



# Final Report

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**on the  
International Space Station  
Phase 1 Program**



**NASA Advisory Council  
Task Force on the Shuttle-Mir Rendezvous  
and Docking Missions and the  
Task Force on ISS Operational Readiness**

**July 1999**





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Task Force on ISS Operational Readiness  
July 1999



# 1 Letter

## From Gen. Stafford to Dr. Parkinson

LT. GEN. THOMAS P. STAFFORD  
1006 CAMERON STREET  
ALEXANDRIA, VA 22314

July 4, 1999

Dr. Bradford W. Parkinson  
Chairman  
NASA Advisory Council  
Washington, DC 20546

Dear Dr. Parkinson:

Enclosed is the NASA Advisory Council (NAC) Task Force on the Shuttle-Mir Rendezvous and Docking Missions and Task Force on International Space Station (ISS) Operational Readiness' Final Report on the ISS Phase 1 program.

When the drafting of this report was initiated, our intention was to issue a retrospective summary on the history of the ISS Phase 1 program and the oversight role played by the NAC Task Force on the Shuttle-Mir Rendezvous and Docking Missions. As the writing of the report progressed, however, it became apparent that a number of issues that had surfaced during the ISS Phase 1 program remain applicable to the ISS Phase 2 program. This fact is not a negative reflection of either program; rather, it demonstrates the close linkages that developed between the two programs and the relevance of the ISS Phase 1 program to the ISS Phase 2 program. And, because the two NAC Task Forces also share these linkages, it is appropriate that this report be issued jointly.

As originally envisioned, this report remains primarily a historical summary of the Phase 1 program and the oversight role played by the NAC Task Force on the Shuttle-Mir Rendezvous and Docking Missions. To that end, virtually every finding and recommendation made by that Task Force, together with NASA's response, are listed in the report's Appendix A.

This report also contains findings and recommendations from Phase 1 that pertain to Phase 2. These findings and recommendations, which were discussed and considered at an open meeting of the NAC Task Force on ISS Operational Readiness, held at the Johnson Space Center, on January 28, 1999, are listed in the report's Conclusion. These findings and recommendations are not a list of lessons learned and should not be considered as such. They are simply a listing of those issues from Phase 1 that the Task Forces feel need to be addressed by the Phase 2 program. While this report addresses many of the lessons learned from Phase 1 to Phase 2, we did not feel it was necessary to attempt to put together a comprehensive listing of lessons learned because the ISS Program Office has already published such a list.

On behalf of the Task Forces, I would like to thank the NAC for all of the support it provided over these last 4 1/2 years. I would also like to thank all of the individuals involved in the ISS Phase 1 Program Office for all of the tremendous support they provided. They were always willing to take the time to talk with us and provide us with information and answers, no matter how difficult or routine. I would particularly like to thank all of the individuals who have served as members of the Task Forces and their support staffs. This report is a reflection of all of the hard work and dedication of this team.

Sincerely,



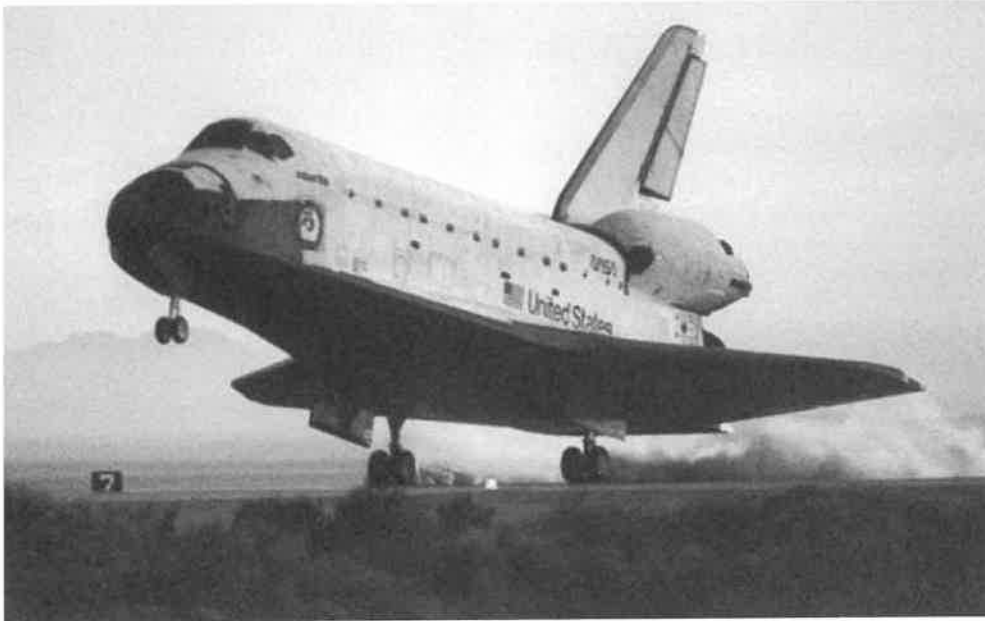
Thomas P. Stafford  
Lt. Gen. USAF (Ret.)

cc:

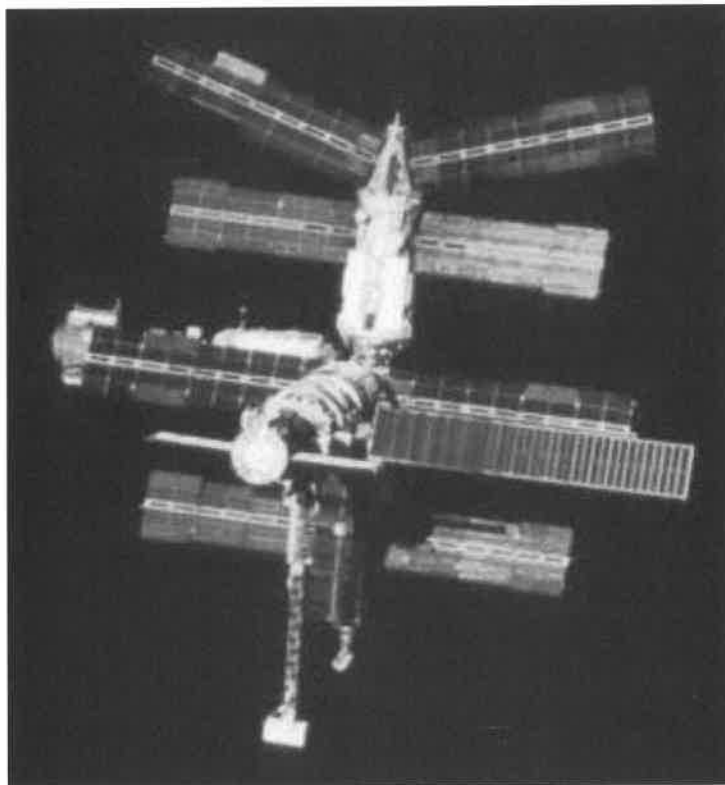
A/Mr. Dan Goldin  
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AI/Dailey  
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Z/Crouch  
JSC/OA/Culbertson  
JSC/OA12/Luna  
MTLO/Baker  
NMLO/Bress



U.S. Space Shuttle *Atlantis*.



Russian space station *Mir*.



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# 2 Introduction

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## **The United States and Russia Establish the Phase 1 Shuttle-Mir Program**

In October 1992, the United States and Russia agreed to conduct a fundamentally new program of human cooperation in space. This cooperative endeavor, involving joint astronaut-cosmonaut crew activities on the U.S. Space Shuttle, the Russian Soyuz spacecraft, and the Russian Mir space station, came to be known as the “Shuttle-Mir program.” The objectives of this program were to:

- Fly a Russian cosmonaut aboard the Space Shuttle (STS-60)
- Fly an American astronaut aboard the Mir space station (via Soyuz TM-21/Mir-18)
- Perform a rendezvous, docking, and joint mission between the Space Shuttle (STS-71) and Mir

In November 1993, this program was expanded to include additional Space Shuttle flights to Mir and additional U.S. astronauts aboard Mir. This expansion identified four or more U.S. astronaut flights aboard Mir for a total of approximately 24 months, with up to 10 Shuttle flights to Mir between 1995 and 1997 (Figure 1). The expanded program became Phase 1 of the International Space Station (ISS) program. The Phase 1 program had four objectives:

1. Provide an environment for the United States and Russia to learn to work together in space
2. Mitigate risks for ISS Phases 2 and 3
3. Learn more about conducting long-term space operations
4. Enable the early utilization of life and microgravity sciences experiments

These missions were complex not only from a technical standpoint, but also from organizational, program management, and cultural perspectives. They involved close cooperation among NASA, NASA contractors, and multiple Russian aerospace organizations led by the Russian Space Agency (RSA). These missions required that each country reexamine the way it conducted space operations. This necessitated the development of new equipment, techniques, and procedures. It required extensive joint training, which was conducted in both the United States and Russia. Divergent engineering and operational approaches had to be merged. These were the kinds of challenges facing the U.S. and Russian space programs as they began the implementation of the Phase 1 program.

## **NASA Establishes the Stafford Task Force**

NASA recognized that the margin for mission success could be enhanced if a team of experts reviewed the safety and operational readiness of the Shuttle-Mir missions. Therefore, in May 1994, NASA established the NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions. This Task Force became known as the Stafford Task Force, named after its chairman, Lt. General Thomas P. Stafford. The history of the Task Force, from its inception through the end of Phase 1, is chronicled in Section 3 of this report.

NASA - MIR PHASE 1 PROGRAM

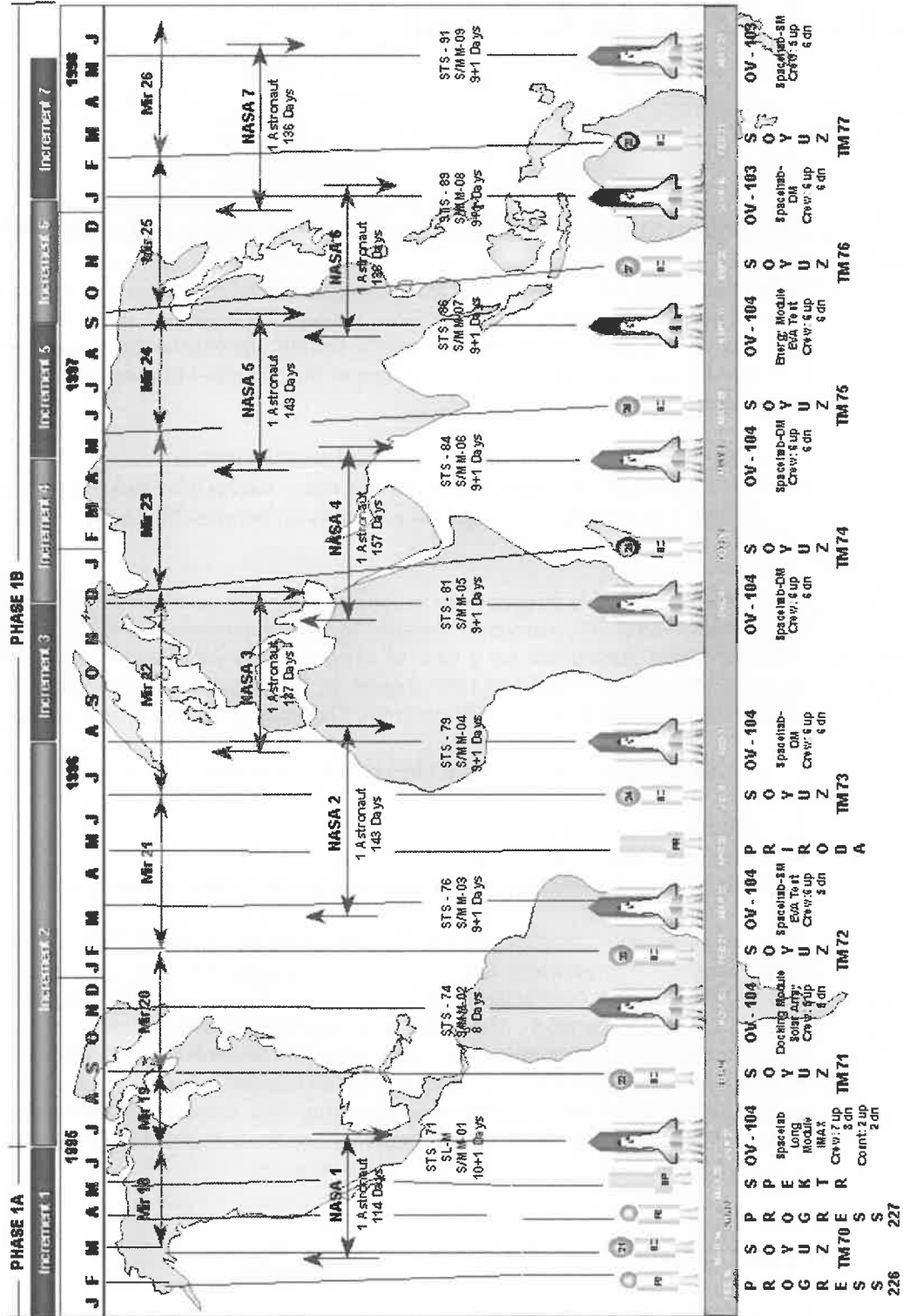


Figure 1. NASA-Mir program (Phase 1) launch schedule.

### Report Structure

During the course of the Phase 1 program, the Stafford Task Force issued numerous findings and recommendations on all aspects affecting the safety and operational readiness of the Shuttle-Mir missions. All of these findings and recommendations, together with the NASA responses, are included in Appendix A of this report. The findings and recommendations fall into seven categories:

- Communications
- Crew health
- Management
- Operations
- Planning
- System safety
- Training

This report contains separate sections on each of these seven issue areas. These sections elaborate on the findings and recommendations presented in Appendix A.

### Future Joint Report on the Phase 1 Program by the Stafford Task Force and Utkin Advisory Expert Council

In early 1995, at the direction of the U.S./Russian Joint Commission on Economic and Technological Cooperation (Gore-Chernomyrdin Commission), NASA and RSA established the Stafford Task Force-Utkin Advisory Expert Council Joint Review Commission. Through the course of the Phase 1 program, the Stafford Task Force worked very closely with the Utkin Advisory Expert Council to conduct joint assessments of significant safety- and operations-related issues. While that cooperation is addressed in this report, it will be the subject of a separate final report on the Phase 1 program. This separate report will be issued jointly by the Stafford Task Force and the Utkin Advisory Expert Council.



# 3 Summary

## of Task Force Activities

### **NASA Establishes Stafford Task Force**

On May 2, 1994, NASA established the NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions, chaired by General Stafford. The purpose of the Task Force was to review Phase 1 planning, training, operations, rendezvous and docking, and management.

### **Stafford Task Force Conducts First Meeting and Issues First Report**

On May 24–25, 1994, the Stafford Task Force conducted its first meetings at the Johnson Space Center (JSC) in Houston, Texas. The Task Force released its first report containing its first set of recommendations on June 6, 1994. The focus of these recommendations was on training and rendezvous/docking issues. General Stafford also established Task Force Working Groups for the following four issue areas: Management; Phase 1; Crew Systems, Training, and Operations; and Vehicle Systems.

### **Stafford Task Force Issues Second Report**

On July 29, 1994, the Stafford Task Force, after conducting multiple working group meetings and open meetings, issued its second report. This report contained numerous findings and recommendations on various elements of Phase 1 joint missions STS-63, STS-71, and STS-74. In addition, the report contained a separate section on Phase 1 project management in which the Task Force recommended that NASA establish a Phase 1 project manager at JSC. This position, and supporting office, had not previously existed. NASA accepted this recommendation and established the Phase 1 Program Office at JSC. Much of the success of the Shuttle-Mir program is credited to this office and the two Phase 1 Project Managers who led it—Tommy Holloway and Capt. Frank Culbertson, USN (Ret.).

### **Stafford Task Force Issues Third Report**

On November 2, 1994, the Stafford Task Force released its third report. The report contained numerous findings and recommendations on the following subject areas: Management; Mission Requirements; Orbiter Docking System; Plume, Docking, and Mated Loads; and Rendezvous and Docking.

## Gore and Chernomyrdin Direct NASA and RSA to Establish a Joint Review Process

On December 15, 1994, during the fourth meeting of the U.S./Russian Joint Commission on Economic and Technological Cooperation (Gore-Chernomyrdin Commission), U.S. Vice President Al Gore and Russian Prime Minister Victor Chernomyrdin directed NASA and RSA to establish a process to review the Shuttle-Mir program. Vice President Gore noted that there was a need for mutual understanding and insight into each other's program activities. NASA and RSA agreed that this joint review committee would be headed by General Stafford and Academician Vladimir F. Utkin. NASA and RSA further agreed that the joint review committee would focus its reviews on issues of safety and reliability.

## RSA Establishes Utkin Advisory Expert Council

On February 14, 1995, RSA established the Advisory Expert Council on Problems Relating to Shuttle-Mir Flights, chaired by Academician Utkin. The Utkin Advisory Expert Council was directed to conduct assessments, both independently and jointly with the Stafford Task Force, in the areas of safety, reliability, and effectiveness pertaining to the completion of the Shuttle-Mir program.

## First Stafford-Utkin Delegations Are Exchanged

In January and February 1995, the Stafford Task Force sent delegations to Russia to initiate preliminary discussions with RSA and Academician Utkin on the format and structure of the Stafford Task Force-Utkin Advisory Expert Council (TF-AEC) Joint Review Commission. The

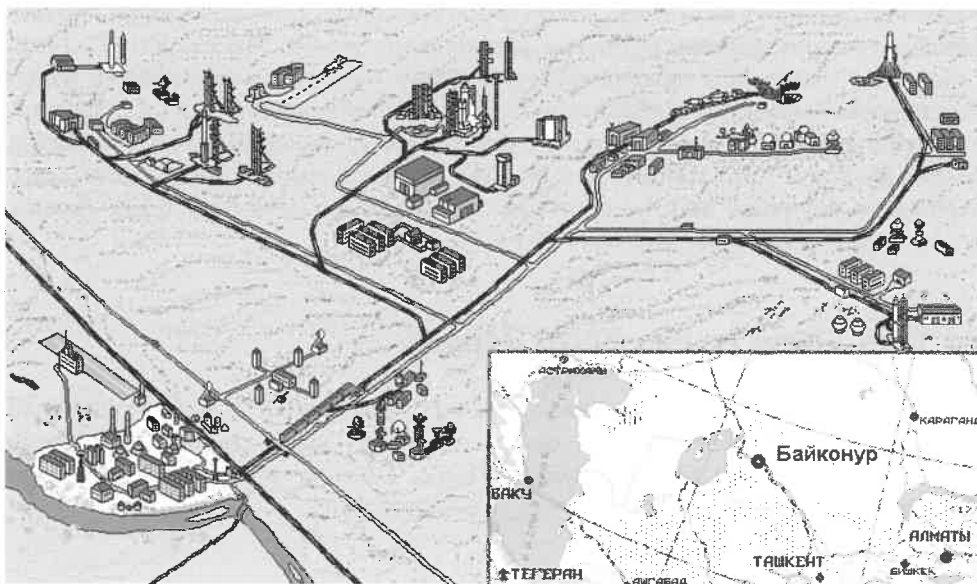


Figure 2. Baikonur Cosmodrome, launch site visited by Stafford Task Force in February 1995.

Stafford delegations also used the opportunity to acquaint themselves with RSA and the other Russian organizations supporting the Phase 1 missions. The delegation visited RSA, the Central Research Institute for Machine Building (TsNII Mash), the Mission Control Center-Moscow (MCC-M), Rocket Space Corporation-Energia (RSC-E), the Khrunichev State Research and Production Space Center, the Gagarin Cosmonaut Training Center (GCTC), and the Baikonur Cosmodrome (Figure 2).

## Stafford Task Force Releases Fourth Report

In March 1995, the Stafford Task Force compiled the observations and recommendations from its trips to Russia into a fourth report. The Task Force found that the Phase 1A missions (Soyuz TM-21, Mir-18, and STS-71) faced no unacceptable risks. This finding was based on data review, interviews, discussions, and site visits conducted by the review team in the United States and in Russia. The report stated:

*At the core of the finding is the conclusion that the interface between the U.S. and Russian civil space organizations is operating effectively and that the processes, hardware, and people necessary to safely complete the Phase 1A missions are in place.*

## Utkin Advisory Expert Council Travels to the United States

In April 1995, Academician Utkin and members of the Advisory Expert Council visited JSC in Texas, the Kennedy Space Center (KSC) in Florida (Figure 3), the Marshall Space Flight Center (MSFC) and Boeing in Alabama, and NASA Headquarters in Washington, D.C. During this visit, the Utkin Advisory Expert Council and the Stafford Task Force discussed issues related to the joint STS-71 flight.

### Utkin Advisory Expert Council Issues Report on STS-71 Readiness

In June 1995, the Utkin Advisory Expert Council presented a report to RSA General Director Yuri Koptev on the readiness of STS-71. The Utkin Advisory Expert Council concluded that "the level of interaction of all Shuttle elements, the experience accumulated during previous missions, and staff qualifications eliminate the grounds for concern and provide confidence in a successful STS-71 launch." This conclusion was based on 67 successful Shuttle launches prior to STS-71, the productive interaction between personnel at the Mission Control Centers in Moscow and Houston, 26 manual dockings in space, high crew qualification, and the successful completion of the STS-63 mission in February 1995, when the Shuttle rendezvoused with Mir to a distance of 33 feet (10 meters).

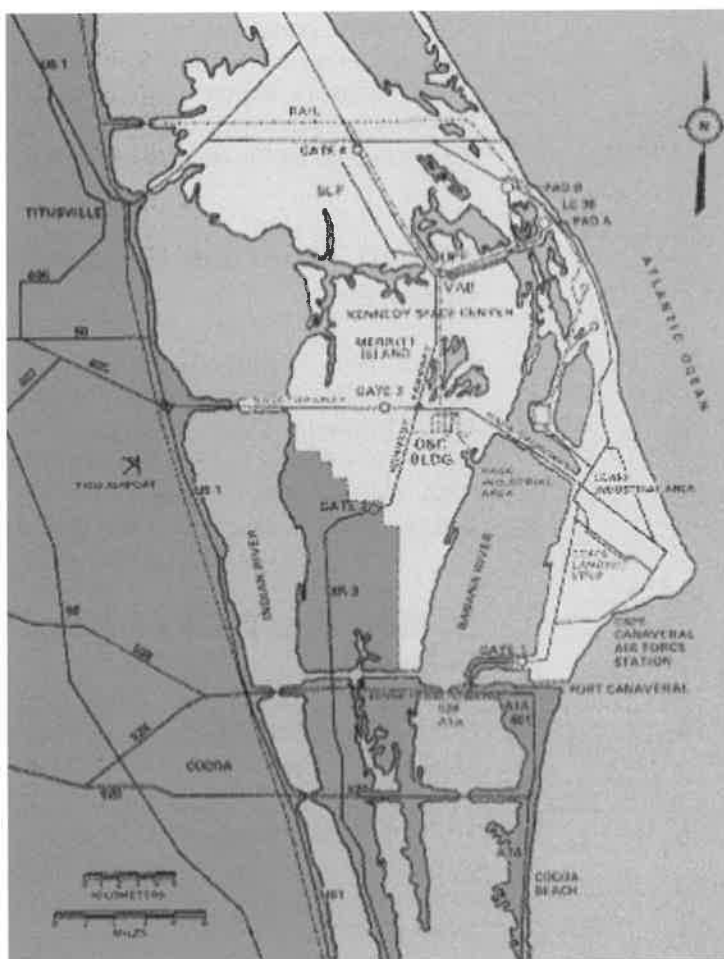


Figure 3. Kennedy Space Center, launch site visited by Utkin Advisory Expert Council in June 1995.

### **General Stafford Sends Letter to Administrator Goldin With STS-71 Readiness Assessment**

After the release of its fourth report on March 1, 1995, the Stafford Task Force continued to monitor the status of preparations for the launch of STS-71. General Stafford sent a letter to NASA Administrator Mr. Dan Goldin on June 22, 1995, in which he provided a detailed update on the issues that the Task Force had identified in its fourth report, as well as the status of a number of emergent issues that had occurred after the release of that report. General Stafford indicated in his letter that all issues had been adequately addressed by the Phase 1 joint program and that STS-71 was ready to fly safely and successfully.

### **STS-71 Confirms TF-AEC Assessments**

The report conclusions of the Stafford Task Force and the Utkin Advisory Expert Council were confirmed by the successful flight of STS-71 and its joint docked operations with Mir. Furthermore, preparations for these separate, independent reports and conclusions provided the foundation for a close working relationship between the Stafford Task Force and the Utkin Advisory Expert Council. Another key ingredient in the successful relationship between the two review groups was the significant support that they received from U.S. and Russian personnel in the Phase 1 program.

### **Stafford Task Force Conducts Review of NASA Management Structure in Russia**

In May 1995, General Stafford sent a Task Force Working Group to Russia to review the structure and staffing of NASA's office in Russia and to report its findings to the full Task Force. While in Russia, the Management Working Group conducted fact-finding meetings with representatives at the following organizations: GCTC (Star City); NASA office in Star City; NASA-2 crew; Boeing/Moscow; Lockheed/Moscow; U.S. Defense Attaché; U.S. Embassy; NASA Moscow Liaison Office; and MCC-M.

### **Stafford Task Force Conducts Review of NASA's ADP/T Infrastructure in Russia**

Concurrent with the review by the Stafford Task Force Management Working Group, a separate Task Force Working Group conducted an assessment of NASA's automated data processing and telecommunications (ADP/T) infrastructure in Russia. The ADP/T Infrastructure Working Group reviewed: (1) the requirement identification, collection, and documentation process; (2) the requirement implementation (design, acquisition, integration/testing, shipment, and site installation/testing) processes; and (3) the sustaining operations and maintenance process.

The ADP/T Infrastructure Working Group reviewed a wide range of source material, including formal and informal documents, memoranda, letters, presentations, and publications. Members of the Working Group also conducted numerous fact-finding interviews with a wide range of individuals, including NASA and contractor managers, engineers, technicians,

and technical staffs located in the United States and Russia. In April 1995, ADP/T Infrastructure Working Group members attended meetings of the Joint Institutional Communications Requirement Working Group at JSC. In May 1995, the ADP/T Infrastructure Working Group received briefings from the Program Support Communications Network at MSFC in Huntsville, Alabama.

## **Stafford Task Force Issues Fifth Report**

The Stafford Task Force Working Groups on Management and ADP/T Infrastructure generated a number of findings and developed a number of recommendations, which were reviewed and endorsed by the full Task Force at an open meeting at JSC on July 19, 1995. Installation of ADP/T equipment in NASA's Russia offices (telephone lines, fax equipment, voice teleconferencing systems, computer equipment, etc.) had been delayed. The Task Force felt good communications capability was essential to the successful accomplishment of the Program objectives, and recommended that the implementation of this capability be given a high priority. These findings and recommendations were included in the fifth report of the Stafford Task Force, which was released on September 21, 1995.

## **First Formal Joint Meeting and Signing of Stafford-Utkin Charter**

In September 1995, the Stafford Task Force and the Utkin Advisory Expert Council conducted their first formal joint meetings in Russia. The discussions focused primarily on the language and scope of the Charter for the TF-AEC Joint Review Commission, as well as developing a schedule for joint activities and joint reports. These meetings were very successful and resulted in the signing of the TF-AEC Charter on September 11, 1995, and the signing of the first TF-AEC protocol on September 13, 1995.

## **NASA and RSA Endorse the TF-AEC Charter**

In an exchange of correspondence on October 16, 1995, and December 1, 1995, RSA General Director Koptev and NASA Administrator Goldin officially endorsed the TF-AEC Charter that General Stafford and Academician Utkin signed on September 11, 1995.

## **STS-74 Readiness Assessment**

On October 17, 1995, the Stafford Task Force conducted an open meeting at NASA Headquarters in Washington, D.C., to review the readiness of STS-74 for launch. The Task Force identified and discussed a number of technical issues associated with the STS-74 mission, including:

- The three candidate methods for mating the Docking Module to the Orbiter Docking System, as well as their reliance on the Remote Manipulator System
- The use of a revised approach profile to be used by the orbiter to dock with Mir, the results of a loads analysis from STS-71, and its applicability to STS-74
- Docking clearances
- Transfer of solar arrays from the Docking Module to Mir

- Separation/undocking techniques
- Close flight spacing of the STS-73 and STS-74 missions

On November 6, 1995, General Stafford sent a letter to Administrator Goldin stating that the complexity of the STS-74 mission, as illustrated by the number of technical issues listed above, served as an excellent precursor to the first ISS assembly flight. General Stafford further stated that the Task Force felt that STS-74 was ready for launch.

### **STS-76 Readiness Assessment**

On March 12, 1996, the Stafford Task Force conducted an open meeting at NASA Headquarters in Washington, D.C., to review the readiness of STS-76 for launch. The Task Force identified and discussed the following technical issues associated with the STS-76 mission, including:

- U.S. Mir astronaut Shannon Lucid not receiving experiment hardware until April because of the launch delay of the Russian Priroda module
- Excessive training demands on Mir-bound U.S. astronauts during the final months prior to launch because of a continuing problem with the timely translation of the experiment flight data files
- A tail-forward approach and docking for the orbiter to accommodate improved communications and downlink coverage for Mir
- The increased transfer quantities of food, water, supplies, and experiments over those on previous flights
- Extravehicular activity (EVA) requirements for a U.S. astronaut to remove an external camera and to install some sample collectors on the Docking Module
- The incidence of a singed O-ring anomaly in the nozzle-to-case joint for the boosters during STS-75

On March 15, 1996, General Stafford sent a letter to Administrator Goldin summarizing the status of the above issues and stating that the Task Force felt that STS-76 was prepared to fly safely and successfully.

### **TF-AEC Joint Review Commission Issues First Report**

On June 27, 1996, the TF-AEC Joint Review Commission issued its first joint report (Figure 4). The report contained issues and resolutions related to the first nine joint missions of the U.S.-Russia Shuttle-Mir program, including:

- STS-60
- STS-63/Mir-17 rendezvous mission
- Mir-18
- STS-71/Mir-18 rendezvous and docking mission
- Mir-19
- STS-74/Mir-20 rendezvous and docking mission
- Mir-20



**Figure 4. Lt. General Thomas P. Stafford and Academician Vladimir F. Utkin sign the first joint report of the Joint Review Commission on June 27, 1996.**

- STS-76/Mir-21 rendezvous and docking mission
- Mir-21

The report also evaluated the Phase 1 programs in the United States and Russia in the areas of planning, training, operations, rendezvous and docking, and management.

### **STS-79 Readiness Assessment**

On September 4, 1996, the Stafford Task Force conducted an open meeting at NASA Headquarters in Washington, D.C., to review the readiness of STS-79 for launch. The Task Force identified and discussed the following technical issues associated with the STS-79 mission, including:

- The impact of the launch delay on medical operations, logistics, science, training, systems integration, the science interface with the Centre Nationale d'Études Spatiales (CNES)/Euro-Mir mission, and the return of astronaut Shannon Lucid to Earth
- The decision to destack and change-out the STS-79 Solid Rocket Boosters (SRB) after a postflight inspection of the STS-78 SRB's had identified heavy sooting and heat effects in the J-joint insulation interface of all six field joints
- A need to purge the Mir prime and backup Elektron oxygen generation systems located in the Kvant-1 and Kvant-2 modules of excessive nitrogen
- Two recent Soyuz U2 booster failures

On September 10, 1996, General Stafford sent a letter to Administrator Goldin summarizing the status of the above issues and stating that the Task Force felt that STS-79 was prepared to fly safely and successfully.

### **STS-81 Readiness Assessment**

On December 11, 1996, the TF-AEC Joint Review Commission conducted its second formal meeting in Russia. The Joint Review Commission reviewed the objectives and readiness of the STS-81 mission to Mir, including:

- Mission goals
- Mir configuration
- STS cargo bay configuration
- Payloads
- Flight plan overview
- Lead operations personnel
- Open work remaining before launch

The Joint Review Commission also reviewed an EVA hatch anomaly that had occurred on STS-80 and an SRB anomaly that had occurred on STS-79. This meeting played an important role in the respective readiness assessments that the Stafford Task Force and Utkin Advisory Expert Council were conducting for NASA and RSA.

On January 8, 1997, General Stafford submitted a letter to Administrator Goldin stating that the Task Force felt STS-81 was ready and safe to fly. However, General Stafford expressed concern over the status of the solid rocket motor throat erosion and recommended that Thiokol provide the Space Shuttle program with data and information to allow a full understanding and a plan of action to correct this anomaly at the earliest date possible.

### **Third Meeting of the TF-AEC Joint Review Commission**

In February 1997, the TF-AEC Joint Review Commission met at JSC in Houston, Texas. The Joint Review Commission discussed the status of the Shuttle-Mir program, certain issues related to the ISS program, and future report and meeting plans for the Joint Review Commission. General Stafford and Academician Utkin signed a protocol on February 21, 1997.

### **Mir Mishaps and Anomalies Affect the STS-84 Readiness Assessment**

In April 1997, General Stafford sent a small delegation from the Stafford Task Force to Russia for a week to meet with the appropriate Russian technical and management experts, including members of the Utkin Advisory Expert Council, to address specific concerns with the Mir space station. These concerns derived from the multiple mishaps and anomalies that Mir had recently experienced, including:

- A fire that broke out in the solid-fuel oxygen generator system in the Kvant-1 module (February 23, 1997)
- An Elektron oxygen generator in Kvant-2 that failed (March 5, 1997) from corrosion and membrane aging, forcing the crew to use backup oxygen canisters for oxygen until the Elektron system was restored in April
- A Progress cargo ship that was unable to redock and had to be deorbited (March 6, 1997)

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- A leak in the coolant loop that forced the crew to shut down temporarily the primary Vozdukh carbon dioxide removal system (April 4, 1997)
- Ethylene glycol leaks that were detected from the coolant system (April 11, 1997)

The Stafford Task Force delegation received detailed reports on all of these mishaps and anomalies and reported its findings to General Stafford and the full Task Force at an open meeting on May 5, 1997, at NASA Headquarters in Washington, D.C. The delegation members reported that the Russians had done a good job of recovering from these incidents, repairing the affected systems and getting them back on line. General Engle expressed concern about the continuing coolant loop leaks caused by corrosion in the aluminum alloy. Colonel James Adamson, U.S. Army (Ret.), said the delegation brought back two important findings:

1. While the reliability of Mir was questionable, Mir had actually grown in robustness over the years as the Russians added new modules and additional redundancy to the station.
2. The United States is learning much from the Russians about what it takes to keep a continuous presence in space.

The full Task Force endorsed the findings of the delegation that had gone to Russia.

On May 7, 1997, General Stafford sent a letter to Administrator Goldin stating that all concerns related to the STS-84 and Mir-23/24 missions had been addressed and that STS-84 was prepared to fly safely to Mir. General Stafford wrote:

*I must say that a month ago, I and my closest advisors were worried that the Mir was in an increasingly eroding condition. I held reservations about exchanging Dr. Linenger with Dr. Foale on STS-84. But, in the past month, the Mir crew has repaired or revised the failing environmental control systems.*

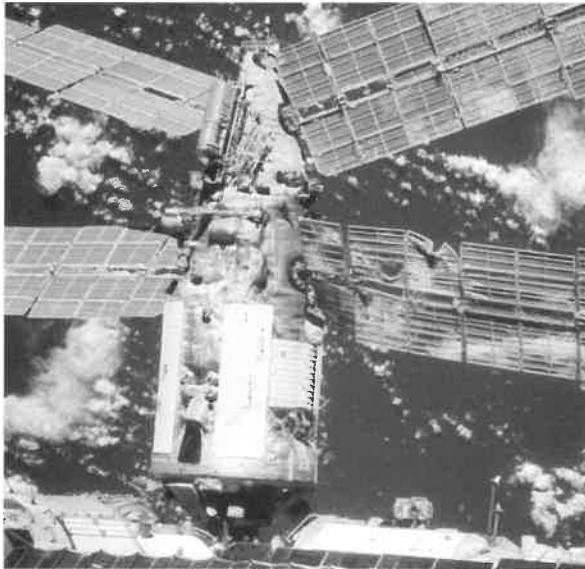
### **Mir Mishaps and Anomalies Continue, Affecting the STS-86 Readiness Assessment**

In September 1997, the TF-AEC Joint Review Commission met in Russia to review the mishaps and anomalies that continued to plague Mir after the successful STS-84 docking mission. These mishaps and anomalies included the following:

- During a test of a new manual docking system, a Progress cargo vehicle collided with Mir, causing a depressurization of the Spektr module (Figure 5). This forced the crew to seal off the module from the rest of the station, cut data cables, and disconnect power cables leading into the module. This resulted in a power loss of nearly 35 percent to the station (June 25, 1997).
- Gyrodynes went off-line, requiring inertial attitude control to be maintained by thruster firing from the Soyuz capsule jets (July 3, 1997).
- Mir lost power after a crew member accidentally disconnected a computer cable, sending Mir into free drift (July 17, 1997).
- The Elektron oxygen generator failed, forcing the crew to use backup oxygen canisters for oxygen until the Elektron system was restored (August 5, 1997).
- Mir's main computer failed, forcing the crew to shut down central systems until the main computer was repaired (August 18, 1997).

- The Elektron system failed once more, again forcing crew to use oxygen canisters (August 25, 1997).

The TF-AEC Joint Review Commission met with key representatives from RSC-E, GCTC, the Institute for Biomedical Problems (IBMP), RSA, and TsNIIMash to assess the safety and operational readiness of the Shuttle-Mir program in light of the June 25, 1997, Progress-Mir collision, the February 23, 1997, onboard fire, and all of the other mishaps and anomalies previously mentioned.



**Figure 5. Spektr solar panel after collision by the Progress M-34 supply vehicle.**

It was during these meetings that all of the contributing causes of the Progress-Mir collision were determined and recognized for the first time. The TF-AEC Joint Review Commission was uniquely qualified and positioned to uncover the true causes of the collision because of the expertise that resided within the Joint Review Commission and the strong personal and professional relationships that had been developed since the Joint Review Commission was established in early 1995.

The Stafford Task Force delegation included members of the Maj. General Ralph Jacobson, USAF (Ret.), Red Team, which General Stafford had established to gain the efficiencies necessary to work such a time-critical issue. General Jacobson's Red Team focused its review on the following two areas:

1. The status of Mir's life support systems and the potential risks associated with those systems and with the electrical power available on Mir for normal life support systems and for science experiments

and anomalies to assess how and whether those responses reduced the risks to crew members aboard Mir

2. The corrective actions taken in response to the mishaps

On September 19, 1997, General Jacobson submitted his Red Team's findings and recommendations to General Stafford in a detailed letter that addressed the two areas described above.

Also occurring on September 19, 1997, General Stafford and Academician Utkin signed a Joint Statement in which the TF-AEC Joint Review Commission found, among other things, that the level of risk posed to the NASA STS-86 and Mir-23/24 crews did not exceed the operational limits originally accepted for this program. The Joint Statement recommended to RSA and NASA that in the future, under nominal operations, ballistic precision rendezvous plus teleoperations would not be attempted without range and range-rate information available to the crew and without the completion of adequate simulation training.

On September 24, 1997, the Stafford Task Force conducted an open meeting at NASA Headquarters in Washington, D.C., at which the Red Team's findings and the TF-AEC Joint Statement were reviewed. General Stafford polled each member of the Task Force to determine whether they concurred with the Red Team's recommendation that NASA proceed with the launch of STS-86 and the continued presence of U.S. astronauts aboard Mir. The Task Force was unanimous in its support of the Red Team's findings and recommendations. At the

conclusion of the meeting, General Stafford met with Administrator Goldin to deliver the Task Force STS-86 readiness assessment. As stated by Administrator Goldin, the Stafford Task Force's assessment was a key factor in the Administrator's decision to go forward with the launch of STS-86 and to continue long-duration U.S. presence aboard Mir.

### Mir in Stable, Productive Condition as the STS-89 Readiness Assessment Is Completed

The TF-AEC Joint Review Commission's recommendation to proceed with the launch of STS-86 and continue the Shuttle-Mir program proved to be correct as Mir entered a period of stable operations. On January 14, 1998, General Jacobson sent a letter to General Stafford containing the Red Team's STS-89 readiness assessment. The letter stated:

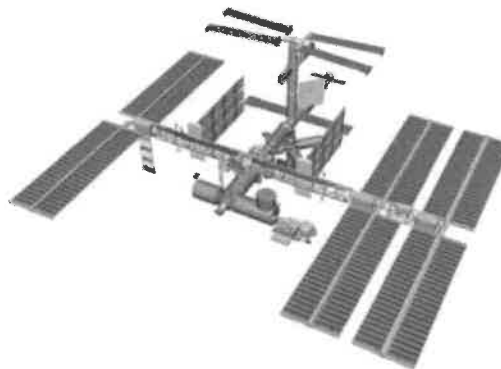
*The Red Team is satisfied that the condition of the Mir continues to be as safe as it has ever been during occupation by U.S. astronauts. We see no more risk in this mission than has been accepted on previous missions and recommend the go-ahead be given for the launch of STS-89 and to continue U.S. presence on Mir with Andy Thomas.*

The Red Team's assessment was unanimously endorsed by the full Task Force at an open meeting. In General Stafford's letter of January 15, 1998, to Administrator Goldin, in which he endorsed and forwarded the Red Team's assessment, he wrote:

*The Mir has been in a stable, productive condition since my Task Force conducted our safety assessment for STS-86, allowing Dave Wolf to focus his efforts on science experiments.*

### The TF-AEC Joint Review Commission Turns Its Attention to the ISS

The TF-AEC Joint Review Commission continued to monitor the status of Mir and was prepared to respond in a coordinated fashion to any safety or operational issue that might arise in conjunction with the Shuttle-Mir program. Such a need never arose. With Mir in a stable and productive condition, the TF-AEC Joint Review Commission, at the request of NASA Administrator Goldin and RSA General Director Koptev, began to turn its attention to ISS-related issues (Figure 6). The Stafford Task Force and Utkin Advisory Expert Council exchanged delegations in January, April, June, September, and December 1998 to review various ISS safety and operational issues. Each of these meetings concluded in protocols signed by General Stafford and Academician Utkin.



**Figure 6. International Space Station depicted in final assembly configuration.**

### STS-91 Readiness Assessment

On May 20, 1998, the Stafford Task Force conducted an open meeting at JSC to assess the readiness of the STS-91 mission, which would return the last U.S. Mir astronaut to Earth and

conclude the Shuttle-Mir program. While Mir remained in a stable condition, there were several minor issues related to the Space Shuttle that the Stafford Task Force reviewed, including:

- A gas leak that had occurred in the galley water line
- A water leak that had occurred in the relief valve for fuel cell three, which would affect how much water the Shuttle would be able to transfer to Mir
- The use of a new ISS docking mechanism on the Shuttle

With the satisfactory resolution of each of these issues, General Stafford sent Administrator Goldin a letter on May 27, 1998, stating that: "Based on this review, it is my assessment that there are no safety of flight or other operational issues which would lead me to recommend against launch at this time."

### **STS-91 Mission Concludes the Shuttle-Mir Program**

In June 1998, the TF-AEC Joint Review Commission met at KSC to conduct ISS-related reviews. While there, the Joint Review Commission members attended the launch of STS-91 on June 2, 1998. The safe return to Earth of STS-91 on June 12, 1998, with U.S. Mir astronaut Andy Thomas aboard, successfully concluded the Shuttle-Mir program (Figure 7).



**Figure 7. Space Shuttle landing.**

# 4

# Communications

Communications play an important role in any organization, but in large, complex, multinational projects such as the Shuttle-Mir program and the ISS program, the role of communications is of critical importance. To a large extent, the success of the ISS will be determined by the program's success in ensuring that adequate communications take place when necessary; this can involve people coming from different cultures, speaking different languages, and speaking from different locations.

The communications-related issues that arose during the Shuttle-Mir program (ISS Phase 1) provided invaluable experience for the assembly and operation of the ISS program (Figure 8). These communications issues fell into three basic categories:

- Ground-to-ground communications
- Space-ground communications
- Personal communications

## Ground-to-Ground Communications

In May 1994, NASA and the U.S. Embassy in Moscow/Department of State completed an agreement for establishing a NASA office at the U.S. Embassy in Moscow. This agreement paved the way for NASA to establish the NASA Moscow Liaison Office (NMLO) and the Moscow Technical Liaison Office (MTLO) at the Embassy. As NASA's eyes and ears in Russia, the NMLO and MTLO required a reliable communications system that would enable them to quickly and effectively communicate with NASA offices in the United States. Because the Russian communications systems were unreliable and inadequate for NASA's purposes, a new system needed to be installed.

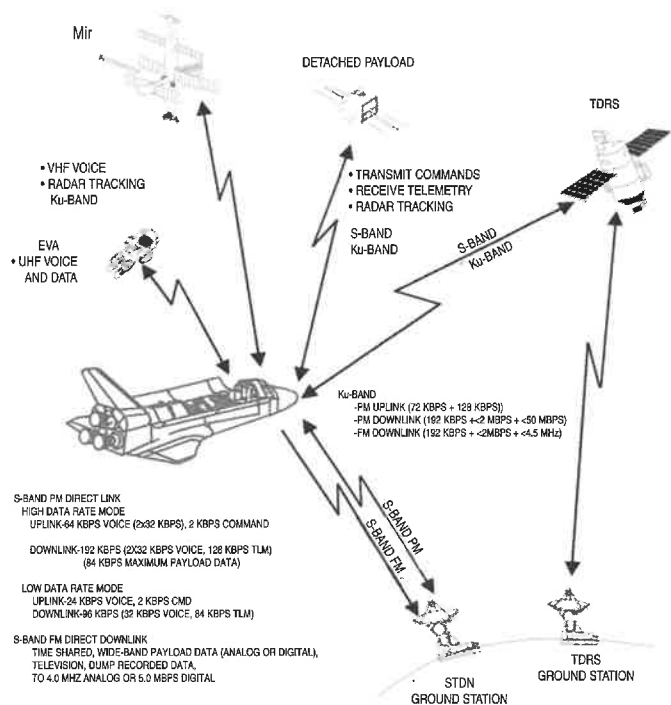


Figure 8. Phase 1 program communications overview.

In its fourth report, issued on March 1, 1995, the Stafford Task Force noted that the installation of institutional ADP/T equipment (including telephone lines, fax equipment, voice teleconferencing systems, computer equipment, etc.) in the NMLO and MTLO offices had been delayed and recommended that the implementation of ADP/T capabilities in NASA's Russia offices be given a high priority.

On April 7, 1995, Dr. Bradford Parkinson, chair of the NASA Advisory Council, wrote to General Stafford:

*I would ask that you continue your activities to . . . review the overall NASA and associated contractor presence in Russia . . . including the communications capability among NASA and contractor sites in Russia and locations in the United States.*

The Task Force issued a number of detailed findings and recommendations on this issue in its fifth report, which was released on September 21, 1995. The ADP/T capabilities of NASA's offices in Russia have steadily improved since that time. Today, adequate ADP/T capabilities exist not only at the NMLO and MTLO, but also at other NASA facilities in Russia, including the NASA offices at RSA, GCTC (Star City), and MCC-M. NASA has even established a business office at the Penta Renaissance Hotel in Moscow (lodging and central meeting location for the majority of NASA TDY personnel in Moscow) and equipped it with quality ADP/T equipment. NASA is to be commended on its commitment to establish and maintain these key capabilities and interfaces (Figure 9).

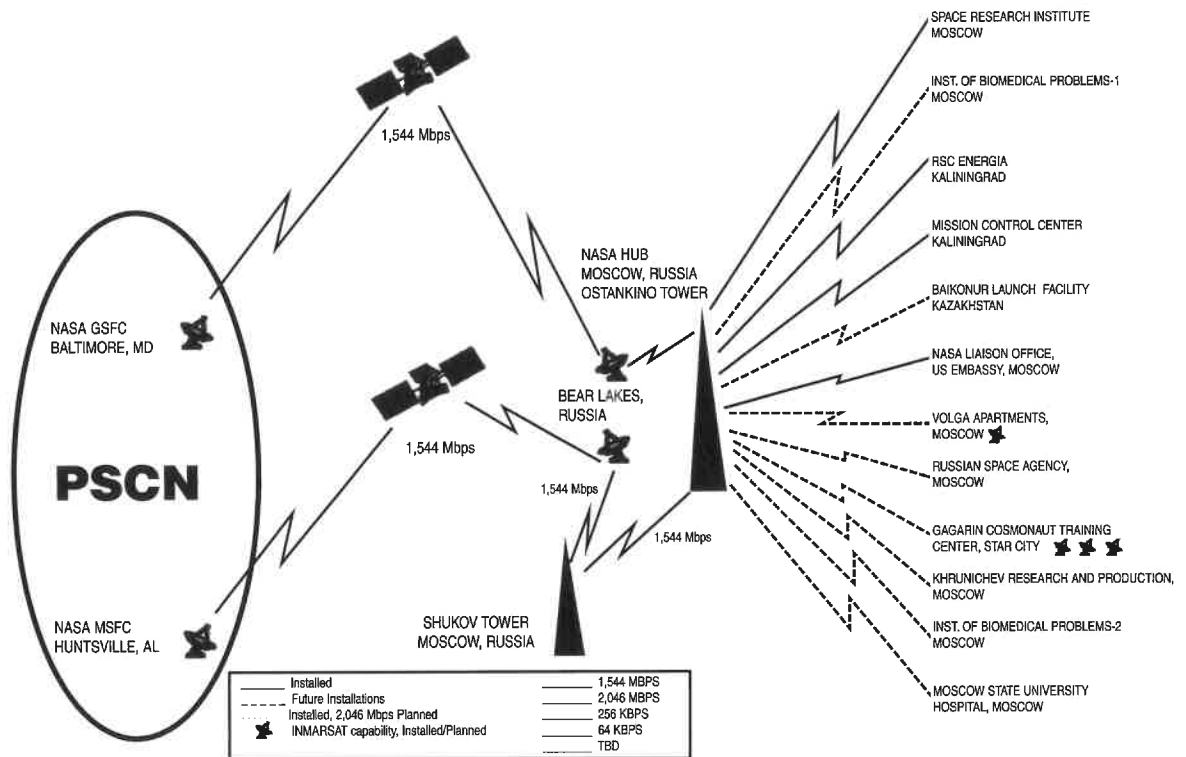


Figure 9. NASA PSCN Russian project overview.

Another important area involving ground-to-ground communications that the Task Force reviewed was the communications and coordination between MCC-M and the Mission Control Center-Houston (MCC-H). This review focused on the coordination of activities between the two control centers to facilitate crew training activities, mission planning, and joint operations.

During the readiness assessment the Task Force conducted prior to STS-86, it became clear to the Task Force that a lack of communications and coordination between MCC-M and MCC-H operations personnel contributed to the decision to attempt the experimental rendezvous procedure utilizing the manual Telerobotically Operated Rendezvous System (TORU) docking mode that resulted in the collision between the Progress vehicle and Spektr module. As a result, the Task Force recommended that communications be improved between the two control centers. Subsequent joint missions demonstrated that this was achieved.

### Space-Ground Communications

The importance of adequate space-to-ground communications was highlighted by several incidents in the Phase 1 program, including the fire in the oxygen generator and the collision of the Progress vehicle with the Mir Spektr module. In both of these incidents, data and voice were not available in a timely manner, and crews were forced to perform actions without active guidance or support from ground controllers.

Space-to-ground communications are limited to line-of-sight access provided by the relative motion of the Mir orbit with the Earth-based ground station antennas. Continuous, or nearly continuous, communications, as available for the Space Shuttle through NASA's Tracking and Data Relay Satellite System (TDRSS), take advantage of the visibilities offered by geostationary satellites and the relatively high-strength STS communications systems to communicate with terrestrial links. Similarly, the Russian Satellite Data Relay Network composed of the Luch, or Altair, communications satellite system is also available for use by Mir. Unfortunately, Mir is not capable of communicating through the TDRSS because of the link requirements and telemetry data format. In addition, communications through the Altair system have been limited because of its availability as a military asset (owing to military rules and priorities), costs to use and limitations of RSA/Energia finances, and its limited hardware and service reliability. As a result, primary communications with Mir are conducted through Russia's network of ground stations. Prior to the dissolution of the Soviet Union, the Soviet space communications network consisted of 16 ground stations and 10 oceangoing ships. Current operations are limited to 10 land installations (Figure 10).

The complexity of the Mir telemetry stream and link margins obviate the practical use of most other ground stations for telemetry; however, Mir has utilized European and U.S. ground stations (including the Wallops Flight Facility, the White Sands Test Facility, and the Dryden Flight Research Center) to handle voice and perform some tracking functions. The paucity of globally distributed ground antennas for telemetry and voice communications, coupled with the poor quality of the signal, has resulted in contact durations of slightly over 10 minutes to, in some cases, less than 5 minutes of communications per orbit (each orbit takes approximately 90 minutes). In some cases, because of the orbital ground track, the duration between communications contact with Russian ground stations can be as long as

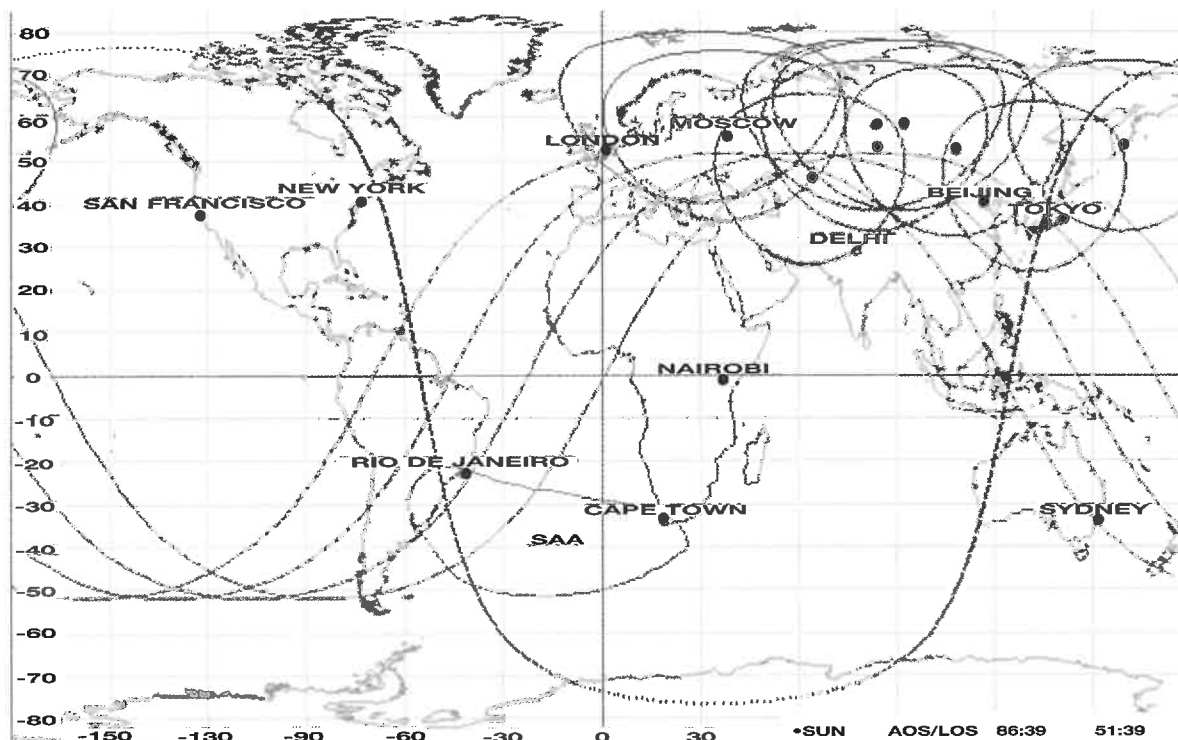


Figure 10. Mir station ground track map showing Russian ground communications station locations and resulting limited coverage.

9 to 10 hours. Many of those contacts were unusable because of dropouts, static, interference (such as a conversation between a U.S. ambulance and its dispatcher interfered with a Wallops contact),<sup>1</sup> configuration errors, the lack of language proficiency, and the lack of ample coordination. For example, although a warning of the Mir onboard fire was received by the Wallops Tracking Station, the warning was in Russian and there were no interpreters at Wallops. As a result, there was no communication of the emergency to management.

ISS operations can take advantage of the lessons learned by the Shuttle-Mir experience. Availability will be dramatically improved with the use of the TDRSS system. However, other TDRSS users, including the Space Shuttle and the Great Observatories, will vie for TDRSS availability and capacity. Any shortfalls caused by TDRSS aging and the potential transition to National Space Communications Program (NSCP) architecture need to be addressed, especially because funding for the NSCP architecture seems to be losing support. This is of particular concern because the Space Operations Management Organization has stressed, in its Consolidated Space Operations Contract competition, that NASA's migration to the NSCP architecture take place in the middle of ISS utilization.

Communications capacity is also an issue. Owing to the limited availability and the data stream requirements, bandwidth availability is limited. As a result, each communications opportunity is tightly controlled and budgeted based on the priority of communications. In the ISS era, the allocation of bandwidth will be a major issue.

<sup>1</sup> NASA 7 MD 113 POSA Report.

## Personal Communications

All of Mir's communications passes are coordinated, controlled, and monitored by MCC-M. As a result, opportunities for private communications for the American crew members were very constrained. Ham radio options, although available, were not private and therefore did not afford the opportunity for crew members to conduct private conversations with their families or with NASA management.

Many of these restrictions have their basis in the lack of opportunities for communications with Mir, which, as mentioned earlier, is a result of the limited geographic diversity of the space communications network. Regardless, the privacy concern is also a function of the communications architecture from MCC-M to MCC-H. The Task Force strongly believes that ISS crews must be given regular opportunities for private conversations with their families and home offices.



# 5 Crew Health

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In the course of Stafford Task Force reviews, issues related to crew health and safety received considerable attention. The Task Force found extensive planning and energy in both the United States and Russia over crew health and safety issues, but enough discontinuity to raise concern. There was a discontinuity of medical cultures, with genuine disagreement as to proper medical testing, monitoring, and care. There also were two parallel histories of space medicine with great pride and independence. The main areas of contention included:

- Development of a Joint Medical Plan
- Environmental monitoring and management
- Communications
- Ground safety in Russia
- Human factors

The Task Force observed a substantial resolution of these issues in the course of its deliberations.

## **Development of a Joint Medical Plan**

The development of a Joint Medical Plan proved to be an extremely difficult matter. A plan was not consummated before the start of the Phase 1 program. Absent a plan, the United States and Russia relied on mutual trust and the excellent history of the Russian space program. The development and evolution of such a plan remain crucial aspects of multinational programs and have been very carefully addressed as lessons learned in the ISS plans.

The Task Force reviewed the overall matter of collaborative medical practice and research, as well as the issue of medical ethics and the study of the cultural dimension of medical practice. Matters of ground safety, logistics, evacuation, staffing, and contingency planning were also addressed and resolved.

## **Environmental Monitoring and Management**

The Task Force could not obtain much data concerning the Mir environment because the Russians historically did not collect this kind of data. However, the biological success of their programs suggested adequate environmental management, and subsequent analyses proved the matter. At the close of the joint Phase 1 program, there were no significant environmental issues.

From April to November 1995, severe environmental challenges were experienced by the Mir crew. Temperature, humidity, and atmosphere concerns became paramount. The Task Force followed this development closely. The Phase 1 program developed a strategy for improving the temperature-humidity regimen of the pressurized compartments on Mir. The strategy

called for augmenting the cooling and dehumidifying systems onboard the Soyuz TM with the Shuttle life support systems. The Task Force was pleased with the Phase 1 program's response to this issue.

## Communications

The Task Force was concerned about the amount of time per orbit that Mir was in voice contact with MCC-M. As mentioned in Section 4, the few minutes of communications per orbit did not permit extensive time for personal communication by the crew or for medical consultation between the crew and their doctors. Communication for medical and personal matters was in strict competition with other operational priorities. This matter was not solved during Phase 1 because of technical constraints. The lack of communications contact may have played a role in the prevailing sense of isolation reported by the crew and in matters of crew performance. Indeed, it became apparent in Task Force fact-finding meetings that crew health issues were neither rare nor trivial among the cosmonauts. The persistence of this communication situation was addressed as the single issue of crew health in the Task Force's fifth report.

After the review of the Soyuz TM-21 joint mission data, the Task Force found that the U.S. crew had feelings of isolation aboard the Mir station, enhanced by a lack of dedicated space-to-ground communication, conversation with family, and contact with other aspects of American culture. Subsequently, NASA negotiated additional communication time, using existing communications links, and a protocol was signed between NASA and the Russians that provided for this expanded communications linkup.

## Ground Safety in Russia

Prior to the TM-21 launch, the Task Force raised concerns related to the emergency medical support for the U.S. crew and support personnel at the Baikonur Cosmodrome and launch facility in Kazakstan. The Task Force found a disconnect between the Russian medical system and NASA's medical expectations. Specifically, the Task Force recommended that all U.S. personnel traveling to Baikonur, where hepatitis B is epidemic, receive hepatitis B inoculations. The Task Force also recommended that a NASA flight surgeon be cleared to accompany the TM-21 U.S. crew member from the Baikonur launch site to Moscow, in the event of a launch mishap. In response to this concern, a NASA flight surgeon was cleared to accompany the TM-21 crew member to Moscow. In addition, the Task Force recommended that the flight surgeons at Baikonur be provided with an independent communications capability allowing direct access to JSC. In response to this recommendation, the NASA flight surgeons were provided with satellite communications links providing direct access to JSC. The Task Force also identified the need to augment the flight surgeon, onsite at the Baikonur launch facility, with a registered nurse/emergency medical technician to assist in the stabilization of the U.S. astronaut in the case of a launch mishap. A registered nurse with intensive care unit (ICU) training was then hired as a consultant, and arrangements were made to provide transportation from Baikonur to support the flight surgeon during the launch phase.



Figure 11. Map showing locations of Baikonur launch facility, Moscow, and U.S. medical facilities at Frankfurt, Germany.

The Task Force also identified a need for the continuity of support in the event of an emergency evacuation from Moscow to a tertiary American hospital facility (Figure 11). Discussions with U.S. Embassy personnel in Moscow resulted in medical plans involving both private and Air Force assets, with all the appropriate preclearances in place.

During discussions with the Russians regarding cosmonaut safety aboard the Space Shuttle on the STS-60, STS-63, and STS-71 missions, the Russians expressed concern over the level of protection provided by the Launch and Entry Suits worn by Shuttle crew members. The Russians were assured that with NASA's procurement/delivery schedule, adequate numbers of ACES-LES (Advanced Crew Escape System-Launch and Entry Suit) garments would be available in adequate numbers and sizes to accommodate all Russian crew members participating on Shuttle flights.

## Human Factors

During the discussions surrounding STS-60, STS-63, and STS-71, the Russians expressed concern related to restrictions placed on the use of treadmills, rowing machines, and other

exercise devices during joint Mir-Shuttle docking missions. The Russians were particularly concerned about the degradation in physical condition of their crews during the time these restrictions were enforced. In response to these concerns, the medical experts from NASA and Russia agreed that these restrictions could result in significant physical deconditioning of the Mir crews and that consideration must be given to coordination between structures and operations experts in developing alternate exercise opportunities and equipment.

In addition, the Task Force found that crew technical and medical support issues were not being well coordinated among the Phase 1 Working Groups or at the Technical Interchange Meetings (TIM). The Task Force and Advisory Expert Council recommended that for effective coordination, technical and medical support issues must be jointly discussed and that Russian working group specialists should attend the TIM's. These issues underscored the need for continued U.S.-Russian efforts to study human factors in connection with Mir space operations to mitigate future risks.

In 1997, the Task Force reviewed a number of difficult matters, including a fire, a Progress-Mir collision, repeated computer failures, and a deep concern about the mechanical competence of the 11-year-old Mir station. The medical concerns were profound. The cooperation between the Stafford Task Force and the Utkin Advisory Expert Council was significant during this period as the two groups studied the issues without much of the defensiveness that had occasionally marked earlier times in U.S.-Russian collaboration. Candid dialog among colleagues with shared issues and concerns, and mutual trust in professional judgment, marked the study and analysis.

Human factors may have played a role in Mir's difficult 11th year. The Task Force found reason for concern about isolation, group psychology, team building, training on the ground, continued training and drills in orbit, and communications. Although space stations are rightly seen as a triumph of human skill and engineering, they are also fragile craft that bring along our highly imperfect species as the only interactive cargo—the only element on the craft that can learn and translate the lessons of space for our evolving population on Earth. Space is humankind's destiny, and we cannot go there entirely by proxy. However, our humanity, for all its richness, will not behave with the crisp predictability of exquisitely engineered materials. It remains the Task Force's emphatic recommendation that human factors relative to Mir and future space travel must be studied by all who participate in space programs to assure the best in human performance. We must assure for humans in space a safe and productive environment for work, living, interaction, communication, and reflection. Mir was an invaluable laboratory to study long-term human presence in space, and its lessons must be studied and the indicated research for the future realized.

# 6. Management

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Multinational management issues proved to be one of the major challenges and successes of the Phase 1 program. During the Task Force effort, the following management issues were addressed:

- Organizational structure
- Multinational systems integration
- Development of an effective multinational management team

## Organizational Structure

During the early work of the Task Force, the supporting management structures for Phase 1 were a principal concern because a coherent infrastructure did not exist. At its second meeting, held at JSC, July 12–13, 1994, the Task Force reviewed the Phase 1 management structure with a focus on program objectives, various support requirements, and existing functional capabilities and organizations.

The Task Force summarized its findings and recommendations from this meeting in its second report, issued on July 29, 1994. As noted in the report, the Task Force found:

*[T]here is no one person or organization clearly in charge of the Shuttle-Mir (Phase 1) Project . . . there are at least four different organizations that claim some management responsibility for Phase 1: the JSC Russian Projects Office, the ISS Phase 1 Manager, the (NASA/RSA Phase 1) Joint Management Working Group, and the Phase 1 Mission Director.*

The Task Force recommended, among other things, that NASA should:

1. Establish a Phase 1 Project Manager and a Phase 1 Project Office at JSC (reporting directly to the Associate Administrator for Space Flight) and delegate to them the responsibility for integration, flight preparation process, and accomplishment
2. Matrix the JSC Russian Projects Office, the NASA/RSA Phase 1 Working Groups (except the Management and Safety Assurance Working Groups), and the ISS Russian Programs Phase 1 Office to the Phase 1 Project Office
3. Designate a Requirements Integration Manager and a Public Information Officer to report to the Phase 1 Project Manager
4. Matrix the Public Relations Working Group to the Phase 1 Public Information Office
5. Designate the ISS Program Manager as the sole source of ISS risk mitigation requirements and the Associate Administrator for Life and Microgravity Sciences and Applications as the focal point for international research requirements and priorities

In response, NASA concurred and largely implemented these recommendations. A Phase 1 Project Manager (reporting to the Associate Administrator for Space Flight) was established at JSC with a staff dedicated to the management of the Phase 1 activities, and the JSC Russian Projects Office was integrated into the Phase 1 Project Office. Matrixed support was designated and provided as recommended, with the ISS Russian Programs Phase 1 Office remaining within the ISS management structure. In virtually every aspect, the intent of the Task Force recommendations was considered and fully implemented. The Task Force members were gratified by the overwhelmingly positive response to their findings and the speed with which they were implemented. In particular, the establishment of a Phase 1 Project Manager and a Phase 1 Project Office at JSC was essential in ensuring the success of the Phase 1 program (Figure 12).

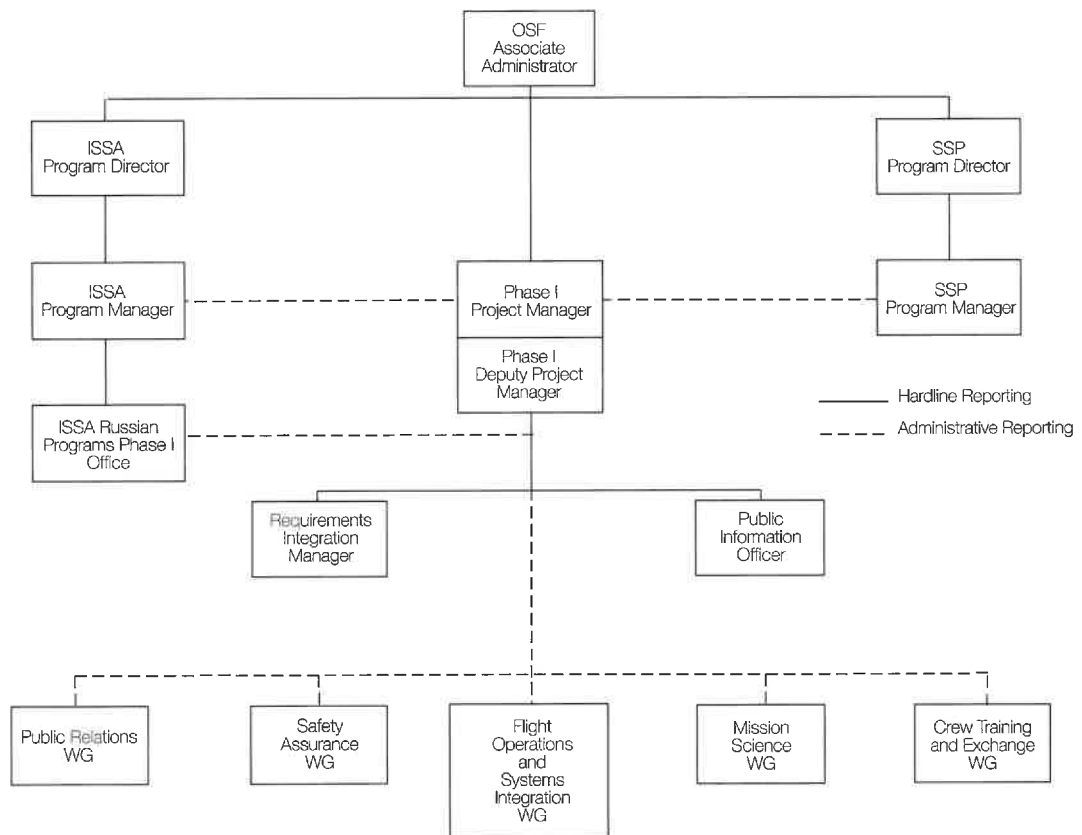
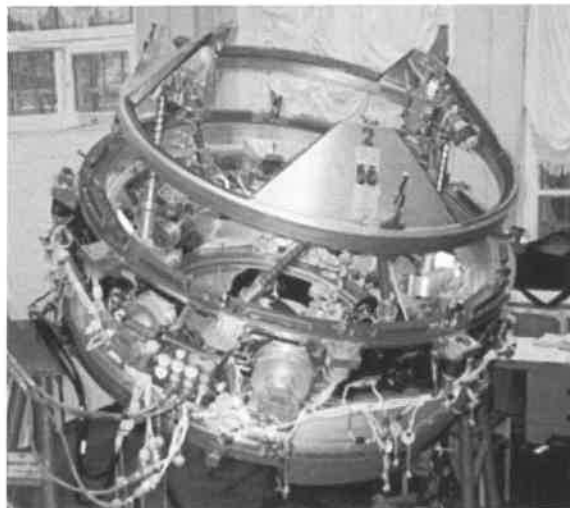


Figure 12. Phase 1 organizational structure.

### Multinational Systems Integration

During meetings held prior to the release of the Task Force's third report on November 2, 1994, the Task Force evaluated the role of Rockwell in integrating the Russian-built Orbiter Docking System. The Task Force concurred with the NASA decision to use Rockwell in this way and recommended that NASA take action to capture this experience and knowledge and develop the required working relationships with RSA prior to the transition to the ISS. In turn, NASA formed a Docking Mechanism Integrated Product Team to provide technical management and oversight for the acquisition of the docking system manufactured by RSC-E for Phase 1 and Phase 2 (Figure 13).



**Figure 13. Brassboard of the Androgynous Peripheral Docking Assembly (APDA), which was designed and manufactured in Russia.**

### Development of an Effective Multinational Management Team

In its fourth report, issued on March 1, 1995, the Task Force addressed the importance of establishing and maintaining long-term professional and personal relationships between U.S. and Russian specialists and managers. The Task Force stated:

*A principal element in the development of mutual trust is the continuity of the NASA team. For the Russians, many of whom have been working within the same area for years and even decades, it is important to deal with the same individuals on the NASA side over time. Only through this continuous exposure and common effort can the necessary joint technical proficiency and trust be established.*

This concern over the impact on the program of any loss of experience on the NASA side led the Task Force to recommend that every effort be made to retain key U.S. personnel who interfaced with Russian organizations.

NASA was successful in ensuring that most of the key personnel did remain in place during the Phase 1 program. In addition, a number of key NASA personnel with Phase 1 experience transitioned into the ISS program, including the Phase 1 Director and Deputy Director. Maintaining the personal and professional relationships between American and Russian specialists and managers will continue to be important to the success of the ISS program.

To facilitate the development of these relationships and to ensure proper technical integration, NASA began in mid-1994 to establish a permanent presence in Russia. Such an extensive presence was unique in the Agency's international experience in both scope and depth. Given the critical nature of these efforts, the NASA Administrator and senior NASA management saw a need for an independent review of NASA's presence in Russia.

As a result, on April 7, 1995, Dr. Bradford Parkinson, chair of the NASA Advisory Council, requested that the Stafford Task Force:

*... review the overall NASA and associated contractor presence in Russia. Specific areas of interest are: structure and relationship of NASA organizations participating in the Phase 1 Program at all sites in Russia; the working relationship among civil servants and NASA contractors in Russia; the distribution of human resources between Phase 1 and Phase 2 activities, including the adequacy of current staffing levels; and the communications capability among NASA and contractor sites in Russia and locations in the United States.*

Following detailed briefings and a trip to Russia, the Task Force, in its fifth report issued on September 21, 1995, recommended that the planned position of NASA Representative in Russia be expedited and that the selection process to name a representative be completed as soon as possible. To maximize the benefits to the Phase 1 program, the Task Force recommended that NASA develop written guidelines that would allow the NASA Representative in Russia to build a credible charter. The Task Force suggested that the NASA Representative in Russia be designated to speak for the Administrator on behalf of all NASA elements operating in Russia and be delegated a series of responsibilities consistent with his oversight and coordinating roles. The Task Force also recommended that each NASA organization operating in Russia provide a charter of its activities to the NASA Representative and coordinate and provide regular status reports to him.

As was the case with the Task Force's recommendation that NASA establish a Phase 1 Program Manager, NASA responded very favorably and soon named a NASA Representative in Russia. The Office of External Relations accepted the challenge of working with the program, staff, and budget offices to develop a charter for the NASA Representative in Russia, as well as clearly define the reporting chain for all NASA operations in Russia. This charter was signed by each of the Associate Administrators at NASA Headquarters and went into effect on October 28, 1997. The NASA team at MCC-M and the Director of Operations in Russia, located at Star City, sent the NASA Representative and the NMLO regular reports on their activities. The Phase 1 program kept the NASA Representative and the NMLO informed about the travel of all individuals or groups traveling to Russia and the purpose of the trips. In all essential ways, NASA responded quickly and positively to the recommendations of the Task Force.

The management structure, experience, and personal contacts established during the Phase 1 program should serve NASA well in transitioning to Phase 2 of the ISS program.

# 7 Operations

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The United States and Russia have taken different approaches to human space exploration. The U.S. experience has focused on short-duration missions with specific science and operational goals. The knowledge and experience gained from each mission were incorporated into succeeding missions. Russia, on the other hand, has focused on establishing and maintaining a permanent human presence in space. The knowledge and experience that it gained were incorporated into spacecraft that were already in orbit. These different experience bases have driven the U.S. and Russian space programs to develop different operations philosophies and procedures.

One of the primary goals of the Phase 1 program was for the United States and Russia to integrate these experiences and learn how to work together in space. The Stafford Task Force focused much of its attention on helping to ensure that this integration of operations philosophies was completed successfully and safely.

In the course of the Task Force investigations, the following operations-related topics were addressed:

- STS-63 test of hardware and operational procedures
- Orbiter Docking System/96-bolt EVA
- Active stack attitude control
- R-Bar approach/Reaction Control System (RCS) plume impingement
- Ku-band antenna power levels
- Untended Mir operations
- Solid-fuel oxygen generator fire
- Progress-Mir collision
- Space Shuttle orbiter

## **STS-63 Test of Hardware and Operational Procedures**

STS-63 represented the only opportunity to test the hardware techniques and operational procedures to be used in Mir rendezvous and proximity operations before attempting the first Shuttle-Mir docking mission on STS-71. The Task Force recommended that the primary objective of STS-63 should be the execution of the planned rendezvous and proximity operations. It also recommended that the launch date for STS-63 be moved forward as much as possible to allow the U.S. and Russian space programs as much time as possible to assimilate the lessons learned from this experience. The Space Shuttle Program Office was already discussing the importance of gaining this experience, and the STS-63 flight requirements documents were updated to reflect increased priority of the rendezvous and proximity operations above the Spacehab-03 operations. However, the program study found the results of even a modest acceleration of the STS-63 launch date to be too costly in terms of STS-63 processing time, the OV-105 launch schedule and flight rate for FY 1995, and the concern of processing crews at KSC.

In addition to the general recommendation of elevating the priority of the rendezvous and proximity operations of the STS-63 mission, the Task Force made several specific recommendations:

1. The verified Shuttle Plume Impingement Flight Experiment (SPIFEX) data from STS-64 must be made available on or before February 15, 1995; the Shuttle Engineering Simulator (SES) should be updated with those data in adequate time to support STS-71.
2. STS-63 should perform Hand Held Laser (HHL) tests against the Mir complex and determine range and range-rate accuracy and stability.
3. STS-63 should perform a range and range-rate checkout of the Trajectory Control Sensor (TCS) against the Mir complex.
4. The Mir Approach Detailed Test Objective (DTO) should be fully implemented.
5. The Space Shuttle should approach to within 30 feet of Mir on STS-63 to accomplish the Near Mir Fly-By Detailed Test Objectives.
6. The Color Television Camera (CTVC) should be manifested on STS-63 and mounted in the Spacehab module to simulate the STS-71 docking system camera.
7. The value of performing attitude flyout tests in Low-Z should be investigated using the CTVC mounted on the Remote Manipulator System elbow camera location.
8. A launch-on-time policy should not be instituted because it could result in missions being scrubbed that might otherwise be launched within the existing 5-minute window.
9. No redundant Payload Bay VHF antenna is required for Shuttle-Mir missions.
10. The test plan for the STS-63 window-mounted antenna should include a performance assessment with respect to Mir antenna patterns.

The Phase 1 Program Office concurred with all of the Task Force recommendations and had already begun the implementation of many of them as part of normal progression. The SPIFEX data from the STS-64 flight provided confidence in the existing plume models, and when implemented into the SES, the resulting analyses helped reduce concerns of the Russian experts with regard to STS RCS plume impingement loads and contamination on the Mir solar panels. This in turn allowed for a bilateral decision for the Shuttle to approach to within 30 feet of Mir, accomplish the Near Mir Fly-By Detailed Test Objectives, and ensure that the Mir Approach DTO was fully accomplished. The HHL, TCS, and VHF antenna tests were completed, and data from these tests provided confidence in these systems for the Mir rendezvous and docking missions to follow.

The CTVC was mounted in the right overhead window of the Spacehab for lighting and resolution evaluation. However, because the approach to 30 feet could be accomplished without the use of the CTVC and because the Commander was intent on not violating the 30-foot distance, the CTVC image was not evaluated. This was not a major impact of the use of the CTVC on subsequent docking missions, but the need to continuously focus the camera during the approach, a characteristic not present in the scene-generated simulations, was not identified until the following (STS-71) docking mission. Prior to being notified of the Task Force recommendation regarding the launch-on-time discussions, the Phase 1 Program Office had reached the same conclusion and hence concurred to plan for a launch window strategy.

## Orbiter Docking System/96-Bolt EVA

The Orbiter Docking System (ODS), which executed the latching and hard dock functions of the Shuttle-Mir docking sequence, used two Androgynous Peripheral Docking Systems<sup>2</sup> (APDS) that were manufactured by RSC-E. A description of this mechanism and sequence can be found in the Task Force's second report dated July 29, 1994. The baseline design provided only one backup system, pyrotechnic bolts, to separate the orbiter and Mir if the mechanical system failed. During development testing, two incidents were cause for significant effort to ensure the safe and positive separation of the two vehicles. One of the active hook cables (hook-cable-actuator assembly) frayed in the proximity of a pulley mechanism, and the deformation of a ball-screw actuator housing was discovered during testing.

In addition, the ODS docking base was attached to the Shuttle External Airlock by 96 bolts (Figure 14). An inspection of the engineering, or brassboard ODS, at the Rockwell facilities in Downey and Seal Beach, California, indicated that the 96 bolts seemed to be accessible by EVA and that the bolt torques (80–105 in-lb.) were low enough for orbiter EVA tools to be used.

The complexity of the Androgynous Peripheral Docking Assembly (APDA) and the test anomalies experienced were of concern to the Task Force. The single level of redundancy for mechanical separation combined with a lack of available reliability and safety certification data for the pyrotechnic bolts encouraged the Task Force to recommend:

1. The ODS active hooks will be cycled as part of the ODS testing to be conducted at KSC prior to STS-71.
2. The EVA approach to remove the 96 bolts . . . should be developed and baselined as a contingency approach for APDS mechanical system and pyrotechnic failures.

The Program Office was in full concurrence with the recommendations. After the redesign of the pulley wheel channel, a full-cycle test program of the active hooks was performed at KSC prior to STS-71. The removal of the 96 ODS bolts by EVA was established as a contingency de-mate option. The required EVA tools, procedures, crew training, and stowage requirements were identified and developed. ODS mockups were built for the Weightless Environment Training Facility (WETF), and the EVA crew was thoroughly trained for the contingency procedure.

The APDS mechanism performed flawlessly during the STS-71 mission—and in fact throughout the remainder of the Phase 1 program. Because of structural limitations, the ISS will

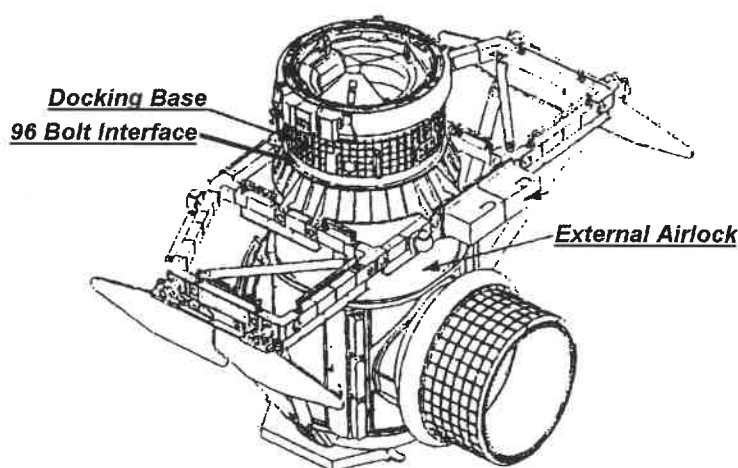


Figure 14. External Airlock and Orbiter Docking System showing location of the 96-bolt interface.

<sup>2</sup> The term APAS is a carryover from the Apollo-Soyuz Test Project and was sometimes used in ISS technical discussions. However, the official U.S. terminology is APDA or APDS, where:

APDA = Androgynous Peripheral Docking Assembly (the mechanism itself)

APDS = Androgynous Peripheral Docking System (mechanism + switching boxes, cabling, etc.)

APAS = Androgynous Peripheral Attachment System (Russian term for the Apollo-Soyuz system)

170 feet before Mir was maneuvered to docking attitude. Once Mir had maneuvered to attitude, the time for the Shuttle to effect docking was reduced to 25 minutes.

## **Ku-Band Antenna Power Levels**

The level of electromagnetic radiation of the Shuttle Ku-band antenna in radar mode at full power exceeded the permissible level of electromagnetic influence on some of the structural elements and equipment of the Mir station. Additional concerns were expressed with regard to the operation of the system in the presence of EVA crew. The Ku-band power limitations and software masking were already employed in the operational procedures, but based on data and analysis of the STS-63, STS-71, and STS-74 flights, it was determined that restrictions and limitations should be examined and, if necessary, additional restrictions should be established.

The Shuttle Ku-band system operated under established procedures that provided dual-redundant protection for both radar and communications functions. Power was automatically switched to low at radar lock-on and was backed up by manual switches. In the communications mode, automatic software masking protected the Mir modules from antenna radiation. This technique was approved as being satisfactory; in addition, the Mir Ku-band antennas were turned off once the Shuttle approaches to within 100 feet. Most of these restrictions and limitations were in place and needed only to be reviewed and confirmed as safe for operations. The Task Force played no active role in the decision, but concurred with the process and conclusions.

## **Untended Mir Operations**

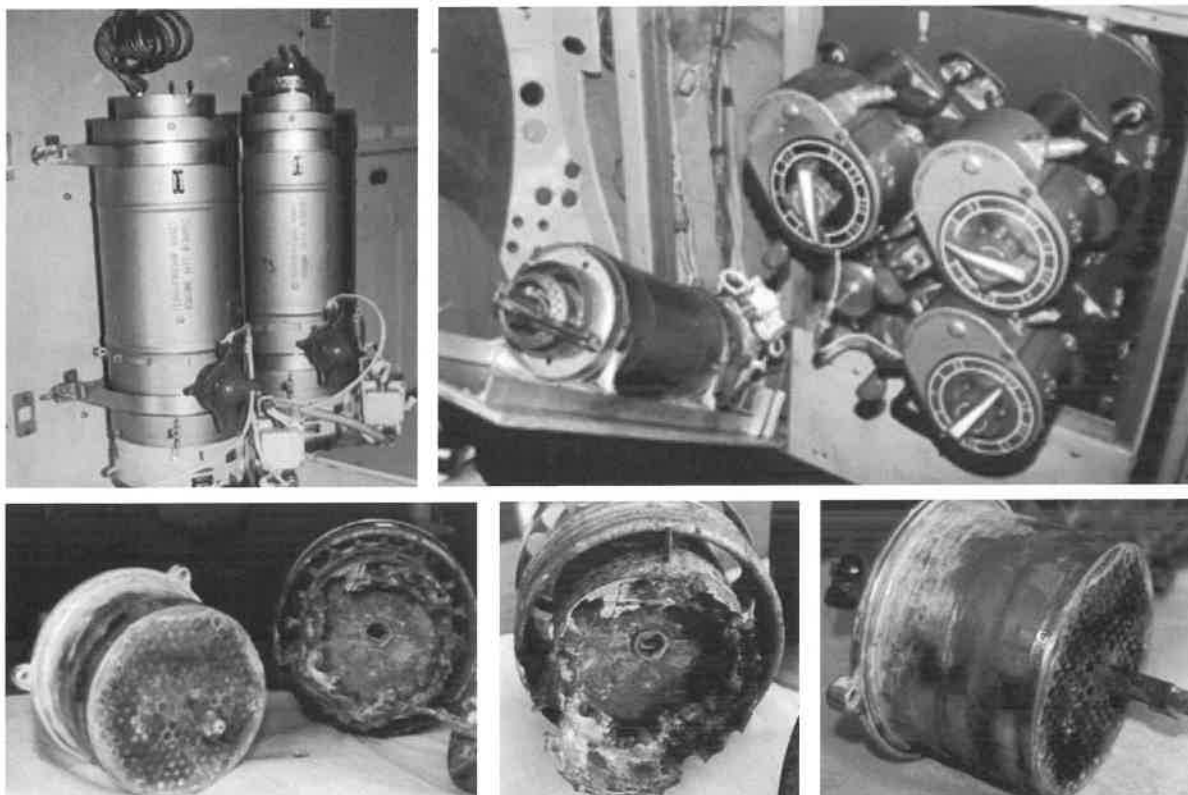
During the Mir-19 mission, the Task Force learned of a desire by the Russians to obtain photos of the mated Shuttle-Mir stack and of the undock and flyout maneuver using the Soyuz TM-21 vehicle. Because the Soyuz was the only return vehicle available to the Mir crew, both Mir-19 crew members would be aboard, leaving Mir unattended. The rationale presented stated that if the Soyuz was unable to redock with the Mir, a crew member left aboard would be without an emergency escape vehicle. Concern was expressed because of previous Mir ACS anomalies, but the fact that Mir was a Russian vehicle and that no American crew were directly involved made it difficult for the United States to influence the decision.

Prior to the STS-71 undock and flyout maneuver, the Mir-19 crew boarded the Soyuz, undocked from Mir, and maneuvered to a distance of 305 to 366 feet from Mir to photograph the undocking of Mir and *Atlantis*. After *Atlantis* had undocked, an erroneously built command was sent from MCC-M, which resulted in Mir's loss of attitude control and transition to free drift. The Mir-19 crew displayed superb piloting skills by executing an immediate return and manual docking maneuver. Under established flight rules, the Shuttle would not dock with Mir in free drift. Had the Soyuz crew been unable to dock, they would have been forced to return to Earth, and Mir would have been untended for an unplanned, extended duration. Because of the level of crew activity required to maintain Mir systems, this could have jeopardized, or even resulted in the loss of, Mir and resulted in the termination of the Phase 1 program.

The Task Force expressed strong objection to conducting any activities involving unmanned Mir operations for other than mandatory reasons. Both NASA and RSA agreed to evaluate and consider conducting external photography of the station only during opportunities such as Mir crew rotation. The NASA Phase 1 program management in turn stressed the risks inherent in such operations and requested that untended operations be conducted only when necessary to conduct essential repairs or maintenance on Mir. There were no further operations conducted by RSA that involved an untended Mir.

### Solid-Fuel Oxygen Generator Fire

On February 23, 1997, at 22:35 DMT, a significant incident happened onboard Mir in the Kvant-1 module. Shortly after ignition of a solid-fuel oxygen cassette in the solid-fuel oxygen generator (SFOG), a fire erupted from the end of the generator where the solid-fuel cassette is loaded (Figure 17). Mir-22 Commander Valery Korzun attempted to grab a wall-mounted fire extinguisher and experienced problems because the fire extinguisher launch pins were still installed. Subsequently, he grabbed an unrestrained fire extinguisher and activated the gas mode. He then grabbed a second extinguisher and activated the water mode. Because of the thick smoke and steam, the crew quickly donned gas masks and, per the emergency checklist, manually shut off the core and Kvant-1 module ventilation systems. The remaining modules had automatic shutoff of their ventilation systems when smoke detectors were activated. Some of the gas masks did not activate when first used and



**Figure 17. Solid-fuel oxygen generator (SFOG) showing stowed and operational locations (top photos) and components damaged during February 23, 1997, onboard fire incident (bottom photos).**

required activating a second gas mask. After the fire was extinguished and the situation stabilized, all atmosphere air revitalization systems were turned on, and the smoke began clearing after about 20 minutes.

RSC-E formed a commission to investigate the cause of the fire, and their findings were communicated to the Phase 1 Program Office. The SFOG and cassette used for the Russian space program were the same type as provided for many years in Russian submarines. The cassettes undergo a thorough initial test of propellant, and then a 1-percent random lot testing in the SFOG. Records showed that 2,425 units had been activated in space and an additional 1,500 on the ground without this failure being observed. The commission believed that the most probable cause of the cassette ignition was damage to the cassette body (case) or plugging of the gas flow outlets. However, even after numerous attempts simulating the suspected causes, ground testing was not able to reproduce the occurrence. The commission concluded that the cassette failure was an isolated event. In addition, the commission recommended additional crew safety procedures and emphasized strict adherence to onboard SFOG operating procedures.

Throughout the commission's investigation, the Task Force was able to maintain current status because TF-AEC member Yuri Grigoriev, Deputy General Designer for RSC-E, was also a member of the commission.

Fortunately, there were no injuries resulting from the incident, and the damage was relatively minor. However, a major concern was that the process for informing NASA of the fire was not conducted in the timely manner agreed to by U.S. and Russian technical and medical representatives. The fire occurred shortly after NASA support personnel left MCC-M for the evening. NASA's operations lead did not find out about the incident until returning the next morning. While the steps taken by the crew and ground operations personnel were timely and correct, the NASA operations lead and flight surgeon should have been notified immediately. Through its communication with Yuri Grigoriev, the Task Force was able to emphasize the magnitude of NASA's concern to the Russian commission.

In addition to the communications issue, numerous lessons learned regarding types and locations of fire extinguishing equipment, design criteria for crew-operated hardware, and crew procedures to preclude blocking escape paths were included in the Phase 1 lessons learned to be applied to the ISS.

## **Progress-Mir Collision**

On June 25, 1997, an on-orbit test of a system designed to demonstrate the ability to manually rendezvous and dock an unmanned Progress cargo vehicle with the Mir space station was performed, without using KURS range and range-rate information. The Progress vehicle collided with the Spektr module, initiating a depressurization and forcing the crew to seal off the Spektr from the rest of the station, cut data cables, and disconnect cables supplying electrical power from the Spektr solar panels. As a result, the Mir space station lost 35 percent of its power.

After the collision, RSC-E released a report that singularly concluded the cause of the collision to be crew error. Data available to the Phase 1 Program Office suggested a number of

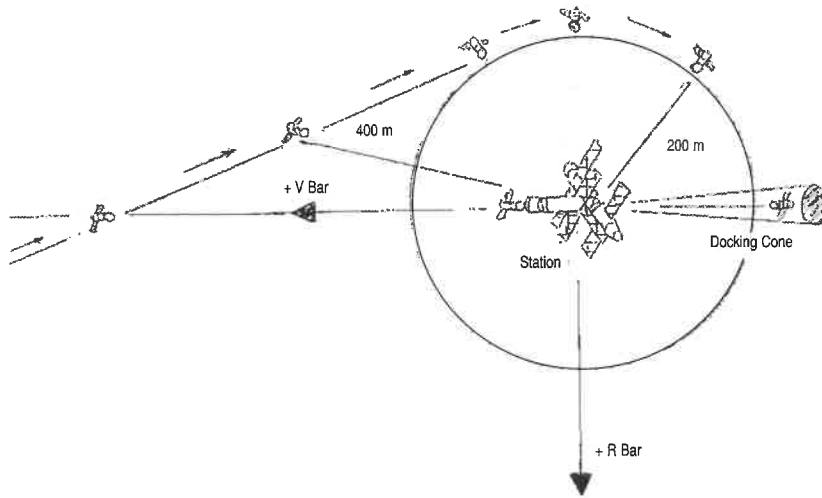
contributing factors that were not addressed in the RSC-E report. In the interest of avoiding a recurrence during ISS operations, and with no intent to affix blame or responsibility, the Task Force was asked to assess the available data and report its findings.

The Task Force was briefed on the initial available data in July 1997 and began to work with program office personnel assembling pertinent hardware, operations, and training information. In September 1997, the TF-AEC Joint Review Commission met with key representatives from RSC-E, GCTC, IBMP, RSA, and TsNIIMash to discuss and better understand the cause of the collision. In submeetings conducted under optimized conditions during the week prior to this full TF-AEC meeting, General Stafford and members of the Task Force had the opportunity to share with Academician Utkin their operational experiences and to express with sincere conviction their deep concerns.

These concerns and convictions were apparently relayed to all the representatives mentioned above, as the meetings were successful in fully identifying and discussing all of the identified disparate, contributing causes of the collision. As described in Section 5, "Crew Health," of this report, "Candid dialog among friends with shared issues and concerns marked the study and analysis." The TF-AEC Joint Review Commission agreed that there was no single cause that could be identified as being the sole or root cause of the accident. It was the cumulative effect of the following string of events and conditions that led to the collision:

- The rendezvous and docking procedure (which was attempted as a test with the objective of determining whether a manual rendezvous and docking could be completed without range or range-rate data) was questionable. This questionable experimental docking mode was being attempted for the first time.
- The test planning was inadequate.
- The safety review process of the test was inadequate.
- Ground rendezvous training for the crew had not included the fidelity of the moving Earth and cloud background images, which added significantly to the complexity of the task.
- It had been 5 months since the crew had undergone minimal rendezvous and docking simulation training. Because Mir lacked an onboard simulator, there was no way for the crew to practice and maintain proficiency—and no way to evaluate the crew's skill.
- The crew and ground lacked referenced or relative vehicle attitude information.
- The accuracy of the method for determining the critical parameters of range and range rate was inadequate. The approaching Progress vehicle recorded (with a TV camera) the image of Mir, which was then transmitted to Mir and projected on a small black and white display for the crew. A grid of squares, which overlaid the display, was used to estimate range and range rate based on the relative size of the image and squares. Because of apparent dimensional variations with relative vehicle attitudes, and the system's limited resolution, this method has considerable ambiguity, which is manifested as range and range-rate errors. These estimates were further complicated by the moving Earth and cloud background (Figure 18).
- The crew was at the end of a difficult long-duration mission and, as a result, fatigue and stress could have been a contributing factor.
- There was a lack of adequate ground communications; the crew was out of radio contact during the time of the collision.
- The location and orientation of the Progress reaction control thrusters with respect to the center of gravity resulted in the Progress gaining relative velocity when the pitch maneuver was performed.

- Propellant limitations reduced maneuver options and limited the crew to only one rendezvous attempt.
- The thrust of the Progress engines used for braking was lower than nominal, which resulted in the initial relative velocity of the Progress being higher than normal.



**Figure 18. Typical Progress rendezvous path showing overhead approach, resulting in Progress camera transmitting Mir image with moving Earth-cloud background.**

The TF-AEC Joint Review Commission signed a protocol on September 19, 1997, in which it made the following recommendations to NASA and RSA:

1. Under nominal operations, ballistic precision rendezvous plus teleoperations will not be attempted without range and range-rate information available to the crew. Emergency operations, such a rendezvous, may be attempted, provided U.S. and Russian experts both agree with safety conditions for the crew and station, and communications are in place to ensure success. TORU at proximity operations, which has been shown to be controllable, is an acceptable mode of operation.
2. Additional analysis should be performed and corrections made to the procedures for the implementation of the Ballistic Precision Maneuver (BPM)+Teleoperator (TORU) mode of rendezvous and docking operation to prevent crew errors and their possible consequences by including in the procedures the criteria to assess flight safety.
3. The scope and plan of crew training should be modified in terms of TORU mode rendezvous, including the appropriate monitoring for safety assurance.
4. To enhance the reliability of the BPM+TORU mode rendezvous, it is necessary to consider equipping the crew with a means for objective monitoring of relative motion parameters, specifically the employment of laser range finding and a display of the range and range rate.
5. Experimental rendezvous operations should be planned and implemented only by agreement with all parties concerned, and when in contact with MCC.
6. The flight engineer should support the crew commander in all manual rendezvous and docking procedures.
7. An onboard TORU simulator should be developed.
8. The TORU training facilities should be upgraded by including a simulation of the ambient background visual conditions.
9. New experimental modes affecting flight safety should be tested only after their evaluation by Russian and U.S. experts in terms of technical feasibility, completeness, verification by ground tests, and certification of flight readiness according to existing regulations.

10. To clarify the significance of the above-mentioned factors, it is necessary to produce an integrated analysis of the Progress M-34 vehicle rendezvous using the resources of both RSC-E and GCTC, together with TsNIIMash participation.
11. A decision on the further test and verification of the BPM+TORU mode should be made only after all of the above recommendations have been implemented.

## Space Shuttle Orbiter

The ability of the Space Shuttle vehicle and program to accommodate late changes in schedule, manifest, crew size, procedures, and operational requirements contributed greatly to the success of the Phase 1 program. The orbiter proved to be a reliable, flexible, durable, and most accommodating vehicle for a significant stream of new, unique, and demanding requirements.

The capabilities of this unique asset will be required to an even greater extent as the assembly and full-up operations phases (Phases 2 and 3) of the ISS are engaged. Demands for potential ISS reboost, attitude control, logistics, crew exchange, and flight frequency must be factored into vehicle performance capability, ground support requirements, systems, and crew task (software, controls, and displays) planning.

The ISS Program Office must work closely with the Space Shuttle Program Office to ensure the identification of long-range operational requirements. NASA must support identified safety and operational improvements of the Space Shuttle to assure a safe and successful assembly and operation of the ISS.



# 8 Planning

The Shuttle-Mir and ISS programs are not only technically challenging, they are also challenging from a program/project management planning perspective. During the course of the Stafford Task Force review of Phase 1 activities, the Task Force identified several issues in the area of program/project planning. Some of these issues were very mission specific, while others were of a more general program/project planning nature. These issues were addressed in the following two areas:

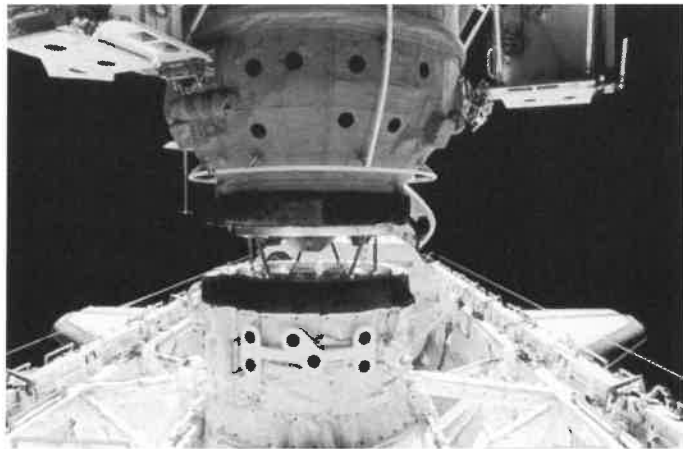
- Multinational systems integration
- Mission and contingency planning

## Multinational Systems Integration

The Shuttle-Mir and ISS programs require the integration of hardware and software that have been developed and produced by multiple international companies and organizations. For example, the APDS was a mission-critical vehicle docking attachment mechanism and avionics developed and produced by the Russians, but it required physical and functional integration and operation by the Space Shuttle program (Figure 19). Transport and fit-check operations became critical, as well as the flow of hardware assets.

The Task Force made a number of recommendations regarding the process of transport and fit-check operations for the APDA system. Specifically, the Task Force recommended that NASA:

- Verify that the shipping environment does not adversely impact the three APDA's following their shipment from NPO-Energia (now RSC-E) where the final fit check will be performed
- Revisit the risk decision and assess the risk involved in handling the DM as well as the ground support equipment needed to perform an ODS/DM fit check



**Figure 19. The Androgynous Peripheral Docking System designed and produced by Russia and integrated physically and functionally by the Space Shuttle program.**

- If not already under consideration, determine the feasibility of installing maximum accelerometers in each of the APDA shipping crates during transportation

NASA responded positively to these recommendations. It implemented postdelivery inspections of each APDA using NPO (RSC-E) interface tooling and a functional test. NASA also announced its intention, budget permitting, to install maximum accelerometers in each of the APDA shipping crates during transportation.

The Task Force notes that the integrated planning for the flow of multinational program-critical assets will become more critical during the ISS program because of the magnitude and complexity of these assets.

### **Mission and Contingency Planning**

The planning of mission and contingency options was highlighted by the opportunity to include three additional missions within the Phase 1 program. The need for flexibility for manifest and mission sequence options carries over to the ISS program.

The capability for rescheduling mission activities and adjusting priorities was required frequently during Phase 1. For example, in its readiness letter to Administrator Goldin prior to the launch of STS-76 in March 1996, the Task Force noted that the delayed launch of the Priroda module to Mir would result in the hardware for Shannon Lucid's experiments not being available until the arrival of Priroda in April 1996. This illustrated the importance of being able to adjust the research timeline to accommodate real-time hardware delivery schedule changes. The Phase 2 and 3 programs will have to show the same kind of flexibility in this area as displayed in the Phase 1 program. The Task Force notes the need for proactive planning systems that can respond to changes in resource availability.

The Task Force noted differences in the operational approaches of the United States and Russia to such basic program areas as redundancy management and training. It is of critical importance to recognize these differences and to make adjustments that will allow for effective joint operations. When adjustments for joint operations are not feasible, a common standard must be developed and applied to all parties.

The Task Force was chartered to assess the safety and operational readiness of the Shuttle-Mir missions. The Task Force addressed issues related to mission science only when those issues were likely to impact the safety or operations of the mission. Such a situation occurred prior to Norm Thagard's flight to Mir on Soyuz-70 in March 1995. The expected late arrival of experiment hardware and flight procedures was likely to affect Thagard's training and ability to complete the objectives of the science program. The Task Force felt that the goals of the science mission should be adjusted accordingly. Therefore, the Task Force recommended that:

*[E]mphasis in the science area should focus solely on Thagard's efforts to characterize the Mir Station environment and provide valuable lessons on how to best achieve U.S. scientific goals aboard the Mir Station. The successful completion of specific experiments should be viewed within this*

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*context rather than as a separate measure of success.*

In its response to this recommendation, NASA acknowledged that it had learned a valuable lesson in the area of coordinating scientific efforts with its Russian counterparts. NASA noted:

*The Russian philosophy in this area is quite different from the American philosophy. The Russians often deliberately train to a limited degree pre-flight and continue the training process during their long duration missions in order to conduct the science. In the American process, the crew is trained extremely well prior to flight because Shuttle flights are fairly short and little, if any, opportunity may exist for on-orbit training. Both sides are learning valuable lessons in this area.*

The Phase 1 program provided NASA and RSA an opportunity to begin to develop a joint approach to mission planning and program/project management philosophies. The benefits to the ISS program of this opportunity are substantial and will be felt for many years.



# 9.

## System Safety

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The Phase 1 program offered a unique opportunity to examine the system safety review and issue resolution process between the United States and Russia. All learning supported the early assumption that both sides have robust processes.

### Safety Review Process

The Phase 1 systems safety review process was structured around the Joint Safety Assurance Working Group, which was created to evaluate and implement safety requirements for the Shuttle-Mir program. The primary objective was to ensure the safety and health of the astronauts and cosmonauts during the performance of joint American-Russian operations conducted on the Mir space station.

The technical reviews conducted by the Stafford Task Force complemented the safety process established and carried out by the Phase 1 program and the Joint Safety Assurance Working Group. The Task Force, often working jointly with Russia's Utkin Advisory Expert Council, worked independent of the Phase 1 program's safety assurance process to assure NASA that the program process was working and resolving all critical issues.

Prior to the flight of any Shuttle missions to Mir, the Task Force focused much of its attention on safety issues associated with the dynamic loads that would be experienced by the mated spacecraft. In this regard, the Task Force recommended that NASA:

- Fully analyze and understand the robustness of the Russian Mir model to assess stack dynamic response
- Conduct a loads analysis DTO for STS-74 that corresponded to the DTO conducted for STS-71
- Fully analyze the Russian Mir structural dynamics model to determine the digital autopilot controllability and structural integrity
- Validate the structural model of the Mir solar panels and understand the panel loads constraints
- Demonstrate through practice runs the Agency's ability to rapidly exploit the flight data to be gathered by the loads analysis DTO
- Reduce Mir structural model uncertainty by maximizing digital autopilot stability margins
- Track the refined loads analysis resulting from the higher fidelity models recommended

Also prior to the first Shuttle-Mir docking mission, the Task Force reviewed safety issues associated with the procedures and equipment that would be used to dock the two spacecraft. In this area, the Task Force recommended that NASA:

- Ensure that all ISS APDS specifications were properly documented in the RSA APDS procurement specifications and implemented
- Continue to look for ways to improve the APDS
- Perform a fit check on the ground of the ODS APDA and the DM APDA

In each of the above instances, NASA responded positively to the recommendations and took effective action.

Safety issues associated with potential plume impingement and plume modeling were another area that the Task Force reviewed prior to the first Shuttle-Mir mission. The Task Force encouraged NASA to process all SPIFEX data expeditiously and provide the results to the Russians as quickly as possible to enable them to update their loads calculations on critical Mir elements. NASA provided these data to Russia and worked closely with Russian plume specialists to better understand the close-in plume loading effects on critical Mir elements. The NASA and Russian experts agreed that planned mission operational margins and constraints were very adequate.

The Task Force reviewed issues associated with ensuring that the Space Shuttle maintain the capability to rapidly and safely de-mate with the Mir station if it was required to do so in an emergency. The Task Force recommended that NASA prepare a contingency plan that provides an alternative method for Shuttle-Mir de-mating in the event that the testing of the pyrotechnic bolts produced unacceptable results. NASA developed a contingency EVA plan that would allow the Shuttle to de-mate from Mir by removing the 96 bolts from an independent interface plane of the ODS. The plan called for utilizing this contingency EVA only if both the primary means (latch motors) and secondary means (pyrotechnic bolts) of de-mating were not successful in releasing the APDA latches.

### **Safety Issue Resolution Process**

After NASA and Russia successfully demonstrated their ability to safely conduct proximity operations, rendezvous and docking operations, and mated operations, the Task Force turned its attention to reviewing specific safety issues associated with each Shuttle-Mir mission and each long-duration stay on Mir by U.S. astronauts. In 1997, a number of incidents onboard Mir offered the opportunity for the Task Force to work together with the Utkin Advisory Expert Council to review issues and reach a further common understanding of vehicle safety.

In April 1997, the Stafford Task Force met in Russia with the appropriate Russian technical and management experts, including members of the Utkin Advisory Expert Council, to address specific concerns with the Mir space station. These concerns were derived from the multiple mishaps and anomalies that Mir had recently experienced, including: a fire that broke out in the solid-fuel oxygen generator system in the Kvant-1 module (February 23, 1997); an Elektron oxygen generator failure in Kvant-2 apparently caused by corrosion and membrane aging (March 5, 1997); a Progress cargo ship unable to dock and that had to be deorbited (March 6, 1997); and a number of leaks in the coolant loop (April 4 and 11, 1997).

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In September 1997, the TF-AEC Joint Review Commission returned to Russia to review the mishaps and anomalies that continued after the successful STS-84 docking mission. These mishaps and anomalies included: a Progress cargo vehicle collision with Mir (Figure 20), causing a depressurization of the Spektr module (June 25, 1997); motion control system gyrodynes going off-line, requiring inertial attitude control to be maintained by thruster firing from the Soyuz capsule jets (July 3, 1997); Mir loss of power after a crew member accidentally disconnected a computer cable, sending Mir into free drift (July 17, 1997); failed Elektron oxygen generators (August 5 and 25, 1997); and a main computer failure (August 18, 1997).



**Figure 20. Mir Spektr module showing damage caused by the Progress M-34 collision.**

An overall safety assessment of Mir points to two important lessons learned for the ISS. First, Mir is designed for long-duration flight and has adopted a “fail-to-maintenance” or “run-to-failure” operations concept. This approach is more consistent with that of a submarine or a ship at sea than that of the aircraft concept of operation used on the Shuttle program. Mir has adequate backup of critical systems, usually using components of different design (reliability through diversity). If a failure occurs, the backup system is used while repair of the failure is accomplished. Unlike Mir, the Shuttle relies on system redundancy, usually using components of the same design. When a failure occurs, the redundant components are used while operational procedures (such as a return to Earth) are executed. There are a number of benefits to the “fail-to-maintenance” philosophy adopted for Mir that makes for a robust system. This “fail-to-maintenance” philosophy should be considered for the ISS.

The second important lesson learned is derived from the events following the Progress-Mir collision. The collision provided the first demonstration of a critical decompression and highlighted the joint inability to identify, repair, recertify, and reconstitute the breached Spektr module. The Task Force feels that the entire issue of module repair, recertification, and reconstitution needs to be addressed in Phase 2. Both the fire and the collision—two events that are statistically significant over the planned lifetime of the ISS—highlighted the importance of immediate action by the crew. However, in the case of the collision, the procedures for damage assessment, including those for intravehicular activities (IVA) were developed in reaction to the event; until this collision, the IVA environment had never been categorized, nor had processes for damage assessment been codified. Furthermore, no processes to characterize the condition of the breach, such as the weld or web impingement or structural deformation, have been developed to determine potential remediation or repair. Although the procedures for ground certification of the flight hardware are codified in contract, there are no parallel certification standards for reconstituting and recertifying a breached module for occupancy in space. Given the frequency of autonomous resupply and the ambient debris environment, the Task Force believes that these proactive procedures for a breached vessel and for other significant statistical events be addressed at the appropriate degree of fidelity.

The TF-AEC Joint Review Commission concluded that the Mir recovery had gone well; NASA and Russia had done a good job in recovering from the incidents and repairing the affected systems and reestablishing them back on line. While the reliability of Mir was questionable, the Task Force believed that Mir had actually grown in robustness over the years as new modules and additional redundancy were added to the station.

# 10. Training

The Russian experience base of long-duration human space flight missions versus the American experience base of short-duration flights has resulted in two distinct training philosophies based on different objectives and cultures. The Phase 1 program provided an opportunity for NASA and Russia to begin to integrate these philosophies as the two sides moved together toward the new era of long-term multinational space operations during the ISS program. Additionally, the Task Force benefited from observations made during the Phase 1 program and gained an appreciation for the magnitude of the ISS Phase 2 training task.

The Phase 1 training program, with the exception of Shuttle-unique training and training for the U.S. science experiments, was focused in Russia, under the direction of GCTC. It involved specified training in the Russian language, classroom training, and training in the Russian mockups and simulators (Figure 21). Mir was a mature program and spacecraft and, correspondingly, had a mature training process in place. As guest participants, it was the responsibility of the U.S. crew members to adjust to the Russian training methods and philosophy.

The differences in training philosophies were manifested in numerous ways, including:

- Backup crews
- Training templates
- Training pace
- Documentation
- Availability of material

## Backup Crews

Russia exercises parallel training for integral backup crews. If one member of the primary crew is unable to fly on the mission, the entire crew is normally replaced by the backup crew. This Russian training philosophy emphasizes crew compatibility—crews must demonstrate an ability to work well together through months of training. NASA's policy has been to replace just the individual crew member deemed unable to fly, rather than replacing the entire crew.



**Figure 21. Soyuz full mission training simulator located at Gagarin Cosmonaut Training Center (GCTC) in Star City, Russia.**

However, NASA is adopting the practice of using backup crews for the long-duration ISS expeditions. The Task Force endorses this decision and commends NASA for implementing this approach.

## Training Templates

The different philosophies regarding backup crews have other ramifications on training as well. The Russian training templates for specific systems are consciously minimized—that is, they do not train to the same level of detail for each system, each contingency, and each experiment as NASA does. The Russians have adopted this approach for two reasons. First, for each mission on which they fly, Russian crews nominally complete two full training cycles—once as the backup crew and once as the primary crew. Second, long-duration orbital flights are slower paced than short-duration flights. Because the majority of the mission is in a stable, on-orbit environment, training for every possible contingency is less critical than during the dynamic phases of, for example, a Space Shuttle flight. The Russian approach is to achieve essential basic skills to ensure success in time-critical operations. They rely on real-time on-orbit planning and execution, taking advantage of the relatively stable pace of long-duration flights.

NASA trains dedicated teams (ground control and flight crews) to perform every conceivable contingency operation, using extensive high-fidelity integrated simulation training to rehearse entire timeline sequences. Almost no anticipated on-orbit activities are unrehearsed. NASA's training templates are longer and more detailed because U.S. crews are normally only exposed to the training once. The relatively short-duration flights also require a more intense pace, less time allocated to each operation, and less opportunity for on-orbit planning, rehearsal, and response to off-nominal situations. This, in turn, drives repetition into the templates.

NASA ISS training templates are not being satisfied, in part because of the increased resource loading (mostly facilities). The Task Force believes that for ISS training, the requirements defined in the current templates should be made more consistent with the backup crew and long-duration space flight philosophies.

## Training Pace

American crews and training personnel are accustomed to a faster paced training program, which they associate with efficiency. They tend to evaluate training more in terms of objectives and the quality and quantity of technical content. The Russians place more importance on building strong interpersonal crew relationships in nontechnical activities. They use the training period to prepare crews for long-period isolation in close quarters with other crew members. Long-duration flights in confined spacecraft present difficult problems, even for crews with common cultures. The Task Force recognizes that preparing international crews to accommodate these issues will be even more challenging.

### Documentation

Another dynamic that the Task Force observed in Phase 1 was the importance of providing training documentation to crews in their native language. Getting training documents translated effectively to/from Russian/English has proven to be both difficult and costly. Also affecting this issue is another difference in training philosophy between NASA and Russia—NASA has developed detailed, technical training manuals and workbooks that the crew can study on their own and prepare for interactive lectures. Russia does not produce such large, complete detailed manuals because it relies much more on direct classroom lecture instruction. For initial ISS flights, the Task Force observed an unequal distribution of workload in translating documents. NASA has had to commit considerably more resources to translate its large training documents than Russia needed to translate its documents. That issue aside, it is still an onerous process to translate the documents. To date, the first translated drafts of either language can be considered nothing more than a first iteration. A possible way to achieve a more successful translation process is to have the translators, developers, and trainers from both sides working together from the onset. Even then, it will be a slow, iterative, and costly process.

### Availability of Material

Some problems faced in Phase 1 will be magnified in Phase 2 because it is a new program, whereas Mir was a mature program. For instance, some flight procedures, training documents, training hardware, and training software will not be available in time to support current training templates. The Task Force believes that Phase 2 training templates should be reviewed and, where appropriate, revised in view of realistic availability of resources and time. A subset of current training requirements—those essential for the safe execution of the mission—should be identified. When appropriate, high-fidelity test articles and flight hardware should be used for the training of crews and instructors until suitable training hardware becomes available. Likewise, task trainers should be used until suitable training software is available.

The Task Force believes that the training experience gained from the Phase 1 program is proving essential to the success of the ISS. However, there are a number of outstanding issues remaining regarding training that initially surfaced in the Phase 1 program and have carried over into Phase 2. The necessary cooperative international environment of the ISS program demands a different approach to Phase 2.



# 11 Conclusion

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Beginning with the flight of Russian cosmonaut Sergei Krikalev aboard STS-60 on the Space Shuttle in February 1994, and concluding with the return of U.S. astronaut Andy Thomas from Mir on STS-91 in May 1998, 17 successful short- and long-term exchanges of Russian and American crew were carried out under the Phase 1 Shuttle-Mir program. The Space Shuttle made 10 flights to Mir, with 9 of these flights complete with the rendezvous and docking. The Shuttle delivered six Russian cosmonauts to Mir and returned two to Earth after a long-duration mission. Seven U.S. astronauts stayed on Mir for long-duration missions. Norm Thagard, the first U.S. astronaut to undertake a long-duration expedition aboard the orbital station, made his launch in a Russian Soyuz TM vehicle. Six astronauts in continuous succession spent more than 2 years aboard Mir: Shannon Lucid, John Blaha, Jerry Linenger, Mike Foale, David Wolf, and Andy Thomas. Additionally, large amounts of cargo were delivered to and from Mir by the Space Shuttle. The Phase 1 program met the goals initially established at the start of the program, and it adjusted to the additional expanded goals in a most professional manner. The Russian and American space programs have learned how to work together and overcome the obstacles caused by different languages, cultures, engineering and technical approaches, and operations philosophies. This relationship was tested not only in nominal operations, but in real-time emergency situations.

The experience gained from the Phase 1 program proved to be essential before the United States and its partners could attempt to commence building the largest international technological project ever undertaken—the ISS. The Task Force is convinced that it would have been irresponsible to attempt the ISS program without the benefit of the Phase 1 Shuttle-Mir program to serve as a precursor, just as the Gemini missions prepared the U.S. space program for the Apollo program.

NASA has taken prudent steps to ensure that the lessons learned from the Phase 1 program are incorporated into the Phase 2 and 3 programs. NASA and Boeing developed a comprehensive data base and established a formal process for capturing and transferring the lessons learned. NASA also transitioned many of the key Phase 1 personnel into the ISS program, including the Phase 1 Director and Deputy Director. The Task Force commends NASA for the job that it has done in ensuring that the lessons learned from the Phase 1 program are properly applied to the Phase 2 and 3 programs.

The Task Force is satisfied that the lessons derived from its findings and recommendations have been adequately captured in the NASA/Boeing lessons learned data base. With the release of this final report, the Task Force issues the following final observations on the Phase 1 program, all of which have applicability to ISS Phases 2 and 3:

- Any shortfalls caused by TDRSS aging and the potential transition to an NSCP architecture need to be addressed, especially because funding for the NSCP architecture seems to be losing support. This is of particular concern because the Space Operations Management Organization has stressed, in its Consolidated Space Operations Contract competition, that NASA's migration to the NSCP architecture take place in the middle of ISS utilization.

- Communications capacity and the ability to support and balance technical, scientific, and personal communications need to be carefully monitored. Owing to the limited availability and the data stream requirements, bandwidth availability is limited. As a result, each communications opportunity is tightly controlled and budgeted based on the priority of communications. In the ISS era, the allocation of bandwidth will be a major issue.
- ISS crews must be provided with a comprehensive behavioral, performance, and social program. This program should include regular and convenient access to communication with family and colleagues and the ability to maintain contact with their cultures.
- The human factors experience on Phase 1 must be studied and the lessons learned from it applied to Phases 2 and 3.
- The development of a Joint Medical Plan proved to be an extremely difficult matter during the Phase 1 program. The development and evolution of such a plan remain crucial aspects of multinational programs. Although this has been very carefully addressed as a lesson learned in the ISS plans, it needs to be addressed early on within Phase 2 of the ISS program.
- The need for flexibility in manifest and mission sequence options carries over to the ISS program. The Shuttle manifesting flexibility provided an asset without which the Phase 1 program could not have been executed. The need for rapid manifest changes to allow for critical resources to address Mir system failures was provided by both the Shuttle and the Progress. The Task Force notes the need for proactive planning systems that can respond to changes in resource availability. This is particularly important given the duration and criticality of station construction, utilization, and sustainment.
- Phase 1 demonstrated the dynamic nature of long-duration space missions and highlighted areas in which contingency planning should be undertaken. While the Task Force recognizes that it is impossible to plan for the universe of possible contingency operations, there is that subset, including element depressurization and solid-fuel oxygen generator fires, that was encountered in Phase 1 and must be planned for during ISS operations.
- The “fail-to-maintenance” or “run-to-failure” philosophy adopted for Mir makes for a robust system with a number of significant benefits. This “fail-to-maintenance” or “run-to-failure” philosophy should be considered for the ISS.
- It is imperative that flight and training hardware for U.S. experiments as well as flight procedures be available in Russia in accordance with a jointly agreed-on schedule. In the event that the necessary items are not available at least 90 days prior to launch, the experiment should be postponed or canceled.
- An analysis of crew training should include the improvement of onboard training.
- The Task Force believes that for ISS training, requirements defined in the current templates should be made more consistent with the backup crew and long-duration space flight philosophies.

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- A possible way to achieve a more successful translation process is to have the translators, developers, and trainers from both sides working together from the onset.
- The Task Force believes that Phase 2 training templates should be reviewed and, where appropriate, revised in view of realistic availability of resources and time.
- A subset of current training requirements—those essential for the safe execution of the mission—should be identified.
- The repair, recertification, and reconstitution of a breached module or recovery from a major statistically significant event, as demonstrated by flight history, such as the collision and fire in the Phase 1 program, need to be addressed for the ISS at the appropriate level of planning fidelity.
- When appropriate, high-fidelity test articles and flight hardware should be used for the training of crews and instructors until suitable training hardware becomes available. Until the trainers and the training templates are in place, the crew should have access to whatever hardware is available.
- The ISS Program Office must work closely with the Space Shuttle Program Office to ensure the identification of long-range operational requirements. NASA must support identified safety and operational improvements of the Space Shuttle to assure a safe and successful assembly and operation of the ISS.

Russia has had a nearly continuous human presence in space for more than 27 years. The longest continuous American presence in space prior to the Shuttle-Mir program was 84 days on Skylab. Russia's long-term presence in space has given it invaluable experience and know-how. The United States meanwhile, has been operating the world's most versatile and sophisticated spacecraft—the Space Shuttle—for more than 17 years. It, too, has gained invaluable space experience and know-how. The Phase 1 program afforded these two great spacefaring nations the opportunity to learn from one another and develop more effective ways to operate in space. With the initiation of Phase 2, the United States and its partners—particularly Russia—face a new set of challenges. To be successful, they will have to build on what has already been accomplished in Phase 1.





# Appendices

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# Appendix A

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## Task Force Findings and Recommendations Matrix



## The Final Report of the International Space Station Phase 1 Program

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
C1	Fourth Report	Implementation of NASA institutional ADP/T capabilities in Russia must be given a high priority.	NASA concurred and implemented.	Communications
C2	Fourth Report	The Phase 1 Program Office should reassess adequacy of Mir station communications coverage to enhance mission safety as well as mission success.	NASA accepted recommendation and activated VHF ground stations at the Dryden Flight Research Center and the Wallops Flight Facility.	Communications
C3	Fifth Report	To maximize interface opportunities between the orbiting Mir crew and the prelaunch Shuttle crew prior to Shuttle launches to the Mir station, efforts should be made to ensure that the crews are provided with additional communications opportunities during the weeks preceding the mission.	Following the successful STS-71 docking mission, the Phase 1 program established the Transfer Tiger Team to review the logistics transfer process and make recommendations for improvement. This team recommended that Shuttle and Mir crews should conduct communications sessions prior to Shuttle launches to review transfer procedures and timelines. Prelaunch conference between crews greatly benefited the docked operations.	Communications
C4	Fifth Report	The Joint Institutional Communications Requirements (JICR) Working Group and JSC Institutional Communications Requirements Panel should continue current processes until the U.S./Russian JICR document is signed.	The U.S./Russian JICR document was signed on June 21, 1995.	Communications
C5	Fifth Report	The site-specific implementation plans should be finalized within a 6-week timeframe following RSA/NASA joint signing of the U.S./Russian JICR Document.	NASA concurred and implemented.	Communications
C6	Fifth Report	The Program Support Communications Network (PSCN) should include instructions for users of institutional ADP equipment/software delivered to Russia as part of the deliverable Request for Service packages. Training requests should be addressed on a case-by-case basis.	PSCN developed and distributed a comprehensive "Quick Reference Guide" for this equipment on August 17, 1995.	Communications
C7	Fifth Report	Prior to implementation completion, a logistics and depot maintenance plan should be developed. From this plan, a funding profile should be developed.	NASA concurred and implemented.	Communications
C8	Fifth Report	A property control/inventory system should be developed for all equipment located in Russian and U.S. facilities, including portable ADP equipment located at the MTLO.	NASA concurred and implemented.	Communications

# Appendix A

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
C9	Fifth Report	<p>The focal point of this activity will be in Russia; therefore, an Institutional Communications Director (ICD) position should be established in Russia with the following major tasks:</p> <ul style="list-style-type: none"> <li>• Report directly to the NASA Moscow Senior Representative</li> <li>• Be responsible for the oversight of implementation of the site-specific plans</li> <li>• Act as Contracting Officer's Technical Representative (COTR) for operations and maintenance contracts</li> <li>• Approve all changes to the signed NASA/Russian JICR Document</li> <li>• Be responsible for budget controls</li> <li>• Coordinate Russian activities with MSFC management</li> </ul>	<ul style="list-style-type: none"> <li>• The ISS Program Office agreed, believing that this position should fall under the Code I Russian Representative and be funded by NASA Headquarters.</li> <li>• The ICD oversight of the implementation of site-specific plans should be restricted to coordination only.</li> <li>• The Chief Information Officer (CIO) could not accept the recommendation of making the ICD a COTR for operations and maintenance.</li> <li>• The CIO could not concur on the recommendation of making the ICD responsible for budget controls, noting that it creates a situation that may lead to untimely response to program requirements and does not fit into the current manner of budgetary control.</li> <li>• The CIO noted that the ambiguity of the final task suggested by the Task Force that the ICD coordinate Russian activities with MSFC management could be solved by placing an MSFC employee on PSCN support to perform that coordination.</li> </ul>	Communications
C10	STS-76 Readiness Letter	To accommodate improved communications and downlink coverage on Mir, a first-time tail forward approach of the Shuttle was to be utilized.	The tail forward approach had been trained for and was not a concern.	Communications
C11	STS-86 Readiness Letter	Improved orbit-to-ground communications should be considered.	This was considered but not accepted because of cost constraints.	Communications
C12	STS-86 Readiness Letter	There should be improved coordination between MCC-M and MCC-H.	Accepted and implemented. Coordination between the control centers continued to improve with each mission.	Communications
H1	Second Report	The Office of Space Flight's Chief Medical Officer will chair the Medical Policy Board for the development of medical support for ISS Assembly (ISSA) risk mitigation and all NASA/RSA joint development of medical support for ISSA risk mitigation.	The Medical Policy Board has continued to evaluate the data and lessons learned from the Phase 1 program. This information has been incorporated into the medical requirements documents. In addition, Multilateral Medical Boards and Working Groups were created to fully address these issues.	Crew Health
H2	Fourth Report	The NASA flight surgeons at the Baikonur launch site must be provided with an independent communications capability allowing direct access to JSC.	It has been arranged that NASA flight surgeons, while at the Baikonur launch site, will have access to a satellite communications link, which will allow direct access to JSC.	Crew Health
H3	Fourth Report	A NASA flight surgeon must be cleared to accompany the Soyuz TM-21 U.S. crew member from Baikonur to Moscow in the event a medical evacuation is required.	A NASA flight surgeon has been cleared to accompany the Soyuz TM-21 U.S. crew member from Baikonur to Moscow in the event of a medical evacuation.	Crew Health
H4	Fourth Report	All NASA personnel working at the Baikonur Cosmodrome must be immunized against hepatitis B.	NASA medical support personnel working at the Baikonur Cosmodrome have been immunized against hepatitis B, and others traveling to site have been encouraged to take the immunizations.	Crew Health

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ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
H5	Fourth Report	The NASA flight surgeons should be supplemented with a registered nurse/emergency medical technician because the flight surgeons will not be working in close proximity to one another at the launch site.	A registered nurse with intensive care unit training has been hired as a consultant, and arrangements have been made with the Russians to transport her to and from Baikonur to support the flight surgeons during the launch.	Crew Health
H6	Fourth Report	Prior to the Soyuz TM-21 launch, NASA must investigate the clinical resources available for treatment of the U.S. member of the crew as well as the practical options for transferring care of the crew member to U.S. care at the Chkalovsky Air Base, including medical evacuation to the U.S. Air Force Base at Ramstein, Germany.	The Russians have the responsibility for medical support at the launch and recovery sites. NASA augmented the Russians' capability with trained personnel, equipment, supplies, and plans for aeromedical evacuation. In addition, U.S. flight surgeons have evaluated the Chkalovsky Air Base health care capability. Medivac capability has also been made available.	Crew Health
H7	Fourth Report	Medical communications between IBMP and NASA JSC should be done by dedicated service available throughout the Phase 1A missions.	Medical communications capability between JSC and the Russian MCC with a dedicated communications link to IBMP has been established.	Crew Health
H8	Fourth Report	The Joint Medical Support Plan should be agreed on and implemented promptly to avoid potential conflicts during the course of the missions.	NASA provided several iterations of a Joint Medical Support Plan to the Russians, but the plan was never completed and signed.	Crew Health
H9	Fourth Report	The remaining invasive protocol for Mir-18 Main Expedition crew members, the calcium-chloride infusion scheduled to occur aboard the Shuttle during STS-71, should be carefully reviewed by medical operations before implementation.	The calcium-chloride infusion scheduled to occur aboard the Shuttle during STS-71 was carefully reviewed by medical operations and by the Human Research Policy and Procedures Committee. Twenty-five micrograms of calcium will be injected in a 1-cc aliquot. This very small amount of stable calcium isotope, while detectable by sophisticated equipment and therefore useful in the study, is not a significant challenge to an individual subject. Medical operations and the Human Research Policy and Procedures Committee approved the infusion planned on STS-71.	Crew Health
H10	Fifth Report	To minimize feelings of isolation among the U.S. crew when aboard the Mir station, efforts should be made to ensure that the U.S. crew are provided with dedicated space-to-ground communications time.	To provide for adequate, dedicated space-to-ground communications time to support the U.S. crew aboard the Mir station, NASA has negotiated for additional communications time using the existing communications link, and a protocol has been signed between the NASA and the Russians.	Crew Health

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
H11	Joint Report	In discussions regarding Russian cosmonaut safety aboard the Space Shuttle on STS-60, STS-63 and STS-71, concerns were raised relevant to the current level of protection provided by the Launch and Entry Suits worn by Shuttle crew members.	During Phase 1, the two types of suits worn during launch and entry were the Launch and Entry Suit (LES) and the Advanced Crew Escape System-LES (ACES-LES). The ACES-LES was created to replace the LES, but both were designed to facilitate quick and safe egress/escape in an emergency occurring during prelaunch, in flight, or post-landing and to protect crew members from: (1) loss of cabin pressure, (2) environmental extremes, (3) effects of prolonged gravity, and (4) contaminated atmosphere. The LES was a partial-pressure suit with mechanical pressure exerted by pressure bladders that cover most (but not all) of the body. The ACES-LES is a full-pressure suit that covers the entire body. ACES-LES suits were acquired at the rate of approximately one per month. With the procurement/delivery schedule, adequate numbers and sizes of these suits were available to accommodate all Space Shuttle crews by the end of calendar year 1997.	Crew Health
H12	Joint Report	During docking and joint activities between Mir and STS-74, numerous restrictions in the use of treadmills, rowing machines, or other exercise devices have been imposed, having a negative impact on the physical conditioning of the cosmonauts.	Medical experts from both sides agreed that these restrictions may have resulted in a significant decrease of physical conditioning of the Mir crews. Consideration was given to coordination between structures and operations experts in developing alternative exercise equipment and opportunities.	Crew Health
H13	Joint Report	During Mir-18, astronaut Norman Thagard noted that communication with his family was limited and needed to be expanded.	To minimize feelings of isolation among the U.S. crew aboard the Mir station, a joint agreement was implemented for an overall communications plan that ensured that U.S. crew members were provided with dedicated space-to-ground time for both personal and mission-related communications.	Crew Health
H14	Joint Report	From April to November 1995, an unfavorable situation occurred onboard the Mir station with the environment's temperature-humidity regime. Although the temperature and humidity of the station environment, in general, was in the allowable range, it became a source of discomfort for the crew.	<p>The following measures were implemented to remedy the situation on the station:</p> <ul style="list-style-type: none"> <li>• Additional measures for the improvement of the temperature-humidity regime of the pressurized compartment on Mir with the help of the cooling and dehumidifying system on Soyuz TM and the life support system on the Shuttle</li> <li>• Test activation and calibration of the onboard air conditioning system (ACU-3)               <ul style="list-style-type: none"> <li>• Collection and removal of accumulated condensation</li> </ul> </li> <li>• Monitoring of the free condensation inside the pressurized compartment of the Mir station</li> </ul>	Crew Health

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ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
H15	Joint Report	Crew technical and medical support issues were not being well coordinated among Working Group 8 and the Technical Interchange Meeting (TIM) groups.	For effective coordination of crew, technical, and medical support issues, it was necessary to provide for regular attendance in the TIM's by Russian Working Group specialists, particularly regarding the authority of medical provisions of the crew. It would be prudent to have Russian specialists from Working Group 8 participate in the TIM.	Crew Health
H16	Joint Report	Biomedical support in providing safety and efficiency of the crew was a very important element in joint operations. Unfortunately, two different bio-medical structures were developed in the United States and Russia. Unlike the biomedical structure at NASA, there is no biomedical division in RSA. Instead, biomedical issues have been worked among Energia, IBMP, and the State Scientific Center, with very little coordination.	AEC recommended that RSA establish a chief position with responsibility and authority for medical operations. The establishment of such a structure should provide adequate biomedical structures and help to simplify the agreement and implementation of the joint biomedical efforts.	Crew Health
H17	STS-86 Readiness Letter	Joint U.S.-Russia effort to study human factors in connection with Mir operations should be undertaken to mitigate future risk.	Open. Recommendation carried over to the ISS program.	Crew Health
M1	Second Report	A Phase 1 Project Manager (reporting to the Associate Administrator for Space Flight) with a small staff located at JSC should be established.	A Phase 1 Program Manager (reporting to the Associate Administrator for Space Flight) was established at JSC with a staff dedicated to the management of the Phase 1 activities.	Management
M2	Second Report	The JSC Russian Projects Office should be matrixed to support the Phase 1 Project Manager with the Director for the JSC Russian Projects Office serving as the Phase 1 Deputy Project Manager.	The JSC Russian Projects Office was integrated into the Phase 1 Project Office when it was established.	Management
M3	Second Report	The joint NASA/RSA working groups, with the exception of the Management Working Group and the Safety Assurance Working Group should be matrixed intact and with the necessary administrative support from JSC to support the Phase 1 Project Manager.	NASA concurred and implemented.	Management
M4	Second Report	The Phase 1 Project Manager should be responsible for the management direction and oversight of the integration and flight preparation process and accomplishment of the objectives for each Phase 1 mission.	NASA concurred and implemented.	Management
M5	Second Report	The ISSA Russian Programs Phase 1 Office currently reporting to the ISSA Program Manager should be matrixed intact to the Phase 1 Project Manager.	The ISSA Russian Programs Phase 1 Office was matrixed to the Phase 1 Project Manager, but it remained within the ISSA management structure.	Management

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
M6	Second Report	A Requirements Integration Manager should be designated and report directly to the Phase 1 Project Manager and be responsible for assembling all Phase 1 requirements and assisting the Phase 1 Project Manager in developing the Phase 1 Project Plan.	The Requirements Integrated Product Team was formed to manage the requirements for the Phase 1 Shuttle missions. The chair of the team reported directly to the Phase 1 Project Manager. Other requirements were integrated through the working group structure. For example, Mir operational requirements were managed through the Mir Operations and Integration Working Group. Science requirements were integrated through the Mission Science Working Group.	Management
M7	Second Report	A Public Information Officer should be designated as a staff assistant to the Phase 1 Project Manager to achieve the maximum media benefit from the Phase 1 missions.	A JSC Public Information Officer supported the Phase 1 Program Manager very closely throughout the program.	Management
M8	Second Report	The Public Relations Working Group should be matrixed to the Phase 1 Public Information Officer intact.	The chair of the Public Relations Working Group reported directly to the Phase 1 Project Manager.	Management
M9	Second Report	The ISSA Program Manager should be designated as the sole source of ISSA risk mitigation requirements.	Implemented.	Management
M10	Second Report	The Associate Administrator for Life and Microgravity Sciences and Applications should be designated as the focal point for the international research community's requirements and priorities.	Implemented.	Management
M11	Third Report	The Task Force concurred with NASA's decision to retain Rockwell as the party responsible for the overall technical integration role for ODS and DM development and implementation. NASA should take action to capture this experience and knowledge and develop the required working relationships with RSA prior to the transition to Phase 2.	The NASA/JSC Phase 1 and Space Shuttle programs formed a Docking Mechanism Integrated Product Team tasked to provide technical management and oversight for acquisition of the RSA/RSC-E-manufactured docking mechanisms for both the Phase 1 and Phase 2 programs. NASA modified the existing Space Shuttle Program systems integration contract to assure Rockwell will continue to provide the required technical support to NASA for both multi-Mir and ISSA missions, which includes supporting NASA in the overall technical integration role for the ODS development and implementation.	Management
M12	Fourth Report	Every effort should be made to retain key U.S. personnel who serve as interfaces to Russian organizations in their respective positions.	A number of key personnel with Phase 1 experience were transitioned into the ISS program, including the Phase 1 Director and Deputy Director.	Management

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ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
M13	Fifth Report	<p>Written guidelines should be developed to enable the NASA Representative in Russia, once selected, to build a credible charter. To be most effective, the charter must clearly state that the NASA Representative in Russia:</p> <ul style="list-style-type: none"> <li>• Speaks for the Administrator on behalf of all NASA elements operating in Russia</li> <li>• Has direct access to the NASA Administrator</li> <li>• Advises the NASA Administrator and senior NASA officials on U.S. foreign policy objectives and Russian space developments as they affect NASA program activities</li> <li>• Assures that the initiation, formulation, coordination, negotiation, implementation, and monitoring of bilateral and multilateral agreements with Russia are consistent with U.S. foreign policy and NASA program/project guidance</li> <li>• Coordinates through the NASA Office of External Relations (Code I) for management of administrative and support functions in Russia</li> <li>• Has the authority to remove from Russia any NASA civil servant or NASA contractor who exceeds the charter of his or her respective organization or who jeopardizes the Agency through his or her actions</li> </ul>	<p>The Office of External Relations strongly supported the recommendation to have a credible charter and worked with program, staff, and budget offices to develop a charter for the NASA Representative in Russia to define a clear reporting chain for all NASA operations in Russia.</p>	Management
M14	Fifth Report	<p>The selection process for a NASA Representative in Russia with expanded responsibilities should be completed as soon as possible.</p>	<p>A NASA representative in Russia was selected following a thorough search of candidates.</p>	Management
M15	Fifth Report	<p>Each NASA organization operating in Russia must provide a charter for its activities to the NASA Representative in Russia. This charter must clearly spell out the scope of the organization's activities and the roles of any civil servants or contractors working in or traveling to Russia.</p>	<p>On November 28, 1995, the NASA Representative in Russia was briefed at JSC by Phase 1 representatives on the responsibilities and scope of activities of all Phase 1 program personnel operating in Russia.</p>	Management

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
M16	Fifth Report	Each NASA organization operating in Russia must coordinate with and provide regular status reports to the NMLO regarding its activities in Russia.	It was decided that the Phase 1 Program organizations will send faxes that state names of travelers, dates of arrival and departure, and purpose of the trip to the NMLO for each person or group traveling to Russia in support of the Phase 1 program. For periodic reporting from persons involved in long stays, the NMLO was added to the distribution list for weekly Mir status reports, which were generated by the NASA support team in MCC-M. Also, regular reporting from Star City was established by the Director of Operations in Russia, who planned to send formal reports to the NMLO every 2 weeks and coordinated with the NMLO during the interim as needed.	Management
M17	Fifth Report	<p>Each NASA organization operating in Russia should develop a plan to:</p> <ul style="list-style-type: none"> <li>• Actively recruit qualified candidates</li> <li>• Offer the benefits (e.g., housing, home leave, differential pay, etc.) necessary to attract qualified candidates</li> <li>• Carefully screen candidates</li> <li>• Provide a career development path for each individual who chooses to serve</li> <li>• Ensure adequate language and cultural training (the National Foreign Affairs Training Center 44-week course is highly recommended by the Department of State and the Department of Defense)</li> <li>• Develop a pool of qualified and prepared candidates available to serve in Russia</li> </ul>	Candidates for long-term positions in Russia were chosen from applicants requesting such duty. These candidates were carefully screened by personnel very experienced in the type of job to be performed and who usually had experience working in Russia. Language training had been lacking for most because of time limitations in the Phase 1 program, but our goal was to provide 6 months of intensive Russian training for all personnel to be stationed in Russia for long periods. All of the flight surgeons, most of the future Directors of Operations in Russia, and some of the operations personnel met this goal. In certain cases, career development incentives were available. Benefit incentives to attract qualified candidates to long-term work in Russia were lacking, although we believed that NASA should take a proactive position on this issue. We made these recommendations to ISS and NASA management and supported any measures of these types that could be implemented. In addition to incentives, posttour recognition and benefits should also be provided.	Management

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ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
M18	Fifth Report	<p>NASA should develop a comprehensive financial plan for NMLO operations and administrative support. NASA should also assign a budget expert at NASA Headquarters to support the NMLO/MTLO operation. This individual should have the authority to expedite solutions to the unique challenges facing that operation. Each NASA organization operating in Russia should be required to:</p> <ul style="list-style-type: none"> <li>• Clearly spell out, in a written charter, the scope of its activities in Russia and the roles of any civil servants or contractors working in or traveling to Russia</li> <li>• Coordinate with and regularly report status to the NMLO on its activities in Russia</li> <li>• Allocate resources to the NMLO to cover administrative services.</li> </ul>	<p>In their response to this recommendation, the Office of the Chief Financial Officer concurred, stating: "The draft MOU of the Moscow NASA Liaison Office (NMLO) needs a supplement to address specific areas. Tracking and accounting of planned annual expenditures, spending authorization, and a system for disbursement of funds. A procedure for financial data to enter NASA's Financial System and procedures to address emergency funding requirements. Proper steps in place to ensure all regulations/guidelines are followed for procurement of goods, services, leases and hiring practices."</p>	Management
O1	First Report	To derive early operational experience in advance of the first Mir docking mission, the primary objective of STS-63 should be Mir rendezvous and proximity operations.	STS-63 flight requirements documents were updated to reflect increased priority above the Spacehab-03 operations.	Operations
O2	First Report	The launch date for STS-63 should be moved forward.	The program found the results of even a modest acceleration of STS-63 to be too costly in terms of either the STS-67 processing time or, alternatively, the OV-105 launch schedule and flight rate for FY 1995.	Operations
O3	Second Report	The verified Shuttle Plume Impingement Flight Experiment (SPIFEX) data from STS-64 must be made available on or before February 15, 1995, the current schedule, and the SES updated with those data in adequate time to support STS-71.	A plan and schedule were developed to acquire, reduce, and analyze the SPIFEX plume impingement data for STS-64 by January 31, 1995.	Operations
O4	Second Report	STS-63 should perform HHL tests against the Mir complex and determine range-rate accuracy and stability.	Discussions were held with the Russians to identify HHL targets on the Mir.	Operations
O5	Second Report	STS-63 should perform a range and range-rate checkout of the TCS against the Mir complex.	The TCS range and range-rate test was developed for STS-63. The TCS unit for STS-63 was a reflight of the STS-64 DTO unit. This unit provided range and range-rate information inside 150 meters using the continuous beam mode of operation and the retroreflectors on the Mir complex.	Operations
O6	Second Report	The Mir Approach DTO should be fully implemented.	The Mir Approach DTO 835 was assigned to the Flight Requirements Document for STS-66, STS-63, and STS-69.	Operations
O7	Second Report	To avoid impacting the RSA assessment teams considering loads, power, and communications, NASA should not propose changing from the planned V-bar approach on STS-63 to an R-bar approach. In addition, NASA should advise that they stand ready and willing to perform either a V-bar or R-bar approach based on the results of the Mir analysis.	The Space Shuttle program concurred because of performance gains and lower plume effects and planned to change to the R-bar technique on STS-74.	Operations

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
O8	Second Report	Because STS-63 represents the only opportunity to test the hardware, techniques, and operational procedures to be used in Mir rendezvous and proximity operations, the Mir-related objectives must be given top priority on the mission.	This recommendation was accomplished by identifying the Mir rendezvous operation as a primary objective after Spartan retrieval.	Operations
O9	Second Report	An approach to within 30 feet of Mir should be made on STS-63 to accomplish the "Near Mir Fly-By Detailed Test Objectives."	The Space Shuttle program concurred with the recommendation and obtained Russian agreement.	Operations
O10	Second Report	The CTVC should be manifested on STS-63 and mounted in the Spacehab module to: <ul style="list-style-type: none"> <li>• Perform a CTVC visibility checkout to include the recording of camera output for postmission evaluation</li> <li>• Evaluate lighting and shadow effects on the target image</li> <li>• Conduct attitude flyout tests in Low-Z</li> </ul>	The Phase 1 team determined that all docking approach testing could be performed on STS-63 using a Spacehab-mounted CTVC fitted with a zoom lens.	Operations
O11	Second Report	The value of performing attitude flyout tests in Low-Z using the CTVC mounted on the Remote Manipulator System elbow camera location should be investigated.	The Remote Manipulator System was not manifested on STS-63 because of performance. However, it was felt that using a Spacehab-mounted CTVC fitted with a zoom lens would meet the full intent of the recommendation.	Operations
O12	Second Report	A launch-on-time policy should not be instituted because it could result in missions being scrubbed that might otherwise be launched within a 5-minute or even shorter window.	The Space Shuttle program concurred that a launch-on-time policy should not be instituted.	Operations
O13	Second Report	No redundant Payload Bay VHF antenna is required for Shuttle-Mir missions.	The Space Shuttle program concurred with no redundant Payload Bay VHF antennas.	Operations
O14	Second Report	The test plan for the STS-63 window-mounted antenna should include a performance assessment with respect to Mir antenna patterns.	The Space Shuttle program concurred, and analysis performed on expected coverage capability and their results were factored into the test requirements.	Operations
O15	Second Report	The ODS active hooks should be cycled as part of the ODS testing to be conducted at KSC prior to STS-71.	The Space Shuttle program concurred, and the requirement was provided to and put in the KSC baseline.	Operations
O16	Second Report	The EVA approach to remove the 96 bolts that fasten the ODS docking base to the ODS external airlock should be developed and baselined as a contingency approach for APDA mechanical system and pyrotechnic failures.	The Space Shuttle program pursued the development of an EVA backup to separate the Shuttle-Mir structure in the event of mechanical or pyrotechnic failures.	Operations
O17	Third Report	Understanding of the Mir ACS should be expanded to encompass response to contact loads during STS-71 and STS-74.	The NASA model of the Mir ACS was validated by the joint flight control team during joint Working Group meetings. The simplified model of the Mir ACS was sufficient for nominal and limited off-nominal STS-71 and STS-74 operations during proximity operations, docking, and mated flight.	Operations

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ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
O18	Fifth Report	The R-bar approach is the preferred approach for operations such as the Shuttle-Mir rendezvous and docking missions.	The R-bar approach was used on STS-71, STS-74, and the remainder of the planned Phase 1 Shuttle-Mir docking missions. NASA has preferred the R-bar approach over the V-bar because of reduced propellant usage and reduced Shuttle RCS plume impingement on Mir.	Operations
O19	Joint Report	The Shuttle Ku-band antenna at full power exceeds the permissible level of electromagnetic influence on some of the structural elements and equipment of the Mir station.	Power was automatically switched to low at radar lock-on and is backed up by manual switches. In the communications mode, automatic masking protected all Mir modules. The Mir Ku-band antennas were turned off once the Shuttle approached to within 100 feet (30.5 meters).	Operations
O20	Joint Report	Prior to the STS-71 undock and flyaway maneuver, the crew of Mir-19 boarded the Soyuz TM-21, undocked from Mir, and maneuvered to a position 305 to 366 feet (93 to 112 meters) away to photograph the undocking of Mir and Atlantis. During these proceedings, an inadvertent command was sent from MCC-M, which resulted in Mir's loss of attitude control and it going to free drift.	Both NASA and RSA agreed to continue to evaluate and consider the safety of conducting external photography of the station and performance of this activity only during opportunities such as crew rotation. Meanwhile, NASA's Phase 1 program management continued to stress the risks inherent in such operations and to request that untended operations be conducted only when necessary to conduct essential repairs or maintenance on the Mir station.	Operations
O21	Joint Report	Prior to the STS-63/Mir-17 rendezvous mission, concerns were expressed by both RSA and NASA regarding the loads and contamination effects of the Shuttle RCS during approach and docking with the Mir station.	By taking advantage of orbital mechanics and by employing the Low-Z RCS thruster type of approach, upfiring RCS jets used for braking and their adverse plume effects on Mir were minimized.	Operations
O22	Joint Report	Prediction of off-nominal or maximum docking loads to be expected during the Shuttle-Mir Phase 1 missions is challenging and not an exact science. It is critical to select a method and technique that will ensure that the lifetime structural design limits of Mir are not exceeded.	To assume absolute worst case loads using limiting values for all contact conditions simultaneously, while highly improbable, would be unreasonably conservative. Although statistical techniques are less conservative and have fewer historical precedents than "worst on worst" techniques, they were chosen for the docking loads discipline with full knowledge that the structures involved had a mature design and operational history. The solution methodology was backed by confidence in the structures involved, simulation accuracy/results, and crew performance in training and data base runs.	Operations
O23	Joint Report	Loads imposed by the Shuttle Primary RCS (PRCS) jets on the structural elements of the Mir station during docking have been studied and the results documented from flights STS-63, STS-71, STS-74, and STS-76. As the Mir configuration changes, it is prudent to continue to perform analyses to verify that loads on all Mir elements are not exceeded.	Load patterns from RCS plumes have been measured using the SPIFEX device on STS-64. Confidence was gained in the plume model and plume analysis techniques by observing Mir solar panel responses during the close proximity operations of STS-71, STS-74, and STS-76. This knowledge would be applied to changes in the Mir configuration as they occur.	Operations

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
O24	Joint Report	Prior to STS-63, several missions recorded oxidizer leaks from the Shuttle RCS. There were no safety-of-flight concerns related to these leaks, and prior to STS-63, they did not threaten mission success. In the proximity of Mir, however, propellant leaks pose significant risks for damage to the critical sensors and power collecting solar arrays of the Soyuz return vehicles and Mir.	Programmatic changes, such as (1) operations improvements, (2) improved valve maintenance, and (3) the pursuit of valve design improvements, were implemented into the Shuttle fleet and were intended to provide a broad range and long-term solution to the concerns about RCS thruster leaks.	Operations
O25	Joint Report	To maintain adequate power margins, the Mir station must fly in an attitude to maximize solar panel exposure to the Sun. The optimum attitude for collecting critical electrical power with the solar panels on Mir is an inertial attitude. During Shuttle rendezvous and docking, the current procedures require Mir to leave this inertial attitude, maneuver to and maintain an orbital attitude, and maneuver the docking module located on the Kristall module so that the docking port on the minus Z-axis of Mir is aligned toward the radius vector (toward Earth). This procedure reduces Mir power reserves and can prevent a one-revolution delay of the docking opportunity.	Rendezvous and docking timelines were modified to allow minimum time for Mir to be out of its optimum solar collection attitude. The Shuttle was flown to a stationkeeping range of 170 feet (52 meters) before Mir was maneuvered to docking attitude. Once Mir maneuvered to attitude, the time for the Shuttle to effect docking was reduced to 25 minutes.	Operations
O26	Joint Report	If the primary DM electromechanical hook activation and the backup pyro-bolt activation fail during the Shuttle undock from Mir, the current procedure is to perform an EVA from the Shuttle to remove the 96 bolts on the ODS and separate at that interface. This procedure would leave the ODS cone attached to the Kristall module and render this docking port on the Mir station unusable.	A proposal was made to activate the docking hooks on the Kristall side of the DM interface, leaving the DM attached to the Shuttle at separation. After separation and flyaway, the 96-bolt EVA would then be performed and the DM jettisoned, leaving the Kristall port accessible for further docking operations. This option was pursued and analyzed to maintain use of the Kristall docking port. The U.S. and Russian teams decided not to use this option to preserve a possible subsequent repair of the failed mechanical hooks and continued use of the DM by the Shuttle for continued logistic flights.	Operations
O27	STS-86 Readiness Letter	Mir is designed according to a "fail-to-maintenance" operations concept, which allows its systems to be completely shut off if they malfunction. NASA builds redundancy within each system in an effort to ensure that it does not fail.	This "fail-to-maintenance" operational concept was listed as a lesson learned for the ISS.	Operations
O28	STS-91 Readiness Letter	The docking system on this flight is the new ISS design that provides the softened docking and residual loads required by the ISS.	The ISS docking system was sufficiently tested for compatibility, with no docking issues remaining for flight.	Operations
O29	STS-91 Readiness Letter	During a tanking test, the fuel cell #3 water relief valve was found to be leaking. The primary impact was that overboard leakage could reduce the amount of water transferred to Mir.	The Space Shuttle program implemented a workaround procedure that maximized water production and transfer by managing water tank pressure to minimize overboard dumping of fuel cell water.	Operations

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ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
P1	Second Report	The feasibility of accelerating the schedule for the second APDA in time to serve as a back-up for STS-71 and the impacts involved in doing so should be investigated.	Accelerating the second APAS for use as an STS-71 spare was investigated and was determined not to be feasible.	Planning
P2	Second Report	It should be verified that the shipping environment does not adversely impact the three APDA's following their shipment from NPO-Energia, where the final fit check will be performed.	Damage from shipping the APDA's from Russia to KSC was considered highly unlikely. However, KSC planned to implement postdelivery inspection criteria that would utilize mechanisms and functional testing.	Planning
P3	Second Report	The risk decision should be revisited and the risk involved in handling the DM assessed, as well as the ground support equipment needed to perform an ODS/DM fit check.	Based on several joint discussions, it was felt that the ODS/DM fit check performed in Russia would not be invalidated because of controlled transportation requirements. However, KSC planned a postdelivery inspection using NPO interface tooling and a functional test.	Planning
P4	Third Report	NASA must retain the flexibility to insert as many as three additional Phase 1 docking missions, up to the 10 agreed on with RSA, for as long as possible.	The NASA baseline manifest provided the Phase 1 program options for an additional three Mir docking missions. The need to commit to the first of these three missions would have to occur no later than early 1996 to complete all three before the start of Phase 2.	Planning
P5	Third Report	If not already under consideration, NASA should determine the feasibility of installing maximum accelerometers in each of the APDS shipping crates during transportation.	It was the intent to implement this capability depending on the cost and schedule impact of doing it.	Planning
P6	Fourth Report	NASA must tailor expectations for science during the Mir-18 Main Expedition because of the late arrival of experiment hardware and flight procedures. Emphasis in the science area should focus solely on astronaut Thagard's efforts to characterize the Mir station environment and provide valuable lessons on how to best achieve U.S. scientific goals aboard Mir. The successful completion of specific experiments should be viewed within this context rather than as a separate measure of success.	It should be noted that the flight experiment hardware and flight procedures arrived according to schedule; however, the equipment was held in Russian customs for 2 weeks prior to delivery to NPO-Energia. This schedule permitted only a minimum period of training prior to the scheduled launch. This process provided valuable lessons in the area of coordinating scientific efforts with our Russian colleagues. The United States and Russia expected that many, if not most, of the scientific objectives would be met even though preflight training time was short. The Russian philosophy in this area is quite different from the American philosophy. The Russians often deliberately train to a limited degree preflight and continue the training process during their long-duration missions to conduct the science. In the American process, the crew is trained extremely well prior to flight because Shuttle flights are fairly short and little, if any, opportunity may exist for on-orbit training. Both sides learned valuable lessons in this area.	Planning

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
P7	Fourth Report	If the assistance of a cosmonaut is not available during the Mir-18 Main Expedition to conduct time critical experiments, the experiments that require such assistance should be rescheduled.	The principal mission of the cosmonauts on Mir-18 was to refurbish and update Mir. Given this priority, cosmonaut assistance with experiments may or may not have been available. If assistance was required and could not be provided, then those items would need to be rescheduled.	Planning
P8	STS-76 Readiness Letter	Because of launch delay of the Russian Priroda module, hardware for Shannon Lucid's experiments would not be available until Priroda arrives in April 1996.	The Shuttle-Mir science program adjusted the research timeline. Although recurrence was unlikely, future science/hardware delivery planning should be able to accommodate real-time hardware delivery schedule changes.	Planning
P9	STS-79 Readiness Letter	The impact of delaying the launch was reviewed with respect to medical operations, logistics, science, training, systems integration, the science interface with CNES/Euro-Mir mission, and the return of Shannon Lucid.	There was little to no impact; supplies were added via Progress-232 launched on August 1, 1996, and the slip helped by providing a more reasonable science operations plan, allowing joint training opportunities, and synchronized the Mir-22 and STS-79 sleep periods.	Planning
S1	Second Report	NASA must evaluate DM safety review schedule acceleration versus risk acceptance.	The Phase 3 safety review was completed prior to the hardware delivery, which was consistent with requirements. No gain was to be realized by accelerating the safety review schedule.	System Safety
S2	Second Report	The robustness of the Russian Mir model must be fully analyzed and understood to assess stack dynamic response.	The recommendation was concurred with, and the joint approach and agreement were transmitted to the Task Force.	System Safety
S3	Second Report	A Loads Analysis DTO corresponding to the STS-71 DTO should be conducted on STS-74. The data this DTO will produce are critical to the safety of the Phase 1 program.	The recommendation was concurred with, and an STS-71 mated Shuttle-Mir PRCS jet pulsing test was negotiated with the Russians during the December TIM.	System Safety
S4	Second Report	The Russian Mir structural dynamics model must be fully analyzed and the resulting digital autopilot controllability and structural integrity determined.	The Mir model with all test-derived updates was provided to the Space Shuttle program's control stability discipline for stability margin analysis.	System Safety
S5	Second Report	NASA should continue to use pressure suits for entry and landing.	The Space Shuttle program concurred with this recommendation.	System Safety
S6	Third Report	NASA should ensure that those items of the Preliminary Delta Requirements for ISSA Program Androgynous Peripheral Docking System (APDS) Hardware memorandum, dated October 14, 1994, which are ultimately identified as the minimum set of requirements necessary to ensure a safe and successful Shuttle/ISSA docking program, be inserted in the RSA APDS procurement specification and implemented.	Representatives from the JSC DM Integrated Product Team conducted meetings and telecons with RSA/RSC-E engineers to define the minimum set of APDS requirements necessary for safe and successful ISSA/Shuttle docking. The ISSA APDS procurement specification was documented with the required APDS modifications and sent to RSC-E.	System Safety

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ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
S7	Third Report	NASA should actively continue to consider options for improving the APDS.	The DM Integrated Product Team continued to evaluate the APDS design and operation to explore new options that would make it more reliable. The separation of critical functions through the connectors and interior circuit board wiring of the new avionics switch box for STS-74 was an example of improved fault tolerance. NASA also implemented the capability to undock the Shuttle from either Mir or ISSA at an independent separation plane with a contingency EVA should both the primary and secondary undocking system fail.	System Safety
S8	Third Report	NASA should prepare a contingency plan that provides an alternative method for Shuttle-Mir de-mating in the event that the testing of the pyrotechnic bolts produces unacceptable results.	NASA developed a contingency EVA plan that would allow the Shuttle to de-mate from Mir/ISSA by removing the 96 bolts from an independent interface plane of the ODS. This EVA would be used on any of the Mir missions only if both the primary means (latch motors) and secondary means (pyrotechnic bolts) of de-mating are not successful in releasing the APAS latches.	System Safety
S9	Third Report	If the reliability and safety certification data for the pyrotechnic bolts continue to be unavailable from RSA, NASA should pursue the option to have replacement pyrotechnic bolts manufactured for STS-74 and subsequent missions that satisfy the NASA certification process.	The STS-74 APAS mechanism were delivered with Russian-built pyrotechnic bolts. NASA investigated the possibility of a U.S.-built pyrotechnic bolt. However, the Limited Rights Notice clause in the RSA contract prohibited the use of Russian data to manufacture equivalent hardware.	System Safety
S10	Third Report	Options should continue to be investigated that will leave the Mir port available for subsequent dockings should the EVA contingency be necessary.	The baselined 96-bolt EVA did not protect the Mir docking port for future dockings. However, Mir port clearance options were defined and evaluated for joint program impact. The options evaluated were (1) installing the STS-74 switch box on every Mir flight and (2) laying in wire from the airlocks interface panel to the ODS/DM interface.	System Safety
S11	Third Report	The possibility of performing the ODS/DM fit check should continue to be pursued. The importance of performing the fit check on the ground before attempting to mate the two units in orbit dictates that all reasonable approaches to performing the fit check be examined. Documented rationale should be provided for methods that are considered but not chosen.	The STS-74 ODS to DM test plan for KSC was approved by the Space Shuttle program's Program Requirements Control Board and implemented.	System Safety

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
S12	Third Report	All remaining SPIFEX data should be processed expeditiously and the results provided to the Russians as quickly as possible to enable them to update their loads calculations on critical Mir elements.	The flight SPIFEX was provided to the Russian plume specialist and discussed in detail at the joint integration Working Group meetings. The Russian/NASA plume load experts believed that the enhanced plume model would provide increased confidence in our joint understanding of close-in plume loading effects on critical Mir elements, reinforcing predictions that our planned mission operational margins and constraints were quite adequate.	System Safety
S13	Third Report	The structural model of the Mir solar panels should be validated and the panel loads constraints understood.	The Russians performed Mir structural dynamic model verification tests based on their assessments of the data and updated their model as necessary. In addition, loads sensitivity analyses were performed by JSC to check the validity of the margins being utilized for Mir load model uncertainty.	System Safety
S14	Third Report	NASA should request RSA to provide their updated plume loads analysis results.	The RSA position was that both cost and schedule made it prohibitive for them to independently verify the NASA plume load calculations. However, based on this situation, JSC performed an independent static solar panel load analysis and was confident that the effects of Shuttle plume loads imparted to the Mir panels were acceptable.	System Safety
S15	Third Report	The analysis team should practice and demonstrate their ability to rapidly exploit the flight data to be gathered by the Loads Analysis DTO.	A near-real-time flight support program, to accommodate a contingency orbiter vernier thruster failure, was developed by JSC in time to support STS-71.	System Safety
S16	Third Report	Mission assurance will be enhanced by reducing Mir structural model uncertainty before flight and maximizing digital autopilot stability margins to this uncertainty even if it exceeds 20 percent.	Digital autopilot stability margins were expanded at the expense of performance, and the notches were designed to incorporate a larger structural uncertainty. Notches were developed to support up to a 30-percent frequency difference; however, this percentage included not only structural math modeling uncertainties, but also solar panel articulation effects, Mir configuration differences, and variations from the number of docking latches engaged.	System Safety
S17	Third Report	Mir's attitude control system must be better understood to evaluate risk associated with Mir control of stack attitude.	NASA performed Mir ACS simulations to gain an understanding of the Mir ACS performance and to evaluate RSC-E's Mir attitude control system analysis. These simulations provided insight into the Mir control system capabilities and allowed NASA to concur with RSC-E's control system commit to flight without an extensive amount of simulations and expense required for a full independent certification.	System Safety

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ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
S18	Third Report	The refined loads analysis resulting from the higher fidelity models recommended should be tracked and progress reports presented to project management to ensure that any loading issues will be identified in sufficient time to mitigate programmatic impact.	The final planned load cycle for STS-71 included a new approach, separation jet firing time histories, and a new plume model. The load cycle results were reviewed by the Phase 1 program director for any program concerns.	System Safety
S19	Third Report	NASA should consider expediting the statement of work to TsNIIMash to provide model validation of critical Mir elements.	An independent activity was initiated by NASA Headquarters, but the effort was terminated; it became clear that the validation results would not be available in time to support JSC analysis activities and the mission certification processes. However, it was felt that the engineering DTO's and various program certification check points provided the program an adequate safeguard against Mir modeling uncertainties.	System Safety
S20	Fourth Report	Reciprocal U.S./Russian payload safety certifications should be assessed.	Reciprocal payload safety certifications were exchanged and recognized under the terms of the Program Managers' Agreements on Safety Certification of payloads for transportation and operations on U.S. or Russian vehicles. Each side conducted a safety analysis of its payloads, including hazard reports, and submitted the results to the other side for approval. Additional data were sometimes requested by the approving side to ensure understanding of the details of the analysis and that all requirements were met.	System Safety
S21	Fifth Report	In future discussions with the Russians regarding untended Mir station operations, particularly during Shuttle-Mir missions, NASA should stress the risks inherent in such operations and request that such operations be conducted only when necessary to conduct essential repairs or maintenance on the Mir station.	The Phase 1 Program Director indicated to the Russians our opinion that leaving the Mir untended for the Soyuz to photograph the Shuttle-Mir undocking was an unnecessary risk to the Phase 1 program. However, because Mir is a Russian vehicle, the Russians were responsible for Mir and Soyuz operations, and they expressed confidence in the untended Mir exercise based on their experience with numerous successful dockings and undockings.	System Safety
S22	Joint Report	The Union of Soviet Socialist Republics (USSR) developed and launched the Mir orbital station in February 1986. The original life resource of the station was 3 years, with the expectation that it would be extended to 5 years. Just prior to the 10th anniversary of Mir, RSA notified NASA of its intention to maintain the Mir station through 1998. Discussions were held at JSC, where NASA and RSA officials agreed to extend the operational life of Mir and resupply it with additional Phase 1 Shuttle rendezvous and docking flights.	In agreeing to extend the lifetime of Mir resources for the support of work under Phase 1, RSA had to conduct the following activities: (1) additional structural verification tests related to increased payload requirements and frequent Shuttle docking; (2) main system (electrical, life support, thermo-regulation, etc.) design parameter improvements to extend the duration and improve the fidelity of operations, especially in relation to increased crew requirements; and (3) instrumental module modifications and usage of motion control systems for Shuttle-Mir docking and joint operations.	System Safety

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
S23	Joint Report	Concerns were raised regarding NASA standards for evacuating U.S. EVA astronauts in an emergency Shuttle deorbit contingency situation when the Shuttle is docked to the Mir station.	In such an emergency, U.S. EVA crew members would terminate their EVA tasks and immediately return to the Shuttle Payload Bay. The crew would commence the undock and separation maneuver and Payload Bay door closure would begin. U.S. EVA crew ingress into the Shuttle airlock could occur simultaneously with or subsequent to the undock and Payload Bay door closing operations. There was no intention of abandoning U.S. EVA crew members at the Mir station in the event of an emergency requiring immediate Shuttle deorbit.	System Safety
S24	STS-76 Readiness Letter	The Russians expressed a desire to be able to jettison the DM in event a 96-bolt EVA separation from Mir was necessary.	An in-flight maintenance procedure would have been required, but this was not trained for, so this procedure was replanned for STS-79.	System Safety
S25	STS-76 Readiness Letter	There was to be a U.S. EVA on this flight to remove an external camera and to install some sample collectors on the DM.	The crew demonstrated in the WETF that they could complete the tasks well within the 6 hours available for the EVA.	System Safety
S26	STS-76 Readiness Letter	During the STS-76 Flight Readiness Review, an SRB singed O-ring anomaly in the nozzle-to-case joint for the boosters used in the STS-75 launch was noted.	A re-review concluded that the nozzle-to-case joint seal was robust and stable and that STS-76 was ready to fly.	System Safety
S27	STS-79 Readiness Letter	It was elected to change out the SRB's after inspection of the STS-78 SRB sooting and heat effect in the J-joint insulation interface of all six field joints.	A return to the pre-STS-78 materials/process was expected to remedy this condition for STS-79 and subsequent flights.	System Safety
S28	STS-79 Readiness Letter	Additional N <sub>2</sub> was needed to purge the Mir Elektron O <sub>2</sub> generation systems, and the Russians requested that the Shuttle deliver a N <sub>2</sub> servicing system.	The Russian N <sub>2</sub> servicing system was delivered on STS-79.	System Safety
S29	STS-84 Readiness Letter	Some of the recent failures, especially the continuing coolant loop leaks caused by corrosion in the aluminum alloy, may continue to plague the Mir crew.	These failures did not constitute a safety-of-flight concern.	System Safety
S30	STS-84 Readiness Letter	Failure of O <sub>2</sub> -producing Elektron units or the Vozdukh CO <sub>2</sub> scrubbers were challenging operational issues.	These failures did not constitute a safety-of-flight concern because there was adequate backup O <sub>2</sub> available and CO <sub>2</sub> removal capability.	System Safety
S31	STS-86 Readiness Letter	Regular fire procedures/drills should be instituted.	Accepted and implemented.	System Safety
S32	STS-86 Readiness Letter	Rendezvous attempts should not be made without availability of range and range-rate data. A manual TORU system is acceptable for docking only if the vehicle is in stable proximity operations status.	The Russians agreed not to attempt rendezvous without range and range-rate displays available to the crew.	System Safety
S33	STS-86 Readiness Letter	Oxygen-generating canisters have low failure rates and are an effective backup system.	Precautionary safety measures were implemented to ensure safe operation.	System Safety

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ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
S34	STS-91 Readiness Letter	A new testing method detected gas levels that had always been present in galley water.	No action required.	System Safety
S35	STS-91 Readiness Letter	Conditions on Mir significantly improved as a result of the repairs made since the fall of last year.	No action required.	System Safety
S36	STS-91 Readiness Letter	There was a recent failure of the "left side" control panel for the Mir control system. This panel is used to switch to the control mode used for docking. The right side control panel is a redundant panel and was operating normally. The laptop control panel for the TORU system can be reconfigured and used, if required. In addition, control mode switching can be accomplished by MCC-M.	No action was taken; the control system was fully redundant.	System Safety
T1	First Report	The mission commander and payload commander for subsequent Shuttle-Mir missions should be named at least 18 months in advance of the scheduled launch date.	The Space Shuttle program concurred, and the JSC Russian Projects Office transmitted a letter to the JSC Center Director advising the office of the Task Force recommendation and program concurrence.	Training
T2	Second Report	The tools, support equipment, training schedule, and equipment fidelity needed should be determined to support the EVA de-mate contingency for STS-71 and, if necessary, subsequent missions.	The Space Shuttle program developed a plan to ensure adequate training for an EVA de-mate contingency on STS-71.	Training
T3	Second Report	EVA procedures should be established, including a method to ensure positive, simultaneous, and symmetrical release.	Specific procedures and hardware were developed to ensure positive and simultaneous release.	Training
T4	Fourth Report	All U.S. crew members who will be serving on the Mir station must be identified no less than 2 years prior to their mission to begin the necessary language training.	The selection of the original U.S. crew members met this criterion. However, Dave Wolf and Andy Thomas were identified within the 2-year window because they had to replace two of the originally selected crew members because of the size restrictions of the Orlan spacesuit.	Training
T5	Fourth Report	It is imperative that flight and training hardware for U.S. experiments as well as flight procedures be available in Russia in accordance with a jointly agreed-on schedule. In the event that the necessary items are not available within that schedule, the experiment should be postponed or canceled.	This remained an issue. The recommendation carried over to ISS program.	Training
T6	Joint Report	Russian-to-English translation of the payload Flight Data File has not been provided to the crew in time for desired training, affecting both training and mission operations.	NASA reached agreement with RSA and RSC-E, in which RSA curators review payload Flight Data File procedures and operations manuals for safety and compatibility with Mir, prior to establishing the procedures in English and in Shuttle format. This essentially moved the procedure review by the curators to immediately before the procedure verification time frame, alleviating the problem.	Training

## Appendix A

ID #	Source Document	Findings/Recommendations	Resolution/Actions Taken	Issue Area
T7	Joint Report	Training time for joint missions is extremely demanding on the assigned crew's availability. If the role of the U.S. crew members while on the Soyuz vehicle is to be limited to emergency undocking and entry functions only, the level of training needed at GCTC may need to be reduced.	Soyuz training for U.S. crew members was reduced to the minimum required for rescue vehicle purposes.	Training
T8	STS-76 Readiness Letter	There is a continuing problem with the timely translation for the experiment Flight Data File, causing excessive training demands on Mir-bound astronauts during the final months prior to launch.	Process improvements were considered by the Phase 1 programs of both countries.	Training
T9	STS-86 Readiness Letter	The analysis of crew training should include the improvement of onboard training.	Open. The recommendation carried over to the ISS program.	Training



# Appendix B

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## Task Force Members



**Members of the NASA Advisory Council  
Task Force on the Shuttle-Mir Rendezvous and Docking Missions and the  
Task Force on International Space Station Operational Readiness**

<b>Members</b>	<b>Dates Served</b>
Lt. Gen. Thomas P. Stafford, USAF (Ret.)	1994–Present
Col. James C. Adamson, U.S. Army (Ret.)	1994–Present
Dr. Bobby Ray Alford	1995
Cdr. Michael Baker, USN	1996
Col. John Blaha, USAF (Ret.)	1997–1998
Benjamin Cosgrove	1997–Present
Joe Cuzzupoli	1995–Present
Dr. Charles Daniel	1995–Present
Dr. John Fabian	1994–Present
Dr. Craig Fischer	1995–Present
Dr. Michael Greenfield	1994–Present
Dr. Daniel Heimerdinger	1996–Present
Maj. Gen. Ralph Jacobson, USAF (Ret.)	1994–Present
James M. Heflin, Jr.	1994–Present
Cdr. Michael Lopez-Alegria, USN	1998–Present
Dr. Ronald Merrell	1995–Present
David Mobley	1994–1995
Dr. Arnauld Nicogossian	1994–1998
Col. Charles Precourt, USAF	1996–1997
Capt. William F. Readdy, USNR	1995–1996
Chester Vaughn	1994–1996
Capt. John W. Young, USN (Ret.)	1994–Present
<b>Executive Secretaries</b>	
William Vantine	1994–1995
Gilbert R. Kirkham	1995–1997
Dennis McSweeney	1997–1999
Philip Cleary	1999–Present
<b>Technical Advisors</b>	
Maj. Gen. Joe H. Engle, USAF (Ret.)	1994–Present
Glynn Lunney	1994–1997
Michael Weeks	1995–1996
<b>Ex-Officio Members</b>	
David Jossi	1995–1996
Jim Snowden	1996–1998
Mark Thiessen	1998–Present
<b>Administrative Officer</b>	
Holly Stevens	1996–Present





# Appendix C

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**Stafford Task Force Phase 1  
Reports and Readiness Letters**



**Stafford Task Force  
Phase 1 Reports and Readiness Letters**

Task Force Reports:

First Report	June 6, 1994
Second Report	July 29, 1994
Third Report	November 2, 1994
Fourth Report	March 1, 1995
Fifth Report	September 21, 1995

First Joint Report of the Task Force and Advisory Expert Council June 27, 1996

Task Force Readiness Letters sent from General Stafford to Administrator Goldin:

STS-71	June 22, 1995
STS-74	November 6, 1995
STS-76	March 15, 1996
STS-79	September 10, 1996
STS-81	January 8, 1997
STS-84	May 7, 1997
STS-86	September 23, 1997
STS-89	January 15, 1998
STS-91	May 27, 1998





# Appendix D

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## Shuttle-Mir Mission Summary Chart



## The Final Report of the International Space Station Phase 1 Program

Mission	Mission Start Event	Mission End Event	Crew	Mission Information
STS-60	STS-60 Launch: 2/3/94	STS-60 Landing: 2/11/94	Cdr: Charlie Bolden Pilot: Ken Reightler MS: Franklin Chang-Diaz MS: Jan Davis MS: Ron Sega MS: Sergei Krikalev	Krikalev is first cosmonaut on Shuttle
STS-63	STS-63 Launch: 2/3/95	STS-63 Landing: 2/11/95	Cdr: Jim Weatherbee Pilot: Eileen Collins MS: Janice Voss MS: Bernard Harris MS: Mike Foale MS: Vladimir Titov	Rendezvous with Mir; cosmonaut Titov on Shuttle
Mir-18/NASA-1	Soyuz-70 Launch: 3/14/95	STS-71 Landing: 7/7/95	Cdr: Vladimir Dezhurov Eng: Gennady Strekalov NASA 1: Norman Thagard	First U.S. astronaut to launch on Russian Soyuz; first U.S. astronaut on Mir
Spektr	Spektr Launch: 5/20/95	N/A	Unmanned	Carries U.S. research hardware
STS-71	STS-71 Launch: 6/27/95	STS-71 Landing: 7/7/95	Cdr: Robert "Hoot" Gibson Pilot: Charlie Precourt MS: Ellen Baker MS: Greg Harbaugh MS: Bonnie Dunbar MS: Norman Thagard Cosmonaut: Anatoly Soloviev Cosmonaut: Nikolai Budarin Cosmonaut: Vladimir Dezhurov Cosmonaut: Gennady Strekalov	First Shuttle-Mir docking; Mir-19 cosmonauts delivered to Mir; Mir-18 cosmonauts returned to Earth; Spacelab mission; Thagard, Dezhurov, and Strekalov return to Earth; Soloviev and Budarin remain on Mir
Mir-19	STS-71 Launch: 6/27/95	Soyuz-70 Landing: 9/11/95	Cdr: Anatoly Soloviev Eng: Nikolai Budarin	
Mir-20	Soyuz-71 Launch: 6/27/95	Soyuz-71 Landing: 2/29/96	Cdr: Yuri Ghidzenko Eng: Sergei Avdeev ESA: Thomas Reiter	Space Shuttle mission
STS-74	STS-74 Launch: 11/1/95	STS-74 Landing: 11/8/95	Cdr: Kenneth Cameron Pilot: James Halsell MS: Jerry Ross MS: William McArthur MS: Chris Hadfield	STS-74 docks with Mir Second Shuttle-Mir docking; delivers Docking Module and Cooperative Solar Array
Mir-21	Soyuz-72 Launch: 2/21/96	Soyuz 72 Landing: 9/2/96	Cdr: Yuri Onufriyenko Eng: Yuri Usachyov	
STS-76	STS-76 Launch: 3/22/96	STS-76 Landing: 3/31/96	Cdr: Kevin Chilton Pilot: Richard Searfoss MS: Rich Clifford MS: Linda Godwin MS: Shannon Lucid MS: Ron Sega	Third Shuttle-Mir docking; first EVA during docked operations; Lucid delivered to Mir; first Spacehab mission to Mir

# Appendix A

Mission	Mission Start Event	Mission End Event	Crew	Mission Information
NASA-2	STS-76 Launch: 3/22/96	STS-79 Landing: 9/26/96	NASA-2: Shannon Lucid	Stay lengthened approximately 6 weeks because of launch slip
Priroda	Priroda Launch: 4/23/96	N/A	Unmanned	Carries 1,000 kilograms of U.S. research hardware
Mir-22	Soyuz-73 Launch: 8/17/96	Soyuz-73 Landing: 3/2/97	Cdr: Valery Korzun Eng: Aleksandr Kaleri CNES: Claude Deshays	
NASA-5	STS-84 Launch: 5/15/97	STS-86 Landing: 10/6/97	NASA-5: Mike Foale	
Mir-24	Soyuz-75 Launch: 8/5/97	Soyuz-75 Landing: 2/19/98	Cdr: Anatoly Soloviev Eng: Pavel Vinogradov	
STS-86	STS-86 Launch: 9/25/97	STS-86 Landing: 10/6/97	Cdr: James Weatherbee Pilot: Mike Bloomfield MS: Wendy Lawrence MS: Scott Parazynski MS: Mike Foale MS: David Wolf Cosmonaut: Vladimir Titov CNES: Jean Loup Chretien	Wolf delivered to Mir; Foale returned to Earth; U.S. EVA; cosmonaut (Titov) on Shuttle; Double Spacehab Module
NASA-6	STS-86 Launch: 9/25/97	STS-89 Landing: 1/31/98	NASA-6: David Wolf	
STS-89	STS-89 Launch: 1/22/98	STS-89 Landing: 1/31/98	Cdr: Terrence Wilcutt Pilot: Joe Frank Edwards, Jr. MS: Bonnie Dunbar MS: Michael Anderson MS: James Reilly MS: David Wolf MS: Andy Thomas Cosmonaut: Salizan Sharipov	Thomas delivered to Mir; Wolf returned to Earth; Double Spacehab Module, OV-105
NASA-7	STS-89 Launch: 1/22/98	STS-91 Landing: 1/31/98	NASA 7: Andy Thomas	
Mir-25	Soyuz-76 Launch: 1/29/98	Soyuz-76 Landing: 8/10/98*	Cdr: Talgat Musabayev Eng: Nikolai Budarin CNES: Leopold Eyharts	
STS-91	STS-91 Launch: 6/2/98	STS-91 Landing: 6/12/98	Cmdr: Charlie Precourt Pilot: Dominic Pudwill Gorie MS: Wendy Lawrence MS: Franklin Chang-Diaz MS: Janet Kavandi MS: Andy Thomas Cosmonaut: Valery Ryumin	Thomas returned to Earth; Single Spacehab Module, OV-103; Alpha Magnetic Spectrometer Payload



# Appendix E

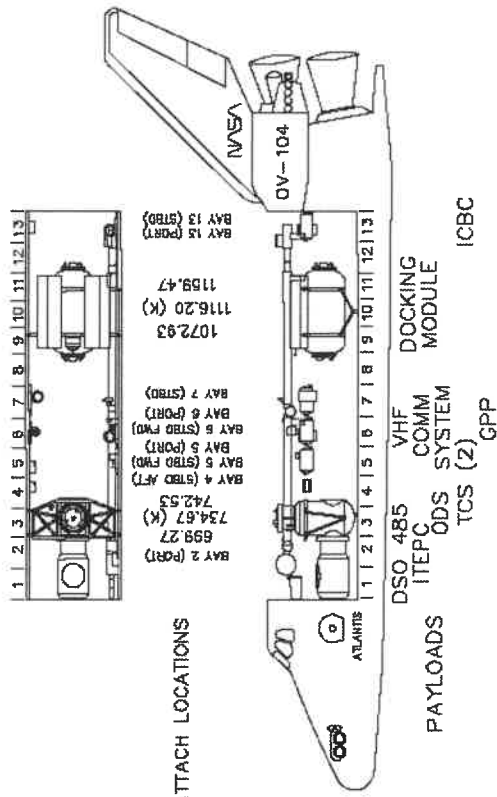
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## Shuttle-Mir Flight Configuration Table

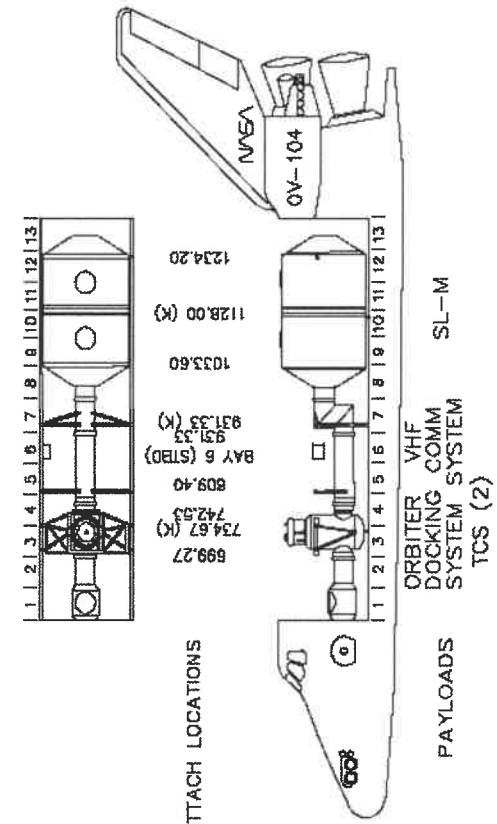


## The Final Report of the International Space Station Phase 1 Program

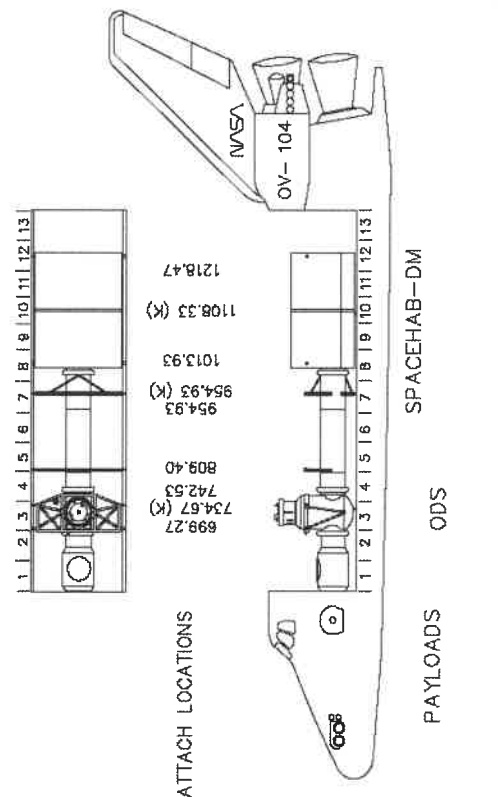
Space Shuttle				Mir	
Config. No.	Flight	Vehicle	Configuration (Figure 22)	Config. No.	Configuration (Figure 23)
1	STS-71	<i>Atlantis</i>	Spacehab	1	Baseline + Spektr
2	STS-74	<i>Atlantis</i>	Docking Module		Baseline + Spektr
3	STS-76	<i>Atlantis</i>	Single Spacehab	2	Baseline + Spektr + DM
4	STS-79	<i>Atlantis</i>	Double Spacehab	3	Baseline + Spektr + DM + Priroda
	STS-81	<i>Atlantis</i>	Double Spacehab		Baseline + Spektr + DM + Priroda
	STS-84	<i>Atlantis</i>	Double Spacehab		Baseline + Spektr + DM + Priroda
	STS-86	<i>Atlantis</i>	Double Spacehab		Baseline + Spektr + DM + Priroda
5	STS-89	<i>Endeavour</i>	Double Spacehab		Baseline + Spektr + DM + Priroda
6	STS-91	<i>Discovery</i>	Single Spacehab + ISS APDS		Baseline + Spektr + DM + Priroda



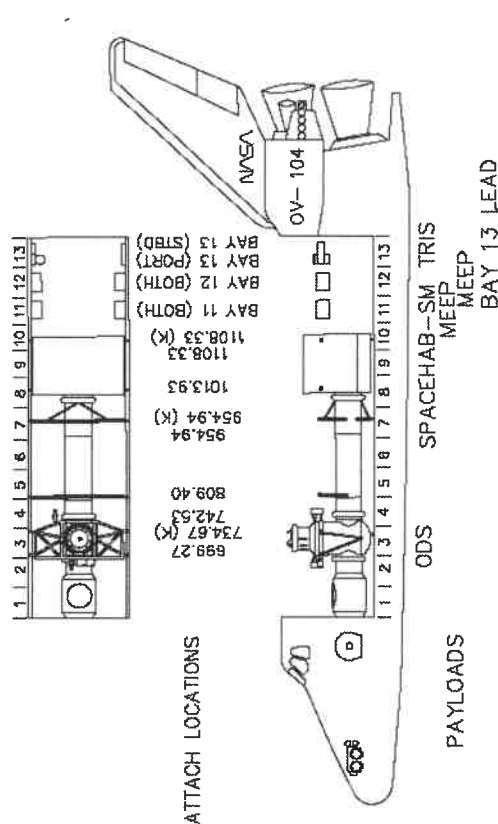
STS-74 (Config. 2)



STS-71 (Config. 1)

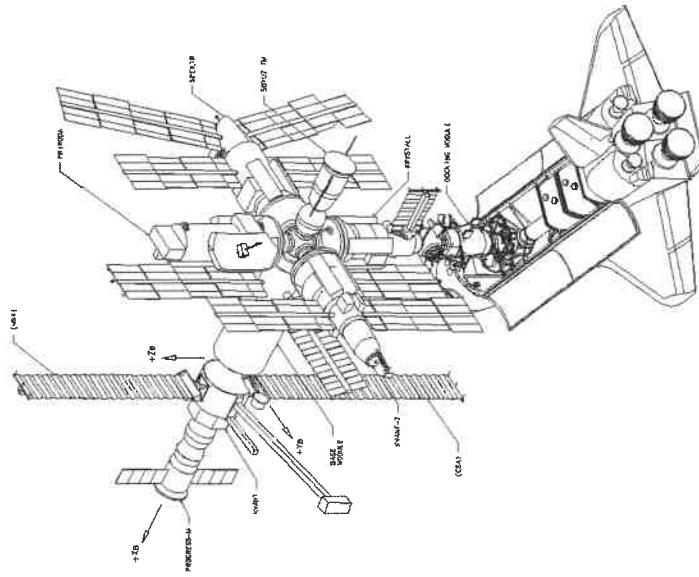


STS-76 (Config. 3, 6)

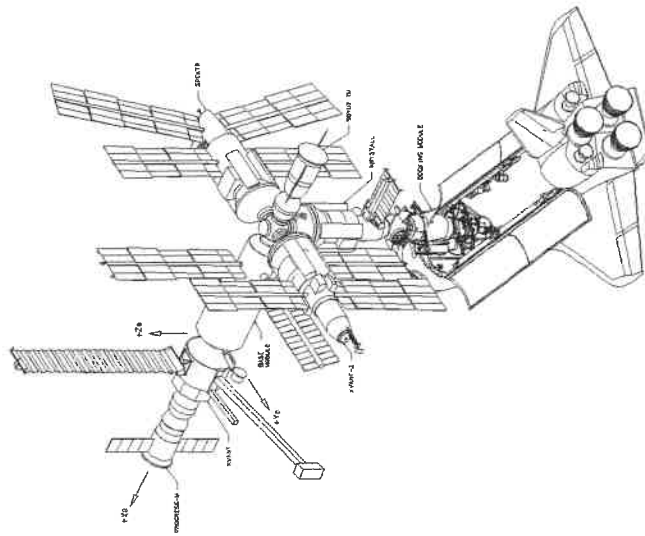


STS-79 (Config. 4, 5)

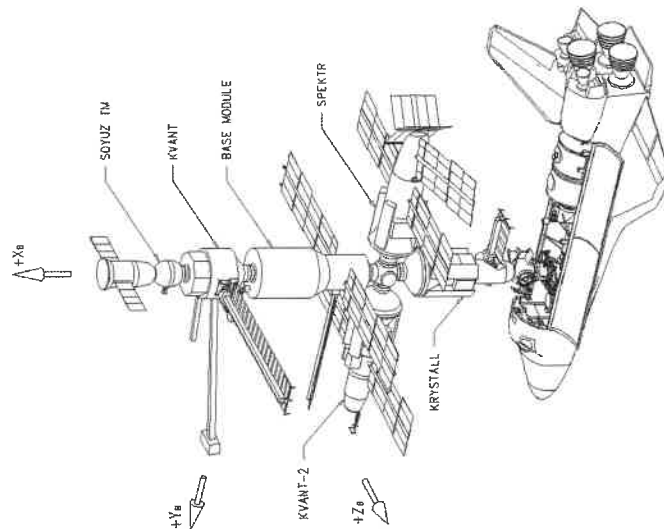
Figure 22. Four basic Shuttle configurations flown to Mir.



Mir-22



Mir-20



Mir-18

Figure 23. Three basic Mir configurations during docked operations.





# Appendix F

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## Acronyms

TIM	Technical Interchange Meeting
TORU	Telerobotically Operated Rendezvous System
TsNIIMash	Central Research Institute for Machine Building
USAF	U.S. Air Force
USN	U.S. Navy
V-bar	Velocity Vector
VHF	Very high frequency
VRCS	Vernier Reaction Control System
WETF	Weightless Environment Training Facility



# Appendix G

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## List of Figures

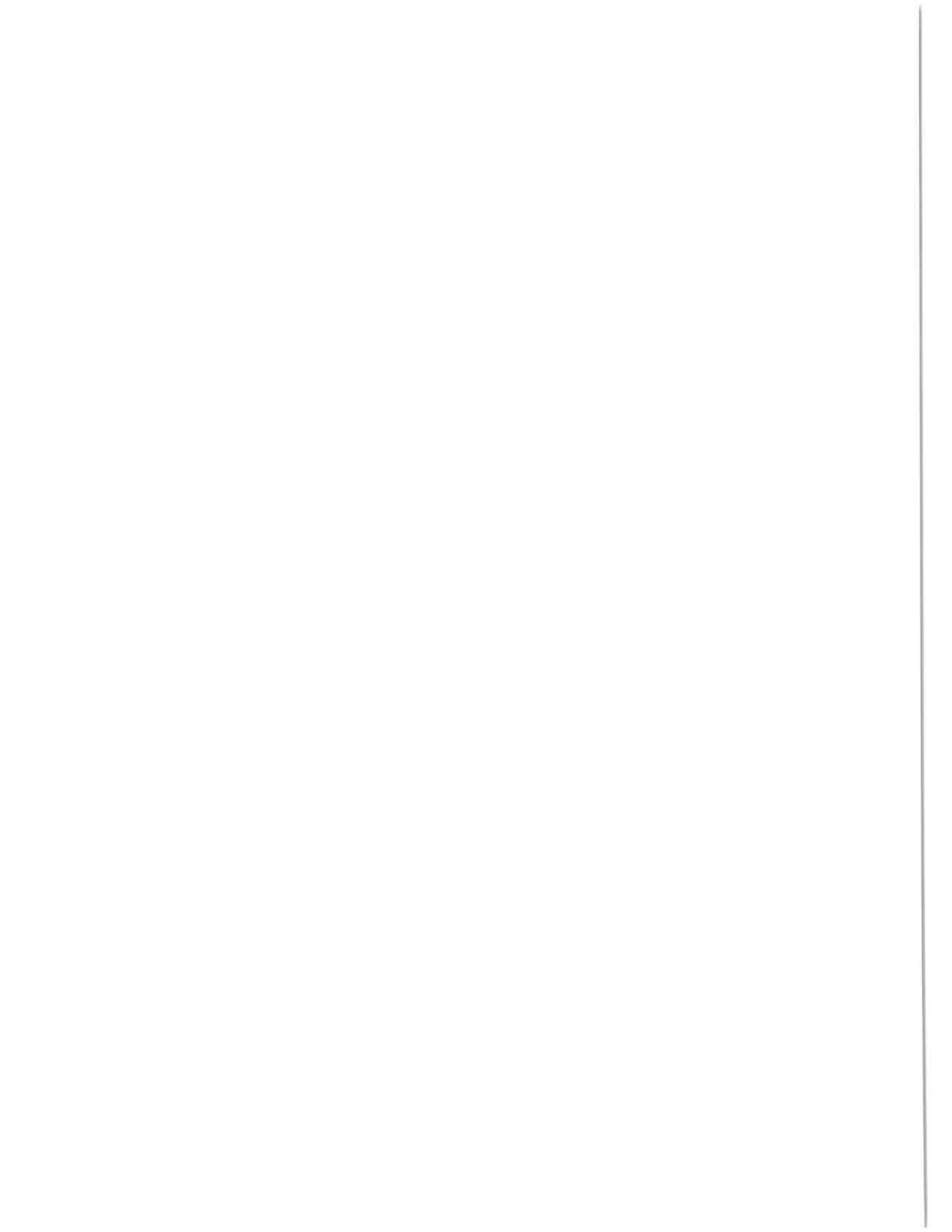


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