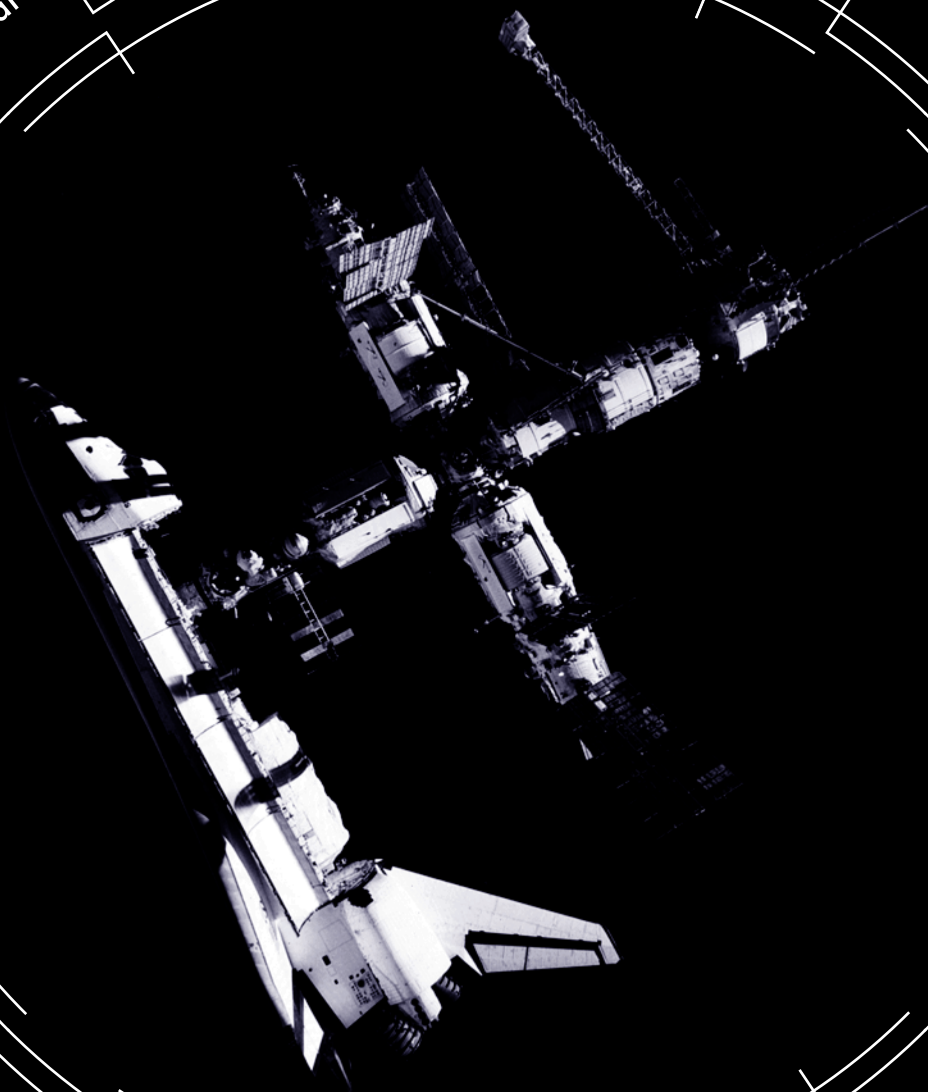
Stafford Task Force - Utkin Advisory Expert Council Joint Commission

International Space Station Phase 1 Program



JOINT FINAL REPORT

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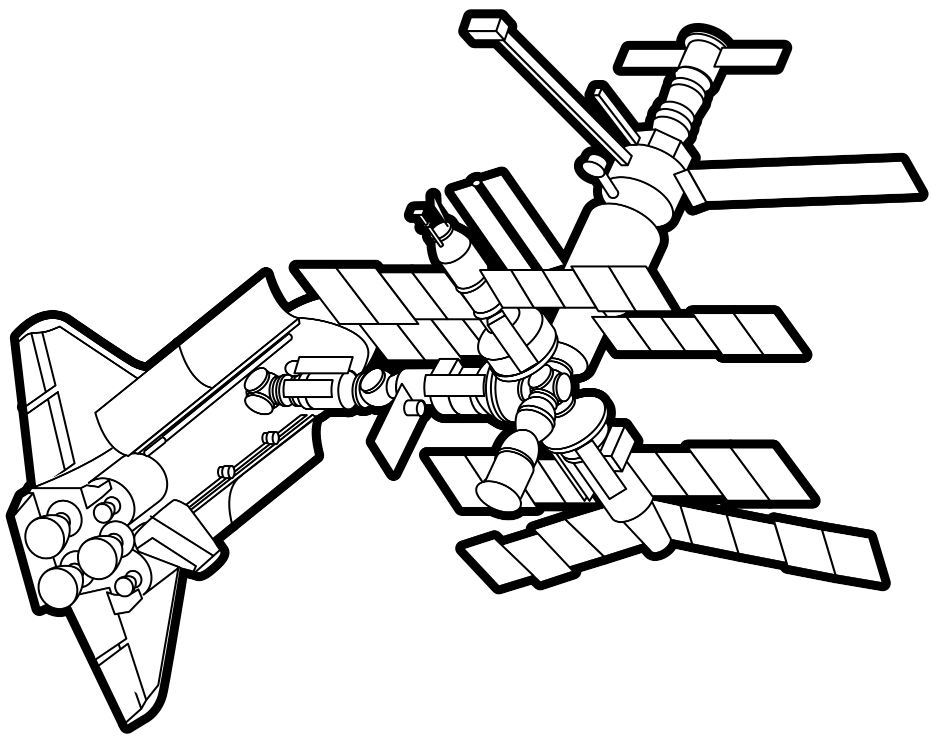


August 20, 1999

Mr. Daniel S. Goldin
Administrator
National Aeronautics
and Space Administration
Washington, DC 20546

Mr. Yuri N. Koptev
General Director
Russian Space Agency
129090 Moscow
Russia

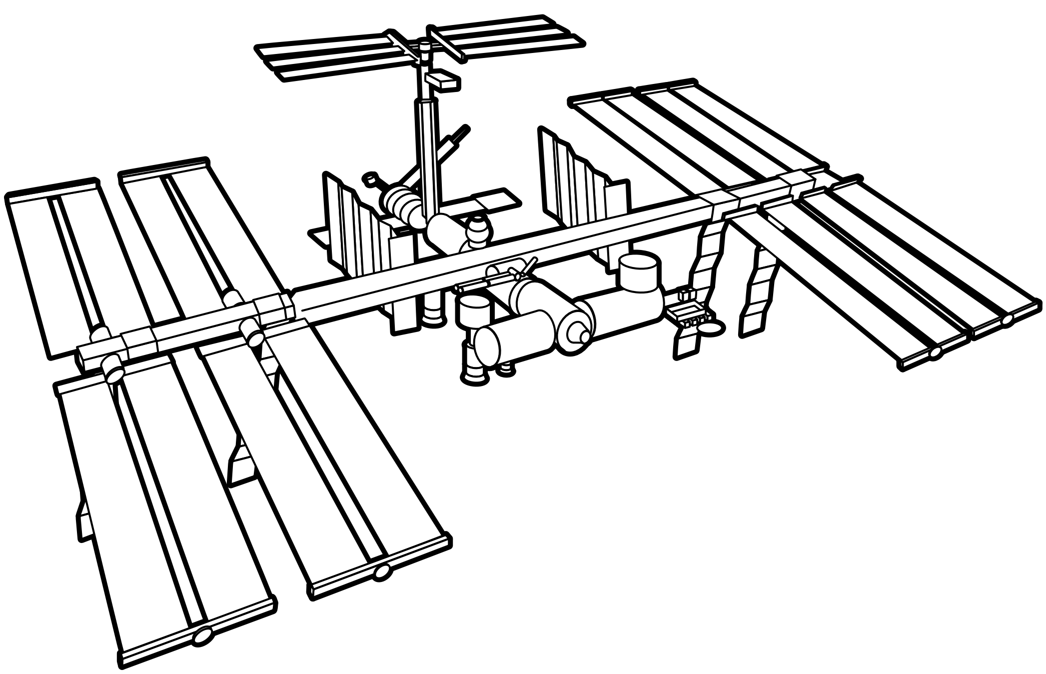
Enclosed is the NASA Advisory Council Task Force and RSA Advisory Expert Council's (TF-AEC) Joint Final Report on the International Space Station (ISS) Phase 1 Program. This report reflects primarily a historical summary of the Phase 1 program and the oversight role played by the TF-AEC Joint Commission. The findings and recommendations expressed in this report resulted from the close working relationship between the Task Force and the Advisory Expert Council during the past four years. Leading experts from both countries participated in the work of the TF-AEC Joint Commission.

The TF-AEC Joint Commission's efforts contributed to NASA and RSA's successful conclusion of the ISS Phase 1 program and the Joint Commission is prepared to continue its work during Phase 2. The TF-AEC will continue to develop recommendations regarding safety and operational readiness, institute plans to reduce the degree of risk, and apply the lessons learned from the Phase 1 program to future missions.

On behalf of the TF-AEC Joint Commission, we would like to thank all the men and women of the International Space Station program for their tremendous support.

Lt. General Thomas P. Stafford, USAF (Ret.)
Chairman
Stafford Task Force

Academician Vladimir F. Utkin
Chairman
Utkin Advisory Expert Council



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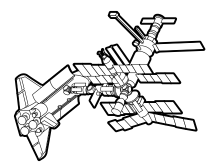
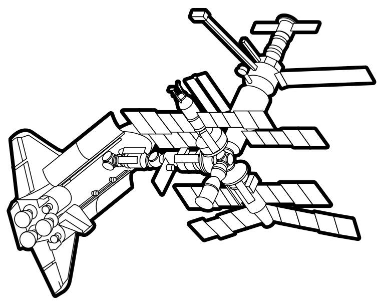
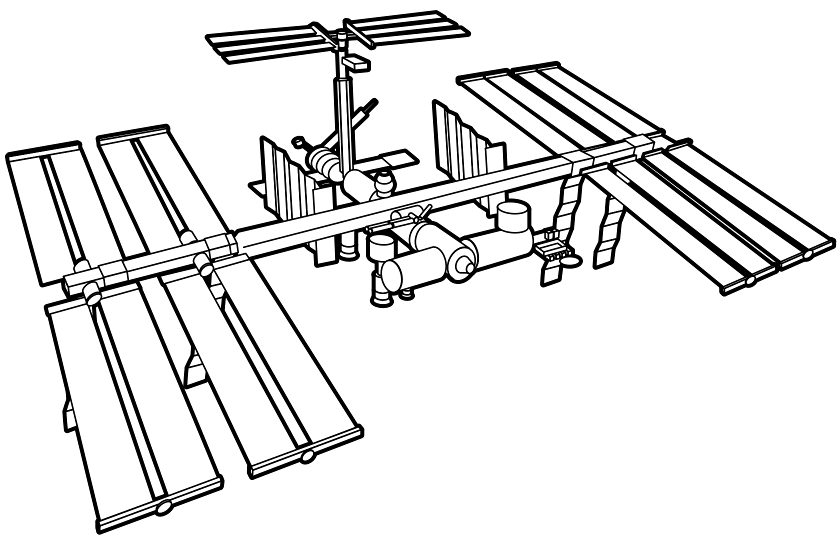






1 INTRODUCTION

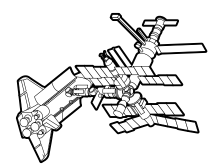
1.1 Goals and Objectives of This Report

A Joint Commission comprising of Lt. General Thomas P. Stafford's Task Force and Academician Vladimir F. Utkin's Advisory Expert Council was commissioned by the National Aeronautics and Space Administration (NASA) and the Russian Space Agency (RSA) in accordance with the Directive issued by the Russian-American Commission on Economic and Technological Cooperation on December 15, 1994. The Joint Commission was established to provide recommendations regarding safety assurance and implementation effectiveness of the joint Shuttle-Mir and NASA-Mir programs designated as Phase 1 of the International Space Station (ISS) program.

The experience developed by the Joint Commission resulted through the cooperation of a diverse group of U.S. and Russian experts who shared a mutual desire to work together. This experience offers completely new opportunities in the creation, management, and execution of such large-scale, multinational, and technically complex projects as the ISS. The Joint Commission is using this experience to assist in the development of preemptive steps for the detection of potential problems during Phase 2 of the ISS program.

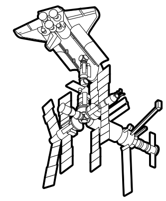
1.2 Historical Background

In October 1992, NASA and RSA reached an official agreement on the implementation of a fundamentally new program of humanitarian cooperation in space. The Shuttle-Mir program combined the joint activities of astronauts and cosmonauts aboard the Space Shuttle orbital vehicle, the manned Soyuz TM transport vehicle, and the Mir space station. At that time, the program was restricted to the following activities:



- Shuttle flight STS-60, whose crew included Russian cosmonaut Sergei Krikalev, the first cosmonaut to fly on the American Space Shuttle
- The launch of the Soyuz TM-21 transport vehicle with a U.S. astronaut, Dr. Norman Thagard, the first astronaut to participate in a mission of several months' duration aboard Mir, as a member of the Mir-18 primary mission crew
- The replacement of the station's Russian-American crew by a Russian crew following operations to rendezvous and dock the Shuttle to the Mir space station

In November and December 1993, the scope of the Shuttle-Mir program was enlarged significantly and became Phase 1 of the ISS program (Figure 1). This expanded program combined the initial Shuttle-Mir program with a series of additional Shuttle flights to Mir, including the rendezvous of Shuttle flight STS-63. The program included additional flights of American crews to the station, making it possible to extend joint Russian-American experiments on orbit for as long as 18 months. Of the 10 possible joint flights planned for Phase 1, NASA and RSA agreed to conduct 7 primary rendezvous and docking flights of the Shuttle to Mir: STS-71, STS-74, STS-76, STS-79, STS-81, STS-84, and STS-86.



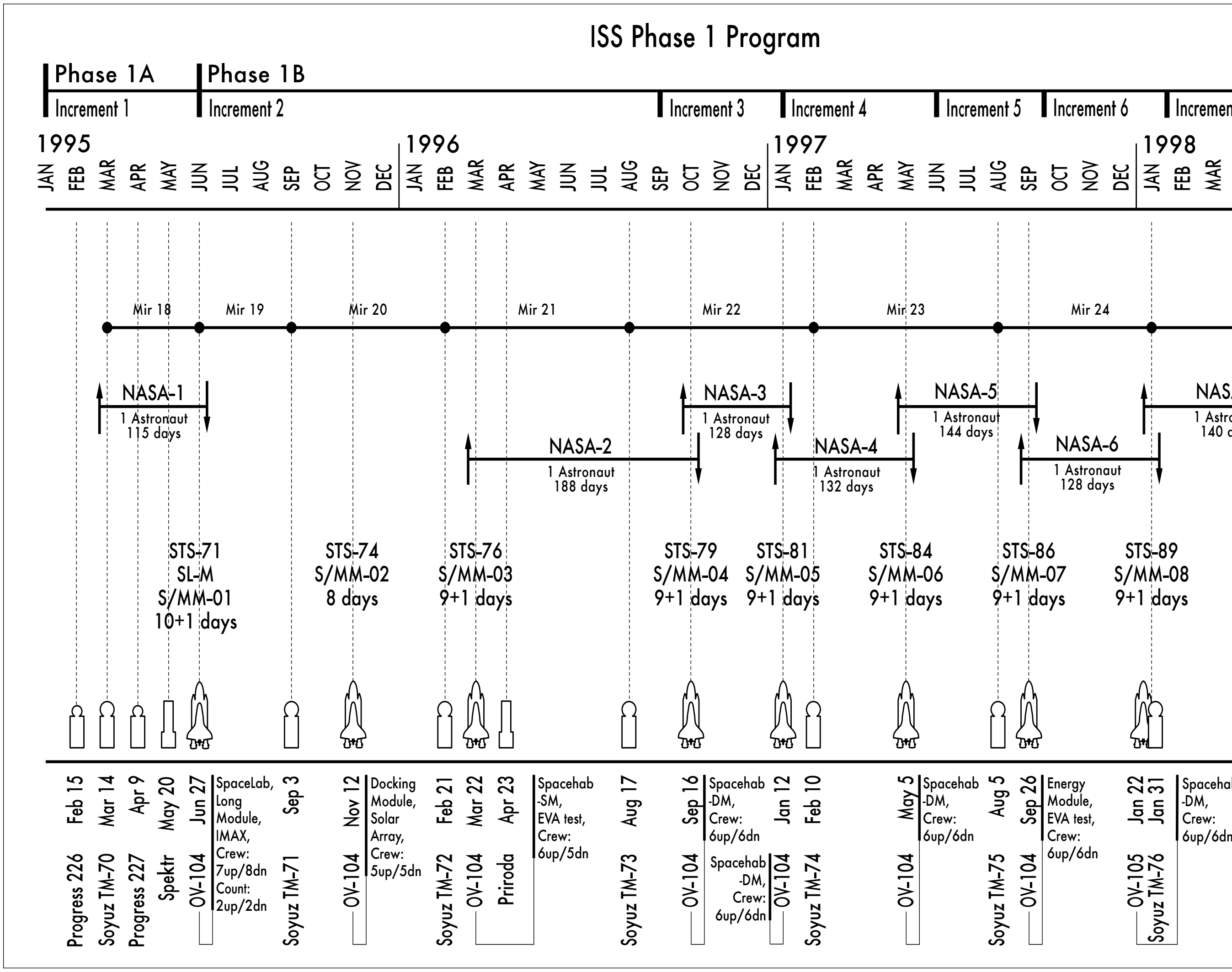


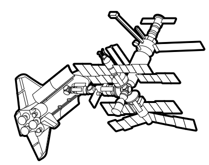
Figure 1: Phase 1 timeline

The Phase 1 program's goal was to lay the foundation for future international cooperation in space and to mitigate the risks associated with the multinational construction and operation of the ISS. Phase 1 also expanded ISS capabilities by combining joint operations in space with a demonstration of multinational space technologies. Moreover, Phase 1 provided early opportunities for expanded on-orbit scientific research activities.

A Contractual Agreement was signed between NASA and RSA on June 23, 1994, in the amount of $400 million to provide Phase 1 supplies and services for the Mir space station, ISS, and specific types of operations for Phase 2. This contract enabled NASA to acquire equipment and services worth approximately $100 million annually until 1997 from RSA and its contractors. This involved both support for the Phase 1 program and activities for the ISS, including:

1. Up to 10 dockings of the Space Shuttle with the Mir space station
2. Up to 21 months of scientific research by U.S. astronauts aboard Mir
3. Performance of three extravehicular activities (EVA) by American astronauts aboard Mir
4. Transportation to Mir of approximately 3.5 metric tons of dry cargo and the same amount of water
5. Operation of approximately 2.3 metric tons of NASA equipment aboard the station
6. Russian development of a docking mechanism
7. Russian development of a docking compartment (module) for use by the Shuttle with Mir
8. Allocation of up to $20 million for conducting joint Russian-American research aboard the space station

In January 1996, the scope of Russian-American cooperation expanded for the third time. In response to the Russians' desire to use Mir through 1998, NASA Administrator Daniel S. Goldin agreed to continue Phase 1 until the end of 1998, as well as to increase, from seven to nine, the total number of Shuttle flights to Mir. During this program extension, the solar dynamics payload was excluded from the cargo manifest for STS-86, another Shuttle flight (STS-89) to Mir was added, and STS-91 was redirected to conduct rendezvous and docking operations with Mir.



In accordance with the Phase 1 agreements and contracts, the Space Shuttle provided assistance in delivering replacement crews to Mir, in replenishing reserves, and in performing payload operations. The Mir space station's capabilities increased continuously through the delivery of both American and Russian hardware and software. In accordance with the Phase 1 contracts, Rocket Space Corporation-Energia (RSC-E) provided a docking assembly (Figure 2) for use on *Atlantis* called the Androgynous Peripheral Docking System (APDS). The APDS is a three-petal system, fabricated from an androgynous hybrid used during the historical Apollo-Soyuz Test Project in July 1975 commanded by astronaut Thomas Stafford and cosmonaut Alexei Leonov. The APDS was installed on the docking compartment that was permanently installed on Mir during flight STS-74.

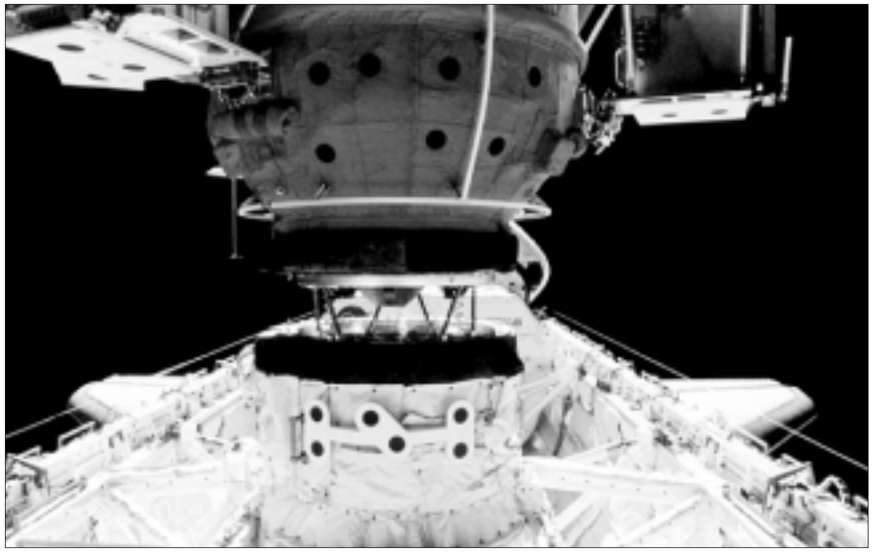


Figure 2: Androgynous Peripheral Docking System (APDS)

From April through August 1995, three flights of the Progress-M cargo vehicle delivered 343 kilograms of equipment to Mir. This equipment was used to conduct NASA life science experiments aboard the station. In 1995 and 1996, two additional scientific research modules, Spektr and Piroda, were docked to the station after being launched on the Proton booster (Figure 3).

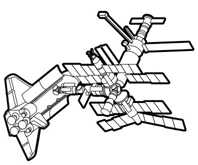


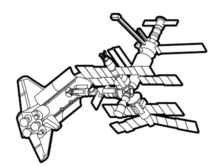
Figure 3: [left to right] Soyuz, Proton, and Space Shuttle launch vehicles used during ISS Phase 1 program

From February 1995 through June 1998, 10 Shuttle flights to Mir were conducted; these included a rendezvous to within 10 meters and nine successful dockings. Eight Russian cosmonauts participated in seven Shuttle flights: STS-60, STS-63, STS-71, STS-84, STS-86, STS-89, and STS-91. The orbiter docked with Mir for nine visits of short duration (2 to 5 days), in addition to seven U.S. astronauts participating in long-duration missions on Mir. Despite the fact that new problems arose that required joint decisionmaking during each joint flight, both sides worked very hard to overcome the differences in culture and technologies to resolve complicated software and hardware issues. The experience acquired from each mission has been used effectively to fine-tune existing procedures for future cooperation. Most significant of all is that the two main entities competing in the exploration of space, having independently developed their skills, just completed the first phase of the planned long-term cooperation in space. They have now reached the point at which they can work well with each other, which is crucial for successful ISS construction and sustainment.

1.3 Organization of the Report

The body of this report consists of sections detailing the following:

Section 2 Joint Commission's role and associated chronology of events
Section 3 Issues addressed by and findings of the Joint Commission
Section 4 Applicability of the Phase 1 program to the upcoming Phase 2 and Phase 3 of the ISS program
Section 5 Joint Commission's conclusions regarding the Phase 1 program
Appendices Selected documentation regarding the composition and tasking of the Joint Commission



2 TASK FORCE AND ADVISORY EXPERT COUNCIL ROLE IN THE ISS PHASE I PROGRAM

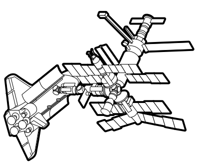
This section provides a chronology of the major events associated with the Joint Commission. The first subsection details the role of the commission as defined by the evolution of events of the program and major tasks performed by the Joint Commission. The second section details the chronology of events in tabular form.

2.1 Stafford Task Force-Utkin Advisory Expert Council Joint Commission

In this subsection, the major milestones shaping the Joint Commission are detailed. In addition, the various taskings and overall responses are summarized in chronological order.

2.1.1 NASA Establishes Stafford Task Force

On May 2, 1994, NASA established the NASA Advisory Council (NAC) Task Force on the Shuttle-Mir Rendezvous and Docking Missions, with Lt. General Thomas P. Stafford, USAF (Ret.), as its chairman. The purpose of the Task Force was to review Phase 1 planning, training, operations, rendezvous and docking, and management.



2.1.2 Stafford Task Force Issues First Three Reports

Between June and November 1994, the Stafford Task Force issued three reports to the NAC. The reports contained recommendations on a number of issues, including management of the Phase 1 program, timing for crew selection and training, and Shuttle-Mir rendezvous and docking flight operations.

2.1.3 Gore-Chernomyrdin Commission Directs NASA and RSA to Establish Joint Review Process on Issues Associated With the Shuttle-Mir Program

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 organize 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 Thomas P. 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.

2.1.4 RSA Establishes Utkin Advisory Expert Council

On February 14, 1995, RSA established the Advisory Expert Council on Problems Relating to Joint Shuttle-Mir Flights, with Academician Utkin as its chairman. 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 Shuttle-Mir program.

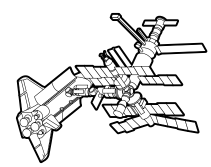
2.1.5 First Stafford-Utkin Delegations Are Exchanged

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 Commission. The Stafford delegations also used the opportunity to acquaint themselves with RSA and the other Russian organizations supporting the Phase 1 missions. The delegations visited RSA, the Central Research Institute for Machine Building (TsNIIMash), the Mission Control Center-Moscow (MCC-M), RSC-E, the Institute for Biomedical Problems (IBMP), the Khrunichev State Research and Production Space Center, the Gagarin Cosmonaut Training Center (GCTC), and the Baikonur Cosmodrome. The Task Force also used this opportunity to visit astronaut Norman Thagard, who was in training at Star City. During this visit, the Task Force determined that agreed-on safety requirements would be satisfied for the Soyuz TM launch and for the first U.S. long-duration mission to Mir. In addition, the Task Force determined that more American support was needed for NASA personnel at Star City GCTC and MCC-M.

2.1.6 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 based on data review, interviews, discussions, and site visits conducted by the review team in the United States and in Russia. The report stated that:

> *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.*



2.1.7 Utkin Advisory Expert Council Makes First Trip to the United States

In April, 1995, Academician Utkin and members of the Advisory Expert Council visited the Johnson Space Center (JSC) in Texas, the Kennedy Space Center (KSC) in Florida, the Marshall Space Flight Center (MSFC) in Alabama, the Boeing facility in Alabama, and NASA Headquarters in Washington, D.C. During this visit, the two review groups discussed issues related to the joint Mir–STS-71 flight.

2.1.8 Utkin Advisory Expert Council Publishes Report on Problems in Supporting the First Joint Flight (STS-71)

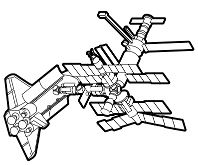
In June 1995, the Utkin Advisory Expert Council presented RSA General Director Yuri Koptev the "Report on Problems in Supporting the First Joint Flight of Mir and STS-71." The Utkin Advisory Expert Council concluded that "the level of interaction of all Shuttle elements, the experience accumulated during previous missions and staff qualifications eliminate the grounds for concern and provide confidence in the success of STS-71." This conclusion was based on the following:

- The 67 successful Shuttle launches prior to STS-71
- Productive interaction between the personnel in the Mission Control Centers in Moscow and Houston
- A total of 26 manual dockings in space
- The successful completion of the STS-63 mission in February 1995, when the Shuttle rendezvoused to within 33 feet, or 10 meters, of Mir in part because of high crew qualification

2.1.9 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 Administrator Daniel Goldin on June 22, 1995, providing a detailed update on the issues identified in the fourth Task Force report. The letter also detailed the status of a number of emergent issues that had occurred after the release of the fourth report. In his letter, General Stafford indicated that all issues have been adequately addressed by the Phase 1 joint program and that STS-71 was ready to fly safely and successfully (Figure 4).

Figure 4: Mir-18 and STS-71 in the first mated flight with rendezvous and docking



2.1.10 STS-71 Supports Stafford Task Force-Utkin Advisory Expert Council Assessments

The report conclusions of the Stafford Task Force and the Utkin Advisory Expert Council were supported by the successful flight of STS-71 and its docking 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 the U.S. and Russian personnel involved in the Phase 1 program.

2.1.11 Stafford Task Force Issues Fifth Report

The Stafford Task Force Working Groups on Management and Automated Data Processing and Telecommunications (ADP/T) Infrastructure generated a number of findings and developed recommendations for review and endorsement by the full Task Force during an open meeting at JSC on July 19, 1995. These findings and recommendations were included in the fifth report of the Stafford Task Force, which was released on September 21, 1995.

2.1.12 First Joint Meeting and Signing of the 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 Commission, as well as developing a schedule for joint activities and joint reports. These meetings were highly 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.

2.1.13 NASA and RSA Endorse TF-AEC Charter

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

2.1.14 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 (Figures 5 and 6).

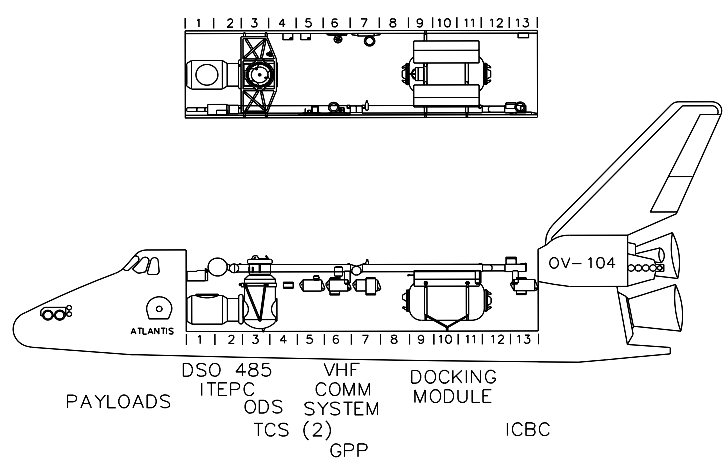
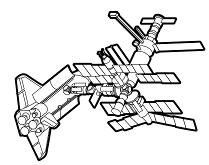


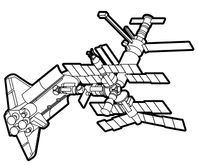
Figure 5: Configuration of the Shuttle orbiter payload bay during flight STS-74



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
- Results of a loads analysis from STS-71 and its applicability to STS-74
- Docking clearances
- The delivery of the Docking Module with externally stowed solar arrays 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.



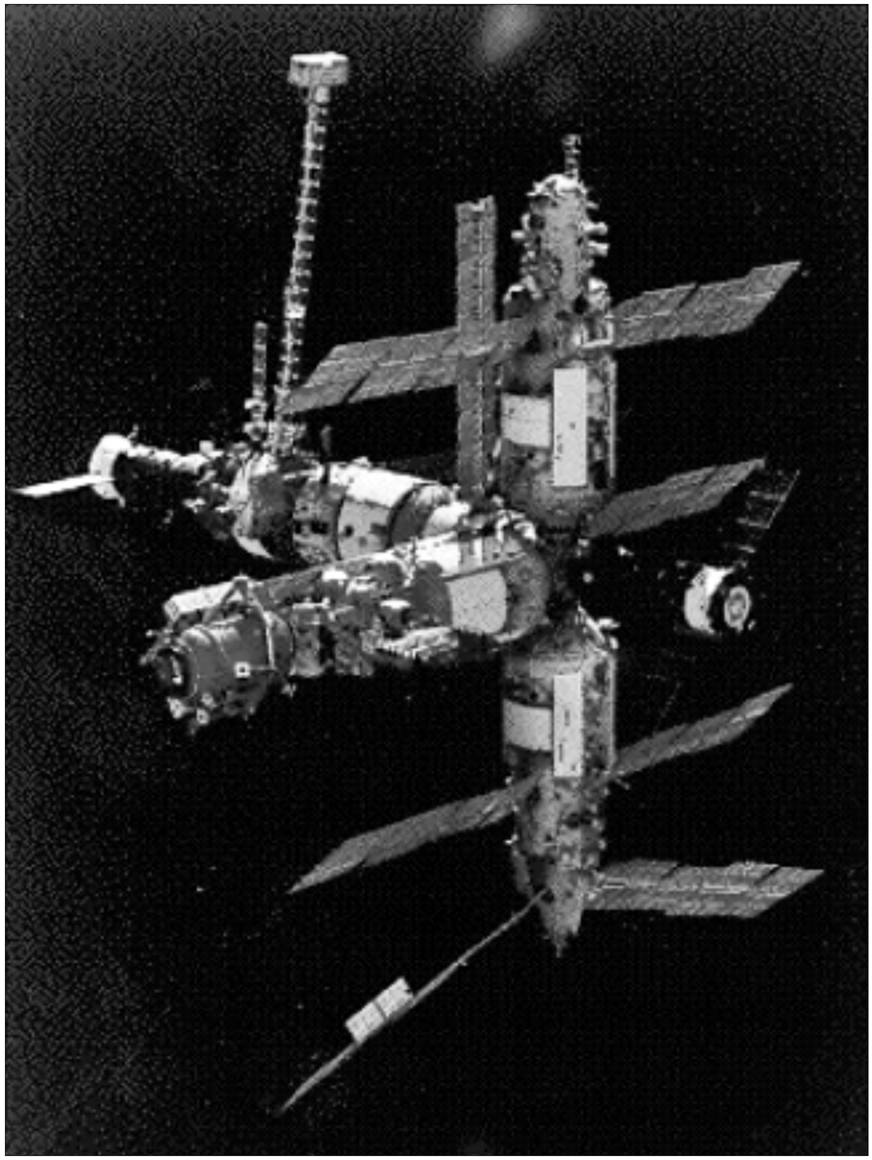


Figure 6:
Mir station
configuration after
STS-74/Mir-20

2.1.15 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 (Figure 7). The Task Force identified and discussed several 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 of quantities of food, water, supplies, and experiments over those on previous flights
- 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.

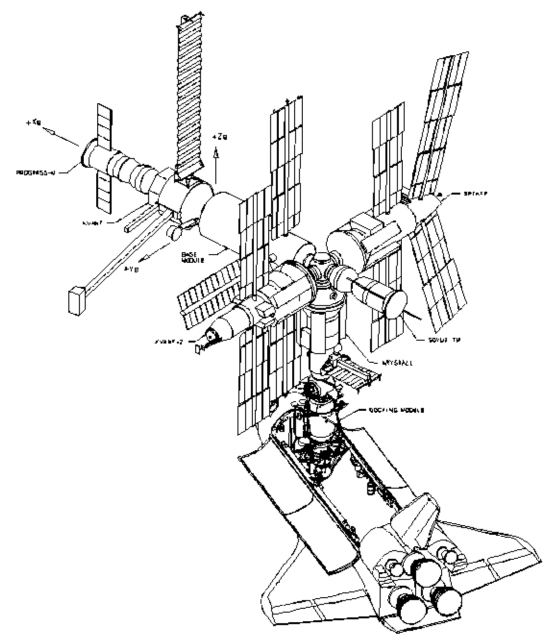
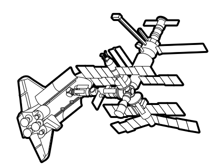


Figure 7:
Mir station and Shuttle orbiter configuration in mated flight during STS-76/Mir-20

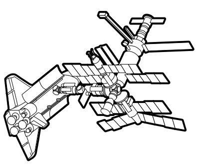


2.1.16 TF-AEC Joint Commission Issues First Joint Report

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

STS-60
STS-63/Mir-17 rendezvous mission (Figure 8)
Mir-18
STS-71/Mir-18 rendezvous and docking mission
Mir-19
STS-74/Mir-20 rendezvous and docking mission
Mir-20
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 (Figure 9), and management.



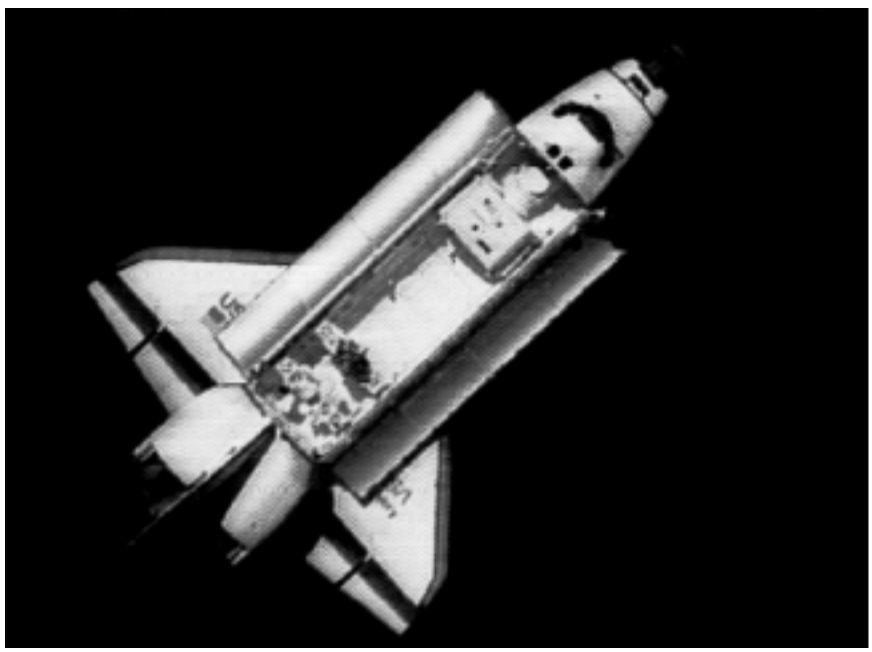


Figure 8: First flight of Shuttle orbiter to Mir station during STS-63

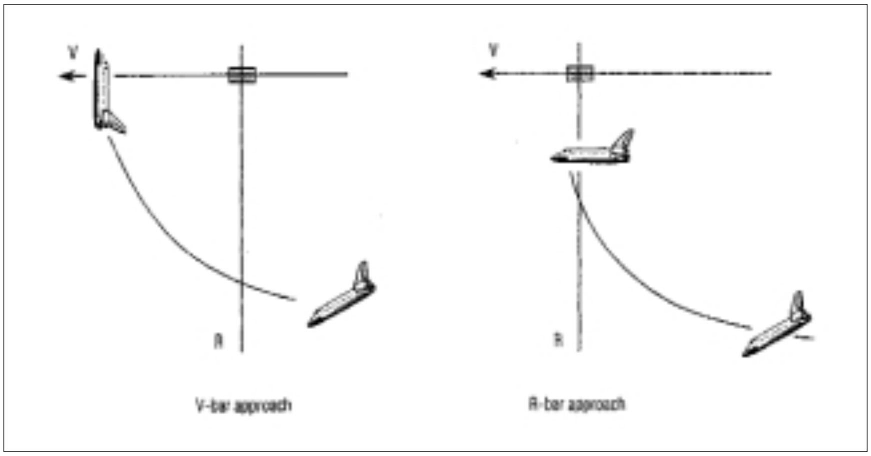
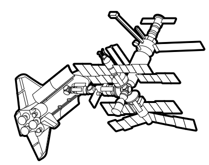


Figure 9: Shuttle rendezvous diagram showing approach along the velocity vector (V-bar) and along the radius vector (R-bar)

2.1.17 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 (Figure 10), including the:

- Impact of the launch delay on medical operations, logistics, science, training, systems integration, science interface with the CNES/Euro-Mir mission, and return of astronaut Shannon Lucid to Earth
- Decision to de-stack and change-out the STS-79 Solid Rocket Boosters (SRB) after a flight 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
- Need to purge excessive nitrogen from the Mir prime and backup Elektron oxygen generation systems located in the Kvant-1 and Kvant-2 modules
- Failure of two recent Soyuz U2 boosters

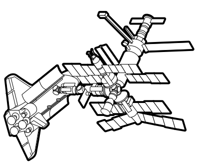


On September 10, 1996, General Stafford sent a letter to Administrator Goldin summarizing the status of the above issues and stating that the Task Force felt that STS-79 was prepared to fly safely and successfully.

2.1.18 STS-81 Readiness Assessment

On December 11, 1996, the TF-AEC Joint Commission conducted its second formal meeting in Russia. The 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



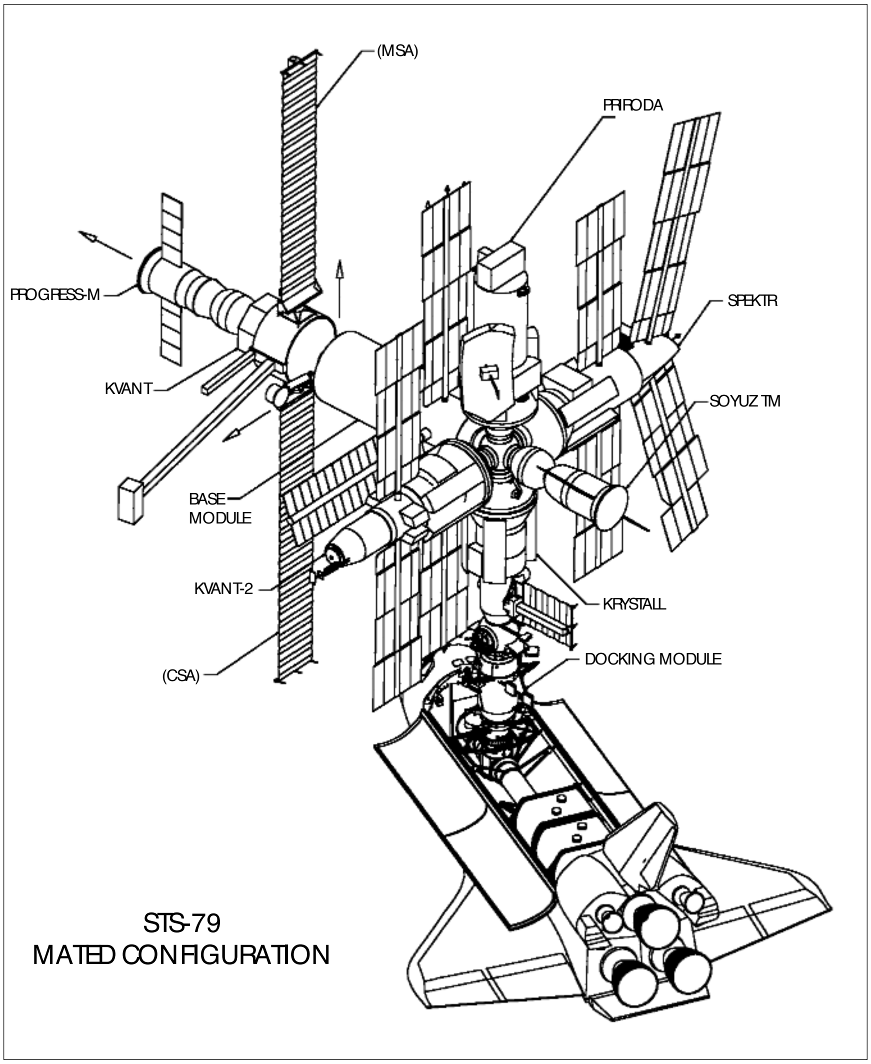


Figure 10: Mir and Shuttle orbiter in mated flight during STS-79, -81, -84, -86, -89, and -91

The commission also reviewed an EVA hatch anomaly (Figure 11) that had occurred on STS-80 and the unexpected erosion of an SRB nozzle (Figure 12) that had occurred on STS-79. This meeting played an important role in the readiness assessments that the Stafford Task Force and Utkin Advisory Expert Council were conducting for NASA and RSA, respectively.

On January 8, 1997, General Stafford submitted a letter to Administrator Goldin stating that he felt that 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.

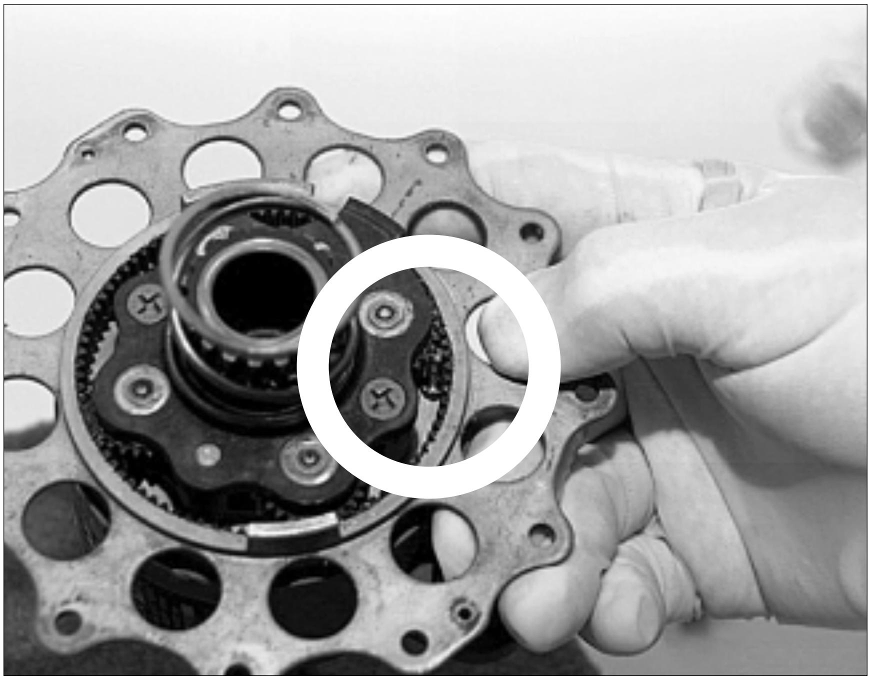
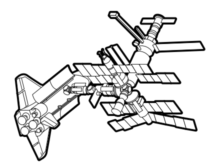


Figure 11:
Loose machine screw that jammed the EVA hatch opening mechanism, cause of the anomaly in flight during STS-80



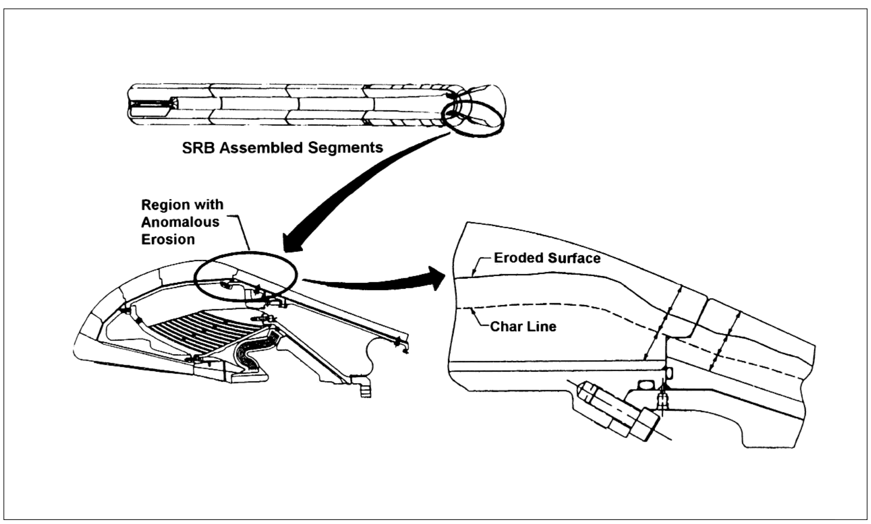


Figure 12:
SRB nozzle erosion during flight STS-79

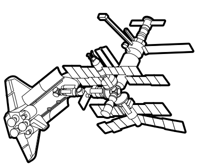
2.1.19 Third Meeting of the TF-AEC Joint Commission

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

2.1.20 Mir Mishaps and Anomalies Affect STS-84 Readiness Assessment

In April 1997, General Stafford sent a delegation from the Stafford Task Force to Russia to meet with the appropriate Russian technical and management experts, including members of the Utkin Advisory Expert Council, to address several 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 (SFOG) system in the Kvant-1 module (February 23, 1997)
- An Elektron oxygen generator in Kvant-2 that failed (March 5, 1997) because of corrosion and membrane aging, forcing the crew to use backup SFOG canisters until the Elektron system was restored in April
- A Progress M-33 cargo ship that was unable to redock and had to be de-orbited (March 6, 1997)
- 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 Task Force delegation received detailed reports on all of these mishaps and anomalies and reported its findings to General Stafford and the full Stafford 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. Maj. General Joe H. Engle, USAF (Ret.), expressed concern about the continuing coolant loop leaks caused by corrosion in the aluminum alloy. Colonel James Adamson, U.S. Army (Ret.), stated that the delegation brought back two important findings:

1. While the reliability of Mir was questionable, the station had actually grown in robustness over the years as the Russians added new modules and additional redundancy.
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.*

2.1.21 Mir Mishaps and Anomalies Continue, Affecting STS-86 Readiness Assessment

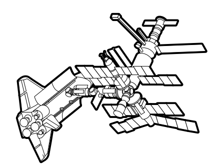
In September 1997, the TF-AEC Joint Commission met in Russia to review the mishaps and anomalies that continued to plague Mir after the successful STS-84 docking mission. These mishaps and anomalies included the following:

During a test of a new manual docking system, the Progress M-34 cargo vehicle collided with Mir, causing a depressurization of the Spektr module (Figures 13 and 14). 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 (SFOG) 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 the crew to use the SFOG (August 25, 1997).

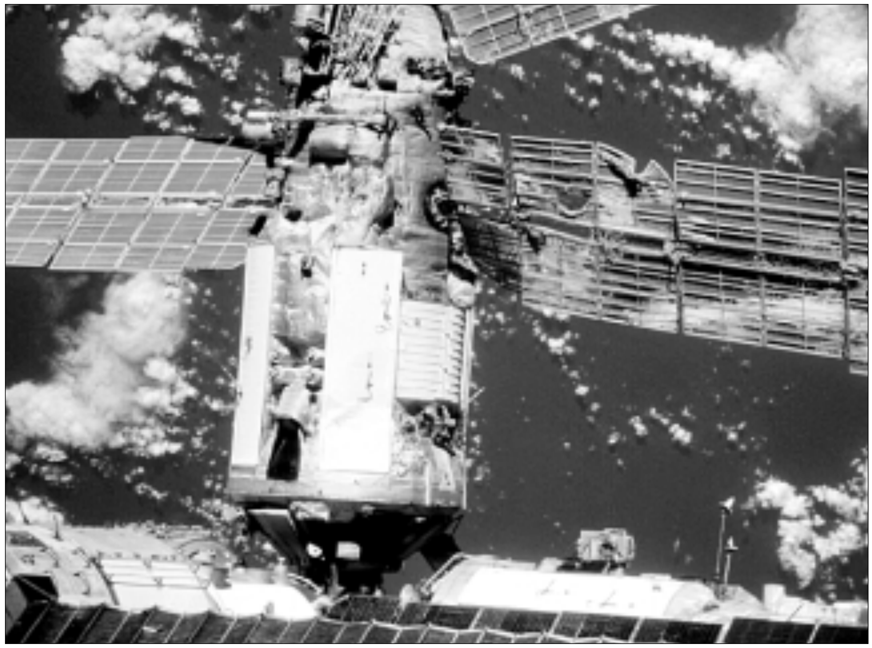
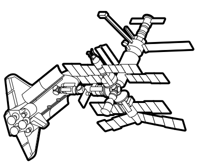


Figure 13: Damage to Spektr module resulting from collision by Progress M-34 cargo vehicle during Mir-23 mission



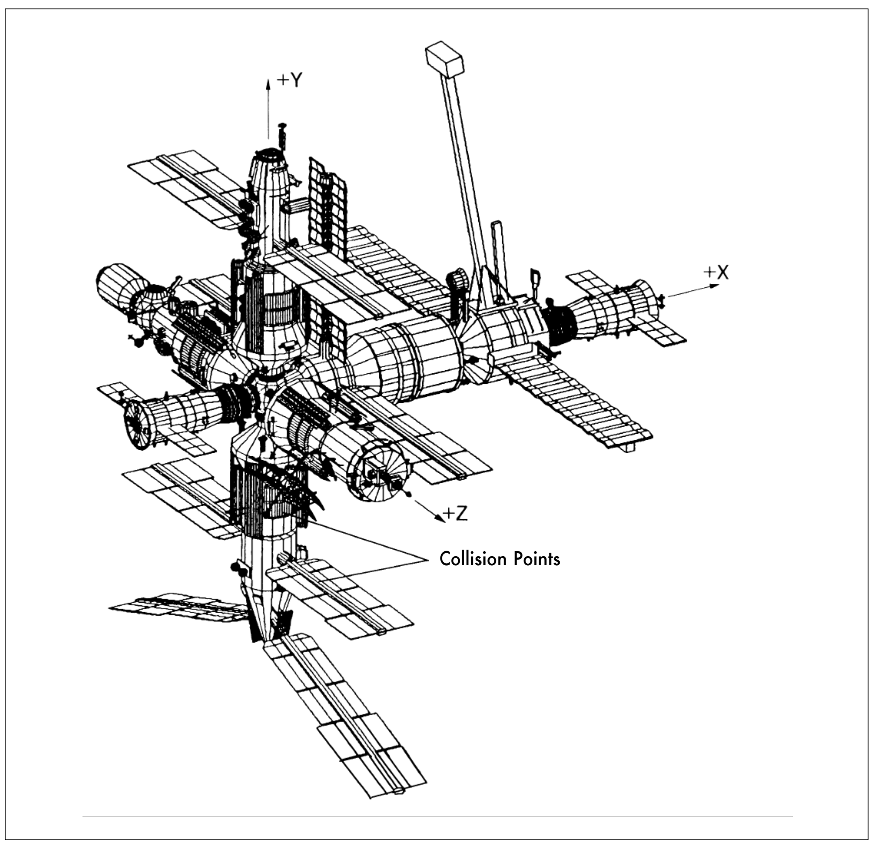


Figure 14: Location of damage to Spektr module resulting from collision by Progress M-34 cargo vehicle during Mir-23 mission

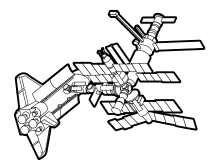
The TF-AEC Joint Commission met with key representatives from RSC-E, GCTC, IBMP, RSA, and TsNIIMash to assess the safety and operational readiness of the Phase 1 program in light of the June 25, 1997, Progress-Mir collision, the February 23, 1997, onboard fire, and the other mishaps and anomalies previously mentioned. It was during these meetings that a more complete understanding of the contributing causes of the Progress-Mir collision were determined and analyzed for the first time. The TF-AEC Joint Commission was uniquely qualified and positioned to uncover the true causes of the collision because of its accumulated expertise and the strong personal and professional relationships that had been developed since the commission was established in early 1995.

The Stafford Task Force delegation included members of the Maj. General Ralph Jacobson, USAF (Ret.)–led Red Team, which General Stafford had established to gain the efficiencies necessary to work on such a time-critical issue. The 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
2. The corrective actions taken in response to the mishaps and anomalies to assess how and whether those responses reduced the risks to crew members aboard Mir

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

Also on September 19, 1997, General Stafford and Academician Utkin signed a Joint Statement in which the TF-AEC Joint Commission stated that the level of risk posed to the STS-86 and Mir-23/24 crews did not exceed the acceptable limits originally defined for this program. The Joint Statement recommended to NASA and RSA that in the future, when performing 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 a closed 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 report the Task Force STS-86 readiness level assessment. As mentioned by Administrator Goldin, the Stafford Task Force's assessment was a key factor in the decision to go forward with the launch of STS-86 and to continue long-duration U.S. presence aboard Mir.

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

The TF-AEC Joint Commission's recommendation to proceed with the launch of STS-86 and continue the Shuttle-Mir program was supported 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 assessment was unanimously endorsed by the full Task Force at an open meeting. General Stafford's letter of January 15, 1998, to Administrator Goldin, in which he endorsed and forwarded the Red Team's assessment, stating:

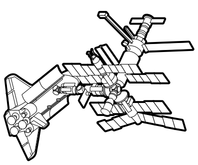
> *The Mir has been in a stable, productive condition since my Task Force conducted our safety assessment for STS-86, allowing Dave Wolf to focus his efforts on science experiments.*

2.1.23 The TF-AEC Joint Commission Turns Attention to the ISS

The TF-AEC Joint 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 Commission, at the request of NASA Administrator Goldin and RSA Director Koptev, began to turn its attention to ISS-related issues. 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.

2.1.24 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 (ISS Phase 1) 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 leak that had occurred in the relief valve for fuel cell three that 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, "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."

2.1.25 STS-91 Mission Concludes the Shuttle-Mir Program

In June 1998, the TF-AEC Joint Commission met at KSC to review issues related to 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 Phase 1 program.

2.1.26 NASA Administrator Goldin and RSA Directory General Koptev Visit With the Stafford Task Force-Utkin Advisory Expert Council (TF-AEC)

On December 2, 1998, NASA Administrator Goldin and RSA Directory General Koptev visited a meeting of the Joint Commission of the Stafford Task Force-Utkin Advisory Expert Council (TF-AEC) at Kennedy Space Center and commended the Commission's work, noting its great contribution to the realization of the Shuttle-Mir and NASA-Mir programs. Mr. Goldin and Mr. Koptev advocated the need for continuing the Joint Commission's work on Phase 2 of the International Space Station program.

2.2 Work Timeline of the TF-AEC Joint Commission During 1995-1998

Notes for the charts on the following four pages:

U.S. delegation visited RSA, TsNIIMash, RSC-E, Khrunichev Space Center, GCTC, and IBMP.

The meeting took place at KSC.

V. Utkin-T. Stafford. The Task Force delegation visited RSA, TsNIIMash, RSC-E, Khrunichev Space Center, GCTC, IBMP, and Baikonur. The delegation was received by RSA General Director Y. Koptev.

The AEC delegation visited JSC, MSFC, KSC, "Boeing" (Alabama), KSC, and NASA Headquarters. The delegation was received by NASA Administrator D. Goldin

The meeting was devoted to 20th anniversary of the joint Apollo-Soyuz Test Project flight.

The international conference was devoted to the 50th anniversary of TsNIIMash.

TF-AEC Working Group at TsNIIMash and the "Olympic-Penta" Hotel: drafting the first joint report.

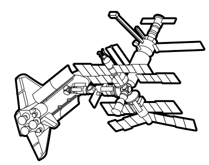
The meeting during which the first joint report was signed took place at JSC.

The meetings took place at Khrunichev Space Center, TsNIIMash, and GCTC.

The Task Force Working Group meeting with the participation of an AEC representative.

ISS Memorandum. ISS Intergovernmental agreement.

V Plenary meetings



Work Timeline of the AEC-TF Joint Commission During 1995-1998

	1994 DEC	1995 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
Sessions of the Russia-U.S. Commission on Economic and Technological Cooperation	V Moscow 12/15/94						V Washington				
Correspondence between NASA Administrator and RSA General Director	From Goldin to Koptev 12/29	Goldin-Koptev 1/20		Koptev-Goldin 3/6		Koptev-Goldin to Cheromyn-Gore 05/25			Koptev-Goldin 8/2 Goldin-Koptev 8/25		Koptev-Goldin 10/16
T.Stafford-V.Utkin Joint Commission meetings		Russia AEC-TF Working Group Moscow, Korolev	V USA Meeting of Stafford-Utkin V Russia Meeting of AEC-TF		USA TF-AEC Working Group Houston, Huntsville, C. Canaveral, Washington	Russia Korolev AEC-TF working group		USA Washington Stafford-Utkin		Russia Korolev V AEC-TF	
Mir station missions	from 10/04/94 Mir-17—A. Victorenko, E. Kondakova, U. Merbold			Mir-18—V. Dezhurov, G. Strekalov, N. Thagard; NASA-1 (N. Thagard)				Mir-19—A. Soloviev, N. Budarin		Mir-20—Y. Gidzenko	
Program	Shuttle-Mir program (Phase 1A of ISS)							NASA-Mir program (Phase 1B o			
Soyuz TM				#21 03/14 (N. Thagard) #20 03/22						#22 09/03 #21 09/11	
Progress M Cargo Vehicle			#26 02/15		# 27 04/09			# 28 07/20			#29 10/08
Shuttle missions to Mir			STS-63 02/02 02/11 (V. Titov)				STS-71 06/27 (A. Soloviev, N. Budarin)	07/04 (V. Dezhuroz, G. Strekalov)			
Modules deployment						Spektr 05/20 on Proton booster					
Signing of documents	Decision to establish AEC-TF for Mir-Shuttle program			TF 4th Report 03/01			AEC 1st Report 06/07			TF-AEC Charter 9/11 TF 5th Report 9/30	

Work Timeline of the AEC-TF Joint Commission During 1995-1998 continued

	1996 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
Sessions of the Russia-U.S. Commission on Economic and Technological Cooperation	V Washington						V Moscow			
Correspondence between NASA Administrator and RSA General Director									Goldin-Koptev 09/03	Koptev-Goldin 10/23
T.Stafford-V.Utkin Joint Commission meetings				Russia Korolev AEC-TF Working Group		Russia Korolev AEC-TF Working Group USA Houston V TF-AEC				TF-AEC Starts W ISS Assesments
Mir station missions	Mir-20		Mir-21—Y. Onufrienko, Y. Usachev, S. Lucid					Mir-22—V. Korzun, A. Kale		
			NASA-2 (S. Lucid)							NASA-3 (J.
Program	NASA-Mir program (Phase 1B of ISS)									
Soyuz TM		#23 02/21 #22 02/29						#24 08/17 (C. Andre-Dee (France))	#23 09/02 (C. Andre-Dee (France))	
Progress M Cargo Vehicle					#31 05/05			#32 08/01		
Shuttle missions to Mir			STS-76 03/22 04/02						STS-79 09/16 09/26	
Modules deployment				Priroda 04/23 on Proton booster						
Signing of documents				Utkin-Stafford-Engle Joint Report		TF-AEC 1st Joint Report 06/27				

Work Timeline of the AEC-TF Joint Commission During 1995-1998 continued

	1997 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT
Sessions of the Russia-U.S. Commission on Economic and Technological Cooperation		V Washington							V Moscow	
Correspondence between NASA Administrator and RSA General Director	Goldin-Koptev 01/05						Goldin-Koptev 07/18			Goldin-Koptev 10/31
T.Stafford-V.Utkin Joint Commission meetings		USA Houston V TF-AEC		Russia Korolev AEC-TF Working Group		USA Durham TF-AEC Working Group			Russia Ryazan Korolev V AEC-TF	
Mir station missions	Mir-22	Mir-23—A. Tsibliev, V. Lozutkin, J. Linenger (thru 5/21), M. Foale (from 5/17)						Mir-24—A. Soloviev, N. Vinogradov, M. Foale (thru		
	NASA-3	NASA-4 (J. Linenger)				NASA-5 (M. Foale)				NASA-6 (D.
Program	NASA-Mir program (Phase 1B of ISS)									
Soyuz TM		#25 02/21	#24 03/02					#26 08/05 #25 08/14		
Progress M Cargo Vehicle				#34 04/05			#35 07/05			#36 10/05
Shuttle missions to Mir	STS-81 01/12 01/22				STS-84 05/15 05/25				STS-86 09/26 10/06 (V. Titov)	
Modules deployment										
Signing of documents		Signing of three Protocols							AEC-TF Joint Statement	

Work Timeline of the AEC-TF Joint Commission During 1995-1998 continued

	1998 JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	
Sessions of the Russia-U.S. Commission on Economic and Technological Cooperation			V Washington								
Correspondence between NASA Administrator and RSA General Director			Koptev-Goldin 03/10	Koptev-Goldin 04/03 Goldin-Koptev 04/07							
T.Stafford-V.Utkin Joint Commission meetings	C. Canaveral TF-AEC Working Group			USA C. Canaveral ----- Russia Korolev AEC-TF Working Group		USA C. Canaveral V TF-AEC			Russia Korolev V AEC-TF		
Mir station missions	Mir-24	*L. Eyharts (ESA) 21 days*			Mir-25—T. Musabaev, N. Budarin, A. Thomas			*V. Baturin (RSA) 8 days*		Mir-26—G. Pad	
	NASA-6	NASA-7 (A. Thomas)									
Program	NASA-Mir program (Phase 1B of ISS)										IS
Soyuz TM	#27 01/29 (L. Eyharts (ESA))	#26 02/19 (L. Eyharts (ESA))						#28 08/03 (V. Baturin (RSA)) #27 08/10			
Progress M Cargo Vehicle			#38 03/15		#39 05/15					#40 10/25	
Shuttle missions to Mir	STS-89 01/15 01/25 (S. Sharipov)					STS-91 06/03 06/12 (V. Ryumin)					
Modules deployment											Pro
Signing of documents	TF-AEC Working Group Protocol 01/22 ISS MOU signed 01/29			AEC-TF Protocol 04/27		TF-AEC Protocol 06/04			AEC-TF Protocol 09/25		

3 ISSUES AND THEIR RESOLUTION

In this section, a series of events occurred that required the direct attention of the Joint Commission. These included:

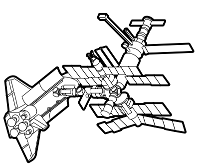
Medical support issues
Crew training problems
MCC-M/MCC-H interaction
Cargo delivery
Joint EVA's by astronauts and cosmonauts
Fire on Mir
Progress M-34 collision with Mir and damage to the Spektr module
Final joint flight of the Shuttle (STS-91) and Mir and the NASA-7 mission

These are addressed in the following sections.

3.1 Medical Support Issues

The Joint Commission devoted significant attention to the reliability of medical support and its impact on crew safety during flight preparation under the Phase 1 program. The following issues were examined:

Planning and management of medical support
Evaluation of crew health status
Monitoring of the habitation environment



3.1.1 Planning and Management of Medical Support

For a number of reasons, significant differences have historically developed in the organization of the American and Russian crew medical support systems and in the support of the fitness of crew members. The most significant differences were:

Focus of the Russian program on long-duration flights on space stations
American focus on short-duration flights on the Shuttle
Differences in health care systems
Absence of a special department in the RSA structure responsible for the organization and performance of medical operations in contrast to NASA (The State Scientific Center–Russian Federation Ministry of Health Care's IBMP performs these functions in Russia.)

These differences created the rather complex issue of coordinating and integrating organizational principles, methodologies, requirements, and medical structures of both nations to ensure the health, fitness, and professional longevity of the joint crews.

Working Group 8, headed by Russians V. V. Bogomolov (IBMP) and V. V. Morgun (GCTC) and Americans Sam L. Poole and Roger Billica (JSC), was formed to solve these problems and, on balance, was successful. During the joint efforts of the Working Group, it was possible to exchange previously accumulated experience while preserving the most important thing—respect for the crew medical support rules and procedures of each side. Through this, acceptable compromises were found to retain the medical responsibilities of each party for decisions regarding their respective crews. As a result, for missions on Mir, the medical support procedures and measures were based on Russian rules; medical management was provided by MCC-M in close cooperation with and direct participation of the NASA flight surgeon. In joint flights on the Shuttle, medical support was provided according to NASA rules, while medical management was provided by MCC-H with the participation of an RSA medical representative. Accordingly, the Russian side bore primary responsibility for flight safety and health support for the crew on Mir flights, while the American side bore this same responsibility for Shuttle flights.

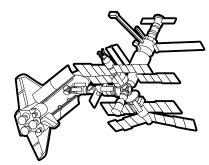
For the clearest possible definition of the authorities and responsibilities for medical support for the Phase 1 program, the Joint Commission noted the inadequacy of the biomedical management structures at RSA and NASA in their first joint report (1996), section 3.5.1, and recommended that:

> *RSA should create a department in its structure and appoint an RSA chief physician responsible for and with authority over medical operations. It is proposed that establishing this department will produce a sufficiently adequate biomedical administrative structure and simplify the concurrence on and practical implementation of joint biomedical procedures.*

As a result, RSA appointed IBMP Director A. I. Grigoryev as the medical supervisor responsible for Phase 1 operations. He and NASA Associate Administrator for Life and Microgravity Sciences and Applications, Arnauld E. Nicogossian, made the final administrative decisions on the solution of medical problems when necessary. As for the medical department within the RSA structure, this issue has not been resolved.

Summary:

The medical operations planning and management system in the Phase 1 program was based on extensive use of previous experience in long-duration space flights and the necessary compromise in the integration of the Russian and U.S. approaches. These compromises met the requirements of international space law establishing the responsibilities of parties launching spacecraft.



The foundations for medical support planning and management during the period of deployment and operation of the ISS were laid out during the joint work process. As a result, a number of regulations were published, with examples including:

"Temporary NASA and RSA Approach to ISS Medical Policy Issues"
"ISS Crew Medical Operations Requirements Document (ISS MORD)"
"Astronaut Medical Examinations Requirements Document: Health Standards for ISS Crews (AMERD)"
"Food Plan During ISS Assembly"

In addition, a number of oversight boards and panels resulted, including the Multilateral Medical Policy and Strategy Board, the Multilateral Space Medicine Board (MSMB), and the Multilateral Medical Operations Panel (MMOP).

From a practical standpoint, the planning and management of medical support should be considered still in the initial stage. As a result, what remains a requirement is the creation of a system for ISS crew safety and medical support that will most fully meet the demands for efficiency, reliability, and operability.

The Joint Commission recommends that:

1. A medical department be created at RSA and that an RSA chief physician be appointed
2. A multilateral medical support planning and management structure for the period of nominal ISS operation be created
3. The health standards (AMERD) be continually improved as they pertain to the issues of elderly persons, the evaluation of radiation load, psychology, and so on.

3.1.2 Evaluation of Crew Health Status

The Joint Commission addressed Shuttle and Mir medical support in the context of the documentation developed by Working Group 8: WG8/NASA/RSA/-E8000, "Joint Russian-American Program, Phase 1, Medical Requirements." The evaluation and certification of the health of the multinational crew members were conducted in complete accordance with these requirements. On Mir, the astronauts primarily used the nominal Russian health monitoring system. The procedures and sequences for in-flight medical examinations of astronauts were concurred with the American flight surgeon, who also regularly held private medical conferences with those astronauts. The results of medical monitoring and the physical fitness of the crew members clearly reflected the dynamics of their health status and made it possible to revise the medical operations support program when necessary. During the course of the Phase 1 program, no intractable medical problems arose. The positive results of the joint work on medical monitoring included:

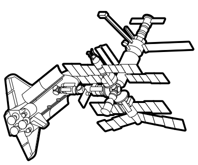
Improvement of the procedures for joint real-time reaction of multinational ground services to flight medical problems

Establishment of reliable communications channels between specialists of multinational medical organizations

Better understanding by the American medical operations specialists of the physical and psychological factors typical of long-duration space flights and of flying as a passenger on the Soyuz TM vehicle

Clearer understanding of medical ethics issues, as well as the importance of demographics in the formation and training of international crews

Preventive Measures:



The Russian Preventive Measures System was used as the basis for measures to protect the crew from the unfavorable ramifications of the long-duration space flight conditions experienced during the Phase 1 program. The preventive procedures for the American complement of the Mir crews were modified slightly and reduced by the American managers. However, with few exceptions, the astronauts strove to follow the recommendations of the multinational medical experts on physical preventive measures; these were transmitted to them either directly or via the American flight surgeon.

Overall, it was concluded that the health of crew members on long-duration flights (not only during the mission, but also after the mission's completion) depends on the preventive measures regimen, especially regarding physical prevention measures. It should also be noted that during the Phase 1 implementation, American specialists conducted studies (NASA-6 and NASA-7) of specific physical exercises that seem to be promising for use by ISS crews. This has resulted in joint work that was conducted to create a modified treadmill with vibration isolation and stabilization capabilities. For the treadmill, both medical and technical requirements were developed, and a mockup of the treadmill was built.

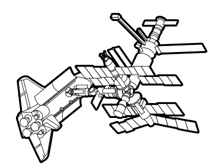
Improvements were implemented to enhance crew safety by creating and improving onboard systems for diagnosis and treatment and by including additional equipment (for example, a defibrillator, a restraint system, a medical kit for treatment, and so forth). In addition to treating the potential physical maladies addressing the crew in orbit, psychological support measures made a significant contribution in maintaining the fitness of crew members and improving their interaction. In addition to the use of a wide range of psychological support measures used in Russian long-duration flights, the Americans developed a computer system for evaluating cognitive processes during space flight—the Crew Status and Support Tracker (CSST). This system enabled a crew member to evaluate his or her own cognitive functions and is intended for further use on the ISS. To improve crew compatibility, a course was conducted to familiarize astronauts with the Russian culture. In recognition of the importance of crew psychology on the performance of long-duration crews, the necessary revisions were made to the crew work program and the communications schedule in accordance with the recommendations of the operational psychological support service (see section 3.3.1 of the first joint report, 1996).

This realization became particularly visible when, according to GCTC data, the members of the joint American-Russian crews stated that greater attention must be paid to psychological compatibility when appointing a crew. For this, the crew training time should be increased, and joint training sessions on survival in emergencies should be conducted. The proposal to expand cultural exchange was noted as being very important.

Summary:
The performance of the joint American-Russian Phase 1 medical support operations made it possible to acquire valuable experience in the bilateral interaction of the ground medical services of the two nations, as well as to work out the means and methods for making operational decisions. The most important result of the medical support for the joint long-duration flights was the preservation of the health and functional reserves of the primary mission crew members, which made it possible to efficiently execute the flight programs and accelerate re-adaptation processes after completion of the flights. A significant volume of scientific information and data on equipment and tests—as well as the use of medical equipment—was acquired. This information must now be generalized and analyzed. On the whole, the goals of Working Group 8 were reached successfully.

Recommendations:
Given the substantial progress of the Phase 1 program, it is recommended that, in the context of the ISS, the multinational medical communities perform the following activities:

1. Continue work to improve preventive methods and systems, including:
   a. The compilation of individual (personal) preventive procedures programs and the improvement of hardware
   b. Modifications to the treadmill, including vibration isolation (and stabilization) and the fabrication of the necessary number of models for tests and exercise development
   c. The examination of ISS trainer equipment sufficient for training a full complement of six crew members
2. Accelerate the development of a crew training program with a fully integrated program to address the crew psychological compatibility problem
3. Cooperate in the development of fundamental research to predict human tolerance to the effect of specific conditions to enhance the reliability and safety of ISS crews



3.1.3 Monitoring of the Habitation Environment

During Phase 1, significant attention was devoted to evaluating the status of the habitation environment on Mir because of the long operation of the station and the periodic deviations and/or malfunctions in the operation of the life support systems. In addition, there were emergency situations that could have had serious medical consequences, such as the fire in the SFOG cartridge, the Spektr module depressurization, and the failures in the complex control system leading to a station power shortage. These situations (some of which were described in the first joint report, 1996, such as sections 3.3.2, 4.3.7, and 4.7.5) required special attention and fast responses from the ground technical and medical personnel. One such incident, the toxic hazard associated with the leak of the ethylene glycol coolant from the thermal control system in 1997, caused special concern within the medical community.

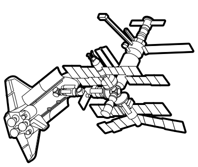
There were regular contacts between Russian and American medical experts to expedite the exchange of information and develop concurrence on both technical and medical matters. Examples included decisions on technical and medical measures that affected hardware repair or replacement, habitation environment monitoring, preventive and protective measures, and the delivery of additional systems and equipment to Mir. However, these contacts were not always timely. As a result, this sphere of activity needs to be improved with regard to future ISS operations. Because the requirements (standards) of the habitation environment within NASA and RSA differ in a number and type of parameters, special attention must be given to not only continuing but also accelerating work to develop unified standards.

The results of the medical monitoring of the crew members' health that was performed during and upon completion of the flights did not reveal any changes in anticipated crew member health. However, the unplanned repair and restoration work disrupted the planned activity of the crews, limited the performance of preventive procedures, and increased the workload of the crew; in this sense, it had an unfavorable influence on the status of the crew. However, no serious medical problems arose here.

Summary:
The primary result of the work to monitor the habitation environment in the Phase 1 program was the gaining of unique joint experience in solving medical and medical-technical problems when various off-nominal situations and emergencies arise during long-duration flights. In addition, many new systems for monitoring the habitation environment of a manned spacecraft were tested and evaluated.

Recommendations:
1. Work to develop multinational standards, as applied to the entire complex of ISS segments, for the improvement of the systems for monitoring the habitation environment (This should include providing the most up-to-date information possible—a measure that should be accelerated.)
2. Develop the documentation of the procedures, methods, and means for monitoring the habitation environment to more fully address off-nominal situations and crew responses

3.2 Crew Training Issues



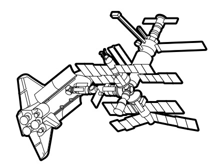
In its first joint report, the Joint Commission emphasized the problems in astronaut and cosmonaut training. This report emphasized the incomplete payload flight data files for prelaunch training and the limitations on the use of trainers for physical training during mated flight. These problems were solved successfully by the participation of appropriate Working Groups. For example, in accordance with the jointly developed document WG/RSC-E/NASA/3407, the payload flight data file is now provided in two languages in the necessary format.

Physical training for the crew during mated flight was reduced based on load constraints of the mated space station and orbiter. This has been shown to reduce structural loads and stresses and does not seem to be detrimental to the health and physical fitness of the astronauts and cosmonauts on Mir since the docked phase does not exceed 2–5 days.

Training of American astronauts for long-duration missions on Mir was conducted, resulting in the information presented in Table 1.

Mission, Astronaut, *Backup*	Begining and Ending Work Dates on Mir	Training With Crews, *Backup*	Astronaut Training Periods	Total Training Time in Hours (Primary/Backup)	Total Crew Training Time in Hours
NASA-1 Norman Thagard *Bonnie* *Dunbar*	Soyuz TM-20 03/16/95 STS-71 07/04/95 (111 days)	Mir-18 Dezhurov, Strekalov	03/01/94- 10/07/94 10/10/94- 02/21/95	883/845	1,728
NASA-2 Shannon Lucid *John* *Blaha*	STS-76 03/24/96 STS-79 09/24/96 (184 days)	Mir-21 Onufrienko, Usachev *Tsibliev,* *Lazutkin*	01/03/95- 06/24/95 06/26/95- 02/26/96	795/1127	1,922
NASA-3 John Blaha *Jerry* *Linenger*	STS-79 09/19/96 STS-81 01/19/97 (123 days)	Mir-22 Korzun, Kaleri *Manakov,* *Vinogradov*	02/23/96- 07/01/96 05/29/95- 07/19/96	795/503/959*	2,257
NASA-4 Jerry Linenger *Michael* *Foale*	STS-81 01/15/97 STS-84 05/21/97 (127 days)	Mir-23 Tsibliev, Lazutkin *Musabaev,* *Budarin*	09/23/96- 12/06/96 11/29/95- 12/20/96	765/605/1,054*	2,424
NASA-5 Michael Foale *James* *Voss*	STS-84 05/17/97 STS-86 10/04/97 (138 days)	Mir-24 Solovyev, Vinogradov *Padalka,* *Avdeev*	01/13/97- 04/09/97 03/04/96- 04/30/97	899/408/840*	2,147
NASA-6 David Wolf *Wendy* *Lawrence*	STS-86 09/28/97 STS-89 01/29/98 (124 days)	Mir-24 Solovyev, Vinogradov *Padalka,* *Avdeev*	09/02/96- 08/27/97 09/02/96- 08/12/97	1081/614	1,695
NASA-7 Andrew Thomas *James* *Voss*	STS-89 01/24/98 STS-91 06/08/98 (135 days)	Mir-25 Musabaev, Budarin *Afanasyev,* *Treshchev*	01/16/97- 12/05/97 09/08/97- 12/05/97	982/553	1,535

Table 1



* Joint training that included the Russian backup crew

The readiness of the NASA astronauts was verified by a Russian commission that conducted tests on the execution of typical daily flight programs as members of the crew on the Mir integrated simulator ("Don-27KS").

The execution of the NASA-Mir joint flights program made it possible to gain significant experience in training international crews. GCTC trained American astronauts on the following:

- The manned transport vehicle Soyuz TM (Figure 15) as the cosmonaut-researcher in the transport vehicle descent phase (if emergency evacuation of Mir were necessary)
- The Mir station as the flight engineer for certain Mir systems on a long-duration mission
- Joint EVA with Russian cosmonauts to implement the science program, inspect Mir, and restore its serviceability
- The joint science program at GCTC and JSC

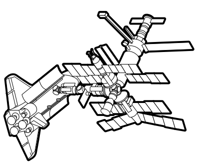


Figure 15: Soyuz TM manned spacecraft trainer at GCTC

Experience was also gained in the medical certification and clearance of astronauts and cosmonauts for flight.

The Phase 1 joint program made it possible to gain significant experience in the long-term interaction of American and Russian experts and international crews. The astronauts, cosmonauts, and multinational experts were able to familiarize themselves with one another, with the partner's space centers, and with the distinctive features of astronaut/cosmonaut training in both America and Russia. This joint work promoted mutual understanding and trust, as well as improvement in the development of common approaches to astronaut/cosmonaut training. In addition, this interaction enhanced the planning and execution of space flights and associated activities. The Phase 1 American and Russian cooperation in space has made it possible to proceed to the next stage of mastery of human space flight—the combination of efforts to build and operate the ISS and the training of crews for its assembly and operation.

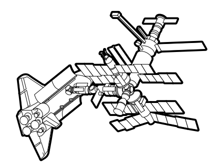
The Joint Commission recommends that:

1. The training in Phase 1 was generally adequate for American astronauts to function as a Mir crew Flight Engineer 2. However, to improve operational safety, the differences in training approaches and philosophies highlighted in the Phase 1 program should continue to be worked toward resolution as part of the ISS training program.

2. The replacement of crews on Mir did not coincide with a complete cycling of crews, so joint training of individual replenishment astronauts and cosmonauts with all of the applicable Mir flight crews was not always possible. As a result, the crew commander did not always know the actual level of training of the replenishment astronaut or cosmonaut, and although the training was completed, the commander did not always have information regarding the comprehensive preparedness of the crew member. This experience must be taken into account during the ISS program.
3. With respect to ISS crew training, the joint training of all members of a specific ISS crew should be conducted as often as possible. This will help improve work efficiency aboard the station and make it possible to address the language and cultural problems encountered when crew members talk to each other and with ground control personnel. In this process, there should be a gradual reduction in the use of interpreters.
4. An analysis of ISS crew actions during space flights and the results of this analysis must be used in training to improve ISS crew performance and enhance the productivity of the onboard crew activities.

3.3 MCC-H/MCC-M Interaction

Real-time operations in joint flights were conducted within the framework of joint flight rules (WG-3/RSC-E/NASA/004/3242). Within this framework, Mir was monitored and supervised by MCC-M, while the Shuttle was monitored by MCC-H. The responsibilities of the Mir and Shuttle crew commanders were distributed in a similar manner. On the basis of this agreement, the parties concurred on each aspect of joint operations. One of the primary tools for implementing these arrangements was the use of joint flight rules developed directly before each flight that documented both planned and contingency operations in case of off-nominal situations. The flight rules reduced the need for real-time decisionmaking, and they enabled sufficiently fast examination and multinational joint concurrence for each action.



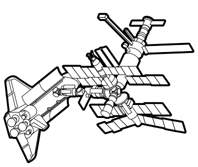
The joint flights required coordination between the two MCC's located thousands of miles apart, in different time zones, and using different languages. Communications systems, processes, and procedures were developed for information exchange so as to coordinate decisions and make plan changes. In addition to the development of these joint capabilities, an exchange program during active flights provided a unique exchange that resulted in simplified technical discussions between the control centers, as well as onsite experience on how the other command culture handles its tasks.

Detailed planning and monitoring of the joint flights were conducted on the basis of mutual agreements within the different technical arenas. For example, attitude requirements were agreed on between the appropriate attitude experts, procedural issues were resolved by experts on specific operations, and so forth. At this level, issue resolution concluded with the development of extensive recommendations for the respective flight directors and flight managers. This proved to be an effective method for resolving technical issues.

The planning and execution of these joint flights included many significant achievements. There were many difficult moments, as a result of both the technical complexity of the task and the practical issues involving technical, language, and cultural differences, all of which affected flight operations. The most significant achievements included the following:

Vehicle docking. Operational methods for the Shuttle's approach to and docking with Mir were developed and constantly improved throughout the entire program. The Mir complex continued to change throughout the entire program as modules were moved and added and solar arrays were moved. Issues pertaining to propulsion system plume impingement, loads upon contact, and vehicle dynamics required constant reevaluation with these changes taken into account. The Shuttle approach was changed in the initial stage of the program from an approach from co-altitude (velocity vector) to an approach from below (radius vector) to reduce propulsion system plume impingement and to improve reaction control system (RCS) contamination exposure conditions for the solar array panels. Dockings were made strictly according to required conditions throughout the entire joint program (Figure 16).

Technical operations of the Shuttle-Mir stack. Mutually compatible Shuttle-Mir complex operations required significant work on attitude control, thermal control, and electric power supply modes, as well as maintenance of the stack's atmosphere. The strategy for attitude control and monitoring of the stack's atmosphere was based on the precept that only one vehicle would have control. Incompatible operational control modes between the Mir station and orbiter control systems were avoided. The Shuttle digital autopilot (DAP) control parameters had to be optimized to provide attitude control using either the vernier or primary RCS jets. The DAP algorithms were modified to allow the larger primary RCS jets to fire, emulating the smaller vernier jets in the event that the verniers were declared failed. This new mode of the DAP was termed "ALT DAP" and added redundancy to Shuttle attitude control capability. In addition, the Shuttle environmental control hardware was modified to allow for oxygen replenishment of the Mir station prior to undocking.



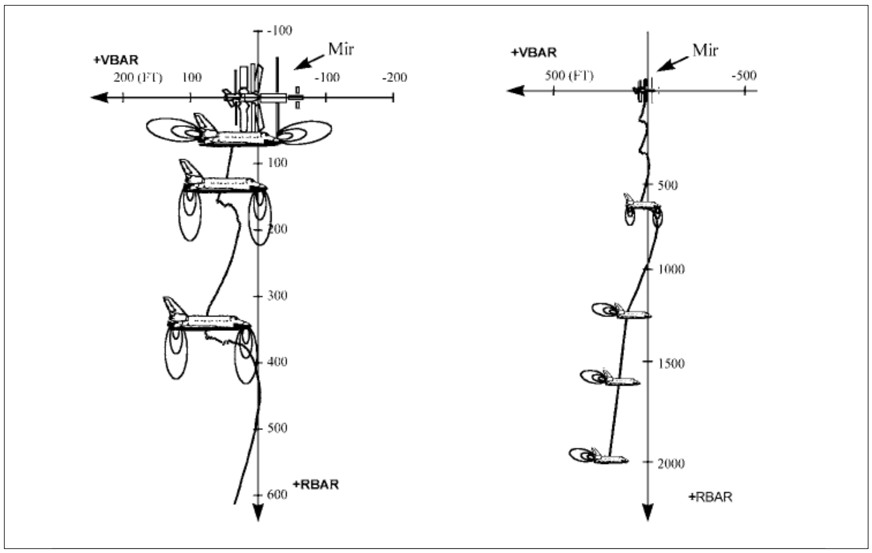


Figure 16: Diagram showing Shuttle orbiter using R-bar approach, which minimized RCS plume impingement on Mir by employing the influence of orbital mechanics

3.4 Cargo Delivery

The conditions of Contract NAS 15-10110 providing for cargo delivery from the Shuttle to Mir in the Phase 1 program were not only fulfilled completely, but were significantly expanded. During nine Shuttle flights to Mir, 15,000 kilograms of various cargo were delivered to the station, and 3,284 kilograms were returned to Earth (Figures 17, 18, and 19).

It was assumed that during the first flights to the ISS, the Shuttle would deliver water, gases (such as oxygen and nitrogen), food, and other cargo for crew life support and would return to Earth the results of scientific research and experiments and failed equipment requiring repair. During the program, it became necessary to deliver Russian hardware to the station to replace failed hardware ("Kurs A" antennas, gyrodynes, and the Elektron and Vozdukh systems), batteries, tools, and instruments. Additional agreements were reached between NASA and RSA on such deliveries, and the results of fulfilling the conditions of these agreements were mutually profitable. As a result, the Russian side was able to employ nine fewer Progress M vehicles and 26 fewer Raduga returnable ballistic capsules.

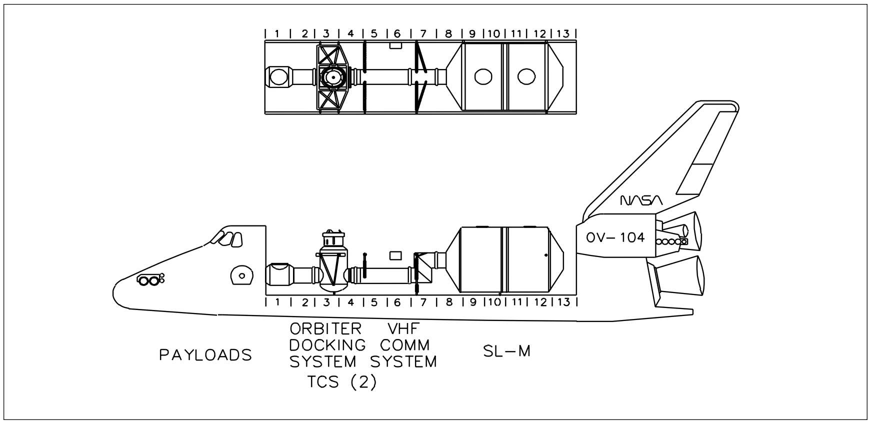


Figure 17: Configuration of the Shuttle orbiter payload bay during flight STS-71

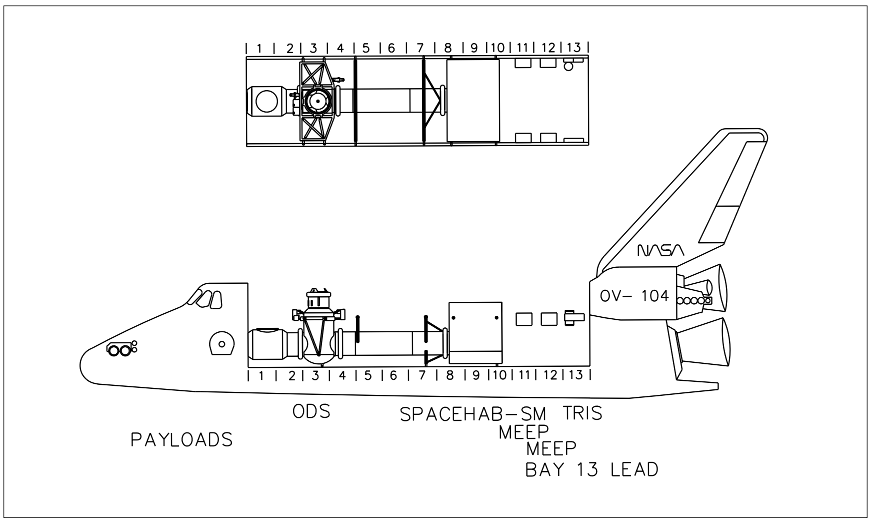
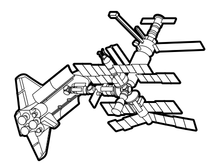


Figure 18: Configuration of the Shuttle orbiter payload bay during flight STS-76



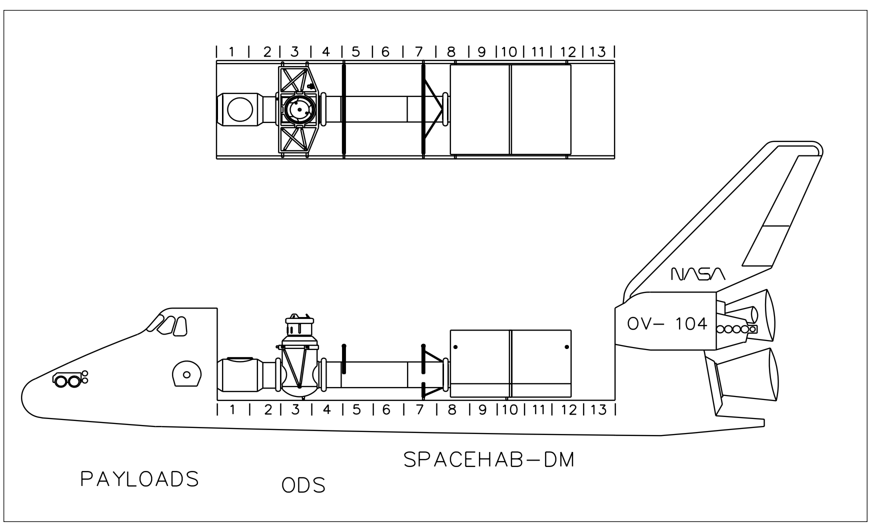


Figure 19: Configuration of the Shuttle orbiter payload bay during flight STS-79

3.5 Joint EVA's by Astronauts and Cosmonauts

The EVA Working Group (Working Group 7) coordinated the efforts that support astronaut and cosmonaut EVA operations under the NASA science program on both the Shuttle and Mir. The Mir EVA program required the participation of U.S. astronauts in joint EVA's with Russian cosmonauts to implement the science program, inspect the modules, and restore the serviceability of station systems and assemblies. The EVA's from the Shuttle to support Mir were determined according to the flight situation on Mir.

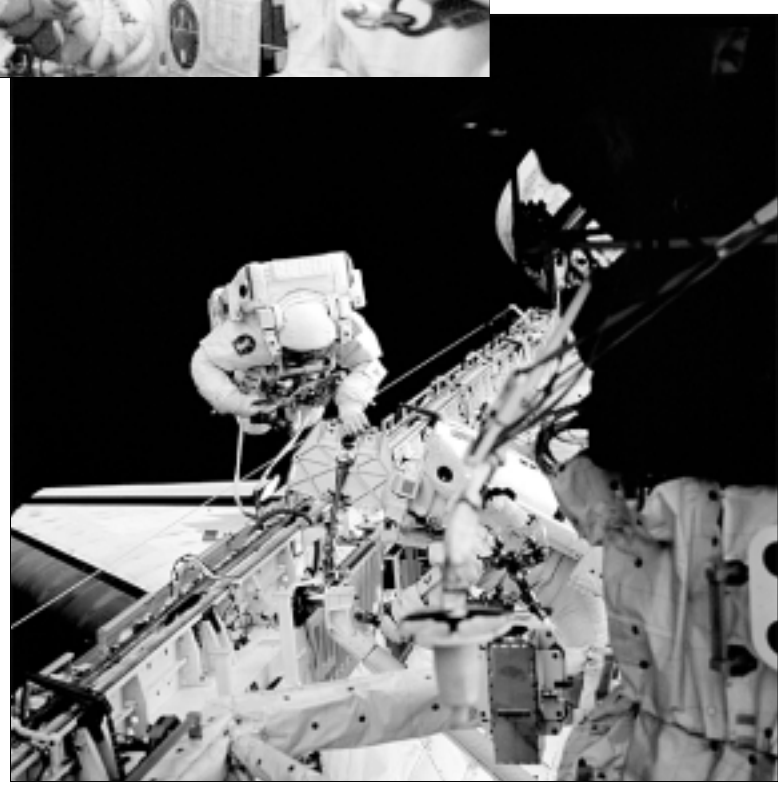


Figure 20: V. Titov and S. Parazynski during EVA operations

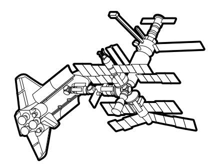
Jerry Linenger was the first U.S. astronaut to perform an EVA in a Russian Orlan-DMA spacesuit, together with cosmonaut A. Solovyev. The program, which included installing the Optical Properties Monitor (OPM), External Dosimeter Array (EDA), Mir Sample Return Experiment (MSRE), and Particle Impact Experiment (PIE) panels, was fulfilled completely. Thermoluminescent Dosimeters (TLD) were installed in the spacesuits. Joint safety tethers based on an American design and mounted on the Orlan-DMA spacesuits were tested.

American astronaut Michael Foale and Russian cosmonaut Solovyev made the second joint EVA on Mir to inspect the Spektr module and to identify places where it may have been depressurized. The Benton dosimeter was also retrieved. While working in open space, astronaut Foale proved himself to be an experienced EVA specialist capable of performing not only the planned program, but also operations that became necessary during the EVA process. Foale's efficient work in open space was also the result of his good knowledge of the Russian language.

The third astronaut, David Wolf, successfully conducted an EVA jointly with Solovyev to work with the SPSR experimental spectroreflectometer. The EVA was successful, and unique experience was gained in evaluating the status of the external coverings of individual sections of the Mir surface.

During the mated flight of STS-86 and Mir-24, astronaut Scott Parazynski and cosmonaut V. Titov, in American EMU spacesuits, transferred a large device for sealing the Spektr module solar array drive from the Shuttle to the Mir docking compartment and secured it (Figure 20). The possibility for restraint by the Russian technique using two safety tethers while working in EMU spacesuits was confirmed. The mutually suitable Yakor foot restraint device for the ISS was tested.

3.6 Fire on Mir



A solid-fuel oxygen generator (SFOG) cartridge caught fire on February 23, 1997 (Figure 21). The fire was contained because of the fast and coordinated actions of the crew (V. Korzun and A. Kaleri). No residual adverse affects to crew health were observed, and the physical damage was determined to be not significant. The fire destroyed the SFOG, and contamination of the atmosphere and the walls in direct proximity to the SFOG by its combustion products was noted.

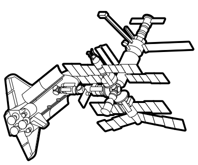
On the basis of the conclusions of S.P. Korolev, RSC-E, and TsNIIMash, the Utkin Advisory Expert Council analyzed the cause of the off-nominal situation on Mir on February 23, 1997, and examined crew safety measures when using SFOG's aboard the station. The following were established as a result:
1. After the cartridge was activated, the combustion front could only move 10 to 18 millimeters. As compared to control samples, an analysis of the traces of temperature impact on the SFOG housing indicated that the maximum temperature and the focus of the ignition were located at a distance of approximately 80 millimeters from the capsule. This could have happened when the direction of the oxygen flow was disrupted because of the lack of a sealing gasket.
2. The presence of residues of active substance and the complete combustion of the cartridge housing indicate that the metal burned and the product decomposed around the perimeter of the cartridge.

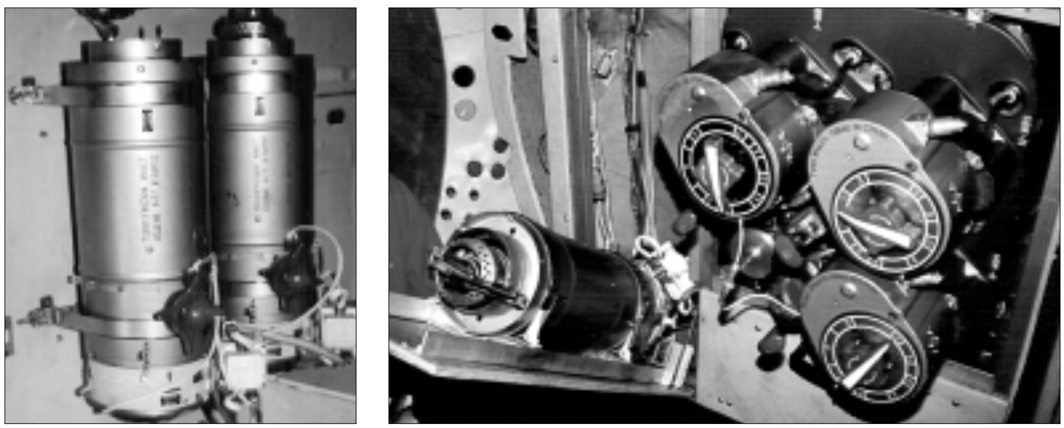
It seems that the fire could have occurred from the following two interrelated causes:
1. The lack of a sealing gasket in the cartridge housing
2. The presence of an organic foreign substance on the internal or external part of the cartridge

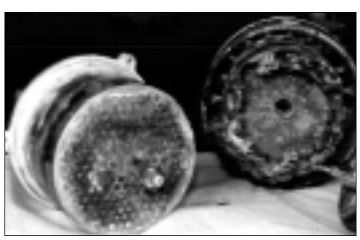
These factors likely led to the ignition of the cartridge's metal housing. The investigation of the possible causes of the ignition of the SFOG will be continued, with the participation of a forensic expert center that will issue an independent conclusion.

The TF-AEC Joint Commission feels that the following must be noted:

1. The analysis of the likely causes of the fire, along with modeling results, seems consistent with the identification of the situation.
2. In view of these conclusions and the available statistics on failures of solid-fuel oxygen (more than 2,000 of the same design used on Salyut and Mir and more than 10,000 similar units used in submarine operations), the failure aboard Mir can be considered a random event.
3. The contingency plans proposed to prevent or contain a similar situation includes additional special inspections of SFOG cartridges, the placement of fire extinguishers in direct proximity to the SFOG's, increased availability of individual crew protective gear (gas masks), and unimpeded access to the crew return vehicle.
4. At the time of publication of this report, the failure analysis has not been either completed or released. The Joint Commission strongly endorses that the final report of the emergency review panel with the analysis of the SFOG fire origin be provided to the ISS program.







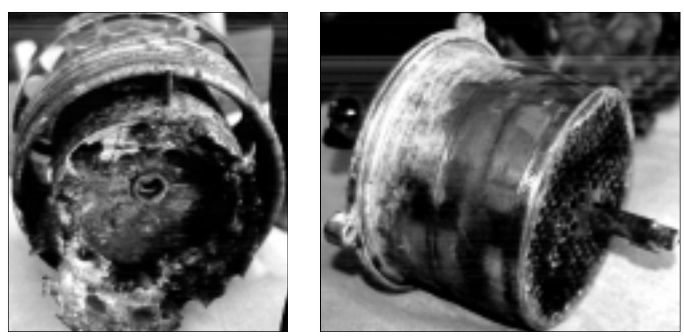


Figure 21: [top row] Solid-fuel oxygen generator (SFOG) showing stowed and operational locations, and [bottom row] components damaged during February 23, 1997, onboard fire incident

3.7 Progress M-34 Collision With Mir and Damage to the Spektr Module

On June 25, 1997, an unmanned Progress M-34 cargo vehicle collided with the Mir space station during a test of a new manual docking system. The collision caused a depressurization of the Spektr module. The crew was forced to seal off the Spektr from the rest of the station, cut data cables, and disconnect power cables leading into the module. As a result, the Mir space station lost 35 percent of its power-generating capability.

After the collision, various organizations released reports on the cause of the collision. These reports were incomplete in their analysis and tended to affix blame on one particular individual or organization. A thorough joint technical review concluded that it was, in fact, much more complicated (Figure 22).

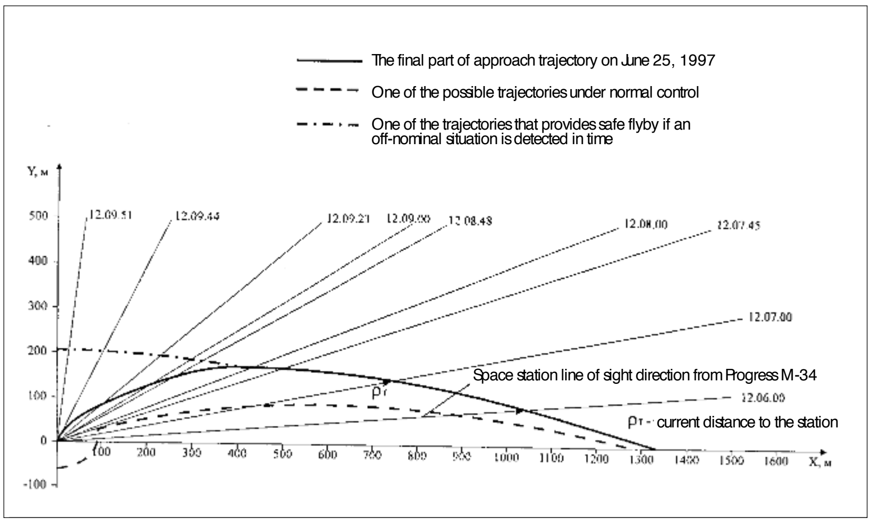
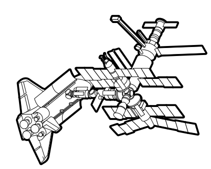


Figure 22: Final part of the flight trajectory during Progress M-34 cargo vehicle's rendezvous with the Mir station



In September 1997, the TF-AEC Joint Commission met with key representatives from RSC-E, GCTC, IBMP, RSA, and TsNIIMash to review and assess the conditions leading up to the cause of the collision.

These meetings were successful in developing a more complete understanding of the causes of the collision. The TF-AEC Joint Commission determined that there was no single event identified as the sole or root cause of the accident. The collision was the result of a cumulative effect of the following string of events:

- The rendezvous and docking procedure (which was attempted as a test with the objective of determining whether a manual docking could be completed without range or range-rate data) was questionable. This experimental docking mode was being attempted for the first time.
- The test planning was inadequate.
- The safety review process of the test was inadequate and did not involve all the key operational organizations.
- Ground rendezvous training for the crew had not included the fidelity of the moving Earth and cloud background images; this added significantly to the complexity of the task.
- It had been 5 1/2 months since the crew had undergone any rendezvous and docking simulation training. Because Mir lacked an onboard simulator, there was no way for the crew to practice 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 cargo vehicle recorded the image of Mir, which was then transmitted to Mir and projected on a

small display for the crew (Figure 23). A grid of squares overlaid the display and was used to estimate range and range rate based on the relative size of the image and squares. Because of perceived dimensional variations with relative vehicle attitudes, and the system's limited resolution, this method has considerable ambiguity, which results as range and range-rate errors.

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 as the crew was out of radio contact with MCC-M during the time of the collision.

The location and orientation of the Progress reaction control thrusters with respect to the vehicle's 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 and the associated ballistic trajectory of the Progress being higher than normal.

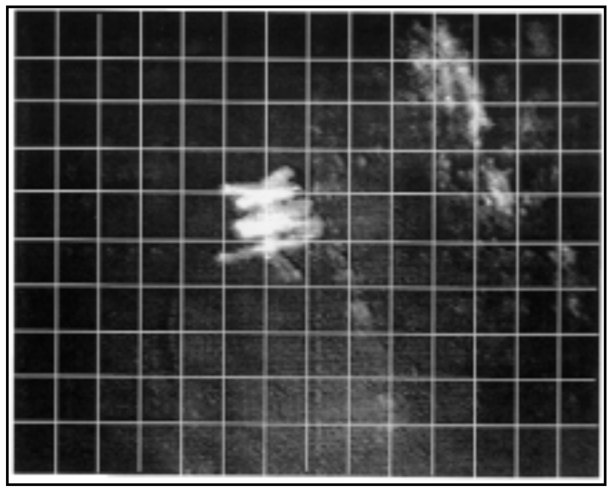


Figure 23: Station display, visible by cosmonauts on the monitor, during the Progress M-34 cargo vehicle's rendezvous with the Mir station

The TF-AEC Joint Commission signed a joint statement on September 19, 1997, in which it expressed the following recommendations to NASA and RSA, including the findings of the TsNIIMash Council as an attachment:

1. Under nominal operations, ballistic precision rendezvous plus teleoperations will not be attempted without range and range-rate information available to the crew. Under emergency operations, such a rendezvous may be attempted, provided that U.S. and Russian experts both agree on safety conditions for the crew and station. In addition, communications must be in place to ensure success. Teleoperator (TORU) at proximity operations, which has been shown to be controllable, is an acceptable mode of operation.
2. Appropriate organizations must perform additional analysis and make corrections to the procedures for the implementation of the Ballistic Precision Rendezvous (BPR) + TORU mode of rendezvous and docking operation. This must be done to prevent crew errors and their possible consequences by including, in the procedures, the criteria to assess flight safety.
3. Modify the scope and plan of crew training in terms of the TORU mode rendezvous, including the appropriate monitoring for safety assurance.

4. Enhance the reliability of the BPR + TORU mode rendezvous by 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. Plan and implement experimental rendezvous operations only when in contact with the MCC.
6. Require that the flight engineer support the crew commander in all manual rendezvous and docking procedures.
7. Develop an onboard TORU simulator.
8. Upgrade the TORU training facilities by including a simulation of the ambient background visual conditions.
9. Test new experimental modes impacting flight safety 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. Clarify the significance of the above-mentioned factors by producing an integrated analysis of the Progress M-34 vehicle rendezvous (Figure 24) using the resources of both RSC-E and GCTC, together with TsNIIMash participation.
11. Postpone the decision of further test and verification of the BPR + TORU mode until all of the above recommendations have been implemented.

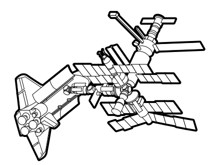


Figure 24: Damage to Spektr module resulting from collision by Progress M-34 cargo vehicle during Mir-23 mission

3.8 Final Joint Flight of the Shuttle (STS-91) and Mir and the NASA-7 Mission

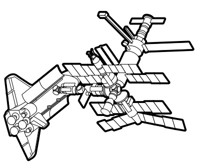
This section addresses the last stage of the Phase 1 program and details the Joint Commission's role in the following areas:

Anomalies of Mir before STS-91
The flight of STS-91
The NASA-7 mission

3.8.1 Anomalies of Mir Before STS-91

On February 20, 1998, a valve on the air scrubber (□□□) in the Kvant-1 module was prematurely opened to the cabin, before the heating cycle had completed its cooldown. This led to the burning of valve seals and the introduction of considerable quantities of smoke into the module. Because of the air distribution system, this smoke soon permeated the entire vehicle, and the levels of carbon monoxide were raised to in excess of 400 ppm. Some of the crew members reported nausea and headaches consistent with carbon monoxide poisoning. After about 2 days, the Vozdukh system removed the smoke and contaminants and the atmosphere was returned to normal.

On May 30, 1998, the central onboard computer on Mir switched off. Until then, this computer had operated without failure for almost 5 months. In accordance with the assigned logic of operation, a simultaneous stoppage occurred in 11 gyrodynes, and the station temporarily lost attitude control. During this period, the solar arrays continued to generate sufficient electric power for the station, owing to the favorable orientation of the station relative to the Sun. The failure of the onboard digital computer created a risk that the docking of Mir with the Space Shuttle planned for June 4, 1998, would be cancelled. Mir's crew replaced the failed computer with a new computer that had been delivered in January 1998 by *Endeavour*. The necessary and successful stages of restoring attitude control took 2 days to complete and involved testing the computer, entering the data base, pointing the station with the thrusters, spinning up the gyrodynes, and inserting the gyrodynes into the control loop. To save station electric power, the operations concept dictated that energy-intensive life support systems, such as Elektron, Vozdukh, and lighting devices, were switched off. On June 1, 1998, the station's attitude control was fully restored. This was maintained with the aid of thrusters, and on the evening on June 2, following MCC-M commands, the crew spun up the gyrodynes and Mir was ready for docking with *Discovery*.



3.8.2 Flight of STS-91

Flight STS-91, the last of nine Phase 1 Mir docking missions, took place from June 2 to 12, 1998.

On June 2, 1998, *Discovery* lifted off from the launch pad at LC-39A at KSC in Florida. In the SPACEHAB module, 1,180 kilograms of Russian cargo was stowed for delivery to the Mir space station, including three storage batteries, food packages, water containers, clothing, sleeping accessories, personal hygiene aids, photographic film containers, and other cargo. Transfers from the Shuttle to Mir included 540 kilograms of technical water, obtained as a byproduct of the Shuttle's fuel cell operation, film to replace the film used for photos taken on the American equipment, and additional American cargo. Approximately 2,000 kilograms of cargo to be returned on Discovery included about 1,000 kilograms of American science equipment, the results of scientific studies and experiments, and personal items.

The ninth and last docking of the Phase 1 program, *Discovery* to Mir, took place on June 4, 1998. During the implementation of joint flights for the Phase 1 program, *Atlantis* docked seven times and *Endeavour* and *Discovery* each docked once with Mir.

During joint flight, after undocking, the two crews attempted to search for the places where the damaged Spektr module was leaking with the aid of a test pressurization of the module. A luminescent gas (nontoxic and noncombustible mixture) was used, and the crew attempted to observe any leaks from potential breach locations on the Spektr module from *Discovery* during a fly-around. All nine cosmonauts and astronauts participated in this work. Unfortunately, because of the unfavorable position of the station relative to the Sun, it was not possible to observe the result visually. However, it is necessary to note that the experience in conducting this operation is undoubtedly important for working on the ISS.

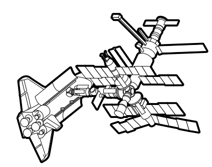
On June 2, 1998, V. Ryumin, who had flown in space three times, including long-duration missions, was included as a crew member on the launch of STS-91 to the Mir station. During the mated portion of the flight, he was able to ingress Mir and make meaningful and comparative observations of the housekeeping, stowage, systems status, and general status of Mir, which will be applicable to ISS planning and operations.

With the landing of *Discovery* at KSC, the mission ended on June 12 with the crew of seven people aboard: Charles Precourt (commander), Dominic Gorie (pilot), Franklin Chang-Diaz, Wendy Lawrence, Janet Kavandi, Valery Ryumin, and Andrew Thomas, who was returning from Mir after a 4-month mission.

Because the Space Shuttle, launch vehicle Soyuz, and transport vehicle Soyuz TM are the primary crew transport vehicles for future flights for ISS assembly and operation, the TF-AEC Joint Commission should examine the safety issues of these vehicles within the scope of the ISS program.

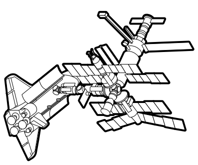
3.8.3 NASA-7 Mission

The Mir-25 commander, Talgat Musabaev, and the seventh American astronaut to serve a long-duration NASA mission on Mir, Andrew Thomas, like his predecessors, noted that problems arose at the beginning of joint work because of differences in culture and technical approach. However, a common language was found, and the crew worked excellently. The mission program was fulfilled completely, and it concluded successfully with the landing of STS-91.



4 EXPERIENCE ACQUIRED IN THE PHASE 1 PROGRAM: ITS USE IN CONSTRUCTING AND OPERATING THE ISS

Phase 1 of the ISS program was completed successfully in June 1998 with the flight of Shuttle mission STS-91 to Mir. This flight included the rendezvous, docking, and mated flight for 6 days. It should be noted that this multinational program enabled the American partners to gain significant knowledge and experience for the development and future operation of the ISS, and it allowed the Russian partners to save transport and cargo vehicles. During the program, the Shuttle delivered more than 15 metric tons of various cargo (spare systems, hardware, water, clothing, food, air, etc.) to Mir and returned approximately 3.3 metric tons of cargo (hardware, onboard systems, the results of scientific research and experiments, etc.) from Mir to Earth. This saved nine Progress M returnable cargo capsules. A wealth of experience was gained in joint operations, control, actions in off-nominal situations, repair and restoration work, and EVA over the nearly 4 years of joint work.



During the joint flights and the implementation of long-duration programs by NASA astronauts aboard the Russian Mir station, American experts gained unique experience in enduring long stays in space, instructing and training crews, conducting operations planning, and maintaining the operability and prolonging the service life of the onboard life support systems. Russian experts, in turn, acquired experience in using the reusable Shuttle as a transport vehicle for supplying Mir, delivering cargoes from orbit to Earth, and replacing crews. One of the most important results of the joint experience was the integration of Russian and American personnel and cargoes delivered to Mir by the Shuttle.

In light of the preparations for joint operations in Phase 2, a special note must be made of the fact that the interaction between MCC-H and MCC-M resulted in successful joint flight control. The experience gained will be used in the Phase 2 program, thus making it possible to solve many potential problems.

Within the scope of Phase 1, eight Soyuz TM manned crew transport vehicles were used to bring the cosmonauts and astronauts aboard Mir. From February 1995 through June 1998, the Shuttle made 10 flights to Mir, with nine of those flights performing rendezvous and docking. U.S. Space Shuttles were used to deliver six Russian cosmonauts—the Mir-22 crew (A. Soloviev and N. Budarin) and visiting crews (E. Kondakova, V. Titov, S. Sharipov, and V. Ryumin)—while cosmonauts V. Dezhurov and G. Strekalov were returned to Earth after a long-duration mission. Norman 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. Seven U.S. astronauts visited Mir during NASA long-duration missions. Six American astronauts, in continuous succession, spent more than 2 years aboard Mir—Shannon Lucid, John Blaha, Jerry Linenger, Michael Foale, David Wolf, and Andrew Thomas. The Progress M transport cargo vehicles were used to deliver various cargoes and fuel to the station. Large amounts of cargo were delivered to Mir by U.S. orbiters *Atlantis, Endeavour,* and *Discovery.* Figure 25 shows Mir's general configuration.

In reviewing the results of this completed stage of Russian-American cooperation and analyzing the experience gained as a result of the Phase 1 program's performance, the following can be stated:

1. The Shuttle flight and docking to Mir experience proved the following:
   - Effectiveness and safety of selected Shuttle/Mir rendezvous and docking plans
   - High level of Shuttle crew training for conducting all rendezvous, approach, and docking operations
   - Sufficient coordination between MCC-H and MCC-M

Adequate level of Mir crew training, including off-nominal situation recovery

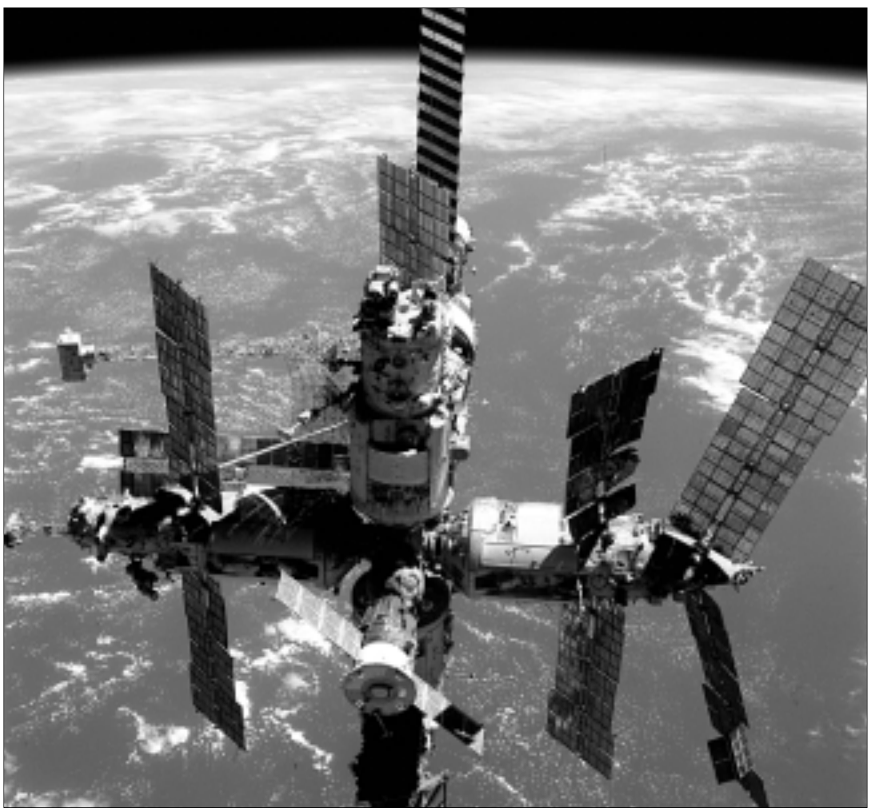
Sufficient accuracy of the Mir attitude control and stabilization system to ensure successful and safe Shuttle/Mir docking

High accuracy of Shuttle manual motion control operations during rendezvous and docking to Mir

Effectiveness and safety of structured algorithms implemented for Shuttle/Mir stack control

Possibility of successful resolution of Shuttle/Mir electromagnetic compatibility problems during docking and mated flight stages

2. The successful completion of the Shuttle-Mir program closed many issues related to mission safety, including rendezvous, approach, docking, mated flight, and undocking control.
3. A first experience was gained in controlling the near-Earth-orbit docking process of such large and complex spacecraft as the Shuttle and Mir station, with a total mass of more than 200 tons. This experience should be applied to the ISS.
4. The results of Phase 1 completion identified several problems that require resolution in the process of building the ISS. One is the problem of station control system reliability—in particular, the problem of ISS attitude hold in the event of any failures or transient malfunctions in the onboard digital computer system channels.



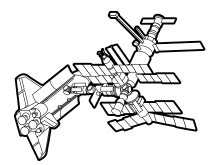


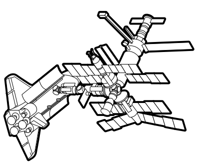
Figure 25: General configuration of the Mir station during primary crews Mir-21, 22, 23, 24, and 25

At the same time, a number of practical results of particular importance for conducting joint work in Phase 2 should be emphasized:

1. Utilization of the Shuttle for station activities:
   Shuttle rendezvous and docking with Mir
   Integration of the Russian-built docking system into the U.S.-built Shuttle
   Development of operational techniques to minimize plume impingement during rendezvous and docking with Mir
   Delivery of cargo (food, water, life support equipment, and gases) to Mir
   Return of cargo (science hardware, parts of onboard systems, etc.) and the results of scientific research and experiments from orbit to Earth
   Mir station crew transfers/replacements
   Attitude control of the Mir-Shuttle stack by using the Shuttle's Reaction Control System vernier jets and ALT DAP mode of primary RCS jets†

2. Joint control of the Mir-Shuttle stack from MCC-H and MCC-M:
   Development of diagrams and documentation to organize communications during joint flights
   Development of joint stack loads analysis and verification process

3. Crew interaction:
   Training of cosmonauts and astronauts in both Russian and U.S. training facilities by using the host country's training techniques and language
   Execution of long-duration international flights (overcoming the language barrier, psychological differences, problems with staying in shape, etc.)
   Development of postflight re-adaptation programs
   Operations to move and install hardware in the Mir-Shuttle stack
   Performance of joint scientific research and experiments
   Interaction of an international crew during an EVA
   An integrated training program to operate ISS medical equipment



4. Maintenance of the operability of onboard systems during long-duration flights, including:
   Thermal control system, especially coolant lines (ethylene glycol)
   Motion control system
   Electrical power system
   Air conditioning system

5. Control of off-nominal situations:
   Fire in the Kvant module
   Leaking of the thermal control system loops
   Progress M-34 cargo vehicle collision with the Spektr module
   Depressurization of one of the station's modules
   Failure of the onboard control complex
   Failure of the onboard digital computer
   Failure/stopping of the gyrodynes
   Loss of station attitude control
   Compressed timelines for the emergency delivery of hardware to the station

† *In some cases, attitude control was provided by Mir.*

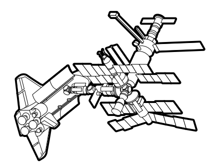
6. Development of joint documentation:
   Joint certification for flight (including experiments and hardware)
   Joint flight data file
   Joint flight rules
   Joint hazard analyses
   Joint medical protocols

7. Station environment research:
   Testing of U.S. spacecraft habitation monitoring aids during long-duration flight conditions

8. Joint ground operations with logistics items:
   Performance of acceptance tests on U.S. science equipment
   Preflight testing of complex cargo assembly
   Development of joint up-mass and down-mass control process flow
   Joint experience in simulating cargo stowage

9. Integration of U.S. and Russian engineering efforts in the search for new methods to develop operational tools and techniques

10. Provision that all docking/proximity operations associated with the ISS will be agreed on by the ISS partners, with the assurance that all parties are involved from the initial planning through the execution phases



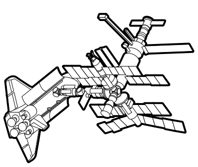
5 CONCLUSION

The results of the 4-year work of the TF-AEC Joint Commission include contributions that made it possible for NASA and RSA to successfully conclude the ISS Phase 1 program. The commission's independent evaluations were significant in helping solve the key problems of joint flights of the Mir orbital station and Shuttle orbital vehicles to improve their safety and effectiveness.

With respect to the work of the TF-AEC Joint Commission, 1997 was a key year. The following events set the tone for that year:

- The fire aboard the station in February and subsequent failures of main onboard systems, which affected crew activities and station operating safety
- The collision of the Progress M-34 cargo vehicle with the station on June 25, 1997, which led to depressurization of the Spektr module and the loss of 35 percent of the electric power generated on the station
- The series of failures of the main computer, resulting in the loss of Mir attitude control and provoking concerns at NASA and RSA

The press, television, and statements by certain influential politicians questioned the safety of further flights on the station and called for a halt in the cooperation in space. In September 1997, the TF-AEC Joint Commission met with key representatives in Russia to address these issues. RSC-E, GCTC, IBMP, and TsNIIMash participated to evaluate objectively the status of the Mir station and to assess the readiness and the degree of risk in continuing the Phase 1 program. The joint statement by the Joint Commission of September 19, 1997, stated that the level of risk posed to the crew for the September launch of Shuttle STS-86 and the crews of Mir-23/24 did not exceed acceptable levels for this program. This enabled NASA and RSA to make the decision to continue the long-term joint flights of American astronauts and Russian cosmonauts on Mir.

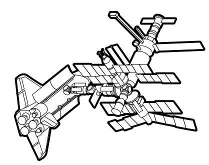


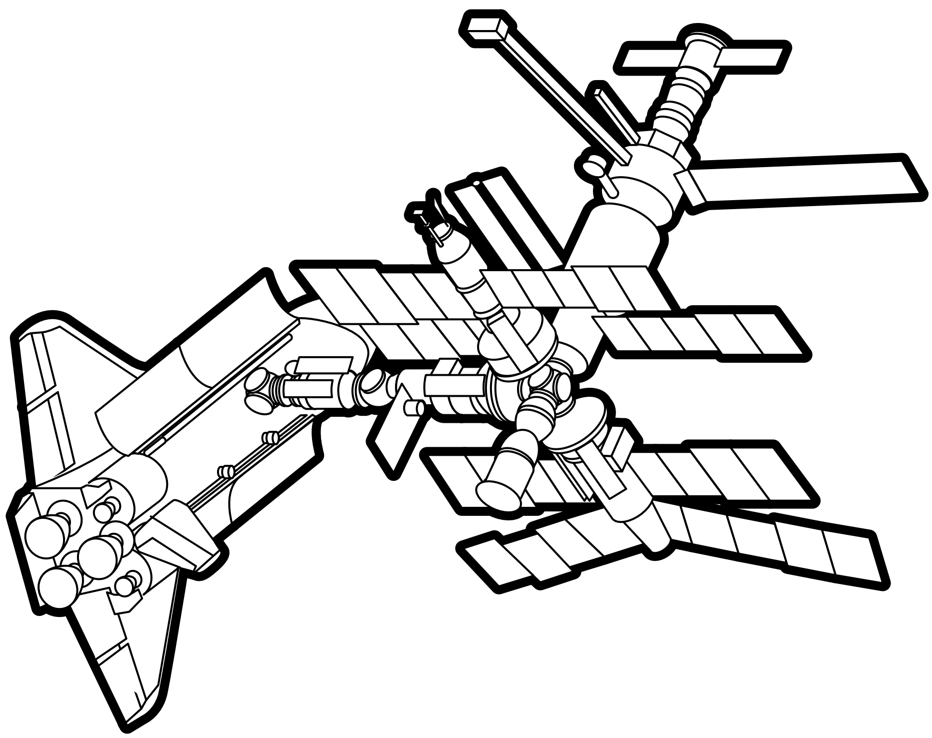
The joint work of the Stafford Task Force and the Utkin Advisory Expert Council during Phase 1 made it possible to create a process for considering the plans and capabilities of one another and to submit recommendations and reports to the NASA Administrator and the RSA General Director. The provision on the Stafford Task Force and the Utkin Advisory Expert Council, as well as the joint action plan developed in September 1997, increased the joint work of the commission. The first joint report was signed in June 1996. The sixth and seventh sessions of the U.S.-Russian Joint Commission on Economic and Technological Cooperation noted the major impact of work performed by the groups headed by General Stafford and Academician Utkin.

NASA Administrator Goldin and RSA General Director Koptev attended a joint session at KSC on December 2, 1998, and expressed their gratitude to the leaders and members of the TF-AEC Joint Commission for their substantial contribution to the implementation of the Shuttle-Mir and NASA-Mir programs. The NASA and RSA leaders noted that the joint work of the commission helped raise the level of trust between the United States and Russia in the field of space cooperation. With their activities, the Joint Commission improved relationships between NASA and RSA and helped eliminate skepticism on both sides of the ocean. The opinion was voiced that further joint work of the Stafford Task Force and the Utkin Advisory Expert Council should be continued during Phase 2 of the ISS program.

With the accumulated experience gained during the Phase 1 program, the TF-AEC Joint Commission is prepared to continue its work in evaluating both the issues underway and those that will come along during Phase 2 of the ISS program. The Joint Commission will continue to develop recommendations regarding technical risk, institute plans to reduce the degree of risk, and apply lessons learned from flights during the Phase 1 program.

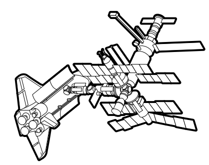
6
APPENDICES





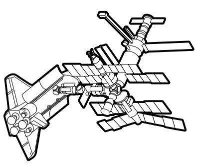
APPENDIX 6.1

TF-AEC MEMBERS



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

Chairman	Dates Served
Lt. General Thomas Stafford, USAF (Ret.) President Stafford, Burke and Hecker	1994–Present
Members	
Colonel James Adamson, U.S. Army (Ret.) Chief Operating Officer United Space Alliance	1994–Present
Bobby Ray Alford, M.D. Executive Vice President and Dean of Medicine Baylor College of Medicine	1995–1995
Commander Michael Baker, USN Astronaut Flight Crew Operations NASA Johnson Space Center	1996
Colonel John Blaha, USAF (Ret.) Astronaut Flight Crew Operations NASA Johnson Space Center	1997–1998
Mr. Benjamin Cosgrove Senior Vice President (Ret.) Boeing Commercial Airplane Group	1997–Present
Mr. Joseph Cuzzupoli Vice President and Program Manager Kistler Aerospace Corporation	1995–Present
Charles Daniel, Ph.D. Chief Engineer for the Space Station Integration Office NASA Marshall Space Flight Center	1995–Present
John Fabian, Ph.D. President and CEO ANSER Corporation	1994–Present



Craig Fischer, M.D. — 1995–Present
Partner
Fischer and Starke Associates

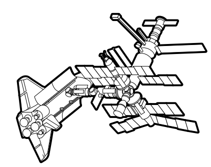
Michael Greenfield, Ph.D. — 1994–Present
Deputy Associate Administrator
Office of Safety and Mission Assurance
NASA Headquarters

Daniel Heimerdinger, Ph.D. — 1996–Present
Vice President
Applied Research, Engineering and Management Corporation

Major General Ralph Jacobson, USAF (Ret.) — 1994–Present
President Emeritus
The Charles Stark Draper Laboratory

J. Milton Heflin, Jr. — 1994–Present
Deputy Chief
Flight Director Office
NASA Johnson Space Center

Commander Michael Lopez-Alegria, USN — 1998–1999
Astronaut
Flight Crew Operations
NASA Johnson Space Center



Ronald Merrell, M.D. — 1995–Present
Lampman Professor and Chair
Department of Surgery
Yale University School of Medicine

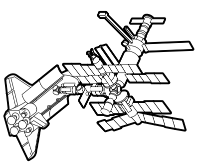
David Mobley — 1994–1995
Assistant to the Center Director for Space Station
NASA Marshall Space Flight Center

Arnauld Nicogossian, M.D. — 1994–1998
Associate Administrator
Office of Life and Microgravity Sciences and Applications
NASA Headquarters

Colonel Charles Precourt, USAF — 1996–1997
Astronaut
Flight Crew Operations
NASA Johnson Space Center

Captain William Readdy, USNR Astronaut Flight Crew Operations NASA Johnson Space Center	1995–1996
Andrew Thomas, Ph.D. Astronaut Flight Crew Operations NASA Johnson Space Center	1999-Present
Chester Vaughn Deputy Director, Engineering Directorate NASA Johnson Space Center	1994–1996
Captain John Young, USN (Ret.) Associate Director (Technical) NASA Johnson Space Center	1994–Present

Executive Secretaries



William Vantine	1994–1995
Gilbert Kirkham	1995–1997
Dennis McSweeney	1997–1999
Philip Cleary	1999–Present

Technical Advisors

Maj. General Joe Engle, USAF (Ret.)	1994–Present
Glynn Lunney	1994–1997
Michael Weeks	1995–1996

Ex-Officio Members

David Jossi	1995–1996
James Snowden	1996–1998
Mark Thiessen	1998–Present

Assistant to the Executive Secretary

Holly Stevens	1996–Present

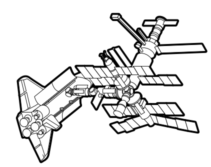
Members of the Utkin Advisory Expert Council

Chairman

Utkin, Vladimir Fedorovich (1995–Present)
Chairman of Advisory Expert Council
Chairman of RSA Coordinating Scientific-Technical Council on Applied Scientific Research on Manned Space Complexes
Director of Central Research Institute of Engineering (TsNIIMash)
Academician of Russian Academy of Sciences
Academician of Ukrainian Academy of Sciences
President of Russian Academy of Cosmonautics
Designer General of "Yuzhnoye" Design Bureau (launch vehicles, spacecraft, etc.), 1971–1990

Council Members

Alexandrov, Yuri Viktorovich (1995–Present)
Member of Advisory Expert Council
Deputy General Director
Deputy Designer General of Pilyugin Scientific Production Center until 1998
Technical Director of "Arkus D" Company
Doctor of Technical Sciences



Aliev, Valery Geidarovich (1995–1997)
Member of Advisory Expert Council
Deputy Designer General of RSC Energia
Doctor of Technical Sciences, Professor

Gazenko, Oleg Georgievich (1995–Present)
Member of Advisory Expert Council
President of Russian Physiological Society
Advisor of Russian Academy of Sciences at the Directorate of IBMP State Scientific Center of the Russian Federation
Academician of Russian Academy of Sciences
Academician of International Academy of Astronautics
Director of IBMP (1969–1988)

Gorodnichev, Yuri Petrovich (1995–Present)
Member of Advisory Expert Council
Chief Engineer of Khrunichev Space Research and Production Space Center

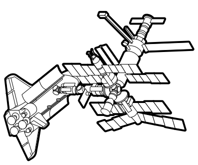
Grigoriev, Yuri Ilyich (1997–Present)
Member of Advisory Expert Council
Deputy Designer General of RSC Energia
Program Director

Klimuk, Peter Ilyich (1997–Present)
Member of Advisory Expert Council
Air Force Colonel General
Head of Russian State Scientific and Research Institute of the Gagarin Cosmonaut Training Center
Professor
Pilot-cosmonaut

Kovalenok, Vladimir Vasilievich (1995–Present)
Member of Advisory Expert Council
Air Force Colonel General
Head of Zhukovsky Higher Military Aviation Institute, Professor
Pilot-cosmonaut

Lukiyaschenko, Vasily Ivanovich (1995–Present)
Member of Advisory Expert Council
Deputy Chairman of Science and Technology Coordination Board on Research Program
Deputy Director of Central Research Institute of Engineering (TsNIIMash)
Head of System Design Center of Central Research Institute of Engineering
Doctor of Technical Sciences, Professor

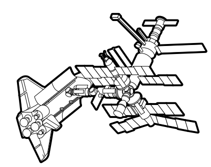
Council Executive Secretary



Vasiliev, Leonid Petrovich (1995–Present)
Executive Secretary of Advisory Expert Council
Deputy Chief of Department for Manned Programs of Central Research Institute of Engineering (TsNIIMash)
Candidate of Technical Sciences

APPENDIX 6.2

TASK FORCE TERMS OF REFERENCE



National Aeronautics and
Space Administration
Office of the Administrator
Washington, DC 20546-0001

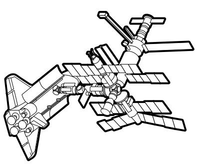
May 2, 1994

TO: M/Associate Administrator for Space Flight

FROM: AD/Acting Deputy Administrator

SUBJECT: Approval of NASA Advisory Council Task Force on Shuttle-Mir Rendezvous and Docking Missions

This memorandum confirms my approval of the Terms of Reference of the NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions.



ORIGINAL SIGNED BY

J. R. Dailey

Enclosure
cc:
I/Ms. A. Accola
ML/Mr. W. Vantine

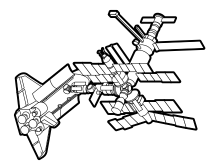
NASA ADVISORY COUNCIL
TASK FORCE ON THE
SHUTTLE-MIR RENDEZVOUS AND DOCKING MISSIONS

TERMS OF REFERENCE

A. BACKGROUND

In October 1992, Russia and the U.S. formally agreed to conduct a fundamentally new program of human cooperation in space. This Shuttle-Mir program involves combined astronaut-cosmonaut crew activities on the Shuttle, Soyuz, and Mir spacecraft. The first in this series was Shuttle mission STS-60 (February 3-11, 1994), which, for the first time ever, carried a Russian cosmonaut into orbit. In March 1995, a U.S. astronaut will be launched aboard the Russian Soyuz 18 space vehicle and will spend 3 months on-board Russia's Mir space station. In January 1995, STS-63 will rendezvous with the Mir space station. In May 1995, a joint U.S.-Russian crew aboard STS-71 will fly to the Mir space station, dock, and perform cooperative science experiments; STS-71 will then return to the United States with the original Mir crew aboard. Following STS-71, a number of additional rendezvous and docking missions with the Mir space station will take place.

These missions will be technically complex undertakings involving close cooperation between NASA and the Russian Space Agency (RSA). New equipment, techniques, and procedures will need to be developed and extensive training conducted. The margin for mission success can be enhanced if a team of experts is created to review all of these preparations on a periodic basis and report its findings and recommendations following each review session.



B. SPECIFIC CHARTER AND REPORTING RELATIONS

Within the context of the overall charter of the NASA Advisory Council (NAC) and its committees, the NAC Task Force on the Shuttle-Mir Rendezvous and Docking Missions shall:

1. Conduct periodic reviews of the preparations for the Shuttle-Mir missions through briefings and interviews at NASA Headquarters, the Lyndon B. Johnson Space Center (JSC), and other facilities as appropriate.

2. In the course of these reviews, address the following areas and make appropriate recommendations:
   a. Training
   b. Operations
   c. Rendezvous and docking

3. Prepare interim reports following each review which detail the Task Force's findings and recommendations with a summary report to be produced prior to the missions and a post-mission report following their conclusion. These reports will be submitted to the Advisory Council.

C. MEMBERSHIP

The Task Force will be chaired by Lt. Gen. Thomas P. Stafford, USAF (Ret.). Members of the task force will be selected from experts in the various disciplines required for such a technical undertaking.

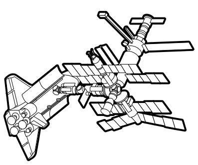
Technical and administrative support will be provided by the Office of Space Flight.

D. DURATION

The NAC Task Force on the Shuttle-Mir Rendezvous and Docking Missions is chartered for a period not to exceed 2 years unless terminated sooner or extended pursuant to the provisions of the Federal Advisory Committee Act.

E. BUDGET

Operations of the Task Force are expected to require approximately $37,920.00 for costs of travel per year for 5-6 meetings per year. The required funds will be provided through the NASA Advisory Council budget. Costs for technical and administrative support will be borne by the Office of Space Flight as appropriate and depending on available funds.



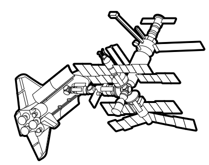
NASA ADVISORY COUNCIL
TASK FORCE ON
INTERNATIONAL SPACE STATION OPERATIONAL READINESS

TERMS OF REFERENCE
January 1999

These Terms of Reference establish the NASA Advisory Council (NAC) Task Force on International Space Station Operational Readiness (IOR). The IOR Task Force is chartered to provide advice and recommendations to the NAC on all aspects related to the operational readiness of the International Space Station (ISS). Specific areas for review by the IOR Task Force may include: space flight operations, including rendezvous, proximity operations, and docking procedures; crew, controller, and support training; aerospace systems test and verification procedures; aerospace structures, loads, and materials; aerospace medicine, including crew health; program and project management; space flight safety, including space flight safety and mission assurance strategies; and readiness of significant ISS launches. The IOR Task Force may also address specific issues and/or areas of interest identified to it by the NAC, or to the NAC by the NASA Administrator or the Associate Administrator for the Office of Space Flight.

The IOR Task Force is further chartered to conduct assessments related to ISS operational readiness with counterpart international advisory review groups, including the Russian Space Agency's Advisory Expert Council.

MEMBERSHIP



The Chair of the IOR Task Force will be appointed by the Associate Administrator for Space Flight with written concurrence from the NASA Administrator or the NASA Associate Deputy Administrator. Membership shall be composed of experts in the disciplines listed in the Annex, although other discipline areas may be considered if the situation warrants. Term of membership will be for the duration of the IOR Task Force.

STRUCTURE

Full voting membership is restricted to persons not employed by NASA (with the exception of two Ex Officio members). The following two positions participate as Ex Officio members: the Deputy Associate Administrator for Safety and Mission Assurance and a representative from the Astronaut Office. NASA civil servants (with the exception of two Ex Officio members) may support the IOR Task Force, but only as nonvoting Technical Advisors.

MEETINGS

The IOR Task Force will meet as often as necessary to fulfill its responsibilities. It is expected that approximately four plenary meetings of the IOR Task Force will be held annually. Meetings of IOR Task Force working groups may be held more often. The IOR Task Force working groups will report to the full IOR Task Force.

JOINT MEETINGS WITH INTERNATIONAL ADVISORY REVIEW GROUPS

The IOR Task Force will conduct joint meetings with counterpart international advisory review groups, including the Russian Space Agency's Advisory Expert Council (AEC). These meetings may result in signed "Summaries of Discussion" or other joint documents, which will be reported to the NAC. The IOR Task Force will in no way represent NASA or the U.S. Government or conduct foreign relations during its joint meetings with international advisory review groups. The sole purpose of interaction with Russia's AEC, or any other international advisory group, is to develop advice to NASA and the NAC.

REPORTING

The IOR Task Force will report its findings and recommendations to the NAC.

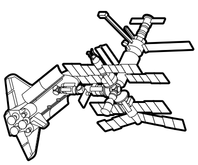
ADMINISTRATIVE PROVISIONS

The Executive Secretary will be appointed by the Associate Administrator for Space Flight and the Associate Administrator for External Relations. The Executive Secretary will serve as the IOR Task Force Designated Federal Official.

Technical and administrative support will be provided by the Office of Space Flight.

BUDGET

Travel funds for IOR Task Force members will be provided by the Office of Space Flight or the Office of External Relations. Operations of the IOR Task Force are expected to require approximately $60,000 for costs of travel per year, including fact-finding site visits and approximately four IOR Task Force plenary meetings per year.



Costs for technical and administrative support will be borne by the Office of Space Flight, as appropriate and depending on availability of funds. Any other expenses associated with the IOR Task Force will be funded by the Office of Space Flight or the Office of External Relations.

DURATION

The IOR Task Force is chartered through the end of Phase 2 of the ISS program, or 2 years from the date these Terms of Reference go into force, whichever comes first, unless terminated sooner or extended pursuant to the provisions of the Federal Advisory Committee Act.

Annex

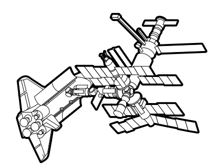
NASA Advisory Council
Task Force on
International Space Station Operational Readiness

Required Areas of Expertise

New and replacement candidate members will be continually sought and considered for membership. Emphasis will be focused on those who have expertise and experience to make contributions in disciplines that include, but are not necessarily limited to:

Space Flight Operations
Crew, Controller, and Support Training
Aerospace Systems, Test, and Integration
Aerospace Structures, Loads, and Materials
Aerospace Medicine
Program and Project Management
Russian (and Other IP) Expertise
Space Flight Safety

This list will be modified as required. In addition, outside experts may be called in to assist or augment the IOR when unique or additional expertise is required.



Space Flight Operations

Extensive knowledge and experience in all areas of space flight operations, including:
- Ground prelaunch/post-landing
- Launch
- Rendezvous, proximity operations, docking*
- Vehicle maintenance
- EVA
- Entry/landing

* Extensive knowledge and experience in spacecraft rendezvous, proximity operations, and docking procedures and mechanics, including: flight trajectories; flight procedures; rendezvous and docking aids; attitude control; types of approaches (such as V-Bar and R-Bar approaches); plume impingement/plume modeling; and tools for range and range rate.

Crew, Controller, and Support Training

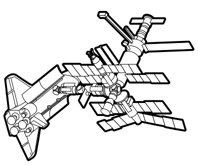
Extensive knowledge and experience in all areas of crew, controller, and support training, including:
- Training procedures and requirements*
- Training documentation
- Crew and support exchanges with international partners

* Extensive knowledge and experience in different types of training and training tools, including classroom, mockups, simulators, neutral buoyancy, onboard, and so on.

Aerospace Systems, Test, and Verification

Extensive knowledge and experience in all areas related to aerospace systems, test, and verification, including:
- Flight guidance, navigation, and control
- Thermal/aerothermal
- Communications*
- Environmental control and life support system (ECLSS)
- Software**

* Extensive knowledge and experience in: ground-to-orbit communications; orbit-to-ground communications; and ground-to-ground communications (such as communications between MCC-H and MCC-M).
** Extensive knowledge and experience in: large-scale government software systems; software integration; software development and life cycle; corrective action implementation; and independent verification and validation.



Aerospace Structures, Loads, and Materials

Extensive knowledge and experience in aerospace structures, loads, and materials, including:

- Spacecraft structural design
- Materials
- Spacecraft loads and dynamics
- Thermal control

Aerospace Medicine

Extensive knowledge and experience in aerospace medicine, including:
- Crew health and health maintenance
- Life support systems
- Crew compatibility enhancement

Program and Project Management

Extensive knowledge and experience in the management of large, complex aerospace projects.

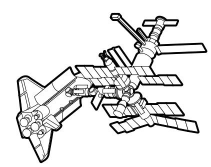
Russian (and Other IP) Expertise (Technical and Cultural)

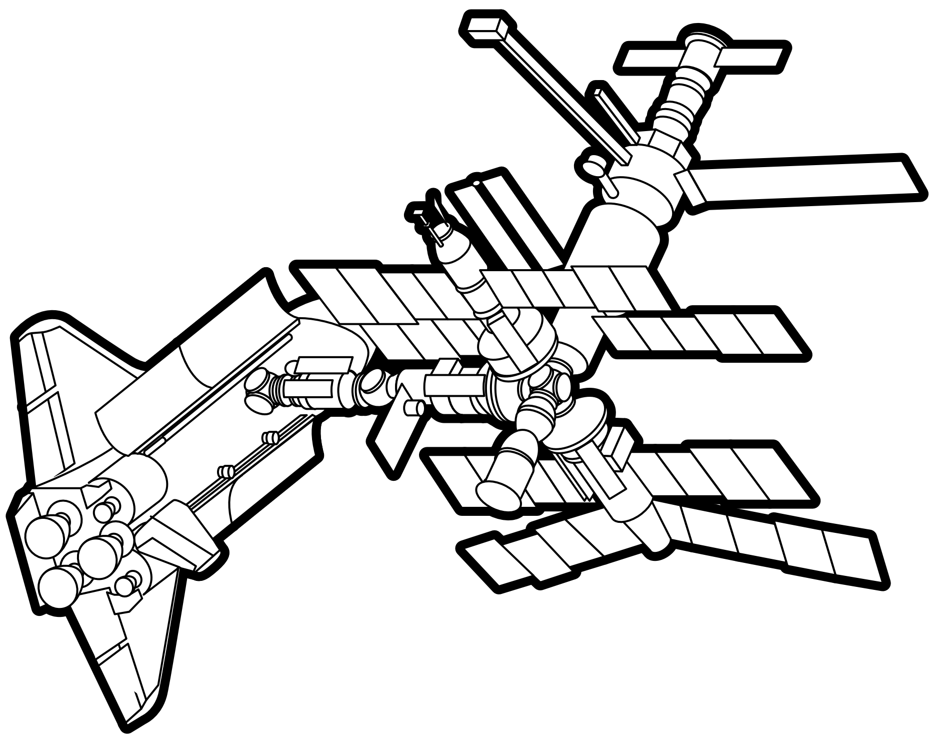
Extensive technical and cultural knowledge and experience with ISS partner countries, including*:
- Russian aerospace organizations (personnel and structure)
- Russian space vehicles
- Russian space operations policies and methods
- Negotiations with Russian individuals and aerospace organizations

* Expertise and experience in dealing with the other ISS partner countries is likely to be required in the future as the program advances closer to the launch dates of their elements.

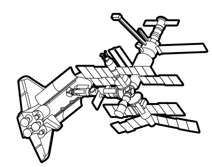
Space Flight Safety

Extensive knowledge and experience in all areas of space flight safety, including:
- Space flight safety and mission assurance strategies
- Risk management and probabilistic risk assessment methodologies
- Spacecraft and space systems test and verification procedures
- Safety requirements
- Vehicle safety
- Payload safety
- Ground safety





APPENDIX 6.3
AEC CHARTER



MISSION STATEMENT ON ADVISORY EXPERT COUNCIL

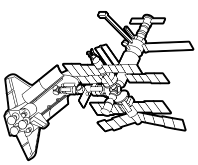
APPROVED
RSA Director General
Yu. N. Koptev
February 11, 1996

MISSION STATEMENT
On the Goals of the Establishing, Status, Tasks and Organization of the Activity of the Advisory Expert Council on Problems in Support of Joint Flights of the Mir Station and Shuttle
Academician V. F. Utkin, Chairman

1. Rationale for Establishing.

The Advisory Expert Council on problems in support of joint flights of the Mir station and Shuttle was established in accordance with agreements reached in the meeting between Russian Prime Minister V. Chernomyrdin and U.S. Vice President A. Gore on December 15, 1994, and RSA orders BO-21-74 of January 12, 1995. The composition of the Council was confirmed by the RSA Director General on February 14, 1995.

2. Objective for Establishing of Advisory Expert Council.



The objective of the establishing of the Advisory Expert Council was to reveal problematic issues associated with the joint flights of the Mir station and Shuttle and to develop measures to improve the level of reliability, safety, and efficiency of the planned program for joint Russian-American space flights by a specially established group of highly qualified experts not directly involved in the Shuttle-Mir and NASA-Mir programs.

3. Status of Advisory Expert Council.

The independent Advisory Expert Council was formed by RSA from the most authoritative scientists and industry experts with the authority to check the course of training and level of readiness and detect unresolved key problems in support of the Shuttle-Mir and NASA-Mir programs in the first phase of construction of the International Space Station.

Upon the results of the work of the Advisory Expert Council, the authority of the Council may be extended to subsequent phases of this program by appropriate decision of the RSA management.

4. Tasks of Advisory Expert Council.

4.1. Conduct of independent expert evaluations of the level of readiness of technical systems and support services for performance of the planned work program, as well as the levels of safety, reliability, and efficiency for forthcoming joint flights of the Mir station and Shuttle.

4.2. Detection of deficiencies existing and key problems, and analysis of their criticality.

4.3. Evaluation of the sufficiency of crew training for performance of their functions and of the correspondence of the aids for training them to the requirements on flight.

4.4. Development of recommendations directed toward eliminating deficiencies revealed and improving the safety, reliability, and efficiency of forthcoming work.

4.5. Preparation and presentation to management of technical reports on the status of work being conducted in accordance with the program adopted.

5. Authority of Advisory Expert Council.

The Advisory Expert Council functions within the scope of the authorities concurred by NASA and RSA, with the following guaranteed capabilities provided:

1. Visits to enterprises involved in the joint program, and familiarization with the course of work.

2. Free access to design and working documentation on the Mir and Shuttle within the scope of the concurred work program.

3. Creation of working groups (WG) on specific problems in the Shuttle-Mir and NASA-Mir programs.

4. Involvement of leading experts on the Shuttle-Mir and NASA-Mir programs in the work of the Council.

5. Presence at the development of the most important flight stages, as well as in the preparation for a flight as a whole.

6. Participation in the work of meetings and in the resolution of technical issues in the Shuttle-Mir and NASA-Mir programs.

6. Organization of Activity and Work Program.

6.1. Academician V. F. Utkin is the Chairman of the Advisory Expert Council.

6.2. The membership of the Advisory Expert Council is selected by its Chairman and approved by the RSA Director General.

6.3. The Advisory Expert Council works in both Russia and in USA by agreement with NASA.

6.4. The work of the Advisory Expert Council is conducted in accordance with the Schedule and Work Plan concurred by NASA and RSA.

6.5. The Work Plan of the Advisory Expert Council may provide for visits to developing enterprises and manufacturing plants, mission control centers, cosmonaut training centers, ground experimental sites and launch complexes (cosmodromes), scientific research and other organizations involved to some extent in the Shuttle-Mir and NASA-Mir programs, as well as conduct of the following measures:

regular meetings of the Advisory Expert Council to generalize the results of study of technical and program documentation, visits to industrial enterprises and sites involved in the Shuttle-Mir and NASA-Mir programs, and development of the corresponding recommendations;

joint meetings of the Advisory Expert Council and the Task Force of the NASA Advisory Council for Shuttle-Mir flights with rendezvous and docking, headed by Lt. Gen. Thomas P. Stafford, USAF, to generalize and concur in rules for technical and organizational actions aimed at assuring safety, reliability, and efficiency in implementation of the Shuttle-Mir and NASA-Mir programs;

meetings of the chairmen of the Council and Commission and NASA and RSA management to present, concur, and approve the results of the work of the expert groups and make the necessary organization and technical changes in the program.

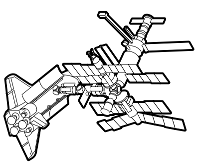
6.6. RSA supports the work of the Council in accordance with its chartered activities.

original signed by. . .

Deputy General Director, RSA
B. A. Ostroumov

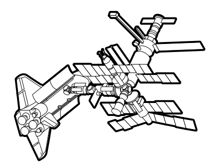
original signed by. . .

Chief, Piloted Programs Directorate, RSA
M. V. Sinelshchikov



APPENDIX 6.4

TF-AEC CHARTER

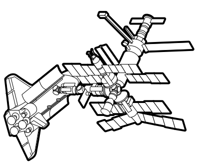


CHARTER
SHUTTLE-MIR TASK FORCE
AND
ADVISORY EXPERT COUNCIL

Chronology

In May 1994, the Task Force on the Shuttle-Mir Rendezvous and Docking Missions was established by the NASA Advisory Council with Lt. Gen. Thomas P. Stafford, USAF (Ret.), as its chairman. The purpose of the Task Force is to review Phase 1 planning, training, operations, rendezvous and docking, and management. It provides interim reports containing specific recommendations to the Advisory Council and the NASA Administrator. To date, the Task Force has produced four independent reports.

Russian Prime Minister Chernomyrdin and U.S. Vice President Gore, at the December 15, 1994, meeting of the Gore-Chernomyrdin Commission (GCC), directed the General Director of the Russian Space Agency, Mr. Yuri Koptev, and the NASA Administrator, Mr. Daniel Goldin, to establish a process to review each other's program plans and capabilities and to report periodically to the GCC. In response to this direction, Mr. Koptev and Mr. Goldin agreed to form a joint committee. This committee, headed by Academician Vladimir Utkin, Director of the Central Institute for Machine Building (TsNIIMash), and Gen. Stafford, was charged to provide joint reports to the RSA General Director and the NASA Administrator.



General Director Koptev appointed Academician Utkin to chair the Advisory Expert Council on Mir Station and Shuttle Vehicle Joint Flights Support Problems and formally approved its membership on February 14, 1995. The Advisory Expert Council was instructed to provide independent assessments of the state of affairs, elaboration of recommendations, and additional measures, if necessary, of the level of reliability, safety, and efficiency of the planned program associated with the joint Russian-U.S. missions. The first independent report of this commission was produced on June 7, 1995.

Charter

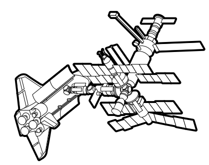
Academician Utkin's Advisory Expert Council and Gen. Stafford's Task Force will jointly assess issues concerning the technical risks, risk mitigation plans, and lessons learned from the rendezvous and docking missions. These assessments will result in at least two joint reports to be submitted to the General Director of the Russian Space Agency and the NASA Administrator: the first report assessing Mir-18-22, STS-63, STS-71, STS-74, STS-76, and STS-79; and the second assessing Mir-23-24, STS-81, STS-84, and STS-86.

In addition to their joint efforts, the independent work of the Advisory Expert Council and the Task Force will continue through Phase 1 with the participation in and the review of all aspects of the activity of their respective programs. Each will continue to produce independent separate reports containing necessary recommendations prior to each mission and, should the need arise, for emergent issues. The Advisory Expert Council will submit its independent reports and recommendations to the General Director of the Russian Space Agency. The Task Force will submit its independent reports and recommendations to the NASA Administrator through the NASA Advisory Council.

original signed by. . .	*original signed by. . .*
Lt. General Thomas P. Stafford	Academician Vladimir F. Utkin
September 11, 1995	September 11, 1995

APPENDIX 6.5

JOINT STATEMENT SEPTEMBER 1997



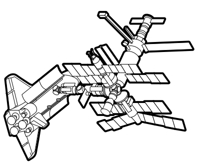
JOINT STATEMENT (PROTOCOL) OF JOINT MEETING IN SEPTEMBER 1997 AT RYAZAN AND TSNIIIMASH

JOINT STATEMENT
T. Stafford/V. Utkin Joint Commission

TsNIIMash
Korolev, Moscow Region,
Ryazan,
September 14-19, 1997

INTRODUCTION

In accordance with the wishes of Mr. Daniel Goldin, NASA Administrator, and Mr. Yuri Koptev, Director General of the Russian Space Agency, a meeting of the Advisory Expert Council of Academician V. Utkin and the Task Force of General T. Stafford was held in Russia in Moscow and Ryazan on September 14-19, 1997. The Advisory Expert Council-Task Force Joint Commission evaluated the status of the Mir station from February through September 1997, with a focus on examination of all issues pertaining to the safety of the Mir station, procedures and methodology for overcoming future operational safety problems, and also consideration and use of this experience in the development and operation of the ISS.



The Advisory Expert Council-Task Force Joint Commission concentrated its efforts on evaluation of the Shuttle-Mir program in the context of the following issues:

A. Status of Mir station

B. Examination of the Progress M-34 collision

1. Status of station after June 25, 1997
   a) electrical power systems;
   b) life support systems, including solid-fuel oxygen generator;
   c) communications and television systems;
   d) crew;
   e) control systems;
   f) telemetry;
   g) Spektr module;
   h) preparation for EVA;
   i) implementation of science program and specific experiments;
   j) Priroda and Krystall modules.

2. Plan for restoration of Spektr module
   a) restoration of electrical power system-preliminary results of restoration operations (EVA) during Mir-24 mission on August 22, 1997.
   b) search for leak sites and elimination of them (in the process of 5 and 6 EVA's during Mir-24 mission;
   c) possibility for NASA involvement in restoration of Spektr module;
   d) evaluation of operability of science hardware.

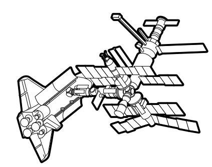
RESULTS

1. The Advisory Expert Council-Task Force Joint Commission finds that conditions on Mir have improved over the past 3-4 months as a result of repair operations on the following systems: the Elektron, Vozdukh, thermal control, reclaimed drinking water monitoring, electrical power, motion control, attitude control, and communications systems. There are no life support systems without system redundancy. The status at present does not impose any constraints on launch.

2. The Advisory Expert Council-Task Force Joint Commission feels that the risk level for the NASA STS-86 and Mir-23/24 crews does not exceed the operating limits accepted for this program.

3. Attempts to execute precision ballistic docking in remote control mode shall not be made in nominal operations unless the crew has range and velocity data. In off-nominal operations, an attempt at such a rendezvous can be made provided that Russian and American specialists have reached a concurred decision on crew and station safety and if communications are available for successful performance of these operations. The remote control mode (TORU) shall be viewed as a suitable control method at close ranges for operations which can clearly be monitored.

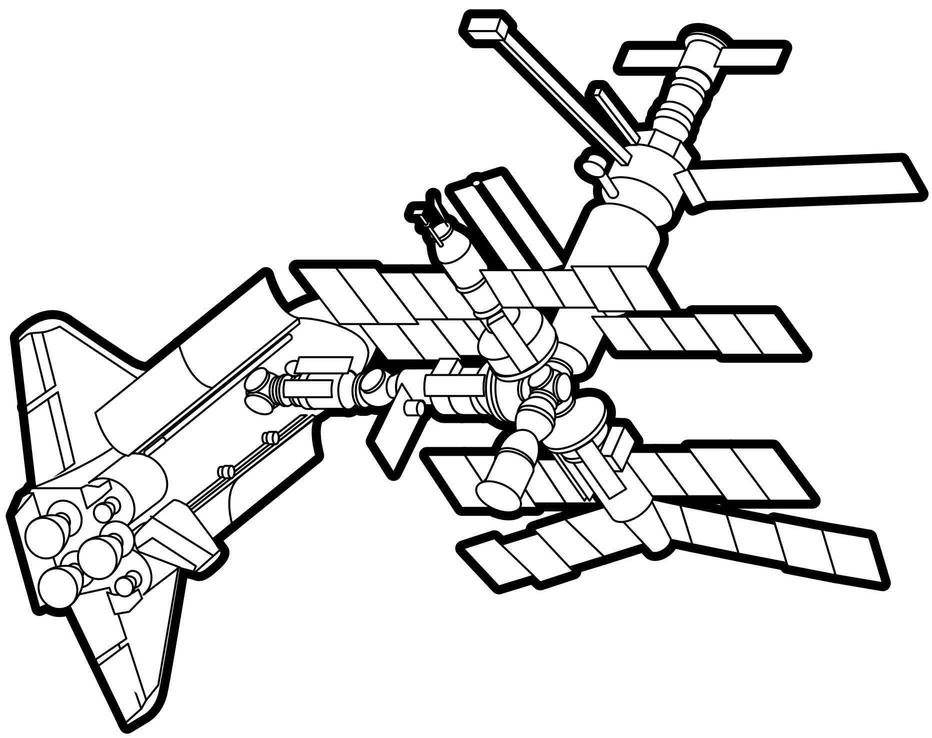
4. The Advisory Expert Council-Task Force Joint Commission accepts the proposed recommendations set forth in the TsNIIMash conclusion from analysis of the causes of the collision of the Progress M-34 vehicle with the Mir station on June 25, 1997, and the recommendations on preventing such collisions in the future. Further, the Advisory Expert Council-Task Force Joint Commission proposes that NASA participate in implementation of points 4, 8, and 10 of the recommendations.



FUTURE WORK

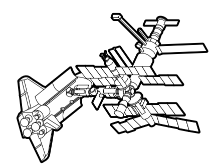
The Advisory Expert Council and T. Stafford's Task Force will continue independent evaluations of safety and operational readiness under the Shuttle-Mir program. In particular, the Advisory Expert Council and T. Stafford's Task Force will hold future joint technical meetings and examine the Shuttle-Mir program as it applies to the operational readiness of the ISS.

original signed by. . .	*original signed by. . .*
Lt. General Thomas P. Stafford	Academician Vladimir F. Utkin
September 19, 1997	September 19, 1997

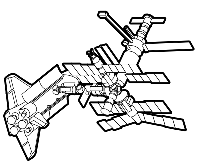


APPENDIX 6.6

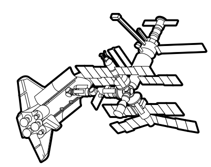
ACRONYMS

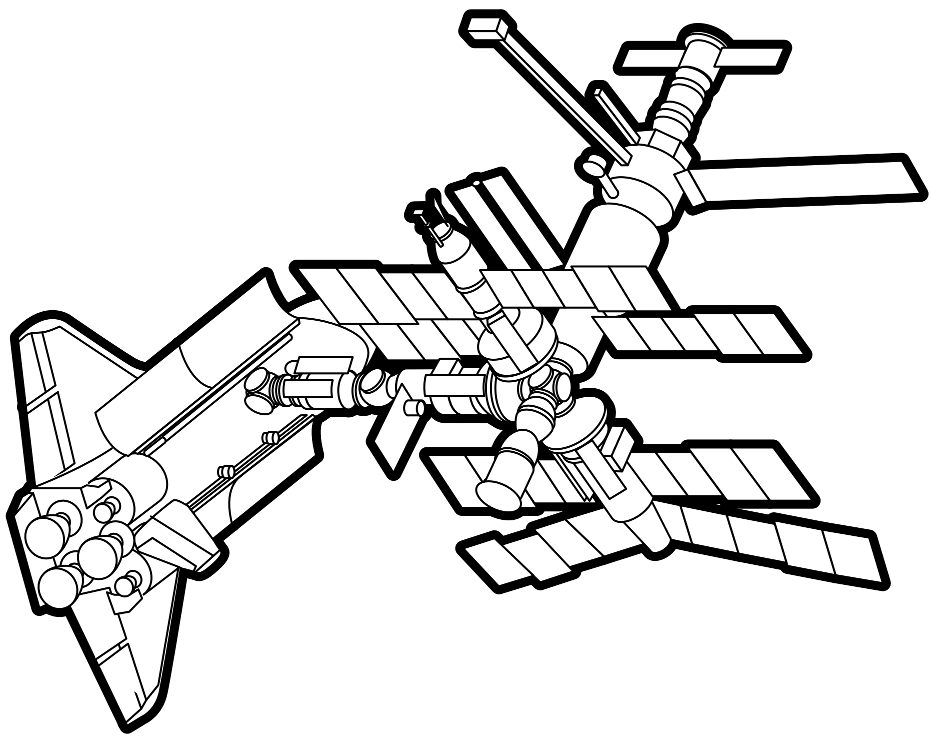


English Designation	Expansion or Standard Term
ADP/T	Automated Data Processing and Telecommunications
AEC	Advisory Expert Council
AEC-TF	Joint Commission
AMERD	Astronaut Medical Examinations Requirements Document
APDA	Androgynous Peripheral Docking Assembly
APDS	Androgynous Peripheral Docking System
BPR	Ballistic Precision Rendezvous
CNES	Centre Nationale d'Etudes Spatiales (France)
CSST	Crew Status and Support Tracker
DAP	Digital Autopilot
DM	Docking Module
ECLSS	Environmental Control and Life Support System
EDA	External Dosimeter Array
EMU	Extravehicular Mobility Unit
ESA	European Space Agency
EVA	Extravehicular activity
FGB	Functional Cargo Block
GCC	Gore-Chernomyrdin Commission
GCTC	Gagarin Cosmonaut Training Center
IBMP	Institute for Biomedical Problems
IOR	International Space Station Operational Readiness
IP	International Partner
ISS	International Space Station
ISS MORD	ISS Medical Operations Requirements Document
JSC	Johnson Space Center
KSC	Kennedy Space Center
LC	Launch Complex
MCC-H	Mission Control Center-Houston
MCC-M	Mission Control Center-Moscow
MOU	Memorandum of Understanding
MMOP	Multilateral Medical Operations Panel
MSFC	Marshall Space Flight Center
MSMB	Multilateral Space Medicine Board
MSRE	Mir Sample Return Experiment
NAC	NASA Advisory Council
NASA	National Aeronautics and Space Administration (USA)
OPM	Optical Properties Monitor
PIE	Particle Impact Experiment
R-bar	Radius Vector
RCS	Reaction Control System
RSA	Russian Space Agency
RSC	Rocket Space Corporation
RSC-E	Rocket Space Corporation-Energia
SFOG	Solid-Fuel Oxygen Generator
SRB	Solid Rocket Booster



English Designation	Expansion or Standard Term
STS	Space Transportation System
TF	Stafford Task Force
TF-AEC	Joint Commission
TLD	Thermoluminescent Dosimeter
TORU	Telerobotically Operated Rendezvous System
TsNIIMash	Central Research Institute for Machine Building
USA	United States of America
WG	Working Group





APPENDIX 6.7

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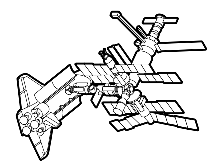

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   Joint Statements on Mir-Shuttle, Mir-NASA, and ISS programs:
   December 15, 1994
   January 29, 1996
   July 27, 1996

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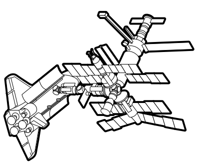
D. Goldin to Yu. Koptev	December 29, 1994
D. Goldin to Yu. Koptev	January 20, 1995
Yu. Koptev to D. Goldin	March 6, 1995
Yu. Koptev to D. Goldin	August 2, 1995
D. Goldin to Yu. Koptev	August 25, 1995
Yu. Koptev to D. Goldin	October 16, 1995
D. Goldin to Yu. Koptev	December 1, 1995
D. Goldin to Yu. Koptev	September 3, 1996
Yu. Koptev to D. Goldin	October 23, 1996
D. Goldin to Yu. Koptev	January 5, 1997
D. Goldin to Yu. Koptev	July 18, 1997
D. Goldin to Yu. Koptev	October 31, 1997
Yu. Koptev to D. Goldin	March 10, 1998
Yu. Koptev to D. Goldin	April 3, 1998
D. Goldin to Yu. Koptev	April 7, 1998
D. Goldin to Yu. Koptev	November 25, 1998



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V. Utkin to Yu. Koptev	August 8, 1995
V. Utkin to Yu. Koptev	August 27, 1996
Yu. Koptev to V. Utkin	October 15, 1997
V. Utkin to Yu. Koptev	February 19, 1998
V. Utkin to Yu. Koptev	June 25, 1998
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V. Utkin to Yu. Koptev	November 25, 1998

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STS-91	May 27, 1998

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AEC-TF	June 20, 1996	AEC-TF	December 26, 1997
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TF-AEC	July 12, 1996	TF-AEC	January 15, 1998
TF-AEC	July 15, 1996	TF-AEC	January 19, 1998
AEC-TF	July 16, 1996	TF-AEC	February 20, 1998
TF-AEC	August 31, 1996	AEC-TF	March 10, 1998
AEC-TF	September 4, 1996	TF-AEC	March 12, 1998
TF-AEC	September 20, 1996	TF-AEC	March 30, 1998
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TF-AEC	November 1, 1996	AEC-TF	May 26, 1998
AEC-TF	December 2, 1996	TF-AEC	June 18, 1998
TF-AEC	December 5, 1996	AEC-TF	June 22, 1998
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TF-AEC	January 17, 1997	TF-AEC	July 20, 1998
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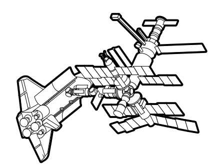

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Participants	Date	Issues
AEC-TF	September 13, 1995	Charter for the Council and Task Force
TF-AEC	February 21, 1997	Phases 1 and 2 Program Overview
AEC-TF	September 14–19, 1997	Joint Statement of Joint Meeting in September 1997 at Ryazan and TsNIIMash
TF-AEC WG	January 22, 1998	ISS Training for Early Crews
AEC-TF WG	April 27, 1998	Training for Initial ISS Missions. 2A & 2A.1 Ingress
TF-AEC	June 4, 1998	ISS Status
AEC-TF WG	September 25, 1998	ISS Training. Software. 2A & 2A.1 ISS Ingress.
TF-AEC	December 2, 1998	Status of Mir and ISS
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