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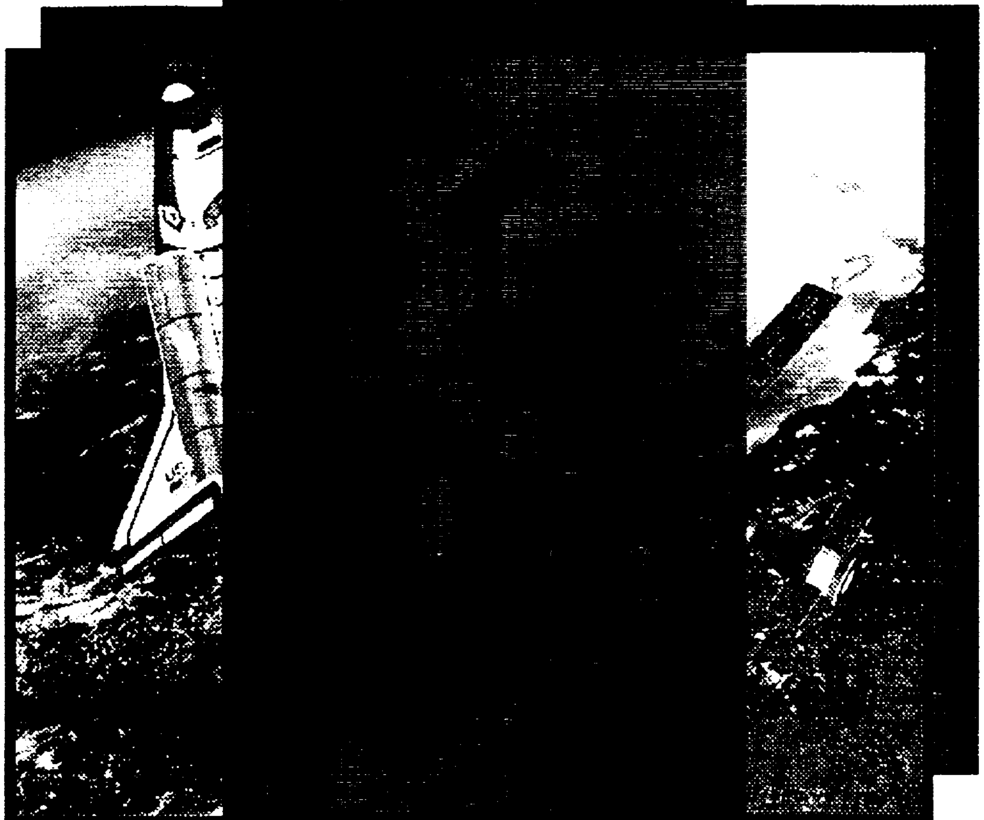

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THIRD REPORT OF THE
NASA ADVISORY COUNCIL
TASK FORCE ON THE
SHUTTLE-MIR RENDEZVOUS AND DOCKING MISSIONS

NOVEMBER 2, 1994

THOMAS P. STAFFORD
1006 Cameron Street
Alexandria, VA 22314

November 2, 1994

Dr. Bradford Parkinson
Chairman, National Aeronautics and
Space Administration Advisory Council
National Aeronautics and Space Administration
Washington, DC 20546-0001

Dear Dr. Parkinson:

On 11 and 12 October 1994, I convened the third meeting of the NASA Advisory Council Task Force on the Shuttle-Mir Rendezvous and Docking Missions at the Johnson Space Center (JSC). This report is based on the material presented at the third meeting as well as extensive work done by individual Task Force members and our technical support staff prior to the meeting.

I would like to highlight the fact that the Task Force members and staff received complete cooperation from all the individuals, both civil servant and contractors, we worked with during the review process. This type of support is critical to the success of any external advisory group and is very much appreciated.

Beyond the high level of cooperation that the Task Force received, I also want to point out the excellent work that has been done throughout the Phase 1 program. This was made apparent in the well organized, comprehensive briefings presented at the meeting. It is clear that the newly appointed Phase 1 Program Manager, Mr. Tommy W. Holloway, has already had a positive impact on the process. Mr. Holloway's grasp of the overall strategy for Phase 1 as well as the technical details is most impressive as is his obvious ability to channel and motivate the diverse group of people involved in the program.

One aspect of the Shuttle-Mir program which continues to cause the Task Force concern is the complexity and reliability of the Androgenous Peripheral Docking System (APDS) portion of the Orbiter Docking System. At this point, the pyrotechnic bolts which serve as the primary backup system for the mechanical approach for releasing the docking hooks still have not been certified to NASA standards. In the absence of such certification, the only remaining backup option is the EVA to remove the 96 bolts which connect the ODS docking base to the external airlock. If this option becomes necessary, the only port on Mir capable of docking the Orbiter will be permanently blocked. As a very similar system will also be used for the Space Station and will rely on the same demate procedures, these issues are critical to the entire program, not just Phase 1.

I will convene the next meeting of the Task Force in the first quarter of CY 1995. At that time, we will review the following issues:

- Status of the Orbiter Docking System
- Preliminary results from STS-63
- Preparations for STS-71 and STS-74
- Status of Shuttle-Mir launch constraints, performance improvements, and abort planning
- Training for the mating of the Docking Module to the Orbiter Docking System during STS-74
- Status of the OV-103 OMDP modification decision
- Civil servant/contractor staffing plan for Russia
  - Interaction of Phase 1 and Phase 2 personnel
  - NASA and contractor functions
  - Transition from Phase 1 to Phase 2

In the interim, individual Task Force members, technical advisors, and technical support staff will work with the Phase 1 team to obtain additional data and insight in these areas.

Sincerely,

Thomas P. Stafford

Thomas P. Stafford

cc:
NASA/HQ/Code A/Mr. Goldin
NASA/HQ/Code A/Gen. Dailey
NASA/HQ/Code A/Mr. Mott
NASA/HQ/Code M/Gen. Pearson
NASA/HQ/Code M/Mr. Wisniewski
NASA/HQ/Code M/Mr. O'Connor
NASA/HQ/Code M/Mr. Trafton
NASA/HQ/Code M/Mr. Vantine
NASA/HQ/Code I/Ms. Accola
NASA/HQ/Code A/Dr. Huntoon
NASA/JSC/Code MA6/Mr. Holloway

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1.0 INTRODUCTION

In May 1994, the Task Force on the Shuttle-Mir Rendezvous and Docking Missions was established by the NASA Advisory Council. Its purpose is to review Phase 1 (Shuttle-Mir) planning, training, operations, rendezvous and docking, and management and to provide interim reports containing specific recommendations to the Advisory Council.

Phase 1 represents the building block to create the experience and technical expertise for an International Space Station. The Phase 1 program brings together the United States and Russia in a major cooperative and contractual program that takes advantage of both countries' capabilities.

The content of the Phase 1 program consists of the following elements as defined by the Phase 1 Program Management Plan, dated October 6, 1994:

- Shuttle-Mir rendezvous and docking missions
- Astronaut long duration presence on Mir
- Requirements for Mir support of Phase 1 when astronauts are not on board
- Outfitting Spektr and Priroda modules with NASA science, research, and risk mitigation equipment
- Related ground support requirements of NASA and the Russian Space Agency (RSA) to support Phase 1
- Integrated NASA and RSA launch schedules and manifests

The first meeting of the Task Force was held at the Johnson Space Center (JSC) on May 24 and 25, 1994 with a preliminary report submitted to the NASA Advisory Council on June 6, 1994. The second meeting of the Task Force was held at JSC on July 12 and 13, 1994 and a detailed report containing a series of specific recommendations was submitted on July 29, 1994.

This report reflects the results of the third Task Force meeting which was held at JSC on 11 and 12 October, 1994. The briefings presented at that meeting reviewed NASA's response to the Task Force recommendations made to date and provided background data and current status on several critical areas which the Task Force had not addressed in its previous reports.

The material presented in this report has been organized into the following subject areas:

- Management
- Mission Requirements
- Orbiter Docking System (ODS)
- Plume, Docking, and Mated Loads
- Rendezvous and Docking

Within each section, any previous Task Force recommendations applicable to the subject area are listed; observations and findings are detailed; and new recommendations are identified.

2.0 MANAGEMENT

2.1 Management Structure/Roles and Responsibilities

2.1.1 Previous Recommendations

2.1.1.1 The Task Force recommended a number of management changes for Phase 1 in its second report. The following is a brief synopsis of those recommendations (for a complete listing please see the second report of the Task Force dated July 29, 1994):

- A Phase 1 Project Manager should be established who represents and reports directly to the Associate Administrator for Space Flight and is accountable for the implementation of Phase 1.
- The Phase 1 Project Manager should oversee the development of a Project Plan.
- The JSC Russian Projects Office should be matrixed to support the Phase 1 Project Manager with the Director of the JSC Russian Projects Office serving as the Phase 1 Deputy Project Manager
- The Director of the JSC Russian Projects Office should continue to coordinate the administrative activities of the Joint Working Groups which are matrixed operationally to the Phase 1 Project Manager.
- The joint NASA/RSA working groups should be matrixed intact and with the necessary administrative support from the JSC to support the Phase 1 Project Manager
- The International Space Station Alpha (ISSA) Russian Programs Phase 1 Office should be matrixed intact to the Phase 1 Project Manager. The Russian Programs Phase 1 Office Manager should continue to coordinate the RSA contract activities.
- The ISSA Program Manager should be designated as the sole source for ISSA risk mitigation requirements.
- The Associate Administrator for Life and Microgravity Sciences and Applications should be designated as the focal point for the international research community's requirements and priorities.
- The Office of Space Flight(OSF) Chief Medical Officer should chair the Medical Policy Board for the development of medical support for ISSA risk mitigation and all NASA/RSA joint development of

medical support for ISSA risk mitigation. The OSF Chief Medical Officer should coordinate those requirements with RSA through the joint NASA/RSA Medical Policy Board and the Phase 1 Project Manager.

2.1.2 Observations

On October 6, 1994 the Associate Administrator for Space Flight, Jeremiah W. Pearson III, signed a decision package outlining a new Phase 1 Program Management Plan. This Phase 1 Program Management Plan was concurred on by the Program Managers for the Space Shuttle and Space Station, the Deputy Associate Administrators for Space Shuttle and Space Station, the Deputy Associate Administrator for Life and Microgravity Sciences and Applications, and the Director of the Johnson Space Center.

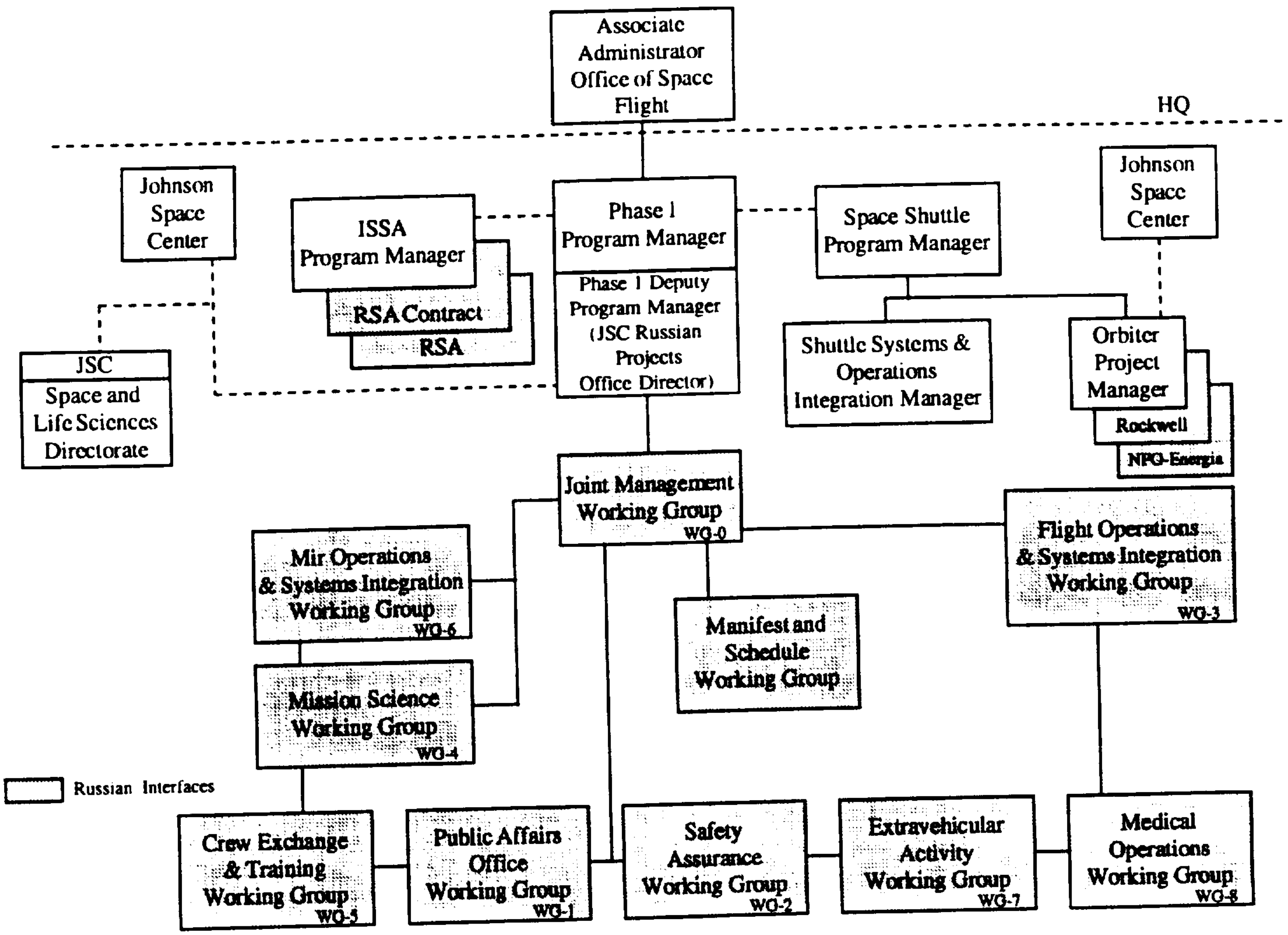
The Phase 1 Program Management Plan describes the organizational structure, joint working group structure, roles and responsibilities, and top-level plan to develop and execute the Phase 1 program. The Phase 1 Program Management Plan specifically addresses the Task Force's previous recommendations as follows (please reference the organization chart on the following page).

<u>Structure</u>

The Phase 1 Program Management Plan establishes a Phase 1 Program Manager, Mr. Tommy W. Holloway, with a small staff located at the Johnson Space Center who will have overall responsibility for Phase 1. Mr. Holloway's sole responsibility will be as the Phase 1 Program Manager and he will not have dual responsibilities in any other organization. He is accountable for the implementation of Phase 1 and he represents and reports directly to the Associate Administrator for Space Flight. He will ensure that management of full-time Mir operations as well as Shuttle-Mir operations and cargo integration is adequately addressed. Additional responsibilities include:

- Chair the Phase 1 Management Group, which will establish a Phase 1 Manifest and a Resource Allocation Plan.
- Chair the Phase 1 Program Review Control Board (PRCB).
- NASA Chair of the Joint Management Working Group.
- Chair of the Orbit Mission Management Team for Phase 1 flights.

Phase 1 Management Structure



The JSC Russian Projects Office has been matrixed to support the Phase 1 Program Manager with the Director of the JSC Russian Projects Office, Mr. Frank Culbertson, serving as the Phase 1 Deputy Program Manager. The Director of the JSC Russian Projects Office will continue to coordinate the administrative activities of the Joint Working Groups which have also been matrixed operationally to the Phase 1 Project Manager .

The International Space Station Program Office (ISSA) will manage the ISSA risk mitigation program and provide requirements to the Phase 1 Program Manager. In addition, the ISSA Russian Programs-Phase 1 Office will be matrixed to the Phase 1 Program Manager. In this capacity, it will monitor, administer, and be responsible for the conduct of the Phase 1 portion of the $400 million contract with RSA. ISSA's Manager, Russian Programs-Phase 1, is the Program Manager for the contract. The Deputy Manager, Russian Programs-Phase 1, is the Contracting Officer's Technical Representative (COTR) for the contract.

The Office of Life and Microgravity Sciences and Applications (OLMSA) will constitute and manage a Payload Steering Committee (PSC) that will identify all Level 1 science, research, and associated risk mitigation requirements. It will provide resources for science and technology hardware development, associated experiments, and mission management. Level II management and implementation responsibility for the Phase 1 OLMSA program has been delegated to the JSC Space and Life Sciences Directorate (SLSD). SLSD will be responsible for maintaining OLMSA cognizance via the PSC of all EVA, risk mitigation, and medical operations requirements under consideration for Phase 1.

The Office of Space Flight Chief Medical Officer will chair the Medical Policy Board for the development of medical support for ISSA risk mitigation and all NASA/RSA joint development of medical support for Phase 1.

The Phase 1 program integration between NASA and the Russians will continue to be done through the joint working groups (see organization chart on page 5). These working groups are co-chaired by RSA and NASA management who are responsible for the management of their respective area.

Program Control

The Phase 1 Program Review Control Board (PRCB) will be responsible for baselining and controlling the requirements and documents for the Phase 1 Program. Top Level Phase 1 schedules will be developed and controlled by the Phase 1 Program Manager (Phase 1 PRCB). The normal Shuttle mission preparation production schedule, however, will be used to schedule the shuttle activities, modified as required to support joint Mir/Shuttle flights.

The Phase 1 PRCB will be responsible for and delegate to the Phase 1 Control Board (CB) certain responsibilities. The CB will manage and control the U.S. resource allocations on Russian launch vehicles and on the Mir. This includes managing NASA input to the Russian launch vehicle manifests and providing configuration control of the U.S. hardware on Mir. It will provide support to the Russians for hardware processing, checkout, installation, long-term sustaining engineering, and certification of flight readiness for NASA hardware deployed on the Mir, Spektr, and Priroda. It will also manage, integrate, and provide operations requirements and real time support to the Russians for the Mir operations which do not involve Shuttle. Top level Mir support schedules will be developed and controlled by the Phase 1 CB.

The Phase 1 CB will also be responsible to the Phase 1 Program Manager for flight readiness determination and will sign certificates of flight readiness (CoFR) for each Mir increment and applicable Shuttle flights for NASA supplied hardware for Spektr, Priroda, and Mir, Mir integration support to RSA, and NASA supplied operational requirements for Mir.

The existing Space Shuttle Program Requirements Control Board (PRCB), Mission Integration Control Board (MICB), Systems Integration Review (SIR), and Orbiter Change Control Board (CCB) will continue to manage Shuttle hardware and implementation of Shuttle missions to support joint operations.

Conclusions

It is the Task Force's opinion that this plan eliminates duplicate program structures and capitalizes on existing experience, minimizes the impact on the existing interfaces with the Russian Space Agency, provides a single focused team for overall Phase 1 planning, coordination, and implementation, and facilitates further the coordination between the Space Shuttle Program, the ISSA, the payload community and the Russian Space Agency. The key to success, however, will be the implementation of the plan. For it to succeed, the Phase 1 Program Manager and his team will require the unstinting cooperation of all the NASA organizations in this critical program.

2.1.3 Recommendations

No additional recommendations.

2.2 NASA Presence in Russia

2.2.1 Issue: Should NASA civil servants assume the role currently performed by Rockwell in the technical integration of NPO-Energia hardware into the Orbiter Docking System and Docking Module following STS-71?

2.2.2 Observations

Rockwell possesses both the requisite technical knowledge and working relationships with NPO-Energia. The schedule and delivery dates remain ambitious, Phase 1 development is nearing completion, and any disruption could endanger an already very ambitious schedule.

2.2.3 Recommendation

2.2.3.1 The Task Force concurs with NASA's decision to retain Rockwell as the party responsible for the overall technical integration role for Orbiter Docking System and Docking Module development and implementation. NASA should take action to capture this experience and knowledge and develop the required working relationships with RSA prior to the transition to Phase 2.

3.0 MISSION REQUIREMENTS

3.1 Technical and Science Objectives

3.1.1 Issue

The primary objectives of the Phase 1 program are as follows:

1. Reduce technical risks associated with the construction and operation of the international space station.
2. Conduct combined international space operations and joint space technology demonstrations.
3. Provide early opportunities for extended scientific and research activities.

Although the objectives are well defined, the Task Force encountered a level of confusion regarding the process for collecting requirements from the different sources, their prioritization, and their assignment to a specific mission. In its report dated July 29, 1994, the Task Force observed that the:

> "three sources of mission requirements for Phase 1 are neither well coordinated nor focused. There is confusion and uncertainty about priorities with regard to ISSA risk mitigation, joint operations, and utilization as well as organizational responsibility for collecting and integrating these requirements."

3.1.2 Observations

<u>Phase 1 Mission Management Group</u>

The Task Force found that NASA has made significant progress in this area since the first Task Force meeting in May. The most significant step is the creation of a Phase 1 Management Group, chaired by the Phase 1 Program Manager, which is now responsible for baselining and maintaining the Phase 1 Manifest and Phase 1 Resource Allocation Plan. Requirements are to be submitted to the Management Group by the following organizations:

- Space Station Program Office (SSPO): Provides all ISSA risk mitigation operational and hardware test and demonstration requirements.
- Payload Steering Committee (PSC): Constituted and managed by the Office of Life and Microgravity Sciences and

Applications (OLMSA), the PSC provides all science, research, and associated risk mitigation requirements.
- Space Shuttle Program (SSP): Provides all SSP operational and hardware test and demonstration requirements.
- JSC/Extravehicular Activity (EVA) Office: Provides all EVA development and testing requirements.
- Public Affairs Office (PAO): Provides all public affairs requirements which utilize mission resources.
- JSC/Space and Life Sciences Division (SLSD): Provides all medical and operational support requirements.

The process of selecting experiments within each discipline was a subject in several presentations made to the Task Force, specifically in the areas of risk mitigation and science.

<u>Risk Mitigation</u>

In the area of risk mitigation, two main goals have been identified for Phase 1. These goals and their subsidiary elements are as follows:

- Risk mitigation for ISSA Phases 2 and 3
  - U.S. hardware development, operations, crew procedures, and crew health.
  - Experiments addressing:
    - ISSA control and Automated Rendezvous and Docking (AR&D).
    - The environment at 51.6 degree inclination (micrometeroids, debris, and contamination).
    - EVA assembly and maintenance tasks.
    - Crew health and life support.
    - Structural dynamics characterization and vibration isolation.
    - Operational techniques.
- Working processes involving joint U.S. and Russian technical teams
  - Mir lifetime extension: Photovoltaic array replacement.
  - Technology demonstration: Solar dynamics prototype.

Responsibility for selecting the experiments necessary to meet these requirements was assigned to the Phase 1 Integrated Product Team (IPT). The Phase 1 IPT created a very methodical experiment review and evaluation process to assess the proposals for risk mitigation experiments submitted to it. The IPT evaluated and ranked each experiment both on technical merit and cost/payback benefit.

At the end of the review and evaluation process, the IPT had determined that 25 percent of the proposed experiments were directly applicable to ISSA risk. The baselined experiments thus selected went through an extensive review process which included the ISSA Phase 2 Analysis Integration Team (AIT), Space Station Program Office management, JSC/Space and Life Sciences Directorate (peer review), the NASA Administrator, and an independent Phase 1 risk mitigation assessment team at NASA Headquarters.

It is evident that the effort involved in identifying and selecting these experiments has been very focused and well organized. The experiments which survived this rigorous process have been tentatively assigned to specific Shuttle-Mir missions or Shuttle missions. Only those experiments which require extended durations or presence on Mir have been assigned to the Mir rendezvous and docking missions. Although the master schedule for these experiments will certainly change based on experience and circumstances, the degree of planning conducted to date and the flexibility of the organizations involved will certainly mitigate such impacts.

<u>Science</u>

The process for identifying and selecting Phase 1 science experiments is divided into two segments. The first involves those missions (STS-60, Mir 18, and STS-71) which were addressed in the original agreement with Russia. Within the NASA science community these missions are considered Phase 1A. When the level of cooperation with Russia expanded to include their participation in ISSA, the opportunity for science expanded considerably. These missions (i.e., STS-74 and subsequent missions) are considered Phase 1B.

The process involved in selecting the Phase 1A experiments has already been completed as dictated by the mission schedule -- the STS-60 mission was flown in February 1994, the Mir 18 mission is currently scheduled for March 1995, and the STS-71 mission is slated for late May 1995. Several pieces of experiment hardware have already arrived at Mir, carried aboard a Progress flight in

August. A U.S. astronaut, Norman Thagard, will be transported to Mir on the Mir 18 flight and remain there for three months. At the end of that period, Thagard and his fellow Mir cosmonauts, will be returned to Earth aboard STS-71, the first Shuttle-Mir rendezvous and docking mission. In taking advantage of this extended duration and joint operations with the Russians, the objectives for STS-71 include:

- Retrieving the data and samples collected during the 90-day Mir mission onto the Shuttle for postflight analysis.
- Collecting data and samples from the long duration crew members which will improve our understanding of the effects of long duration space flight on the human body.
- Comparing U.S. and Russian hardware and protocols within the same investigation to obtain a mutual understanding of scientific approach and equipment.
- Obtaining postflight life sciences data on the long duration crew to understand physiologic recovery mechanisms and the effects of the countermeasures.

The prioritization of research and payloads opportunities during Phase 1 is being performed and executed by research interests both within NASA and the broader academic community. A process has been established that is both driven by the concerns of the scientific and technological communities and is responsive to the very rapid planning cycle required by the Phase 1 program.

After initial negotiations with the Russians as to the resources expected to be available on Mir, representatives of the major research disciplines in NASA's overall orbital research program worked with the Shuttle organization responsible for resources on the Orbiter/Spacelab combination to determine what payload hardware could be ready for operation during the Phase 1B program given schedule and budget constraints. <u>First priority</u> was placed on selecting payloads that make use of the long-term orbital operations available on Mir by placing facilities-class hardware on Mir, with resupply, sample return, and payload enhancement carried out by Shuttle missions docking at Mir over the two and one-half year Phase 1B period. This includes using the Shuttle for the launch and return of long-duration crewmembers (both U.S. and Russian) for the purpose of obtaining thorough and calibrated pre- and post-flight medical data. The <u>second priority</u> is to make use of the Shuttle as an opportunity to conduct research during Shuttle free-flight periods before and/or after docking with the Mir.

While the payload selection was driven primarily by stringent practical constraints such as schedule, budget, and hardware availability, the selection of the specific investigations to be performed with this hardware is being carried out through open solicitations to the worldwide academic community through NASA Research Announcements and Announcements of Opportunity from the various discipline science organizations. An external peer review process is being utilized to make actual science content selection, thus driving the investigation-unique supplies to be carried to Mir by the various Shuttle flights.

Conclusions

In creating the Phase 1 Management Group and assigning to it the responsibility for collecting and integrating Phase 1 mission requirements, the Office of Space Flight has alleviated the Task Force's concerns in this critical area. This major step, coupled with the excellent work done by the source organizations in carefully reviewing and prioritizing their requirements, will help ensure that NASA and the nation gains the greatest possible benefit from the Phase 1 program.

3.1.3 Recommendations

No additional recommendations.

3.2 Number of Shuttle-Mir Rendezvous and Docking Missions

3.2.1 Issue: During earlier presentations to the Task Force, it became evident that the precise number of Shuttle-Mir missions required to meet Phase 1 objectives had not been clearly established. The number of such missions will have considerable impact on the overall Shuttle manifest and could require a second Orbiter to be modified to dock with Mir.

3.2.2 Observations

The consensus displayed on this issue during the briefings was impressive. The head of the Phase 1 IPT, who is responsible for risk mitigation requirements; the science community; the Shuttle Manifest and Schedule Office; and the Phase 1 Program Manager were unanimous in stating that all critical Phase 1 objectives can be accomplished with seven Shuttle-Mir missions. In fact, the point was clearly made that payloads exist for only seven missions given the scheduling constraints imposed by various hardware modules. The case was also made that microgravity science will, in most cases, be better served by Shuttle flights dedicated to that purpose rather than Shuttle-Mir missions.

To ensure flexibility, NASA has preserved the option of flying up to ten missions as stated in the original implementing agreement with Russia. During the September 22 - 28, 1994 meeting of the Joint Mission Working Group in Moscow a firm commitment was obtained from RSA to keep the options for Shuttle-Mir missions 8, 9, and 10 open. As stated in the protocol from that meeting, "The decision on an additional mission shall be mutually agreed upon no later than 18 months before the proposed launch date."

A comprehensive approach to Shuttle-Mir manifesting exists and it appears that NASA will be able to adjust the plan as circumstances dictate. There are a number of factors, however, which NASA must consider in committing to a specific number of launches.

First is the primary Phase 1 objective -- risk mitigation. As discussed in the previous section, NASA has done a thorough job of identifying, reviewing, and selecting the risk mitigation experiments. Experience has shown, however, that such experiments are an iterative process. The knowledge gained from a particular mission will most certainly result in some level of replanning and redesign. This can, in-turn, create a need for additional on-orbit testing. For those experiments which require Shuttle-Mir flights or extended presence aboard Mir, the need for several iterations could increase the demand for Shuttle-Mir missions beyond the seven currently planned.

Another consideration is the need for NASA and RSA to develop and refine a joint operations capability. NASA will be working with RSA in an environment which it has not experienced since the days of the Skylab long duration missions. This will require a complete change of culture from the current scenario of relatively short Shuttle missions. The NASA operations team will have to transition from the current bursts of activity surrounding each Shuttle mission to sustained support for Mir activities involving U.S. astronauts which will span months rather than days or weeks.

The recent Joint Management Working Group agreement provides the option to add missions back into the schedule. In all subsequent negotiations and agreements with RSA that touch on this subject, similar guarantees must be secured.

3.2.3 Recommendation

3.2.3.1 NASA must retain the flexibility to insert as many as three additional Phase 1 docking missions, up to the ten agreed upon with RSA, for as long as possible.

3.3 Modification of Second Orbiter for Shuttle-Mir Docking

3.3.1 Issue: The requirement to modify a second Orbiter for Shuttle-Mir docking can result from one of two conditions. If more than seven Shuttle-Mir missions need to be completed in the time allotted (i.e., prior to January 1998), a second Orbiter -- *Discovery*, Orbiter Vehicle-103 (OV-103) -- will be needed. Should *Atlantis* (OV-104), the only Orbiter currently capable of Mir docking, experience any significant down-time, a second Orbiter will be required to ensure completion of the planned missions.

3.3.2 Observations

The current baseline Orbiter Maintenance Down Period (OMDP) Airlock Modification for OV-103 includes 1) removal of the internal airlock, 2) installation of the external airlock in the ISSA location, 3) installation of the 5th cryogenic tank set, and 4) installation of plumbing for four additional nitrogen tanks. This configuration would preclude the need for an additional modification period on OV-103, and would provide a backup vehicle to support ISSA First Element Launch (FEL). The disadvantages of performing this complete modification at this time are that OV-103:

- could not support the full Hubble Space Telescope (HST) second servicing mission requirements;
- would lose full cargo bay capability (on a max performance vehicle);
- would lose approximately 4000 lbs. of payload capability and 3 inches of vehicle Center of Gravity (CG); and
- would require new integration hardware to be compatible with Spacehab.

An option to perform the full OMDP modification was presented to the Task Force which would:

- not require removal of the internal airlock;
- scar the vehicle for the external airlock (electrical only);
- install the external airlock;

If OV-103 Mir flights were required once the vehicle is in this configuration, the external air lock could be installed and used with the internal airlock. This process would have a schedule impact to Orbiter processing flow of approximately 15 days. This option supports the full HST requirements and maintains maximum cargo bay and ascent capability on a max performance vehicle. It would, however, require an 11 month ISSA modification period at the Kennedy Space Center (KSC) to remove the internal airlock and install the external airlock prior to ISSA flights. This could create some overlapping of orbiter modification periods, and if so could require additional ground support equipment to remove internal airlocks at two different centers.

The Space Shuttle Program Office recommended deferring the OV-103 post OMDP configuration final decision until April 1995 which meets the Orbiter Project decision need date. This would allow a more thorough and complete assessment of cost, schedule, and operational impacts of the modification decision.

The Task Force concurs with the Space Shuttle Program Office in deferring the OV-103 post OMDP configuration final decision. The Task Force will review the status of the OV-103 OMDP modification decision at the next Task Force meeting.

3.3.3 Recommendations

No additional recommendations.

3.4 STS-63 Shuttle-Mir Objectives

3.4.1 Previous Recommendations

3.4.1.1 Because STS-63 represents the only opportunity to test the hardware, techniques, and operational procedures to be used in Mir rendezvous and proximity operations, the Mir-related objectives must be given the top priority on the mission.

3.4.1.2 An approach of within 30 feet of Mir should be made on STS-63 to accomplish the "Near Mir Fly-By Objectives".

3.4.1.3 The Color Television Camera (CTVC) camera should be manifested on STS-63 and mounted in the Spacehab module in order to:

- perform a CTVC visibility checkout to include recording of camera output for post-mission evaluation;
- evaluate lighting and shadow effects on the target image; and
- conduct attitude fly-out tests in low-Z.

3.4.1.4 Investigate the value of performing attitude fly-out tests in low-Z using the CTVT mounted on the Remote Manipulator System (RMS) elbow camera location.

3.4.2 Observations

Mission Priorities

As reported to the Task Force, the Mir rendezvous and proximity operations to be conducted on STS-63 have now been established as the primary payload on that mission. During the phasing maneuver, a number of the experiments involving the Shuttle Pointed Autonomous Research Tool for Astronomy (SPARTAN) will be completed while SPARTAN is still attached to the RMS. As a result, the STS-63 crew will be able to rendezvous with Mir and conduct the proposed proximity operations prior to the free flight of SPARTAN.

Approach to Mir

Regarding the approach of the Orbiter to Mir during proximity operations on STS-63, another significant outcome of the September meeting of the Joint Management Working Group was the agreement by RSA to allow an approach to within 10 meters (32.5 feet). This important agreement resulted from the thorough work done by NASA in explaining the benefits of such an approach to the RSA representatives.

CTVC Camera

The CTVC will be flown aboard STS-63 in order to perform a checkout of the Mir docking target and related visibility issues. Although the RMS will not be available on either STS-63 or STS-71 to simulate the CTVC position on STS-74, the Task Force is satisfied that an adequate evaluation with associated data can be performed based on the results obtained from the Spacehab CTVC position on STS-63.

3.4.3 Recommendations

No additional recommendations.

4.0 ORBITER DOCKING SYSTEM (ODS)

4.1 ODS Reliability

4.1.1 Previous Recommendations

4.1.1.1 Ensure that the ODS active hooks will be cycled as part of the ODS testing to be conducted at KSC prior to STS-71.

4.1.1.2 Investigate the feasibility of accelerating the schedule for the second Androgenous Peripheral Docking System (APDS) in time to serve as a backup for STS-71 and the impacts involved in doing so.

4.1.2 Observations

<u>ODS Active Hook Cycling</u>

The test requirement for cycling of the ODS active hooks is currently being reviewed. Baselining of the test requirement is expected by mid-October. Serious consideration is being given to performing this test using a passive docking ring rather than simply cycling the hooks.

<u>Second APDS as Backup for STS-71</u>

It is not possible to accelerate the delivery of the second APDS because it will be undergoing testing and fit checks for STS-74. The second APDS will be used on the STS-74 ODS where it will be mated to the Docking Module on-orbit prior to Mir docking. It will need to remain at NPO-Energia[1] until the testing, particularly the fit checks with the Docking Module, are completed. Given the importance of those activities, the Task Force recognizes that the second APDS will not be available at KSC as a backup for STS-71.

<u>Additional Observations</u>

The complexity of the APDS portion of the ODS, manufactured by NPO-Energia in Russia, and the test anomalies experienced to date

[1] NPO-Energia is now RKK-Energia. To avoid confusion, however, NPO-Energia will continue to be used for the purposes of this report.

continue to be a subject of concern to the Task Force. However, there is an increasing level of confidence among the individuals in the ODS avionics and mechanical systems areas with regard to the current APDS subsystem. This confidence has evolved as they became more familiar with the device and monitored testing of it. The Task Force recognizes that differences between NASA and RSA in design approach, documentation philosophy, test and certification procedures exist and must be accommodated. In addition, budget and time constraints preclude major redesign modifications. However, every reasonable effort must be made to specifically identify those items which cause concern, and to modify within reason those items which increase confidence level within existing budget constraints.

The Orbiter Project Office has provided the Space Station Program Office with a set of preliminary ISSA docking hardware requirements which are changes to the current APDS specifications. This document attempts to spell out the minimum set of requirements necessary to ensure a safe and successful Space Shuttle/Space Station docking program. These requirements, when finalized, will be inserted into the RSA APDS procurement specifications.

The Task Force concurs with the scope, content, and rationale of the proposed Orbiter Project requirements. It also recognizes the urgency involved in identifying, as completely as possible, those specific items requiring redesign so that the resulting specifications can be included in the negotiations with RSA and the resulting implementation process. It is important, however, to acknowledge the importance of this subsystem and to maintain the option to respond to significant anomalies which are encountered or necessary improvements which are identified as NASA gains on-orbit experience with the system.

4.1.3 Recommendations

4.1.3.1 NASA should ensure that those items of the *Preliminary Delta Requirements for ISSA Program Androgynous Peripheral Docking System (APDS) Hardware* memorandum dated October 14, 1994 which are ultimately identified as the minimum set of requirements necessary to ensure a safe and successful

Shuttle/ISSA docking program be inserted in the RSA APDS procurement specification and implemented.

4.1.3.2 Because of the importance of this subsystem, NASA should actively continue to consider options for improving the APDS.

4.2 Pyrotechnic Bolt Demate Contingency

4.2.1 Observations

The reliability and safety certification data for the pyrotechnics bolts employed on the Shuttle/Mir Orbiter Docking System (ODS) emergency separation subsystem have not been made available to NASA. The explanation for not providing the data is that the pyrotechnic bolts are classified SECRET because they are also used in various military applications. Without this data, the only means that NASA has for determining the risk associated with this critical hardware is to conduct independent testing to certify the bolts for the Shuttle/Mir STS-71 mission. The certification requirements include the Phase 1 Baseline Review, the Phase 2 Production Review, and Phase 3 Lot Acceptance and Certification Review.

In an effort to meet the intent of the certification requirements, NASA and Rockwell, working with NPO-Energia, are proposing to take the remaining 60 pyrotechnic bolts for the lot used in the STS-71 APDS and perform a test program to provide data for that particular lot. This test program was developed by identifying the primary concerns which included; 1) Corrosion, 2) Dudding, 3) Assembly/Process Control, 4) Age Life, and 5) Design Performance. Successful completion of the proposed test program will enable NASA to develop an adequate level of confidence in the Russian pyrotechnic device and subsystem for the proposed STS-71 mission. The pyrotechnic bolts used in the STS-74 APDS will be from a different manufacturing lot than those used on STS-71. Testing on a quantity of bolts from that lot will be required in order to certify the bolts used in STS-74 and subsequent missions.

4.2.2 Recommendation

4.2.2.1 NASA should prepare a contingency plan that provides an alternative method for Shuttle-Mir demating in the

event that the testing of the pyrotechnic bolts produces unacceptable results.

4.2.2.2 If the reliability and safety certification data for the pyrotechnic bolts continues to be unavailable from RSA, NASA should pursue the option to have replacement pyrotechnic bolts manufactured for STS-74 and subsequent missions which satisfy the NASA certification process.

4.3 EVA Demate Contingency

4.3.1 Previous Recommendations

4.3.1.1 The EVA approach to remove the 96 bolts which fasten the ODS docking base to the ODS external airlock should be developed and baselined as a contingency approach for APDS mechanical system and pyrotechnic failures.

4.3.1.2 Determine the tools, support equipment (e.g., handholds, portable foot restraint locations, etc.), training schedule, and equipment fidelity (e.g., Weightless Environment Test Facility, mock-ups, etc) needed to support the EVA demate contingency for STS-71 and, if necessary, subsequent missions.

4.3.1.3 Establish EVA procedures including a method to ensure positive, simultaneous, and symmetrical release.

4.3.2 Observations

EVA removal of the 96 ODS bolts by EVA has been established as a contingency demate option. As the third means of separation of the Orbiter from the Mir docking port, the EVA method will be required in the event that the mechanical docking hooks fail to retract properly and, subsequently, the pyrotechnic bolts do not free the docking hooks. The EVA will require that the Shuttle-Mir stack be stabilized through relatching of the docking hooks.

Planning and preparation for the EVA have already begun. Major strides have been made in the following areas:

- Overall operational scenario
- Hardware requirements
  - EVA compatible nuts and bolts
  - Bolt removal tools
  - Restraining clamps
  - EVA support equipment
  - ODS mockups for use in the Weightless Environment Training Facility and 1 g. training
- Procedures development
- Crew training
- Stowage requirements

Although the Task Force views these developments as very positive, members of the Task Force will continue to track development of the EVA option.

Furthermore, the Task Force would like to note that the current EVA plan will leave the Mir port unaccessible for docking. Although the STS-71 mission preparation timeline dictates that the removal of the 96 bolts be the focus of EVA preparations and training, NASA should continue to consider other EVA-based options which would not block the Mir port.

4.3.3 Recommendations

4.3.3.1 Continue to investigate options which will leave the Mir port available for subsequent dockings should the EVA contingency be necessary.

4.4 ODS/Docking Module (DM) Fit Checks

4.4.1 Previous Recommendations

4.4.1.1 Verify that the shipping environment did not adversely impact the three APDSs following their shipment from NPO-Energia where the final fit check will be performed.

4.4.1.2 Revisit the risk decision and assess the risk involved in handling the Docking Module as well as the ground support equipment needed to perform an ODS/DM fit check.

4.4.2 Observations

The final decision has not been made regarding the fit check of the ODS/DM mechanical interface. There is, however, reluctance to perform this task due to the extensive ground support and handling equipment required, including some possible facility limitations.

4.4.3 Recommendations

4.4.3.1 If not already under consideration, determine the feasibility of installing maximum accelerometers in each of the APDS shipping crates during transportation.

4.4.3.2 Continue to pursue the possibility of performing the ODS/DM fit check. The importance of performing the fit check on the ground before attempting to mate the two units on-orbit dictates that all reasonable approaches to performing the fit check be examined. Documented rationale should be provided for methods which are considered but not chosen.

4.5 Docking Module Safety Reviews

4.5.1 Previous Recommendation

4.5.1.1 Evaluate DM safety review schedule acceleration vs. risk acceptance.

4.5.2 Observations

Based on the June 1995 expected delivery date of the DM, the Joint Safety Assurance Working Group has scheduled the milestone safety review consistent with the required delivery dates of the safety data packages per the RSA contract. That schedule is as follows:

• US/RSA contract states delivery of DM payload safety data	11/15/94
• Delivery of DM ground safety data	12/15/94
• DM Payload Safety Data Pack (NASA/Rockwell/NPO-Energia)	12/02/94

• DM Payload Safety Data Pack (NASA/Rockwell/NPO-Energia)	12/02/94
• Shuttle Payload Safety Review Panel Meeting (joint flight and ground) Phase 1/2	02/15/95
• NPO-Energia Phase 3 Safety Data	03/15/95
• Phase 3 Data Pack (NASA/Rockwell/NPO-Energia)	03/31/95
• Phase 3 Panel Meeting	05/08/95
• DM delivery to KSC	06/01/95

4.5.3 Recommendations

No additional recommendations.

5.0 PLUME, DOCKING, AND MATED LOADS

5.1 Plume Loads

5.1.1 Observations

Shuttle Plume Impingement Flight Experiment (SPIFEX)

The data from the SPIFEX experiment conducted on STS-64 has been received and preliminary data analysis is underway. Data analysis is to be completed by December 30, 1994. A quick-look overview of the data shows measured plume pressures are bounded by math model estimates. Preliminary data shows excellent agreement between the model and axisymmetric nozzle case

Plume Loads Calculations

JSC initially performed solar panel plume loads calculations with the solar panels modeled as perfectly flat, smooth, thin plates. The loads path in these calculations is plume loading on mathematical plates transmitted to the solar panel spine, modeled as a mathematical beam. Photographs indicated that the Kvant module panels have a surface shape of accordion pleats and are not attached along the length of the mast but only at the base and tip. The accordian shade model has since been included in the loads analysis.

Russian Loads Predictions

The Russian loads predictions have not been presented to nor reviewed by NASA analysts.

5.1.2 Recommendations

5.1.2.1 Process all remaining SPIFEX data expeditiously and provide the results to the Russians as quickly as possible to enable them to update their loads calculations on critical Mir elements.

5.1.2.2 Validate the structural model of the Mir solar panels and understand the panel loads constraints.

5.1.2.3 Request that RSA provide their updated plume loads analysis results.

5.2 Docking Loads

5.2.1 Previous Recommendations

5.2.1.1 The robustness of the Russian Mir model must be fully analyzed and understood in order to assess stack dynamic response.

5.2.2 Observations

NASA's current Mir attitude control system (ACS) expertise was developed to evaluate Mir attitude responses to Shuttle plume excitations during proximity operations. Additional analysis tasks are being added, including response to contact loads during STS-71 and STS-74.

5.2.3 Recommendation

5.2.3.1 Expand understanding of the Mir attitude control system to encompass response to contact loads during STS-71 and STS-74.

5.3 Mated Loads

5.3.1 Previous Recommendation

5.3.1.1 A Loads Analysis Development Test Objective (DTO) corresponding to the STS-71 DTO should be conducted on STS-74. The data this DTO will produce is critical to the safety of the Phase 1 program.

5.3.1.2 The Russian Mir structural dynamics model must be fully analyzed and the resulting Digital Auto Pilot (DAP) controllability and structural integrity determined.

5.3.2 Observations

Loads Analysis DTOs

The Orbiter Project Office is planning to perform a Loads Analysis DTO corresponding to that of STS-71 for the STS-74 mission. These DTO data will be used to verify the adequacy of Primary Reaction Control System (PRCS) DAP code for vehicle loading and stability. It has been predicted that it will require less than 12 hours to analyze these data, but this time estimate should be validated.

DAP Stability Margins

Recent non-linear simulations performed at Draper Laboratories have identified stack instabilities in both PRCS and Vernier Reaction Control System (VRCS) control modes with first-guess notch filter designs. The notch filters were redesigned to be very wide (up to the 10th order) and stability has been simulated in the presence of the prescribed 20 percent uncertainty.

Mir Adaptive Notch Filters

It is believed that Mir exploits "adaptive notch filters" in its attitude control system. Program assurance would be increased by verifying the performance of these notch filters when they control the mated Shuttle-Mir stack.

5.3.3 Recommendations

5.3.3.1 The analysis team should practice and demonstrate their ability to rapidly exploit the flight data to be gathered by the Loads Analysis DTO.

5.3.3.2 Mission assurance will be enhanced by reducing Mir structural model uncertainty before flight and maximizing DAP stability margins to this uncertainty even if it exceeds 20 percent.

5.3.3.3 Mir's attitude control system must be better understood in order to evaluate risk associated with Mir control of stack attitude.

5.3.3.4 **Track the refined loads analysis resulting from the higher fidelity models recommended in 5.1.2.2-3, 5.2.3.1, and 5.3.3.1-3 above. Present progress reports to project management to ensure that any loading issues will be identified in sufficient time to mitigate programmatic impact.**

5.3.3.5 **Consider expediting the Statement of Work to TSNIIMASH to provide model validation of critical Mir elements to support Recommendations 5.1.2.2, 5.3.1.1, and 5.3.3.2 above.**

6.0 RENDEZVOUS AND DOCKING

6.1 Rendezvous and Docking Training

6.1.1 Previous Recommendation

6.1.1.1 The verified Shuttle Plume Impingement Flight Experiment (SPIFEX) data from STS-64 must be made available on or before 15 February 1995, the current schedule, and the Shuttle Engineering Simulator (SES) updated with that data in adequate time to support STS-71.

6.1.2 Observations

As mentioned in Section 5.0 (Plume, Docking, and Mated Loads) above, the SPIFEX equipment performed successfully aboard STS-64. The Task Force was advised that the SPIFEX test results and updating of the plume model will be completed by January and incorporated into the SES by February 1995. The updated model will also be used to reevaluate the proximity operations and mated loads analysis currently being used for mission planning.

6.1.3 Recommendations

No additional recommendations.

6.2 Tools for Rendezvous and Docking (TRAD)

6.2.1 Previous Recommendations

6.2.1.1 During STS-63, perform Hand Held Lidar (HHL) tests against the Mir complex and determine range-rate accuracy and stability.

6.2.1.2 During STS-63, perform a range and range rate checkout of the Trajectory Control System (TCS) against the Mir complex.

6.2.2 Observations

The Task Force was advised that the test plan for the HHL and TCS components of the Tools for Rendezvous and Docking (TRAD) system includes the tests recommended by the Task Force. The testing will be performed under Development Test Objective (DTO) 836.

6.2.3 Recommendations

No additional recommendations.

6.3 Mir Approach Development Test Objective (DTO 835)

6.3.1 Previous Recommendation

6.3.1.1 Ensure that the Mir Approach DTO is fully implemented.

6.3.2 Observations

DTO 835 has been baselined in the Flight Requirements Documents for STS-66, STS-63, and STS-69. With the agreement now in place with RSA which will allow an approach within 30 feet of Mir on STS-63, NASA maintains that all the DTO objectives can be met.

6.3.3 Recommendations

No additional recommendations.

6.4 V-Bar or R-Bar Approach for STS-63 and STS-71

6.4.1 Previous Recommendation

6.4.1.1 To avoid impacting the RSA assessment teams considering loads, power, and communications, NASA should not propose changing from the planned V-bar approach on STS-63 to an R-bar approach. However, in all subsequent, relevant discussions with RSA, the reduced RCS braking requirements of the R-bar approach and the associated plume loads and contamination reductions should be emphasized. In addition, NASA should advise that they stand ready and willing to perform either a V-bar or R-bar approach based on the results of the Mir analysis. A date for the decision on the approach should be established to provide adequate time for crew training.

6.4.2 Observations

The Task Force was briefed on the probable launch delay of the Spektr module. The absence of the Spektr module as part of the Mir complex may impose significant changes to the original operations plan.

First, the attitude of the Mir stack may need to rotated 90 degrees about the velocity vector axis to accommodate Mir solar power generation requirements. This will require the Orbiter to approach in an attitude different from that verified and practiced to date.

Second, the need to keep the Mir solar arrays in a solar track mode (i.e., pointed at the Sun) rather than in a feathered position (i.e., perpendicular to the Shuttle approach vector) may require the entire approach and docking process to be conducted through low-Z reaction control system firings. Maintaining a low-Z approach within the last 30 feet of the approach, rather than switching to a norm-Z approach at 30 feet, will impact precise attitude control.

Third, the possibility also exists that Mir power constraints may result in a change from the planned V-bar approach to an R-bar approach. If a decision is delayed too long, the crew will either have to be trained in both approaches or have their training compressed into a less than optimum schedule.

6.4.3 Recommendations

No additional recommendations.

6.5 Payload Bay (PLB) Very High Frequency (VHF) Antenna

6.5.1 Previous Recommendation

6.5.1.1 Ensure that the test plan for STS-63 window-mounted antenna includes performance assessment with respect to Mir antenna patterns.

6.5.2 Observations

Analysis is currently being performed on the Mir antenna pattern and the resulting coverage capability. These results will be factored into the VHF communications test plan.

6.5.3 Recommendations

No additional recommendations.

7.0 APPENDIX A: ACRONYM LIST

ACS	Attitude Control System
AIT	Analysis Integration Team
APDS	Androgenous Peripheral Docking System
AR&D	Automated Rendezvous and Docking
CB	Control Board
CG	Center of Gravity
CoFR	Certificate of Flight Readiness
CMEV	Command Message Encoder Verifier
CR	Change Request
CTVC	Color Television Camera
DAP	Digital Autopilot
DM	Docking Module
DTO	Development Test Objective
ET	External Tank
EVA	Extra-Vehicular Activity
FEL	First Element Launch
HHL	Hand Held Lidar
HST	Hubble Space Telescope
IMU	Inertial Measurement Unit
IPT	Integrated Product Team
ISSA	International Space Station Alpha
Lidar	(Li)ght (D)etection (a)nd (R)anging
JSC	Lyndon B. Johnson Space Center
KSC	John F. Kennedy Space Center
MOA	Memorandum of Agreement
NASA	National Aeronautics and Space Administration
NSTS	National Space Transportation System
OAST-Flyer	Office of Aeronautics and Space Technology - Flyer
ODS	Orbiter Docking System
OLMSA	Office of Life and Microgravity Sciences and Applications
OMDP	Orbiter Maintenance Down Period
OSMA	Office of Safety and Mission Assurance
OV	Orbiter Vehicle
OV-103	*Discovery*
OV-104	*Atlantis*
PCMMU	Pulse Code Master Modulation Unit
PFR	Portable Foot Restraint
PGSC	Payload and General Support Computer
PIO	Public Information Officer
PLB	Payload Bay
PRCB	Program Review Control Board

ACRONYMS (Continued)

PRCS	Primary Reaction Control System
Prox Ops	Proximity Operations
PSC	Payload Steering Committee
R-bar	Radius Vector
RCS	Reaction Control System
RMS	Remote Manipulator System
ROCC	Range Operations Control Center
RPOP	Rendezvous and Proximity Operations Program
RSA	Russian Space Agency
RTLS	Return to Launch Site
SAREX	Shuttle Amateur Radio Experiment
SES	Shuttle Engineering Simulator
SLSD	Space and Life Sciences Division (JSC)
SPARTAN	Shuttle Pointed Autonomous Research Tool for Astronomy
SPAS	Shuttle Pallet Satellite
SPIFEX	Shuttle Plume Impingement Flight Experiment
SRB	Solid Rocket Booster
SSP	Space Shuttle Program
SPO	Shuttle Program Office
SSPO	Space Station Program Office
TCS	Trajectory Control Sensor
TRAD	Tools for Rendezvous and Docking
V-bar	Velocity Vector
VHF	Very High Frequency
VRCS	Vernier Reaction Control System
WETF	Weightless Environment Training Facility
WG-0	Joint Management Working Group
WG-1	Joint Public Relations Working Group
WG-2	Joint Safety Assurance Working Group
WG-3	Joint Flight Operations and Systems Integration Working Group
WG-4	Joint Mission Science Working Group
WG-5	Joint Crew Training and Exchange Working Group
WG-6	Joint Mir Operations and Systems Integration Working Group
WG-7	Joint Extravehicular Activity Working Group
WG-8	Joint Medical Operations Working Group

8.0 APPENDIX B: TASK FORCE MEMBERSHIP LIST

Chairman
Lt. Gen. Thomas P. Stafford, USAF (Ret.)
Stafford, Burke and Hecker, Inc.
1006 Cameron Street
Alexandria, VA 22314

Task Force Members
Col. James C. Adamson, USA (Ret.)
President
Monarch Precision
464 Carmine Drive
Cocoa Beach, Florida 32931

Dr. John Fabian
President and CEO
ANSER
1215 Jefferson Davis Highway
Suite 800
Arlington, VA 22202

Dr. Michael A. Greenfield
Deputy Associate Administrator
Office of Safety and Mission Assurance, Code Q
National Aeronautics and Space Administration
Washington, DC 20546-0001

Mr. James M. Heflin, Jr.
Flight Director Office, Code DA8
Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, TX 77058

Maj. Gen. Ralph Jacobson, USAF (Ret.)
President and CEO
The Charles Stark Draper Laboratories
555 Technology Square
Cambridge, MA 02139

Mr. David Mobley
Assistant to the Center Director
for the Space Station, Code DA01
George C. Marshall Space Flight Center
National Aeronautics and Space Administration
Marshall Space Flight Center, AL 35812

Dr. Arnauld E. Nicogossian
Deputy Associate Administrator
Office of Life and Microgravity Sciences
and Applications, Code U
National Aeronautics and Space Administration
Washington, DC 20546-0001

Mr. Jay Greene (replacing Mr. Chester Vaughan)
Associate Director, Engineering Directorate, Code EA
Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, TX 77058

Capt. John Young, USN (Ret.)
Special Assistant for Engineering, Operations, and Safety
Office of the Director
Lyndon B. Johnson Space Center
National Aeronautics and Space Administration
Houston, TX 77058

Executive Secretary
Mr. William L. Vantine
Office of Space Flight, Code M
National Aeronautics and Space Administration
Washington, DC 20546-0001

Technical Advisors
Maj. Gen. Joe H. Engle, USAF (Ret.)
President
Engle Technologies, Inc.
1906 Back Bay Court
Houston, TX 77058

Mr. Glynn Lunney
President
Rockwell Space Operations Company
Code R01A
600 Gemini Avenue
Houston, TX 77058-2777

Mr. Michael Weeks
Deputy Director, National Aerospace Plane
Office of Aeronautics, Code R
National Aeronautics and Space Administration
Washington, DC 20546-0001