....	
Microbiological Investigations of the <i>Mir</i> Space Station During NASA 2/3 (Micro) ....	
Space Acceleration Measurement System (SAMS) .....	
<i>Mir</i> Audible Noise Measurement (MANM) .....	
Enhanced Dynamic Load Sensors on <i>Mir</i> (EDLS).....	
Micrometeoroid/Debris Survey of <i>Mir</i> ( <i>Mir</i> Photo Survey).....	
<b>Section 2: Microgravity &amp; Materials Science</b> .....	<b>2-1</b>
Forced Flow Flamespread Test (FFFT).....	
Candle Flame in Microgravity (CFM) .....	
Interface Configuration Experiment (ICE).....	
Binary Colloidal Alloy Tests (BCAT) .....	
Protein Crystal Growth GN2 Dewar (PCG-DEWAR) .....	
Ambient Diffusion Controlled Apparatus (DCAM).....	
Commercial Protein Crystal Growth (CPCG).....	
Commercial Generic Bioprocessing Apparatus (CGBA) .....	
Biotechnology System Facility (BTS).....	
Biotechnology System Diagnostic Experiment (BTSDE) .....	
Cartilage in Space (BTS-Cart).....	
<i>Mir</i> Structural Dynamics Experiment (MiSDE) .....	
Microgravity Isolation Mount Facility (MIM).....	
Microgravity Glovebox Facility (MGBX) .....	
High-Temperature Liquid Phase Sintering (OLiPSE).....	
Queen's University Experiment in Liquid Diffusion (QUELD) .....	
Materials in Devices as Superconductors.....	
Mechanics of Granular Materials (MGM).....	
<b>Section 3: Space Sciences</b> .....	<b>3-1</b>
Particle Impact Experiment (PIE).....	
<b>Section 4: Developmental Biology</b> .....	<b>4-1</b>
Incubator - Integrated Quail Experiments on <i>Mir</i> (Quail) .....	
Integrated Plant Experiments on <i>Mir</i> (Greenhouse) .....	

<b>Section 5: Earth Science .....</b>	<b>5-1</b>
Visual Earth Observations (OBS) .....	
<b>Section 6: Human Life Sciences .....</b>	<b>6-1</b>
Renal Stone Risk Assessment During Long-Duration Spaceflight (E651) .....	
Crew Member and Crew-Ground Interactions (E628) .....	
The Effect of Long-Duration Spaceflight on the Acquisition of Predictable Targets (Gaze) .....	
Effects of Long-Duration Spaceflight on Eye, Head, and Trunk Coordination During Locomotion (E644) .....	
Anticipatory Posture .....	

**Attachment 11.6: Phase 1 Symposia Presentations Continued**  
**Presentations From March 31-April 2, 1998 Symposium**

<b>Symposium Overview</b> .....	<b>i</b>
<b>List of Attendees</b> .....	<b>ii</b>
<b>Section 1: Environmental Monitoring</b> .....	<b>1-1</b>
Analysis of Volatile Organic Compounds on <i>Mir</i> (SSAS/GRAB).....	1-2
Collecting <i>Mir</i> Source and Reclaimed Water for Postflight Analysis (Water).....	1-10
Water Quality Monitor (WQM).....	1-20
Crew Medical Restraint System (CMRS).....	1-34
Volatile Organic Analyzer (VOA).....	1-40
Environmental Health Anomalies/Air Pollutants.....	1-47
<b>Section 2: Vehicle Dynamics</b> .....	<b>2-1</b>
Space Acceleration Measurement System (SAMS).....	2-2
<i>Mir</i> Audible Noise Measurement (MANM).....	2-11
Enhanced Dynamic Load Sensors on <i>Mir</i> (EDLS).....	2-14
<i>Mir</i> Wireless Network Experiment (MWNE).....	2-28
<b>Section 3: External Environment</b> .....	<b>3-1</b>
Micrometeoroid/Debris Survey of <i>Mir</i> ( <i>Mir</i> Photo Survey).....	3-2
Passive Optical Sample Assembly #1 & #2 (POSA).....	3-8
Polish Plate Micrometeoroid Debris Collector (MEEP).....	3-14
Optical Properties Monitor (OPM).....	3-21
<b>Section 4: Combustion Science</b> .....	<b>4-1</b>
Forced Flow Flamespread Test (FFFT).....	4-2
Candle Flame in Microgravity (CFM).....	4-9
Opposed Flame Flow Spread on Cylindrical Surfaces (OFFS).....	4-17
<b>Section 5: Fluid Physics</b> .....	<b>5-1</b>
Interface Configuration Experiment (ICE).....	5-2
Angular Liquid Bridge Experiment (ALB)	
<b>Section 6: Material Science</b> .....	<b>6-1</b>
Microgravity Isolation Mount Facility (MIM).....	6-2
Queen's University Experiment in Liquid Diffusion (QUELD).....	6-2
Canadian Protein Crystallization Experiment (CAPE).....	6-2

Colloidal Gelatin (CGEL) .....	6-20
Binary Colloidal Alloy Tests (BCAT) .....	6-22
Microgravity Glovebox Facility (MGBX) .....	6-24
High-Temperature Liquid Phase Sintering (OLiPSE) .....	6-32
Liquid Metal Diffusion (LMD) .....	6-55
Mechanics of Granular Materials (MGM).....	6-63
<b>Section 7: Biotechnology .....</b>	<b>7-1</b>
Protein Crystal Growth GN2 Dewar (PCG-DEWAR).....	7-2
Commercial Protein Crystal Growth (CPCG).....	7-5
Single Locker Thermal Enclosure System (STES).....	7-9
Biotechnology System Facility (BTS) .....	7-18
Biotechnology System Diagnostic Experiment (BTSDE).....	7-28
<b>Section 8: Earth Science .....</b>	<b>8-1</b>
Visual Earth Observations (OBS).....	8-2
<i>Mir</i> Window Survey .....	8-12
<b>Section 9: Space Biology.....</b>	<b>9-1</b>
Standard Interface Glovebox Facility (SIGB).....	9-2
Effects of Insect Circadian Rhythmicity (BEETLE).....	9-6
Greenhouse - Integrated Plant Experiments on <i>Mir</i> .....	9-14
<b>Section 10: Human Life Sciences .....</b>	<b>10-1</b>
Assessment of Humoral Immune Function During Long-Duration Spaceflight (Immunity - E621) .....	10-2
Renal Stone Risk Assessment During Long-Duration Spaceflight (E651) .....	10-8
Crew Member and Crew-Ground Interactions (E628) .....	10-16
Sleep Investigations (E639, E710, E663).....	10-25
Effects of Long-Duration Spaceflight on Eye, Head, and Trunk Coordination During Locomotion (E644) .....	10-31
Anticipatory Posture .....	10-41
Bone Mineral Loss and Recovery (E598).....	10-49
Magnetic Resonance Imaging After Exposure to Microgravity (MRI - E586)....	10-51
Protein Metabolism During Long-Term Spaceflight (E613) .....	10-59





**STS-63 and STS-86 cosmonaut Vladimir Titov conducts an experiment in the Spacehab module**



**NASA 4 astronaut Jerry Linenger**