Section 13 - Applications to the International Space Station (ISS)

Authors:

Pavel Mikhailovich Vorobiev, Co-Chair of the Cargo and Scheduling Subgroup

Lynda Gavin, Technical Assistant to the Phase 1 Program Manager

13.1 Unique Issues

The developers of the ISS program face many issues that are unique in world practice.

An analysis of the results of *Mir*-Shuttle and *Mir*-NASA program implementation showed that a significant number of these issues have already been resolved and could be successfully be used in the ISS program.

Together, the experience acquired in fulfilling the joint Russian-American program and which can be adapted for ISS operations, is presented in eleven separate blocks in Figure 13.1.

Each block represents activities in several areas with each area having several dozen or even hundreds of separate resolved issues. Thus even today, as practical missions are carried out for the *Mir*-NASA program, several thousand issues regarding the interaction between the ISS Russian and American segments have been worked out.

13.2 Use of Shuttle for the Space Station Logistics Support

The **first block** examines utilization of the Shuttle for transport and engineering support of the orbital station. This is the most significant achievement.

Before making flights to the *Mir* station, the Shuttle carried out solitary flights as a carrier of satellites and scientific labs with no active dockings or payload deliveries to a station.

In nine Shuttle flights to *Mir*, several docking alternatives were developed. The Shuttle docked with the station in three of its configurations: to the axial and lateral nodes of the Kristall module and to the docking compartment, which was mated to the Kristall module.

The Shuttle itself had two configurations: docking using its docking module (DM) and the special Russian docking compartment, which remained on the station after the docking. The Shuttle docked along the velocity vector and to the nadir and performed a fly-around of *Mir*. During STS-91, the Shuttle was in a configuration characteristic of the ISS.

The experience gained from various dockings will be applied to the first stage of ISS assembly.

As a delivery vehicle for various payloads sent to *Mir*, the Shuttle became a peer of the Progress-M spacecraft. Over the course of nine missions, it has delivered 22.9 metric tons of payloads, including large DMs, to the *Mir* station.

EXPERIENCE IN COOPERATION FROM JOINT RUSSIAN - U.S. PROGRAM *MIR*-NASA APPLICABLE TO ISS

Figure 13.1

1. Shuttle use for the space station logistics support

- developed Shuttle-to-*Mir* docking operation
- gained experience in delivery of large-sized modules and logistic cargo to *Mir*
- returned cargo from space station in each mission
- verified the use of Shuttle for U.S./Russian crew rotation
- proved efficiency of use of reusable vehicles of Shuttle and Buran type

2. Interaction between international crews

- verified long-term international missions, including psychological support
- verified operations for hardware
- installation/dismantling, equipment transfer from Shuttle to *Mir* and back
- gained experience in joint science
- experience of crew medical support has been gained
- verified interaction in EVAs
- international crew training experience gained
- gained experience in increment of tasks during the flight

3. Space station systems serviceability over a long-term mission

- thermal control system, including hydraulic lines of heat-transport medium
- on-board cabling
- main propulsion unit
- pressurized hull
- power supply system

4. Experience in off-nominal situations recovery

- fire in Kvant module
- leakage in thermal control system loops
- life support system repairs
- Spektr module depressurization
- repair of the onboard computer system

5. Joint ground operations with logistic items

- development joint upmass and downmass process flow
- verified complex cargo assembly and preflight testing
- gained joint experience in simulating cargo accommodation
- performed large amount of acceptance tests of U.S. scientific equipment

6. Research of Station Environment

7. Russian/U.S. cargo integration

- food supplies, water
- crew life support equipment (water containers, CO_2 cartridges, PHA, clothing, Braslet, Electron-B, etc.)
- crew safety support equipment (IELK)
- equipment for *Mir* operation (gyrodyne, batteries, current converter ПЕФБ-1 etc.)
- medical kits
- tools and repair equipment
- gases O_2, N_2

8. Development of joint documents

9. Gained experience in joint Shuttle/*Mir* complex control from MCC-H/MCC-M

10. Science Research Accomplishments

11. Experience in combining two space engineering schools, both of which were developing independently before

Among the cargo are the following: Russian: gyroscopes, an Elektron, storage batteries, life-support system hardware, water for the crew, and more than 200 types of American science equipment.

However, the Shuttle did not just deliver cargo to *Mir*. It also returned the results of experiments, scientific devices, and *Mir* station hardware for analysis and reuse: gyrodynes, an Elektron, remote-operator control mode equipment and Kurs hardware, storage batteries, and much else. Over the course of nine flights, the Shuttle vehicles returned 7.8 metric tons of cargo. The total mass of the cargo traffic was 30.7 metric tons.

The experience gained from delivery and the return of Russian cargo will be virtually completely incorporated in Phase 2, since the ISS Russian segment systems are in many ways identical to those installed on *Mir*. It will also be expedient to apply experience acquired from the delivery and return of American science equipment to the ISS.

During the flights, various alternatives for delivering and returning crews were developed. The crew consisting of Dezhurov, Strekalov, and Thagard was launched in the Soyuz-TM and returned on the Shuttle, while Solovyev and Budarin took off on the Shuttle and returned in the Soyuz-TM.

American astronauts Shannon Lucid, John Blaha, Jerry Linenger, Michael Foale, Dave Wolf, and Andrew Thomas were launched and returned on the Shuttle. All of these methods will be implemented for the ISS. The first ISS crew will launch in the Soyuz-TM and will return on the Shuttle.

On the whole, fulfillment of transport operations by the Shuttle has proven the effectiveness of utilizing reusable vehicles for supplying orbital stations.

13.3 Interaction Between International Crews

The **second block** reflects experience acquired in the sphere of cooperation between international crews. The American astronauts spent a total of 942 days on *Mir*, thus exceeding the total presence of all foreign astronauts on the Salyut and *Mir* stations. The successful experiences of American astronauts in long-duration flights on *Mir* of from 115 to 188 days and their flights with two Russian crews that replaced one another are of great importance in ISS program planning. Practice has shown that it is not necessary to limit the length of missions to three months or to launch and return with the same crew. This was confirmed when A. Solovyev and M. Foale, who were launched aboard different spacecraft, performed an extravehicular activity (EVA) on 6 September 1997.

Loading and unloading the Shuttle in orbit is one of the most important and labor-intensive operations. There were doubts at the start of the program as to whether the *Mir* and Shuttle crews would have enough time to perform these operations during a short five-docked day mission. Today these operations have been successfully developed. Russian cosmonauts and American astronauts work smoothly and very quickly. During STS-86, the total mass of cargo transferred from the Shuttle to *Mir* and vice versa was 4525 kg.

The *Mir* and Shuttle crews have acquired experience in simultaneously conducting two science programs based on joint experiments, which will undoubtedly be important for the ISS.

One feature of the American science program is the large quantity of science equipment that is replaced during each Shuttle flight (on average, 600 kg), which is anticipated for the ISS.

Joint EVA experience should be mentioned. Linenger, Foale, and Wolf egressed in Russian space suits, and Titov worked in an American space suit during STS-86. During EVAs, cosmonauts worked with American payloads, while astronauts worked with Russian ones during STS-86. The astronauts on the station accompanied the cosmonauts during EVAs, and helped them with operations.

Other accomplishments were training astronauts and cosmonauts in each other's language, methodologies, development of tools to facilitate technical operations in orbit, and the creation of efficiencies in mission training. Training of astronauts and cosmonauts conducted at each other's space centers broadened the scope of training techniques, styles and methods. Experience was gained in astronaut training as cosmonaut researcher and onboard engineer-2 for individual systems during *Mir* long-duration missions.

13.4 Space Station System Serviceability Over a Long-Term Mission

The **third block** is very important because the experience acquired in long-duration station system support in space is unique. The *Mir* station is in its 13th year of flight, and several problems, such as the biocorrosion of the thermal control system, became apparent only in the 12th year of operation. The experience gained has made it possible to adopt measures to ensure 15 years of flight and 10 years of operation of such basic systems and ISS module assemblies as the thermal control system, the onboard cable network, the integrated propulsion system, the pressure hull, pumps, valves, and equipment for controlling the pencil-beam antenna. Considering the fact that this experience was gained during the actual flight of the orbital station, it is invaluable.

A joint understanding was developed on how noncritical systems can be operated until they fail, then can be replaced through routine maintenance without compromising safety or mission success. In addition a joint understanding was developed that multiple oxygen-generating systems are essential to ensure uninterrupted operations while maximizing safety margins.

13.5 Experience in Off-Nominal Situations Recovery

In the **fourth block**, all of the emergency situations that are listed occurred on *Mir* and were successfully eliminated by the crews with the participation of American astronauts.

Of course, the emergency situations on *Mir* were not specially planned; nevertheless, the experience in resolving the situations is doubtless a contribution to the ISS program.

It is especially important to mention preparations for repressurizing the Spektr module. So far, only plans for such operations have been drawn up for the ISS. They have become necessary for the *Mir* station. Working under the shortest of deadlines, RSC-Energia (RSC-E) and the Khrunichev Space Center developed repair hardware for sealing possible leaks in space. The hardware has been tested, was sent to Kennedy Space Center (KSC), and was delivered to *Mir* during STS-86 in September 1997.

Unfortunately, despite the repair operations which were conducted, including crew EVAs, up to now it has not been possible to repressurize the Spektr module. However, the results obtained during full-scale testing may in fact be included in the scope of work performed for the ISS.

13.6 Joint Ground Operations With Logistics Items

The **fifth block** notes categories of joint work during ground preparation of payloads.

Presently, virtually all ground service operations necessary for transport of Russian payloads on the Shuttle and American payloads on *Mir* modules and Progress and Soyuz vehicles have been developed and fine-tuned with consideration of the specific requirements of equipping the orbital station.

This allows American and Russian experts, in particular, to quickly resolve issues concerning delivery of emergency payloads. Thus, in April 1997, a month before the launch of STS-84, a 140-kg Elektron unit was stowed in the Spacehab module. In August of that same year, and a month before the launch of STS-86, 300 kg of repair equipment for the Spektr module was placed in the Spacehab and on the mid-deck. Experience in real-time stowage of payloads on delivery vehicles for the orbital station will certainly be incorporated into Phase 2.

Preparation operations and preflight testing of integrated payloads have been developed. The Russian Spektr and Priroda modules and Progress-M spacecraft have delivered 2000 kg of American science equipment which has been tested at different places, including the Baikonur launch site. At the same time, a Russian DM and solar array units were prepared and placed in the Shuttle payload bay (STS-74) at KSC.

Acquired experience in joint preflight testing of integrated payloads, in particular the DM, will be applied to the ISS program when the Russian science power platform and its solar arrays are prepared for transport on the Shuttle.

All means of information exchange, including joint mockups, are widely used for payload stowage operations.

It is important to note the concurred work of American and Russian experts in flight safety assurance for the Shuttle when carrying Russian payloads and when docked with *Mir*, including during execution of the American science program.

Acceptance test procedures for the primarily American science equipment, including the issuance of safety certificates, have been adjusted.

All of these inconspicuous operation categories will be a characteristic part of the ISS program, and less time will be required to adjust them.

13.7 Research of Station Environment

The **sixth block** comprises activities on station environment studies including *Mir*-Shuttle stack attitude control. A rack for isolating sensitive scientific experiments from disturbing vibrations caused by normal crew activity was successfully tested on *Mir*. Data was collected on effect of long-duration exposure of hardware to space environment through the *Mir* Environmental Effects Payload, which was deployed and retrieved by astronauts and cosmonauts on joint space walks.

For the first time experience was gained in attitude control of a big and flexible structure *Mir* + Shuttle. Attitude control was supported by both reaction control jets (*Mir* and Shuttle) and gyrodynes. Particularly, the procedure of using jets of the Progress vehicle for desaturation of gyrodynes will be used during attitude control of ISS for desaturation of both Russian gyrodynes and American control moment gyrodynes.

13.8 Russian/U.S. Cargo Integration

The **seventh block** concerns issues regarding integration of Russian and American payloads. This integration falls under two categories.

- developing and utilizing American equipment and life-support systems delivered to *Mir*;
- constantly expanding the list of partners' payloads in national transport vehicles.

Today, *Mir* uses American life-support systems as well as traditional Russian equipment and life-support systems.

Here is a partial list:

- the Kvant module has a Russian solar array deployed on one side and an American solar array deployed on the other;
- 50% of foodstuffs have been American while the other 50% have been Russian;
- both American and Russian CO2 absorbers, water storage tanks, medical kits, instruments, and water have been used;
- after the Shuttle is docked, its air is exchanged with the air of the *Mir* station.

Of particular note as a contribution to Phase 2 is the resolved problem of using a Shuttle power-supply system byproduct, water, on the orbital station. On the one hand, it was not necessary to load the Shuttle with water because water accumulated by the end of the flight, but on the other, this water could not be stored for long on the station, which is necessary for a long-duration flight.

Thus, throughout these flights, Russian and American experts worked in turn to resolve this issue, and now, the ISS crew will be able to consume water delivered during each Shuttle flight with no problems.

13.9 Development of Joint Documents

The **eighth block** notes that joint documents were issued for the *Mir*-NASA program.

There are fairly many such joint documents. More than fifteen were issued on operations alone for each flight.

Documents such as the Russian cargo manifest and interface control documents are wholly transferable to Phase 2.

Experience in creating joint Russian-American documents is already widely used in the development of ISS documentation, and this has accelerated the work process.

13.10 Experience Gained in Joint Shuttle/*Mir* Complex Control From MCC-H/MCC-M (Mission Control Centers in Houston and Korolev)

The **ninth block** is concerned with the large experience gained by both sides in the joint control process of the *Mir* and Shuttle during nine short- and seven long-duration missions.

Shuttle and *Mir* were originally developed independently of each other and there was no compatibility between the two. MCC-M and MCC-H also operated under individual programs independently of each other.

The potential experience in MCC joint operations was only available from the short-duration Apollo-Soyuz Program, completed in 1975. This experience was fully utilized, but it was insufficient.

The Phase 1 tasks were of two types:

- conduct scientific experiments;
- gain operational experience for use in Phase 2.

Many engineering as well as operational decisions were required in order to ensure the capability of *Mir* and Shuttle and joint control of the mated vehicles from two MCCs, separated from each other by thousands of miles, in different time zones, each with their own traditions and languages. Flight control took place under changing *Mir* configurations and constantly developing tasks. In this way, it was like simulating the process of ISS development on orbit.

All Phase 1 tasks were successfully completed, which serves as proof of the technical capabilities of both sides.

As a result it is possible to ascertain that during the course of Phase 1 a foundation was created for successful Phase 2 preparations, and the technological structure and methodology of joint flight control for future international programs such as the ISS were created and refined.

We can note acquired experience in the following areas:

- study of flight control experience of Russian and U.S. vehicles;
- structure of the joint vehicle control groups of different countries;
- structure of the joint ground and flight data files for flight control and crew operations;
- the set of technical operations for joint flight planning of vehicles from both countries;
- the set of procedures for jointly making decisions for both nominal flight and in emergency situations;
- mutual use of capabilities of the partners' flight and ground segments;
- communications system and data exchange for flight control between MCC-M and MCC-H;
- organizing international crew operations and the interaction of the MCCs with the crews;
- simultaneous execution of two or more science programs from different countries;
- procedures for publicizing information about flight activities;
- integration of *Mir* and Shuttle onboard systems.

In addition, the joint flight of the two 100-ton vehicles—the Shuttle and the *Mir* station in mated flight—in many ways simulated the flight of the American and Russian ISS segments, since the complex has many distinctive characteristics of the international station: the docked Shuttle, a large crew, two science programs and joint experiments, transfer and stowage of cargo and so on, that also applies to Phase 2.

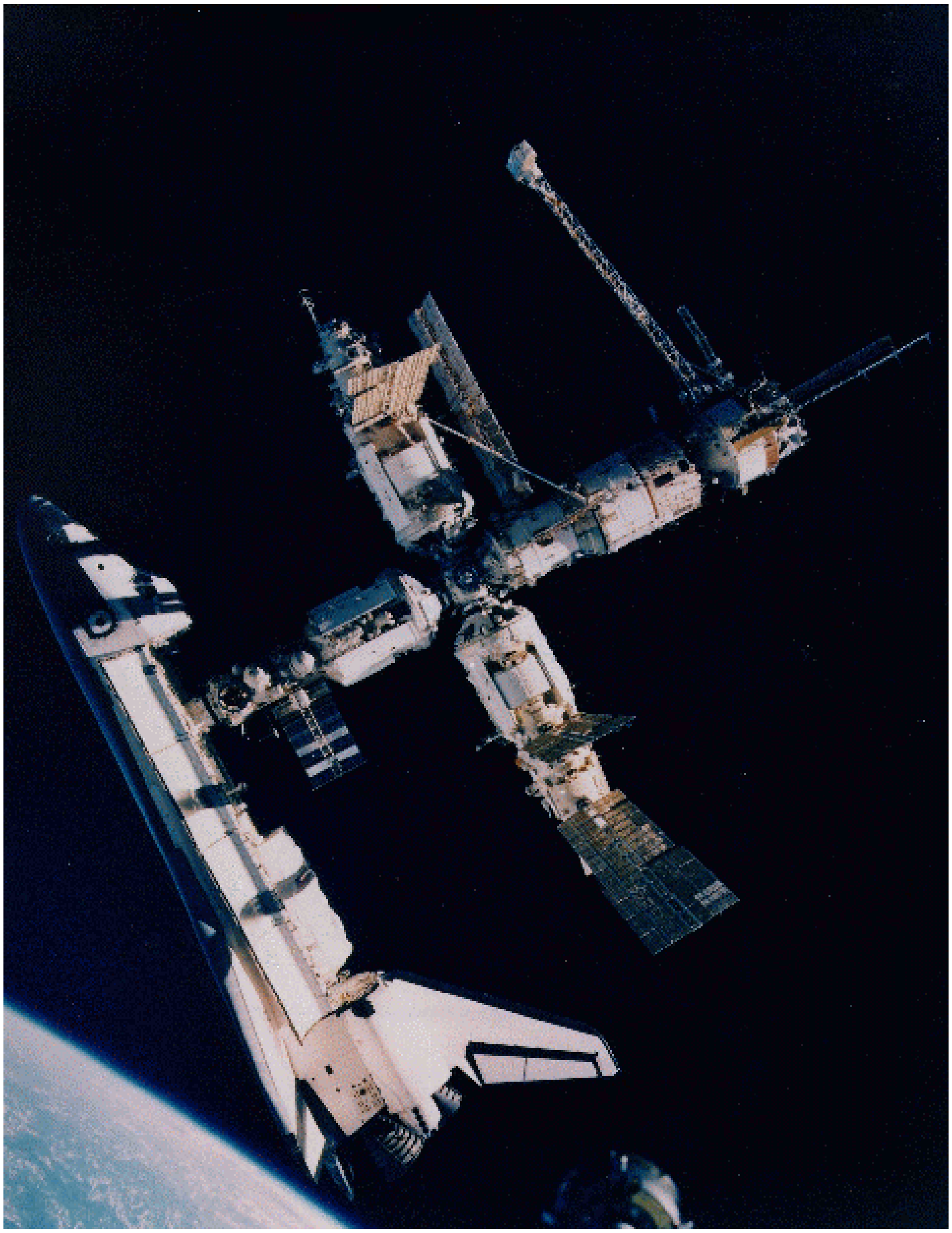
13.11 Science Research Accomplishments

The **tenth block** represents the many important scientific accomplishments of the Phase 1 Program. These accomplishments are summarized well in section 11 of the report under the subheading “WG-4 Accomplishments.”

13.12 Combining Experience of Two Space Engineering Schools

The **eleventh block** describes how, on the whole, two technical schools of space engineering were successfully integrated during implementation of the *Mir*-Shuttle and *Mir*-NASA programs. Furthermore, issues of separate work locations, different technical and spoken languages, and production of identical documentation were resolved.

Resolving the issues listed above required the diligent work of hundreds of Russian and American specialists. Their efforts made the program highly productive.



***Atlantis* docked to *Mir* during STS71**

The Shuttle *Endeavor* lands at KSC after STS-89