

Section 10 - Crew Operations on *Mir*

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10.1. Introduction

Continuous habitation and operations of NASA astronauts onboard the *Mir* began with the docking of Shuttle STS-76 on 24 March 1996. Beginning at that time, international crews consisting of two Russian cosmonauts and one American astronaut worked on board the *Mir* station.

One of the features of the *Mir*/NASA program was connected with the procedure of rotating astronauts to the *Mir*. After the first NASA astronaut, Norman Thagard, the rotation of astronauts utilized the Shuttle spacecraft, which docked with the *Mir* docking module (DM). Shannon Lucid, the NASA-2 mission astronaut, performed the first long-duration flight under the *Mir*-NASA program. She was delivered to the *Mir* station on 24 March 1996 to join the *Mir*-21 crew working on the complex. Later, there were five more successful missions (NASA-3, NASA-4, NASA-5, NASA-6, and NASA-7). Seven Shuttle dockings with the *Mir* were performed during this time to complete American-Russian transport operations. The program of NASA astronaut stays on the *Mir* complex ended on June 8, 1998, after the undocking of the *Mir* complex and Shuttle STS-91. The total of 7 astronauts participated in the long-duration missions on board the *Mir* within the framework of *Mir*-Shuttle, *Mir*-NASA programs; 3 of them as cosmonaut researchers, 4 astronauts as *Mir* flight engineers-2. U.S. astronauts worked on orbit together with members of 6 Russian main expeditions: *Mir*-18, *Mir*-21, *Mir*-22, *Mir*-23, *Mir*-24, and *Mir*-25.

10.2. Joint Activities of *Mir* and Shuttle Crews

Joint activities of astronauts and cosmonauts while on orbit were determined by mission plans for *Mir*, Soyuz TM, Progress M, Shuttle, and documents developed by several WGs.

The results of this activity are presented in corresponding sections of this report.

Crew joint activity began the moment communications were established between the *Mir* and the Shuttle (approximately three hours prior to docking). From that moment the crews worked from a common flight data file, which included a joint timeline and joint flight procedures.

During the mated flight of the Shuttle and the *Mir* there was a wide range of joint operations including:

- exchanging seat liners and personal equipment of astronauts in the Soyuz vehicle;
- transferring Russian and American cargo from the Shuttle to the *Mir* to re-equip and repair onboard systems and hardware for scientific research and to supply the crew with food and water;
- transferring Russian, American, and European Space Agency cargo from the station to the Shuttle for subsequent return to Earth;
- completing a line of experiments aimed at decreasing the risks in assembling the International Space Station (ISS);

- holding joint press conferences and other symbolic activities;
- joint planning of crew activities on the *Mir*-Shuttle complex.

After undocking, the Shuttles performed a fly-around of the station and conducted still and video-photography of the *Mir* complex exterior surfaces which included the goal of detecting the leak site on the Spektr module during flights STS-86, -89, and -91.

10.3. NASA Astronaut Crew Transfers

During *Mir*-Shuttle mated operations, flight crew transfer occurred between the astronaut that was completing his flight and the astronaut that was arriving on the complex. In their postflight reports, the NASA astronauts noted that the crew transfer was a very important process and the successful completion of the flight program might depend upon the proper organization of the transfer. With the goal of ensuring a rapid adaptation by the astronaut arriving on the complex, it is advisable to create a single procedure for all astronauts and include in it the following steps:

- correction of the flight data file in accordance with the actual condition of the scientific equipment;
- psychological support for the astronaut arriving on the complex (above all, render assistance in psychologically adjusting to extended flight);
- render assistance when using amateur radio communications;
- prepare scientific equipment and hardware for transfer (clear placement of scientific equipment according to predetermined storage locations, marking the hardware and lockers);
- filling out log books for hardware and the electronic version of the inventory taking into account the actual condition and location of scientific equipment and hardware;
- instruct the arriving astronaut about the following issues:
 - * assuring crew safety;
 - * placement of scientific equipment and hardware;
 - * changes that took place during the flight to the scientific equipment and the astronaut's activity algorithm in operating and servicing the scientific equipment;
 - * demonstrating how to perform individual scientific experiments and the procedures for placing the scientific equipment into its initial state;
 - * explaining and demonstrating how to perform daily procedures and servicing of the complex's onboard systems in accordance with the duties assigned to the astronaut.

As experience has shown, taking these steps allows the arriving astronaut to partially adapt to these issues and to begin to work independently within four-five days of flight. Complete adaptation occurs after approximately three weeks of operations on the complex.

In planning the handover it is necessary to consider that it is more difficult for the American astronaut to complete the handover than the Russian crew. The Russian crew has both the commander and the flight engineer involved. The

American astronaut has to complete his handover alone.

In the first flights under the *Mir*/NASA program the astronauts noted a lack of time allocated for crew handover. In the future, the planning situation will be significantly improved, however all of the astronaut's free time is devoted to handover.

10.4. Accomplishments

While completing the *Mir*/NASA program, the astronauts onboard the *Mir* complex completed the following tasks during their work:

- acquisition of experience in extended operations by astronauts on board the station;
- performance of scientific research and experiments in various disciplines;
- refining the interaction between the partners in the joint space program.

10.5. Objectives

The primary objectives of the scientific program were:

- obtaining technical and procedural experience in performing scientific research in the conditions on the orbital space station;
- studying the *Mir* complex environment concerning microgravity conditions and performing experiments in fundamental biology, studying microgravity, and Earth observations from space;
- performing experiments which demonstrate selected technology and hardware, to confirm ISS designs and procedures;

10.6. Crew Responsibilities

Practically all parts of the scientific research and experiments were completed by NASA astronauts. Russian cosmonauts were required to participate in cases where NASA hardware interfaced with the *Mir* complex and to render the necessary assistance when performing experiments and during off-nominal situations.

We learned from experience that the level of actual participation of Russian cosmonauts was larger than was identified in the program documentation, especially when contingency situations with scientific equipment occurred.

In addition to the research duties, the NASA astronauts rendered assistance in operating individual systems on the complex, provided EVA support inside the complex, and participated in three extravehicular activities (EVAs) with Russian cosmonauts.

NASA astronaut - *Mir* Mission flight engineer-2 responsibilities included:

- to implement scientific experiment and research program;

- to inventory their scientific program hardware;
- to conduct crew handover;
- to participate in cargo transfer operations;
- to perform housekeeping operations on board *Mir* (cleaning, preventive measures);
- to maintain own life support and ability to work;
- to communicate with Mission Control (MCC);
- to provide TV reports, videorecording and photography;
- to utilize life support systems in nominal modes;
- to participate in maintenance activities;
- to perform EVA if it is planned in the mission program;
- to perform activities to recover from contingency situations.

Some of the NASA astronauts noted in their postflight reports that during spaceflight they did not consider themselves to be a full-fledged flight engineer since in the operations plan only scientific experiments were prescribed for them. In the astronauts' opinion, they could and should be able to perform many standard duties of the flight engineer. This would decrease the workload on the Russian cosmonauts and allow the American astronauts to acquire experience operating the *Mir*'s service systems and to improve the crew interaction system. For this it was necessary to define a specific list of flight procedures which the American astronaut would complete and would be thoroughly trained in on Earth and planned for in the daily operations plan.

Such procedures could include:

- activating/deactivating the Elektron-V system;
- standard operating of the trace contaminants filtering unit (БМТ) and the Vozdukh atmospheric purification systems (COA);
- receiving radiograms via packet-type communications, etc.

This list could be increased as experience is acquired by the American astronauts. In connection with this, the NASA astronauts noted that during the final astronaut training stage for spaceflight it is necessary to increase the number of training sessions with the Crew Commander observing the astronaut's operating and servicing onboard systems so that the Crew Commander can make an objective evaluation of the astronaut's level of professional training. In reality, the astronaut was forced to prove his professional training to complete duties in operating and servicing the complex's onboard service systems to the Russian cosmonauts in flight.

10.7. EVA Operations

While Russian cosmonauts were performing EVA, the NASA astronaut was responsible for supporting them inside the *Mir* complex. Among these duties were:

- issuing commands from the Simvol consoles and equipment;
- still and video photography of the EVA process;

- working with the communications equipment

For various reasons, not all of the NASA astronauts received the same training in EVA support. Therefore additional in-flight training was required for several of them (Shannon Lucid, David Wolf, and Andrew Thomas).

During the supplemental in-flight training of the astronauts, the following issues were covered:

- sequence of interacting with the cosmonauts working in open space (which communications systems are used and the order of use);
- knowledge of the list of commands given by the astronaut inside the station (which consoles are used and the sequence for working with these consoles);
- off-nominal situations and the actions to recover from them jointly with the other crew members.

While completing the *Mir*/NASA program the NASA astronauts, as part of the Russian-American crews, completed three EVAs in open space from the *Mir* complex. Information on the EVAs is presented in Table 10.1.

EVAs in Open Space From the *Mir* Complex

Table 10.1

№	EVA crew	EVA date	EVA length (hrs)	Primary tasks of the EVA
1	V.V. Tsibliev J. Linenger (USA) (<i>Mir-23</i>)	04/28/97	4:58	Installation of the optical properties monitor (OPM) on the DM. Installation of the Benton dosimeter on the pressurized-scientific compartment (IIHO) of Kvant-2. Disassembly of the PIE, MSRE scientific equipment from the special airlock module (IIICO).
2.	A.Ya. Solovyev M. Foale (USA) (<i>Mir-24</i>)	09/06/97	6:00	Inspection of the depressurized Spektr module's exterior surface. Inspection of the external cooling radiator (HXP) panel. (External cooling radiator panel mounting brackets № 111 and 113 were broken, and №. 110 and 112 were bent. In the area where the VSTI was opened no visible damage was detected). A special gauge was used to measure the circular gap around the SA-2 drive unit. (The gap was uneven. The gauge moved freely on the unpressurized module (HFO) side, and did not move on the docking assembly side). Securing the handrail package near the "Miras" equipment on the unpressurized module. Rotating SA-4 and supplemental SA-4. Disassembling the Benton dosimeter from the Kvant-2 instrument-scientific compartment.
3	A.Ya. Solovyev D. Wolf (<i>Mir-24</i>)	01/14- 15/98	3:52	Egress from the instrument-scientific module. Inspect the egress hatch, detect risks of catching on the locks). Take measurements with the space portable spectral reflectometer on the exterior surface of the pressurized-cargo compartment-1. Make a TV report near the egress hatch about D. Wolf's first EVA. Close the egress hatch using primary and reserve locks (the special airlock module is not pressurized. Air-locking operations in the instrument-scientific compartment).

10.8. Interactions of the Russian-American Crews With the Main Real-Time Operations Management Group and the NASA Consultant Group at MCC-M

Planning operations and controlling the joint Russian-American crew was performed by the MCC Main Real-Time Operations Management Group and the NASA Consultant Group.

In the crews' opinion, during the initial stage of NASA astronauts' operations on the *Mir* complex there were not adequate interactions between the NASA Consultant Group and the Main Real-Time Operations Management Group which created problems when organizing crew operations. The NASA Consultant Group frequently changed the astronauts' work program and did not make the Main Real-Time Operations Management Group and the Crew Commander aware of the change. This was noted in the postflight reports of the *Mir-21* and *Mir-22* crew. When organizing the interaction for the international crew, problems were encountered connected, apparently, with other stereotypical activities of American astronauts during flight on the Shuttle. This relates to the peculiarities of transmitting information to the crew, the distribution of responsibilities in maintaining vital functions, and others. There were occasions when changes to the current day's program were made independently and were not agreed to by the Crew Commander. The astronaut was given directions for these changes by the American Consultant Group. After approximately a month of joint flight, these shortcomings were mostly eliminated. This situation was repeated when the NASA Consultant Group at MCC changed. In the future, based on the experience acquired in planning joint operations and in refining the interaction plans between the Main Real-Time Operations Management Group and the NASA Consultant Group, these problems, to a significant degree, will not exist. The crews noted that there was no loss of information at MCC and the crew members sufficiently informed each other about all issues discussed following each communications session.

However, both the NASA astronauts and the Russian cosmonauts noted the necessity to improve planning and organizing radio exchanges on the "Crew-Main Real-Time Operations Management Group" channel. It is necessary to continue work to improve equipment and procedures for exchanging information using packet communications and to automate the process as much as possible, ensuring minimal crew participation in completing the procedures;

A significant number of radiograms under the NASA program contributed to a heavy load on the "MCC-*Mir*" channel. Russian cosmonauts in their postflight reports noted that the inadequate monitoring by the Main Real-Time Operations Management Group of the content of these radiograms led to conditions where information was received on board that was not flight critical (personal letters and secondary questions on American experiments) at the same time that radiograms containing operation information competed for time.

10.9. Conclusions and Recommendations

1. During the course of NASA astronaut operations as part of the *Mir* complex crew, the main objectives of the *Mir*/NASA program were completed. Positive experience was gained in extended operations by astronauts on board the space station, in performing scientific research and experiments, interaction of Russian-American crews with each other and with the ground personnel of the Main Real-Time Operations Management Group and the NASA Consultant Group at MCC-M.
2. *Mir*-Shuttle, *Mir*-NASA program implementation allowed U.S. astronauts and Russian cosmonauts to acquire experience of joint operation onboard the *Mir* and the Space Shuttle which will be further used on the ISS.
3. Cosmonaut and astronaut interaction has been developed during utilization of the *Mir* onboard systems including contingency situations.
4. Experience has been acquired on how to jointly implement scientific programs including contingency operation of scientific equipment. Cosmonaut and astronaut functions during the execution of the scientific program have been updated.
5. Development and tests of Russian crew operation support means on board the *Mir* have been continued and the American COSS (crew on-orbit support system) has been tested.
6. The U.S. inventory control system which is planned to be used on ISS has been further developed.
7. We learned from our joint operation experience that, to ensure quality and efficient operation on orbit, a deeper knowledge of the operational language is needed.
8. The experience acquired during implementation of the *Mir*/NASA program will be useful when training and completing spaceflights under the ISS program.



Mir cosmonauts Budarin and Solovyev



NASA 2 astronaut Shannon Lucid