National Aeronautics and
Space Administration

Office of Inspector General
Washington, DC 20546-0001

NOV 29 2004

Mr. Donald A. Battie
808 Mill Pond Court
Jacksonville, FL 32259

SUBJECT: Freedom of Information Act (FOIA) Request

I am responding to your FOIA request for "a copy of the 10 enclosures to the NASA OIG letter to F. James Sensenbrenner dated August 29, 1997." My initial determination is to provide you copies of the enclosures in their entirety.

Sincerely,

Madeline H Chulumovich

Madeline Chulumovich
Acting Assistant Inspector
General for Audits

Enclosures

286-439-0024

RISK ASSESSMENT - STAFFORD TASK FORCE

In May 1994, Acting Deputy Administrator Jack Dailey established a special task force on the Shuttle-Mir rendezvous and docking missions under the charter of the NASA Advisory Council. Lieutenant General Thomas P. Stafford, USAF (Retired), was appointed chair of this task force (now known as the Stafford Task Force). The task force's charter has been expanded since 1994 to include International Space Station (ISS) operational readiness. The Stafford Task Force works jointly with its Russian counterpart, Academician Utkin's Advisory Expert Council, to assess the safety and operational readiness of the Shuttle-Mir program. In July 1997, the task force established a Task Force Red Team led by Major General Ralph Jacobson, USAF (Retired), to assess the readiness of the STS-86 mission to Mir, scheduled to launch in September 1997.

Many members of the task force are appointed as Special Government Employees (SGE). Travel funds for SGE's are provided through the NASA Advisory Council budget. Any other expenses associated with the task force in providing technical and administrative support are provided either by the Office of the Director at Johnson Space Center or by the Office of Space Flight.

The Stafford Task Force is comprised mainly of individuals currently or previously involved with NASA or the aerospace industry. The SGE appointed members of the task force are subject to conflict of interest constraints similar to those imposed on full-time Government employees. As part of the appointment process, potential SGE's must submit financial disclosure reports. SGE's must not participate in any particular matter that could have a direct and predictable effect on non-Governmental organizations by which they are employed or in which they hold financial interests.

APPENDIX B

June 29, 1997

Mr. Frederick D. Gregory
Associate Administrator for Safety and Mission Assurance
NASA Headquarters
Washington, DC 20546-0001

Dear Fred:

Thank you so much for the kind words in your letter of June 24, 1997 and the exceptionally nice Bohemian crystal bowl that accompanied it. I have placed it on my desk in a prominent place where I can enjoy its beauty as I am working. I do appreciate your thoughtfulness and the effort you made in sending me this most delightful award.

Since I do not get to see you or communicate with you on a regular basis anymore, I would like to take this opportunity to mention something that I believe is of serious importance to NASA, and the Human Spaceflight Safety and Mission Assurance Program. I am sure that the current crisis in the Mir Program is probably foremost in your mind. I am extremely concerned about the safety risks associated with continued operation of the Phase 1 Shuttle/Mir Program. There already have been two incidents this year where the crew has been placed in a basic survival situation. The Mir station is clearly showing significant degradation as it continues to operate beyond its design lifetime. In addition, the decline in the basic infrastructure of the Russian Space Program been well documented in numerous publications, and even in public statements by some Russian space officials.

When NASA originally began the Shuttle/Mir Program, no rigorous safety analysis or risk analysis was accomplished. NASA decided based on the then understood historical performance of safe Mir operations to accept that record as a given. This was done by a subjective review process unlike the systematic safety and reliability analytical techniques utilized for U.S. human spaceflight. If you remember, at that time the Russians were not always forthright about their systems failures or some of the problems that they had in the past. This decision was made at the highest levels of NASA, and the formal safety analysis that was established for the Phase 1 Program was only for the new joint operations activities, new experiments, and new procedures. The acceptance of the existing Mir safety record was driven by management judgment, and therefore no formal and structured documented risk baseline exists for the start of the program. It should be very clear to everyone that the risk level to human safety on the Mir Station has increased somewhat since the early management decisions and agreements were made.

The question becomes, what is the present risk to human safety in this program as the Mir ages and its systems continue to fail and degrade in capability, and as the Russian space program support infrastructure changes as well? What are the expectations for the risk levels to continue to change with time over the planned lifetime of the Phase 1 Program? What is the current risk level as compared with the subjectively determined

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risk level at the start of the Program? NASA has participated in the Mir program with a lower standard as far as Safety and Mission Assurance assessment processes are concerned, and I believe that the risk levels for human safety to be somewhat higher as well. The most important and cogent question is whether the expected benefits of continued operation justify the increasing risk to human safety that are apparent with current operations on the Shuttle/Mir Phase 1 Program.

Early on in the Phase 1 program, some of the flight activities were considered to be in the development path for the International Space Station. The Russian docking system has now been successfully integrated into the Space Shuttle and demonstrated on several flights. The Russian and U.S. operations teams have learned to work together in a real time sense, and have established a successful and functional joint operations approach. I can think of nothing at this point in the Phase 1 Program that is in the critical path for the continued development and beginning of flight operations for the International Space Station. The test of that premise is to answer the question whether or not NASA would not be able to continue with the development of the Space Station if Mir was lost for some reason.

Another purpose for NASA in using Mir during the Phase 1 Program has been the Life Sciences research that unfortunately has had to be curtailed during the times that Mir has had inflight systems problems and contingencies. Likewise, I would doubt that there is any mandatory Life Sciences research remaining on Mir in order to support the development of the Space Station.

The third and perhaps most compelling rationale for the establishment of the Phase 1 Program was apparently based on our Government's foreign policy objectives. The measurement and evaluation process for achievement of success in this arena is by a process and at a Government level that no doubt makes it difficult for NASA to effectively work with. The solution set of possibilities for this Administration to meet the intent of its foreign policy objectives for Russia is probably rich with alternatives, other than continuation of the Phase 1 Shuttle/Mir Program, that could serve a similar purpose without placing human life at risk levels now seen. I cannot imagine a rational decision making process that could not or would not consider other approaches to achieving our Government's needs in this area. The Phase 1 Program may be the easiest perceived approach that our Government could take to meet important international agreements; but considering the increase in risk for all involved, it is time to consider other alternatives. Even given the fact that the Russians have a considerable amount of national pride in operating the Mir Station, there is a point where recognizing the time to go on to other programs is better than suffering an untimely and perhaps disastrous failure while attempting to hang on to a program that has reached the limit of its productive and safe life.

The risk level to the crew on the Mir station is obviously changing with time. The crew has been put in a basic survival mode a couple of times this year already. The Mir is faced with loss of redundancy for some functions, degraded capability in some functions, and is continuing to degrade with time. NASA publicly has the appearance of trying to characterize the recent dramatic events of Mir operations in a way to minimize the idea that there is any safety concern for the crew as a result of the current Mir status. I believe that this stretches the limits of credibility without having a good risk baseline and risk assessment available that supports this premise. High NASA officials and other pundits are quoted in the media as attempting to characterize the dangerous and potentially life threatening situations as "an opportunity to learn for the ISS and how to work effectively with the Russians". In the past, we have relied on training and simulations for this kind of opportunity rather than real life emergencies of the survival category. Of course we have to deal with real life emergencies at times, and we do learn from them, but we shouldn't ever view them as an opportunity. Those of us in the safety profession would view these events as a failure of the management system and our Safety and Mission Assurance processes which should be based on disciplined risk assessment methods, hazard elimination, risk mitigation, and continuous risk reduction throughout the life of the Program.

NASA is making upgrades on the Shuttle flight and ground systems to enhance safety and reduce risk. This is a major Agency initiative. This activity has been given high visibility both within NASA, the Congress, and with outside review groups. Risk reduction is a part of any proper risk management program and it is being done right for the Shuttle. I have not seen a risk reduction program for the Mir operations. The risk level for Mir flight operations is increasing rather than being reduced. NASA management has accepted a different standard for human safety for the Phase 1 Shuttle/Mir Program than it has been willing to accept for either the Shuttle or the International Space Station.

Another factor that perhaps complicates NASA's and the Government's evaluation of the current Mir situation is that it represents a significant technical and operations challenge. NASA and its Russian counterparts are especially good at solving complex problems and coming to the rescue. I can see the enthusiasm and the adrenaline flowing in the NASA team in working on the fixes for the current problems. The attention and focus of the NASA team tends to be concentrated on resolution of the immediate problems. This is a good and important strength that the Agency has, and it is necessary to make spaceflight programs successful. NASA must be careful that this zeal to resolve these operational problems of Mir do not get in the way of a careful and studied assessment of the risks involved with the continued operation of the Mir. Someone has to step back and look at the big picture and ask the question whether or not the return on continued operations of the Mir is worth both the human risk and the dollar cost.

I believe that it is mandatory that NASA put in the effort to develop a rigorous and disciplined risk assessment for the Mir station that will consider the current and expected changes for the remainder of the planned flight program. Due to the present high perceived safety risk levels, this should be accomplished ASAP! The risk assessment should be characterized in a way that rational and credible decisions can be made regarding the continuation or termination of Shuttle/Mir operations. NASA should be very aware of every instance where it has lowered its standards for human safety for the Mir operations in comparison with the standards required for its own programs and make an informed decision for each case. It is time to correct the deficiencies in the safety and mission assurance processes for the Phase 1 Program.

I personally do not see any compelling NASA need for continuation of joint operations with Mir, especially in light of the perceived risk to human life involved. NASA and Russia could both probably well use the cost savings to help with the funding shortfalls on the development of the International Space Station. Finally, should it become clear to NASA that the safety risks for operation with Mir are increasing, NASA management should have the guts to challenge the political basis for this specific activity and offer other alternatives programs for cooperation with the Russian Space Program to the Administration.

Fred, thanks again for so graciously sending me with the crystal dish. It is a very nice thought and I will certainly treasure it for a long time to come!

Sincerely,

Charlie Harlan

APPENDIX C

INFORMAL MEMO

SUBJECT: **Assessment of Mir Maintenance History Data**

FROM: OC7/K. Watson

TO: YA/J. Van Laak

DATE: 27 March 1997

cc:
OC/C. Epp
OC7/A. Butina
OH/J. Nise
OH/D. Lengyel

INTRODUCTION

A quick review of Mir maintenance history data was performed at the request of the Phase 1 Program Office. This review focused on four primary systems: 1. Atmosphere Revitalization System (ARS); 2. Motion Control System (MCS); 3. Thermal Control System (TCS); and 4. Power Supply System (PSS). The emphasis of this review was to identify the history of hardware failures. In general, it did not consider scheduled replacement of life-limited items or consumable items. The source of information for this evaluation was the 0002-series of "Mir Lifetime Extension" quarterly reports provided by RSC-Energia under Contract NAS15-10110. The available data covered a time period extending from late 1994 to late 1996. Caution must be exercised in using this information, though, because of the potential for incomplete reporting of data in the deliverables, ambiguities in the interpretation from Russian to English, and the lack of dates associated with some of the reported events.

SUMMARY CONCLUSIONS

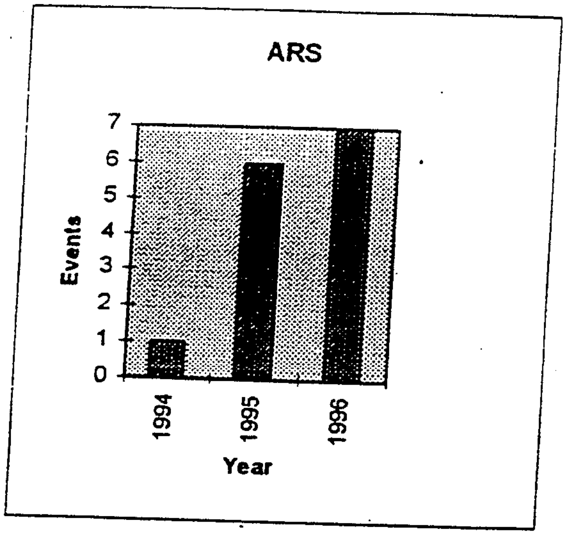
The table below shows the total number of events by system. The second column shows the total number of events - including those occurring after hardware exceeded life limits. The third column shows those failures which occurred before exceeding life limits.

System	Total Number of Events/Failures	Number of Events/Failures Before Life Limit Exceeded
ARS	14	11
MCS	27	27
TCS	22	21
PSS	28	21

The graphs below give some indication of the trend of the frequency of events. However, this can be misleading since the thoroughness of the reporting for 1994 and early 1995 is unclear.

Details of each event are included in the tables on the following pages. Data for each system is presented in two ways. The first table for each system shows the chronology of events for each system on a module-by-module basis. This permits one to develop an impression of the health of each module. The second table for each system is a simple chronology - irrespective of module. This provides a picture of the overall sequence of events onboard Mir for that system. Following the tables for each system, bar graphs are provided which show the number of events in 1994, 1995, and 1996.

CHAP 9(?) WHY RUSSIANS WANT FULLTIME CREWS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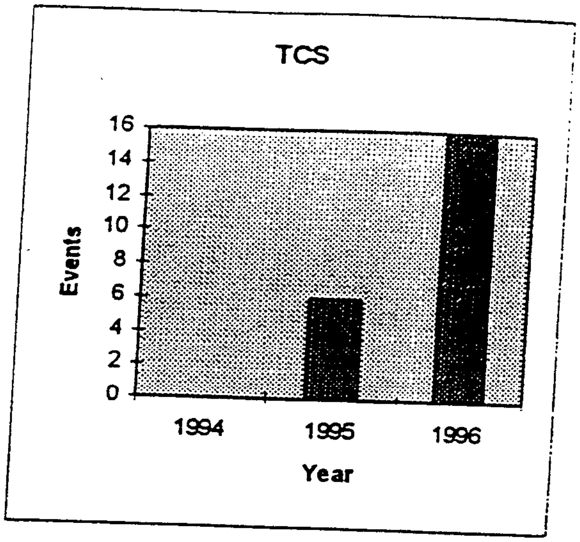
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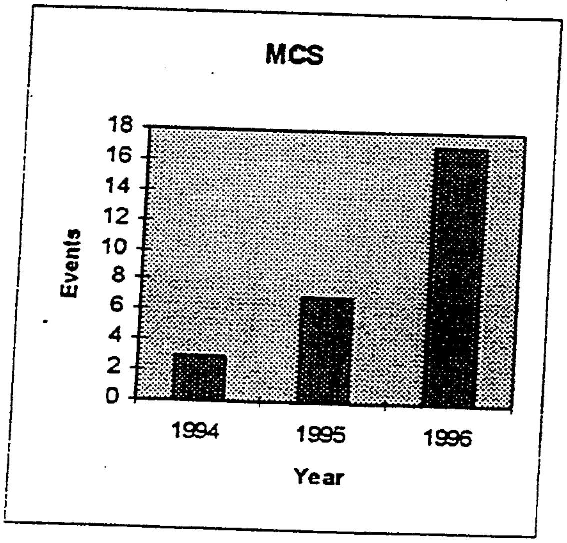
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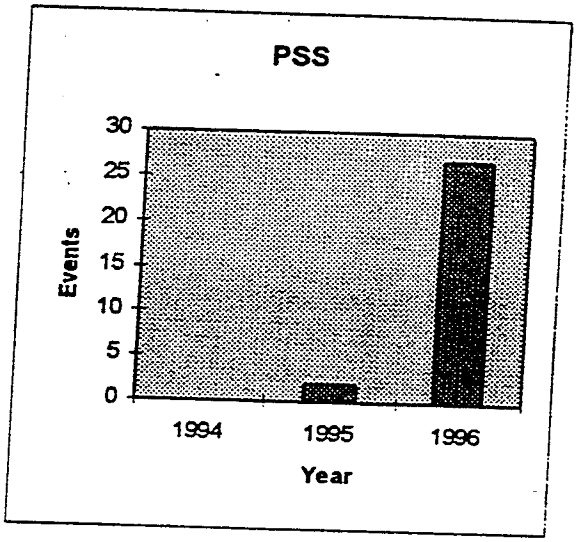
PSS

ARS

(Chronologically by Module)

ref.	Location	Component	Event	Date	Response
2C #1	Core Module	O2 Reaction Storage Cartridge	Chemical Cartridge Filter fired and fire detection system activated	10/15/94	Cartridge operation rules modified
2I p.15	Core Module	Power supply unit in air disinfection plant POTOK 150 MK	Failed	11/13/95	Replaced 12/27/95 with unit launched on Progress M-30
2K p.10	Core Module	Gas analyzing equipment. Consumable elements	Lifetime exhausted	?	Replacements delivered on Progress M-30 and M-33
2E p.28	Core Module	Vozdukh, controller BDP 17KS 8221-0	Controller ORUs "insufficient"	?	Replacement unit delivered on Spektr.
2C #12	Kvant	Vozdukh subsystem vacuum valve (VVK-3)	leakage at 25% of predicted life	2/16/95	analysis
2I p.21	Kvant	Vozdukh. PKO failure	Failed	1/26/96	Replaced on 1/27/96
2I p.22	Kvant	Vozdukh. Vacuum valve unit BVK-42	Failed. Vozdukh off.	4/23/96	Replaced on 4/23/96 with onboard spare.
2K p.23	Kvant	Vozdukh. Vacuum pump BVN	Failed	9/26/96	Replaced on 9/26/96 with onboard spare.
2E p.27	Kvant-2	Electron-B. Current regulator PT-25	Failed	?	Replaced with unit delivered on Progress M-25.
2I p.23	Kvant-2	Electron-B. Hydrogen separator BZ-9	Leakage. Beyond life limit.	10/9/95	BZ, BU, BDD. and BD replaced on 10/15/95.
2I p.27	Kvant-2	Electron-B. Differential pressure controller DPC	Potential contamination.	10/15/95	Electron-B reconnected to reserve hydrogen venting line. DPC replaced with unit launched on Progress M-33.
2I p.28	Kvant-2	Electron-B. Reserve pump	Failed due to excessive bubbles.	1/13/96	System flushed. Procedures revised.
2K p.29	Kvant-2	Electron-B. Nitrogen purge unit BPA-1M	Nitrogen depleted due to heavy use.	?	Replaced with units delivered on Progress M-33 and STS-79
2K p.30	Kvant-2	Electron-B units BZ, BD, BU, and BDD	Life limited.	?	Replacements delivered on Progress M-32.

ARS

(Chronologically)

ref.	Location	Component	Event	Date	Response
2C #1	Core Module	O2 Reaction Storage Cartridge	Chemical Cartridge Filter fired and fire detection system activated	10/15/94	Cartridge operation rules modified
2C #12	Kvant	Vozdukh subsystem vacuum valve (VVK-3)	leakage at 25% of predicted life	2/16/95	analysis
2E p.27	Kvant-2	Electron-B. Current regulator PT-25	Failed	?	Replaced with unit delivered on Progress M-25.
2E p.28	Core Module	Vozdukh, controller BDP 17KS 8221-0	Controller ORUs "insufficient"	?	Replacement unit delivered on Spektr.
2I p.23	Kvant-2	Electron-B. Hydrogen separator BZ-9	Leakage. Beyond life limit.	10/9/95	BZ, BU, BDD, and BD replaced on 10/15/95.
2I p.27	Kvant-2	Electron-B. Differential pressure controller DPC	Potential contamination.	10/15/95	Electron-B reconnected to reserve hydrogen venting line. DPC replaced with unit launched on Progress M-33.
2I p.15	Core Module	Power supply unit in air disinfection plant POTOK 150 MK	Failed	11/13/95	Replaced 12/27/95 with unit launched on Progress M-30
2I p.28	Kvant-2	Electron-B. Reserve pump	Failed due to excessive bubbles.	1/13/96	System flushed. Procedures revised.
2I p.21	Kvant	Vozdukh. PKO failure	Failed	1/26/96	Replaced on 1/27/96
2I p.22	Kvant	Vozdukh. Vacuum valve unit BVK-42	Failed. Vozdukh off.	4/23/96	Replaced on 4/23/96 with onboard spare.
2K p.10	Core Module	Gas analyzing equipment. Consumable elements	Lifetime exhausted	?	Replacements delivered on Progress M-30 and M-33
2K p.29	Kvant-2	Electron-B. Nitrogen purge unit BPA-1M	Nitrogen depleted due to heavy use.	?	Replaced with units delivered on Progress M-33 and STS-79
2K p.30	Kvant-2	Electron-B units BZ, BD, BU, and BDD	Life limited.	?	Replacements delivered on Progress M-32.
2K p.23	Kvant	Vozdukh. Vacuum pump BVN	Failed	9/26/96	Replaced on 9/26/96 with onboard spare.

MCS
(Chronologically by Module)

ref.	Location	Component	Event	Date	Response
2C #4 2D p.72	Core Module	Peripheral Computer PMO MC57301 unit failure	failed	11/27/94	Unit replaced with Kvant 2 spare controller
2C #6	Core Module	Main Computer SALYUT 5B	Channels A &B failed, MCS switch off	12/7-18/94	Computer replaced
2C #9 2D p.71	Core Module	Special Computer Module 4CH-B	Failure results in loss of attitude control and battery discharge	2/2/95	Computer replaced on 2/25/95
2C #14 2D p.73	Core Module?	Main Computer SALYUT 5B	Failed. MCS switch-off. gyrodynes stopped	3/11/95	Main controller CMO, processor TsVU S-5, and VKVU-2 replaced
2D p.70	Core Module	Main Computer SALYUT 5B	Failed during Soyuz TM-21 docking following undocking for Shuttle separation filming.	7/4/95	Dock usingtmanual mode.
2k p.11	Core Module	ODCC software	Erratic operation of Channel B.	6/17/96	Software modified to isolate Channel B.
2J p.11, 2K p.19	Core Module	SIMVOL-D, unit BKKO	Comm failure between display and MCS computer	6/17/96	Replaced on 7/23/96 with unit cannibalized from Kvant .
2J p.10	Core Module	Gyrodynes	All gyrodynes braked due to failures	8/4/96	Refurbished and reactivated.
2J p.12	Core Module	SIMVOL-D	Failure of right display	8/19/96	Use left display
2K p.19	Core Module	SIMVOL-D, unit RP		7/96	Replaced with unit delivered on Progress M-33
2C #3	Kvant	Gyrodyne SG-3E	Failed. Shutdown.	1024/94	Gyrodyne replaced
2E p.56	Kvant	SIMVOL display	Failed.		Use Core Module display.
2I p.24	Kvant	Gyrodynes. Electromechanical unit G16M in fifth gyrodyne.	Failed.	9/5/95	Replaced.
2I p.25	Kvant	ODCC PC Electronika NTS40B, device KA-2, KA-5, KA-6	Failed channels.	1/18/96	Replaced with onboard spare.

MCS

(Chronologically by Module)

continued

ref.	Location	Component	Event	Date	Response
2I p.24	Kvant	Gyrodynes. Unit G16-5 in gyrodyne SG-6D	Failed.	5/24/96	Replaced.
2J p.15	Kvant	Gyrodyne SG-2E. G16-5 magnetic suspension unit	Failed.	6/28/96	Replaced on 6/29/96 with onboard spare.
2I p.25	Kvant	Gyrodynes. Unit G16-5 in fourth gyrodyne	Failed.	7/9/96	Replaced on 8/14/96.
2J p.15	Kvant	Gyrodyne SG-2E	Failed magnetic suspension.	7/14/96	Replaced 8/96.
2J p.14	Kvant	Gyrodyne SG-5E. Units G16-M and G16-5	Failed.	?	Replaced on 8/5/96
2K p.25	Kvant	ODCC OC Electronika, device KA	Failed	?	Replaced on 10/7/96
2K p.26	Kvant	ODCC OC Electronika, PMO-E	Failed during test	9/27/96	Replace with units to be delivered on Progress M-33
2I p.33	Kvant-2	OCC PC Electronika NC40B, device BM (processor 2)	One channel failed in test	1/18/96	Replaced with onboard spare.
2I p.31	Kvant-2	Gyrodynes. Depressurization system	Leakage	?	Inspected. Gaskets replaced.
2I p.32	Kvant-2	Gyrodyne SG-4D	Vacuum leak	4/11/96	Gaskets replaced.
2I p.33	Kvant-2	OCC. Unit PKN-1	Power failure Channel B, test failure Channel A	?	Replacement to be delivered on Progress M-32.
2J p.17	Kvant-2	Gyrodyne SG-4D. Valve EKG4-SVG	Leakage. Gyrodyne deceleration	4/11/96	Seals replaced after 8/6/96
2K p.31	Kvant-2	ODCC OC Electronika, component PMO-D	Failed.	9/27/96	To be replaced with units delivered on Progress M-33.

MCS
(Chronologically)

ref.	Location	Component	Event	Date	Response
2C #6	Core Module	Main Computer SALYUT 5B	Channels A &B failed, MCS switch off	12/7-18/94	Computer replaced
2C #3	Kvant	Gyrodyne SG-3E	Failed. Shutdown.	10/24/94	Gyrodyne replaced
2C #4 2D p.72	Core Module	Peripheral Computer PMO MC57301 unit failure	failed	11/27/94	Unit replaced with Kvant 2 spare controller
2C #9 2D p.71	Core Module	Special Computer Module 4CH-B	Failure results in loss of attitude control and battery discharge	2/2/95	Computer replaced on 2/25/95
2C #14 2D p.73	Core Module?	Main Computer SALYUT 5B	Failed. MCS switch-off, gyrodynes stopped	3/11/95	Main controller CMO, processor TsVU S-5, and VKVU-2 replaced
2D p.70	Core Module	Main Computer SALYUT 5B	Failed during Soyuz TM-21 docking following undocking for Shuttle separation filming.	7/4/95	Dock usingtmanual mode.
2E p.56	Kvant	SIMVOL display	Failed.	?	Use Core Module display.
2I p.31	Kvant-2	Gyrodynes. Depressurization system	Leakage	?	Inspected. Gaskets replaced.
2I p.33	Kvant-2	OCC. Unit PKN-1	Power failure Channel B, test failure Channel A	?	Replacement to be delivered on Progress M-32.
2I p.24	Kvant	Gyrodynes. Electromechanical unit G16M in fifth gyrodyne.	Failed.	9/5/95	Replaced.
2I p.25	Kvant	ODCC PC Electronika NTS40B, device KA-2, KA-5, KA-6	Failed channels.	1/18/96	Replaced with onboard spare.
2I p.33	Kvant-2	OCC PC Electronika NC40B, device BM (processor 2)	One channel failed in test	1/18/96	Replaced with onboard spare.
2I p.32	Kvant-2	Gyrodyne SG-4D	Vacuum leak	4/11/96	Gaskets replaced.
2J p.17	Kvant-2	Gyrodyne SG-4D. Valve EKG4-SVG	Leakage. Gyrodyne deceleration	4/11/96	Seals replaced after 8/6/96
2I p.24	Kvant	Gyrodynes. Unit G16-5 in gyrodyne SG-6D	Failed.	5/24/96	Replaced.

MCS

(Chronologically)

continued

ref.	Location	Component	Event	Date	Response
2J p.14	Kvant	Gyrodyne SG-5E. Units G16-M and G16-5	Failed.	?	Replaced on 8/5/96
2K p.25	Kvant	ODCC OC Electronika, device KA	Failed	?	Replaced on 10/7/96
2K p.11	Core Module	ODCC software	Erratic operation of Channel B.	6/17/96	Software modified to isolate Channel B.
2J p.11, 2K p.19	Core Module	SIMVOL-D, unit BKKO	Comm failure between display and MCS computer	6/17/96	Replaced on 7/23/96 with unit cannibalized from Kvant .
2J p.15	Kvant	Gyrodyne SG-2E. G16-5 magnetic suspension unit	Failed.	6/28/96	Replaced on 6/29/96 with onboard spare.
2K p.19	Core Module	SIMVOL-D, unit RP		7/96	Replaced with unit delivered on Progress M-33
2I p.25	Kvant	Gyrodynes. Unit G16-5 in fourth gyrodyne	Failed.	7/9/96	Replaced on 8/14/96.
2J p.15	Kvant	Gyrodyne SG-2E	Failed magnetic suspension.	7/14/96	Replaced 8/96.
2J p.10	Core Module	Gyrodynes	All gyrodynes braked due to failures	8/4/96	Refurbished and reactivated.
2J p.12	Core Module	SIMVOL-D	Failure of right display	8/19/96	Use left display
2K p.31	Kvant-2	ODCC OC Electronika, component PMO-D	Failed.	9/27/96	To be replaced with units delivered on Progress M-33.
2K p.26	Kvant	ODCC OC Electronika, PMO-E	Failed during test	9/27/96	Replace with units to be delivered on Progress M-33

TCS
(Chronologically by Module)

ref.	Location	Component	Event	Date	Response
2C	Core Module	Valves EK-5, 10	Valve leakage during testing	1/19/95	Valves not used pending analysi.s
2C 2D p.61	Core Module	Air Conditioner VKV-3	Water condensation on body (expired warranty)	1/24/95	Replaced on 3/31/95.
2E p. 32	Core Module	Air Conditioner VKV-3 (unit installed on 3/31/95)	Failed. Not controlling cabin humidity.	?	Undefined.
2I p.16	Core Module	Heating Loop KOB2	Leakage. Coolant escaped and pressure decreased.	4/15/96	Loop isolated. Search for leak. Special equipment delivered for repair on Progress M-32. 9/5/96 PrK coil "hydraulically eliminated" from loop KOB2.
2I p.17	Core Module	Panel PK8	Pressure indicator failed.	5/13/96	Disregard indicator readings.
2J p.10	Core Module	Loop KOB1	Leakage detected	6/20/96	Use until KOB2 repaired then repair. Loop activated on 9/1/96.
2J p.9	Core Module	Loop KOB1	Decrease in pressure drop across pumps detected.	7/16/96	Use until KOB2 repaired then repair. Loop activated on 9/1/96.
2K p.15	Core Module	Loop KOB1, panel 5PS3, unit 5GB6	Leakage in outlet connector	10/16/96	Leaking panel isolated. Loop functional.
2K p.14	Core Module	Loop KOB1, panel 5PS4	Exceeded life limit.	10/23/96	Replaced.
2K p.15	Core Module	Loop KOH1V, hydraulic pump N4	Automatically deactivated	10/30/96	Switch to back-up (N3) on 10/30/96.
2I p.18	Core Module	Fan BP in BKV-3	Fan turned off (possibley caused by moisture in tachometer)	11/10/95	Replaced fan. 11/12/95.
2K p.14	Core Module	Loop KOB1, pumps PKO12	No pressure drop across pumps	11/16/96	Under analysis.

TCS

(Chronologically by Module)

continued

ref.	Location	Component	Event	Date	Response
2D	Kvant	Liquid flow governor RRZh of the external liquid loop	Failed.	?	Connected Kvant loop and Core Module loop KOH2V.
2I p.22	Kvant	IHL Pipeline, loop KOH2V BB	Leak. Crack 12 mm long at bend.	10/31/95	Crack sealed with sealant and fabric. IHL connected to loop KOH1V and activated. KOH2V recharging and bypass line planned.
2I p.30	Kvant-2	Repeat leakage of IHL.	See above.	12/15/95	Pressure vented. Integrity recovered. (?)
2J p.17	Kvant-2	Pump DN7 of VGK loop	Failed.	6/12/96	Switch to pump ON6 on 6/16/96.
2K p.31	Kvant-2	Pump ON6 of VGK loop	Failed.	9/10/96	Switch to pump DN6.
2I p.38 2J p.21	Krystal	Pump ON6 of loop IHL2	No pressure differential at pump.	3/4/96	Switch to backup (DN6). Replaced panel of VGK2 loop on 6/8/96.
2I p.38	Krystal	Fan BT1 GZT	Failed.	3/21/96	Replaced on 3/22/96.
2I p.39 2J p.21	Krystal	Pump DN6 of loop IHL2	No pressure differential at pump.	3/30/96	Switch to loop IHL1. Replaced panel in VGK2 loop on 6/8/96.
2I p.39	Krystal	Panel SPAN of loop IHL1 (pumps ON5, DN5)	Failed.	?	IHL panel replaced on 12/28/95
2J p.22	Priroda	Pump ON5 of SPAN panel loop BGK1	Failed.	5/20/96	Replaced SPAN 7/9/96.
2K p.33	Priroda	Pump ON5 of VGK loop	Failed.	9/20/96	Switch to back-up (DN5).
2J p.24	Spektr	Pump ON5 of SPAN panel in VGK1 loop	Failed.	6/12/96	Switch to back-up. Replacement planned.

TCS

(Chronologically)

ref.	Location	Component	Event	Date	Response
2I p.39	Krystal	Panel SPAN of loop IHL1 (pumps ON5, DN5)	Failed.	?	IHL panel replaced on 12/28/95
2C	Core Module	Valves EK-5, 10	Valve leakage during testing	1/19/95	Valves not used pending analysis
2C	Core Module	Air Conditioner VKV-3	Water condensation on body (expired warranty)	1/24/95	Replaced.
2I p.22	Kvant	IHL Pipeline, loop KOH2V BB	Leak. Crack 12 mm long at bend.	10/31/95	Crack sealed with sealant and fabric. IHL connected to loop KOH1V and activated. KOH2V recharging and bypass line planned.
2I p.18	Core Module	Fan BP in BKV-3	Fan turned off (possibley caused by moisture in tachometer)	11/10/95	Replaced fan. 11/12/95.
2I p.30	Kvant-2	Repeat leakage of IHL.	See above.	12/15/95	Pressure vented. Integrity recovered (?)
2I p.38 2J p.21	Krystal	Pump ON6 of loop IHL2	No pressure differential at pump.	3/4/96	Switch to backup (DN6). Replaced panel of VGK2 loop on 6/8/96.
2I p.38	Krystal	Fan BT1 GZT	Failed.	3/21/96	Replaced on 3/22/96.
2I p.39 2J p.21	Krystal	Pump DN6 of loop IHL2	No pressure differential at pump.	3/30/96	Switch to loop IHL1. Replaced panel in VGK2 loop on 6/8/96.
2I p.16	Core Module	Heating Loop KOB2	Leakage. Coolant escaped and pressure decreased.	4/15/96	Loop isolated. Search for leak. Special equipment delivered for repair on Progress M-32. 9/5/96 PrK coil "hydraulically eliminated" from loop KOB2.
2I p.17	Core Module	Panel PK8	Pressure indicator failed.	5/13/96	Disregard indicator readings.
2J p.22	Priroda	Pump ON5 of SPAN panel loop BGK1	Failed.	5/20/96	Replaced SPAN 7/9/96.
2J p.17	Kvant-2	Pump DN7 of VGK loop	Failed.	6/12/96	Switch to pump ON6 on 6/16/96.

TCS
(Chronologically)
continued

ref.	Location	Component	Event	Date	Response
2J p.24	Spektr	Pump ON5 of SPAN panel in VGK1 loop	Failed.	6/12/96	Switch to back-up. Replacement planned.
2J p.10	Core Module	Loop KOB1	Leakage detected	6/20/96	Use until KOB2 repaired then repair. Loop activated on 9/1/96.
2J p.9	Core Module	Loop KOB1	Decrease in pressure drop across pumps detected.	7/16/96	Use until KOB2 repaired then repair. Loop activated on 9/1/96.
2K p.31	Kvant-2	Pump ON6 of VGK loop	Failed.	9/10/96	Switch to pump DN6.
2K p.33	Priroda	Pump ON5 of VGK loop	Failed.	9/20/96	Switch to back-up (DN5).
2K p.15	Core Module	Loop KOB1, panel 5PS3, unit 5GB6	Leakage in outlet connector	10/16/96	Leaking panel isolated. Loop functional.
2K p.14	Core Module	Loop KOB1, panel 5PS4	Exceeded life limit.	10/23/96	Replaced.
2K p.15	Core Module	Loop KOH1V, hydraulic pump N4	Automatically deactivated	10/30/96	Switch to back-up (N3) on 10/30/96.
2K p.14	Core Module	Loop KOB1, pumps PKO12	No pressure drop across pumps	11/16/96	Under analysis.

PSS
(Chronologically by Module)

ref.	Location	Component	Event	Date	Response
2I, p.19	Core Module	SB Module No. 5, PSS Batteries	Failed.	?	Replaced on 2/21/96.
2I, p.19	Core Module	Device PTAB No. 2, PSS Automation	Failed beyond life limit.		Replaced with device cannibalized from Spektr on 3/12/96.
2I p.45	Core Module	PTSB ERU No. 7, PSS Automation	Failed.	1/8/96	Replaced with device cannibalized from Spektr on 3/6/96.
2J p.12	Core Module	SB Module No. 2, PSS Batteries	Failed beyond life limit.	?	Replaced on 7/8/96.
2J p.13	Core Module	Current Regulator PT-50 No. 11	Failed TM channel.	?	Replaced on 7/8/96.
2K p.21	Core Module	SB Module No. 6, PSS Batteries	Discharge limit sensor operated	?	Replaced on 10/1/96
2I, p.34	Kvant-2	SB Module No. 5. PS Batteries	Capacity reduction, lifetime exceeded.	?	Replaced on 4/17/96
2I p.35	Kvant-2	SB Module No. 4, PSS Batteries	Failed.	?	Replaced on 1/25/96
2I p.35	Kvant-2	SB Module No. 2, PSS Batteries	Capacity reduction, lifetime exceeded.	?	Replaced on 4/9/96
2I p.36	Kvant-2	Device PTAB No. 6, PSS Automation	Failed.	1/13/96	Replaced with unit from Spektr on 1/29/96.
2J p.18	Kvant-2	SB Module No. 4, PSS Batteries	Failed.	?	Replaced with SB Module No. 3 from Priroda on 7/25/96.
2J p.19	Kvant-2	SB Module No. 3, PSS Batteries	Failed.	?	Replaced on 6/8/96.
2J p.19	Kvant-2	BUPT No. 4, PSS Automation	Failed beyond life limit.	?	Replaced on 7/16/96.
2J p.20	Kvant-2	BUPT No. 3, PSS Automation	Failed.	?	Replaced on 6/8/96.
2I p.40	Krystal	SPOS CU	Circuit breaker tripped.	5/29/95	Analysis indicated acceptable to continue operation.
2I p.41	Krystal	SB Module No. 5, PSS SB	Capacity reduction, lifetime exceeded.	?	Replaced on 4/19/96.
2I p.41	Krystal	Device PTAB No. 4, PSS Automation	Failed.	1/14/96	Replaced with unit from Spektr on 1/31/96.

PSS
(Chronologically by Module)
continued

ref.	Location	Component	Event	Date	Response
2I p.42	Priroda	800A units 4.5. and 6, PSS SB	Failed. (swelled with spillage? Of electrolyte).	4/24/96	Replace on 5/2/96.
2I p.43	Priroda	BSKN, PSS Automation	Burning of electrical cables and connectors.	4/24/96	Refurbished.
2I p.43	Priroda	PTAB, PSS Automation	Could not be reactivated following deactivation to save power in response to short circuit. Reduced number of potential docking attempt (however, dockings successfully completed on 4/26&27/96.	4/24/96	None.
2I p.44	Priroda	CBD. PSS SP	Power degradation because of solar panel age and shading.	?	Additional panels delivered and installed.
2J p.23	Priroda	SB Module No. 3. PSS Batteries	Life limit exceeded.	?	Replaced on 8/6/96.
2J p.23	Priroda	BUPT No. 3. PSS Automation	Decreased resistance between PSS automation buses following short circuit.	?	Replace (date TBD).
2K p.34	Priroda	PSS	Voltage drops on PSS buses caused "MOTSA Emergency" command	9/28/96	Procedures modified.
2K p.35	Priroda	SB Module No.5	Discharge limit sensor operated	?	Replaced on 10/2/96
2K p.35	Priroda	SB Module No.2	Off-nominal cycling	?	Replaced on 10/2/96
2E p.61	(Spektr?)	Solar Panel DCB-1Y	Incomplete deployment following redocking.	6/6/95	EVA attempt to manually deploy unsuccessful. Additional EVA required.
2J p.25	Spektr	SB Module No.6, PSS Batteries	Life limit exceeded.	?	Replaced on 8/22/96
2J p.25	Spektr	PTAB No. 7. PSS Automation	Removed for installation on Core Module.	3/12/96	Replaced on 6/12/96.

PSS
(Chronologically)

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2I p.45	Core Module	PTSB ERU No. 7, PSS Automation	Failed.	1/8/96	Replaced with device cannibalized from Spektr on 3/6/96.
2J p.25	Spektr	PTAB No. 7, PSS Automation	Removed for installation on Core Module.	3/12/96	Replaced on 6/12/96.
2I p.42	Priroda	800A units 4,5, and 6, PSS SB	Failed. (swelled with spillage? Of electrolyte).	4/24/96	Replace on 5/2/96.
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2K p.34	Priroda	PSS	Voltage drops on PSS buses caused "MOTSA Emergency" command	9/28/96	Procedures modified.
2I, p.19	Core Module	SB Module No. 5, PSS Batteries	Failed.	?	Replaced on 2/21/96.

PSS

(Chronologically)

continued

ref.	Location	Component	Event	Date	Response
2J p.12	Core Module	SB Module No. 2, PSS Batteries	Failed beyond life limit.	?	Replaced on 7/8/96.
2J p.13	Core Module	Current Regulator PT-50 No. 11	Failed TM channel.	?	Replaced on 7/8/96.
2K p.21	Core Module	SB Module No. 6, PSS Batteries	Discharge limit sensor operated	?	Replaced on 10/1/96
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2J p.18	Kvant-2	SB Module No. 4, PSS Batteries	Failed.	?	Replaced with SB Module No. 3 from Priroda on 7/25/96.
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2J p.23	Priroda	SB Module No. 3, PSS Batteries	Life limit exceeded.	?	Replaced on 8/6/96.
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2K p.35	Priroda	SB Module No.5	Discharge limit sensor operated	?	Replaced on 10/2/96
2K p.35	Priroda	SB Module No.2	Off-nominal cycling	?	Replaced on 10/2/96
2J p.25	Spektr	SB Module No.6, PSS Batteries	Life limit exceeded.	?	Replaced on 8/22/96

APPENDIX D

Mir Space Station Risk Areas

1. Is NASA in a position to adequately assess safety of continued astronaut participation?
    - Are safety assessment groups independent of external concerns (e.g., international politics) and other internal concerns (e.g., Shuttle manifest issues)?
    - What limitations are there on NASA's timely access to data and what are the consequences of these limitations?
    - Is there adequate American partnership on Russian medical, psychological, and safety teams?

2. Astronaut communication: Are adequate systems in place to ensure that the astronauts fully communicate with NASA to ensure their physical and psychological safety and well-being?
    - Are the astronauts trained and subsequently reinforced to fully discuss issues with ground support, mission managers, physicians, psychologists, and human factors specialists?
    - Are NASA support personnel (e.g., ground support, medical, mission managers) fully trained to encourage the fullest communication by the astronauts?
    - Are Russian mission support staff given the training and encouraged to seek fullest communication with Americans to obtain feedback?

3. Astronaut Training:
    - Are astronauts adequately trained to assist cosmonauts in routine and emergency repairs?
    - Are cosmonauts adequately trained to perform Mir maintenance and emergency repairs?

4. What is the physical condition of Mir? Is Mir safe to inhabit for long term flights?
    - Have the collision, fire, leaks of ethylene glycol, power failures, and oxygen generation failures precluded a safe habitation of Mir?
    - Are Mir spare parts and replacements available?
    - Can Russian industry manufacture spare and replacement parts on time or are there other arrangements?

5. Is Soyuz spacecraft adequate as an emergency evacuation vehicle?

5. Is Soyuz spacecraft adequate as an emergency evacuation vehicle?
    - Is adequate access available during emergencies?
    - Is the emergency Soyuz adequately maintained?
    - Is astronaut training on the Soyuz adequate?

6. Does the cosmonaut pay and bonus system hinder space station safety?

7. Length of Mir visits/crew rotations:
    - Are durations of astronaut visits and the mission assignments of cosmonauts structured to avoid undue stress, fatigue, and physical health problems?
    - Should crew exchanges be more frequent to mitigate such adverse consequences?

8. Ground communication with Mir:
    - Does NASA receive timely and accurate versions of Russian ground control/Mir communication?
    - Do communication "blackout" periods adversely impact safety?

9. Science and Research Productivity: Have conditions on Mir degraded to a point at which little or no science or research is conducted?
    - Are principal research gains limited to new understanding of accidents, mishaps, and related crew behavior?
    - Do such gains warrant continuation of joint missions? Are there restrictions on astronauts' participation that unduly limit even this information?
    - Can the closed module be reopened?
    - Can the other Mir modules be safely utilized for planned research and experiments?
    - Can Mir repairs successfully facilitate further science and research activities?

10. What is the impact of any change to American participation on Mir on the Space Shuttle manifest? Does backup or contingency planning provide safe and effective alternatives to maintain number of flights necessary for safety reasons?

11. Would an alternative training and crew preparation site (e.g., American or European location) for Russian spacecraft related to the International Space Station (ISS) enhance ISS national partnerships?

12. Monetary impact of discontinuing or modifying Mir arrangements: Are alternative uses of Mir-related funds acceptable to the Russians?

APPENDIX E

International Space Station

National Aeronautics and Space Administration

International Space Station (ISS)
Phase I-III Overview

Introduction

The International Space Station program has three phases. Each builds from the last, and each is made up of milestones representing new capabilities. Phase I (1994-1997) uses existing assets–primarily U.S. shuttle orbiters and the Russian space station *Mir*–to build joint space experience and start joint scientific research. In Phase II (1997-1999), the core International Space Station will be assembled from U.S. and Russian parts and early scientific research on the station will begin. Phase III (1999-2002) includes utilization flights, during which crews of docked shuttle orbiters will conduct research inside the station's U.S. Laboratory module. Also during this phase European, Japanese, Russian, Canadian, and U.S. components will be added to expand the station's capabilities. Phase III ends in June 2002, when International Space Station assembly is completed and a planned 10 years of operations by international crews commence.

International Space Station Phase I: Shuttle and *Mir* (1994-1997)

Phase I Shuttle Missions

STS-60	February 3-11, 1994	*Discovery*	First Phase I flight
STS-63	February 3-11, 1995	*Discovery*	*Mir* rendezvous
STS-71	June 1995	*Atlantis*	First *Mir* docking; pick up U.S. astronaut and 2 cosmonauts
STS-74	November 1995	*Atlantis*	Docking module added to *Mir*
STS-76	April 1996	*Atlantis*	Shuttle drops off U.S. astronaut at *Mir*
STS-79	August 1996	*Atlantis*	U.S. astronaut picked up; leave replacement
STS-81	December 1996	*Atlantis*	U.S. astronaut picked up; leave replacement
STS-84	May 1997	*Atlantis*	U.S. astronaut picked up; leave replacement
STS-86	September 1997	*Atlantis*	U.S. astronaut picked up; solar dynamic turbine energy module added to *Mir*

International Space Station Phase I serves as a 3-year prologue to station assembly in Phases II and III. Phase I began on February 3, 1994, when veteran cosmonaut Sergei Krikalev became the first Russian to fly on a U.S. spacecraft. On the STS-60 mission, Krikalev worked beside his U.S. crewmates in a Spacehab module in *Discovery*'s payload bay, helping pave the way for future joint research.

The STS-63 mission built on STS-60 experience. On February 6, 1995, *Discovery* rendezvoused with the *Mir* space station in rehearsal for shuttle-*Mir* dockings. For a time it seemed that minor leaks in *Discovery*'s thrusters would keep shuttle and station at a preplanned contingency rendezvous distance of 400 feet. Mission control teams in Houston and Kaliningrad worked together to determine that the leaks posed no threat to *Mir*. The minor problem became a major builder of confidence and joint problem-solving experience for later International Space Station phases. The planned close rendezvous went ahead, with *Discovery* stopping 37 feet from the station. On board *Discovery*, cosmonaut Vladimir Titov conducted scientific research in a Spacehab module with his U.S. crewmates.

On STS-71 (June 1995) Space Shuttle *Atlantis* will dock with *Mir* for the first time. *Atlantis* and *Mir* will be linked on this and all subsequent docking missions by the orbiter docking system, which comprises a Russian docking mechanism atop a U.S. pressurized tunnel mounted in the orbiter's payload bay. The crews will conduct joint research on *Mir* and in a Spacelab module on *Atlantis*. In addition, for the first time the orbiter will be used to change a space station crew, a task which will become a routine part of its

Maintenance is routine, and not nearly as bureaucratic as NASA's inflight maintenance. The urine fan separator had a bearing failure while he was up. The daily plan from ground control just said "replace fan separator". Not a big ordeal, a crew member had a spare and he just fixed it. Merbold feels NASA will have to move in this direction if anything is to ever get done.

Merbold said about 2 hours per day was spent on maintenance. CO2 scrubber was old, and needed a lot of maintenance, but with spares and a backup system, He did not seem concerned about this need for maintenance.

Entry Suits:
The Russian entry suits work at 100% pressure, they are light, comfortable, and offer god mobility. He says they don't offer good thermal protection, but he likes to wear them.

Resonant Frequency:
The MIR has a resonant frequency of about 1/2 Hz. If you did a squat thrust excercise at the right ~~frequency~~-you could make the whole station bounce.

Summary:
Merbold was very descriptive and very factual. He did not editorialize, and he did not speculate (questioners asked poor questions and wanted him to editorialize and speculate). Merbold, however did have some strong feelings, on these issues below.

1) good hardware: The russians have kept up with the logistics requirements for keeping MIR flying for 9 years. NASA does not have a reliable enough transportation system to do this.
2) no place for science: With severe limitations for power, communications, and down weight it is very hard to do science.
3) down weight: Down weight is limited, and things brought down from MIR are subjected to high g loads. The shuttle can help this situation.
4) stowage: There is no stowage protocol, no lists, no inventories. Merbold was very frustrated by this, and he had to delay work or wake people up. He recommends that Thagard create his own MIR stowage list when he first arrives. It may take a few hours, but he'll be time ahead.
5) in flight maintenance: The russians have much more in flight maintenance and much less bureaucracy. Merbold thinks NASA must evolve towards this if they will ever get anything done in long term space flight.
6) interfaces/computers NASA progress-russia: The russian built hardware has difficult crew interfaces, few computers, and limited capabilities - NASA's flight equipment is much easier to use. The Russian progress vehicle is more reliable than the shuttle. He would like to see joint efforts emphasizing each agency's strength, NASA flight hardware launched with Russian Progress vehicles.

7) language: working in more than one language is difficult and unsafe. Sooner or later, joint efforts must be worked using a common language.

APPENDIX H

FIRE INCIDENT REPORT

Until a final report is issued by the Russian Space Agency (RSA), the Russian position on the cause of the Solid Fuel Oxygen Generating (SFOG) canister fire in February 1997, remains unknown. Astronaut Linenger holds the view that the fire burned uncontrollably until all the chemicals were expended. A Russian crew member reported that the fire extinguishers were used to contain the fire. A Johnson Space Center team established to investigate the incident was unable to confirm either statement.

The RSA also established a team to investigate the Mir fire incident. A preliminary report was issued on March 5, 1997. This report listed two possible causes of the fire: (1) damage to the body of the fuel cartridge used,[1] or (2) exposure of the fuel cartridge to humidity. The report said the fire was an isolated event, noting that 1,500 canisters had been activated during the ground development period, and 2,425 were activated during full-scale verification tests without one instance of a fire. A final report on this incident is pending.

The failed SFOG was returned to Kennedy Space Center on STS-84 in May 1997. Although some swab samples were taken of SFOG residue, the unit was left intact and shipped to Russia for analysis. As of the date of this letter, NASA has not received the report from the Russians. The swab samples taken at JSC have not yet been analyzed.

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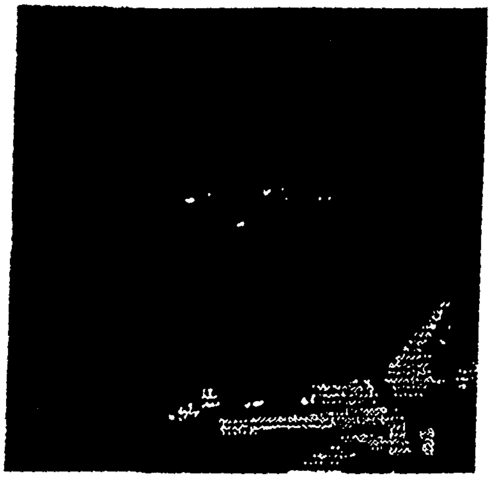
[1] A Mir astronaut stated that the canisters were routinely ignited by using an unorthodox and unapproved procedure of striking the canister igniting area with a hammer.

APPENDIX I



US/Russian Flight Research Program

Lessons Learned

PHASE 1 A

Mir Operations

- Click Here to Review Lessons for Phase 1B
- Click Here to Review Lessons for Phase 2
- Click Here to Return to Lessons Learned Home

Lessons Learned Categories:

- Communications
- Contract Management
- Documentation
- General
- Hardware
- Integration
- Meetings
- Mission Control

  Payload Operations
  Consultant Group

- Operations

  In-flight Timeline
  In-flight Support at TsUP

- Procedures
- Science & Baseline Data Collection
- Training
- Transfers
- Travel & Personal Logistics

SPECIAL NOTE: This documents the Phase 1A Program and the lessons learned at that time. The situation has improved markedly in most areas, but these lessons are retained as a guide to people new to the program.

Communications

Communications

Observations:

There is minimal horizontal information flow within or between organizations on the Russian side. When you provide information to an individual, do not expect that anyone other than that person will receive it.

Russian culture requires long term relationship between US and Russian counterparts to have effective communication.

Dedicated interpreters/translators for working groups is required. The interpreter/translator team was excellent and continually informed the coordinator and the training IPT lead of problems, issues, and events. A readiness review should be conducted in this area.

Baselined program plans are treated as guidelines, not implementation plans.

WG4/NASA/NPOE/GCTC/4003 Mir 18 Post-Flight Program, which was negotiated in May 1994, and signed by joint management, was completely re-negotiated in March 1995. Major changes included the separation of time allotted for rehabilitation and science exercise sessions and the inclusion of break periods. Science activities were reduced by 35% between R+0 and R+15.

After landing, program re-negotiation occurred during daily management meetings between US and Russia. Additional modifications were made to the cosmonaut post-flight program, including:

- No standing BDC performed on landing day
- Postflight program shortened from 22 to 15 days
- R+1 and R+4 were days off
- No BDC involving exercise performed until after R+5

Initial communications capabilities at Star City were fairly basic (E-mail, trunk line, fairly reliable fax). Conditions have improved with the addition of Microsoft mail capability since the summer 1995 and with the planned addition of video telecon capability.

Ever improving communications have helped to enhance the success of future missions (increased satellite time/improved Fax/radiogram capability/air to ground in Houston). The uplink TV capability will be invaluable.

Recommendations:

A "Readiness Review" with the translators/interpreters approximately a week ahead of the scheduled meeting that they will be supporting is valuable in avoiding some minor mix-ups that occurred associated with the May 1995 training (i.e. transportation for the Russians from the airport, more than the required number of interpreters in some cases, and none in others).

Interpreter support of the early arrival of the trainers would give the interpreters the opportunity to become more familiar with the terminology and with the area where they will be working. This will help to speed up translation during the sessions and avoid delays which occurred when the interpreters got lost on site at JSC.

Provide an extra interpreter for any dignitaries such as officials from Gargarin Cosmonaut Training Center (GCTC).

Center (GCTC).

We need to continue to factor in cultural differences.

While in Russia make contacts early and establish relationships because much work gets done following meetings. Get infrastructure in place and try to understand the environment before committing to program implementation.

Contract Management

Observations:

Russians within RSC Energia seem to be genuinely unconcerned about the US/Russian contract between NASA and RSA for the NASA/Mir program. They are so far removed from the charging of money that whether contract payments are received or not appears to have nothing to do with the individual's departments and engineers. Based upon past experiences, the Russian engineers appear to get no benefits from jobs well-done and no penalties seem to be incurred for jobs poorly done.

Dealing with RSA and their contractors is not like dealing with US contractors. Cultural differences and business practices drive much of this.

Russians usually have the strategic advantage of time on their side in negotiations.

Because they have a long established space program, the Russian side does not like to produce products (particularly data deliverables) that they themselves would not normally produce and if they don't want to do something, money is not a motivating factor (e.g. failure reporting and corrective action reports or integrated logistics support plan.)

RSC-E calls the shots in Phase 1 although we have noted that RSA is in charge from an overall perspective.

Establish a Contract Surveillance Plan and regular contract performance appraisals (usually two year). The plan is intended to outline contract management responsibilities, key personnel and processes. It is maintained and distributed by the COTR. The plan outlines performance guidelines and criteria. The plan tracks Russian infrastructure and technical status. The plan can be used for variance Analysis and performance forecasting.

NASA provided business/finance training to RSA and contractors. This had an enormous difference during an audit performed by NASA at RSA in terms of understanding their money flow, controls, and visibility into subcontractors.

NASA and RSA established linkage between technical personnel (joint technical working groups) and their regular forums with contract work (e.g. WG-3 joint ops and integration documents which were generated for the cooperative program (STS-71 and Mir docking mission) also satisfy the data content of Short Term Mission contract milestones).

Occasionally, NASA and RSA technical personnel have attempted to make milestones independent products of a specified value vice being a component of the end item deliverable.

The Billing Matrix (Attachment J-4) has taken a life of it's own even though the SOW takes precedence.

The Billing Matrix (Attachment J-4) has taken a life of it's own even though the SOW takes precedence. RSA and it's contractors (e.g. RSC-E, GCTC, IBMP, et al.) operate in a stove pipe manner. This causes competition to develop for milestone payments rather than performing to the SOW. NASA technical people occasionally fall into the same trap.

Recommendations:

Get a system in place to allow for partial payment of work.

Establish a process for technical evaluation of deliverables early (includes on-line tracking system) and insist on ownership of deliverables by both sides' technical parties.

Establish weekly contract telecon or RSA Liaison Office contact to status deliverables and/or contract issues.

Ensure contract requirements fit technical capabilities and realistic schedules.

Utilize Liaison Office personnel for on-site SR&QA activities, information gathering, technical monitoring and surveillance,a dn GFE accounting.

Documentation

Observations:

US practices in configuration management are not typically well understood. Many Russians are often not experienced at defining standardized formats, operating procedures, outlines, or at maintaining control of changes to documents. Setting up a project management, configuration management system for any activity is a good idea; the Russians have typically not resisted this.

It is recommended that US establish and follow its own documentation guidelines. Russian guidelines for development of 'standardized' documents such as the 100 Series documents are clearly understood by their own engineers. A good and orderly system such as that used by the US has generally not been resisted by the cognizant Russian engineers.

100 series documentation outlines as developed through the Shuttle/Mir Phase 1A Program were ambiguous, redundant, and lend themselves to individual Russian desires. Documentation for 'generic' facilities were frequently developed for use in specific experiments.

The interrelationship between training and flight documentation should have been determined, and agreed upon by the Russians, prior to the first scheduled documentation reviews for NASA/Mir in October/November, 1994.

The Russian technology and medical departments to date have appeared far less proactive in their support of the NASA/Mir program. Both groups seems unfamiliar with joint agreements and joint requirements documentation. Review of documentation with these groups has been slow and repetitive. Often RSCE principals have deferred responsibility to others (e.g. IBMP). The recent promotion of Zeitsin to a department head position has caused an interruption in the review and signature process for documentation that has been in work for two months, covering the GASMAP experiment system.

documentation that has been in work for two months, covering the GASMAP experiment system.

While most of the individuals that the Priroda/Mir integration group have dealt with to date have come from Vrobiev's department, apparently, no one in a management position has ever participated in any module configuration discussions, or more recently, in discussions pertaining to the development of a manifest/configuration definition document. It appears based upon subordinate comments, that their management is unwilling or uninterested in participating in discussions organized by another management group.

Recommendations:

Documentation changes after signature should be minimized. Changes should be made through a standardized bilateral PCN change process. Russians are not well integrated into the PCN process; so the person who needs to know the change still does not participate in the PCN process or see the results of that process.

It is critical for the Russian side to designate the individual(s) with signature authority on specific 100 series documentation. Person(s) responsible for AT-1/AT-2 testing for specific hardware units should participate in the documentation review.

It would be more advisable for a standard format and contents to be agreed upon jointly and signed at a high enough level within RSA/RSC to ensure compliance. This has a potential to save considerable time and translation expenditures.

A better quality control process for the translations must be developed. Poor and incorrect translations have caused repeated delays. A recommended solution would be to hire Russian speaking engineers to be integral in the development and review/editing of 100 Series documentation. This is preferable to having independent translators, who's work cannot be adequately reviewed by either the cognizant project engineers or NASA management.

Identify quality on-site translators for document verification (preferable those that have been involved in the training process).

Russians rarely review documentation or conduct hardware activities unless the document preparer/hardware owner is present. It is NOT worthwhile to prepare and translate drafts of documents well in advance of face-to-face meetings in the expectation that the Russians will review the documentation and bring comments/changes to the meeting. Time is better invested in:

- careful internal review/editing
- keeping draft document to minimum length possible
- translating in time to support reviews at face-to-face meetings

General

Observations:

A business office type facility was needed in Moscow and has been implemented in the Penta Hotel.

Typical delays:

Russian preparation and transmittal of a letter of invitation for a meeting: 4 - 6 weeks

- Russian preparation and transmittal of a letter of invitation for a meeting: 4 - 6 weeks
- Russian arrival for a meeting in the US from time of planned schedule: 6 - 8 weeks
- Russians prepared to support a meeting in Moscow from time of arrangement: 3 - 4 weeks

Generally the accuracy of a schedule can be plotted based on time, before the event, e.g.:

Schedule Time	Anticipated subsequent delay	Real time
L - 1 year	9 months	L - 21 months
L - 6 months	6 months	L - 1 year
L - 3 months	2 months	L - 5 months
L - 1 month	4 - 6 weeks	L - 2-3 months

Judge success based on starting and ending points; don't expect daily advances (Russian's are very patient and don't necessarily respond immediately).

Once established, don't change processes, procedures, and personnel. Russians don't like change for change sake.

Last but not least, get Russian concurrence **during** the process.

Have an established and agreed upon contacts list for science, engineering, operations, and management personnel (similar to a GOSSPL for Spacelab missions).

Recommendations:

Negotiate SPECIFIC contract deliverables, develop methods for monitoring progress.

Develop contingency plans utilizing US resources for critical program milestones.

Maintain a flexible attitude and sense of humor!!!

Hardware

Observations:

Customs problems alone caused a one month delay in the start of Priroda hardware testing.

Common causes of customs problems:

- incomplete addresses; address of sender should be listed; multiple sendees should be identified
- inconsistent values; values must be consistent internally on a document so that total value is equal to quantity times individual values, values must be consistent from one document to another
- inconsistent lists; listing of hardware, including nomenclature and quantities must be consistent from document to document

Any "official" (non-personal) hardware is imported to Russia as one of two classifications, permanent or temporary (residing less than a year). Customs fees and resulting documents are driven by this classification. Hardware is duty-free by joint agreement, although duties are often imposed. Storage and processing fees are always assessed.

processing fees are always assessed.

Customs clearance requires a facilitator, either the Embassy, NASA Liaison Office or a Russian firm.

Duty-free clearance into CTC requires a letter from CTC management identifying shipment as part of joint program.

CTC will not generate a letter until the shipment reaches Russian customs and CTC receives an itemized list of shipment, carrier air bill number and total value of shipment contents.

Shipping restrictions (i.e. this side up) placed on containers are ignored, particularly when in English only.

Thermal insulation only maintains internal temperatures temporarily and was completely ineffective during the winter months due to a very long (~30 day) soak in subfreezing temperatures.

CTC will not accept any shipment without notification 10 days prior to shipment's arrival, with content's list and purpose of shipment.

Hardware is often transported in vehicles with no climate control.

No mechanical equipment is available for unloading or transporting of crates at CTC.

No return shipping support is currently in place at CTC for science hardware (packing expertise, materials, etc.).

Don't expect to find a "clean room" for hardware preparation.

Hardware shipment schedules for Priroda were arranged beginning in April, 1994 and jointly agreed upon. Despite delays to documentation and drawing agreements by the Russians in October/November, hardware was completed per schedule and shipped to Moscow beginning in November, 1994. No attempt was made by the Russians to retrieve hardware from Customs until testing was actually scheduled to take place in March 1995.

The ESA representative stated that they were having a difficult time justifying their expenditures on MIR since they could not show their "legislators" examples of Russian data which made it worth while.

Hardware Delivery - The bulk of the NASA hardware was delivered by the vendor on time. But NPO decided very late to perform exhaustive and surprising acceptance reviews at JSC on both the Flight AND the Training Hardware (e.g. 3 days for a cassette recorder which has flown on multiple Shuttle flights). When the training hardware was finally shipped, some of it was hung up in customs for 2 to 3 months, well past some of the scheduled training sessions. Finally, the training hardware for the Spektr MIPS (computer interface to multiple experiments) arrived from NPO where it had been for three months. NPO insisted that it needed the training hardware to verify the flight hardware. These are just a few examples of problems which need to be addressed with NASA management and that of NPO.

Duty-free clearance into CTC requires a letter from CTC management identifying the shipment as part of the joint program.

When trying to bring the SSAS from Mir 17 back (out of Russia), Russian customs stopped it since it had not been declared on the customs declaration form (of the person trying to leave with it) on the way into the country. Should have had a cargo declaration form filled out by RSC-E when it was brought in - we the country. Should have had a cargo declaration form filled out by RSC-E when it was brought in - we could not do it then, RSC-E would have had to do it, so some pre-coordination required. They would have to meet us at the airport with the form.

Recommendations:

MGAS - high Mir levels of CO2 affected sensors, resulting in the failure of an unimportant autocalibration parameter (phase delay, which does not affect the science). Consider things like this for other instruments.

Get requirements signed to and documented before starting the process. Document where other party requirements are acceptable.

Allocate sufficient time and resources to build and test all of the necessary hardware

Build enough units to have at least one flight unit, one flight back-up unit, and trainers in both the US and Russia.

Ensure that training hardware is available well before the first scheduled training session.

Flight-like hardware must be available for investigators to do full up functional testing of the hardware early in the flow and, at the very least, prior to training and procedure development by the Russian side whenever possible. The hardware will probably see the environments specified in documentation.

Prior to training sessions, all hardware items need to be identified.

For travelers carrying hardware into Russia, hardware should have all shipping documents prepared in advance. RSCE should be provided with copies of these documents well in advance and should be asked to meet traveler and hardware at the airport. Travelers should carry no less than three sets of shipping documents in the event that hardware is retained at customs (one for customs, one for RSCE, one for us to keep).

6-8 weeks for end-to-end hardware shipment.

Provide temperature loggers inside shipping containers that have items with temperature requirements, and be prepared to recover should limits be violated.

Office Automation equipment should be procured through PSCN, who will support delivery and service of equipment.

Data Processing equipment should be procured by local project offices, and hand carried to Russia.

Bring all GSE, supplies, tools, equipment, spares, maintenance gear, bagging and packing material that you may need to process, operate and maintain your hardware in Moscow and at Baikonour.

Assure that the container marking for shipping containers is in compliance with contractual and other agreements. If there are temperature or other storage/handling constraints, mark them clearly in large letters in both Russian and English on the outside of the container.

Prepare shipping lists in English and Russian as far in advance of shipment as possible. Make all appropriate arrangements and fill out forms with JSC transportation and US Customs.

appropriate arrangements and fill out forms with JSC transportation and US Customs.

Make certain shipping documentation is correct (part numbers, etc.).

Make arrangements in advance to minimize the impacts of entry of hardware into Russia (work with Russian counterparts, the shipping company, and the consignee to avoid or minimize the time that hardware is in customs).

When ever possible, ship hardware in pieces that can be hand carried, even upstairs.

Hand carry critical items whenever possible, with proper paper work.

Ship flight and flight back-up units in different containers and on different shipments whenever possible.

After Acceptance Test-2 the Russian side considers the hardware to be "theirs". You may still have access to hardware for tests or check-outs in the electrical mock-up, but the hardware is no longer under your control.

Don't travel to Moscow until confirmation has been received that the hardware has cleared customs.

If possible, place some kind of contractual obligation on RSC E that motivates them to help clear items through customs in a timely manner.

Continuously monitor the status of the shipment, from packing phase at JSC, through pick-up and transport by carrier (requires carrier air bill number) to arrival and customs clearance in Russia.

Documentation must be prepared which identifies/tracks the contents of a specific crate because the items listed on a 290 form do not correspond to the contents of one particular crate. For example out of five items shown on form x, two may have been packed in one crate while the remaining three were packed with one item listed on form y. This significantly reduced the level of traceability for items in a particular crate, especially since there was no indication which items were packed separately. Equipment listed on one 290 form should all be packed into one crate. If this is not possible, a note should be added indicating which items were packed separately and, if so, what crate they were packed in.

Major amount of time to get hardware out of customs is spent simply in waiting for RSCE to take some action. Once their paperwork is complete and filed, hardware can typically be taken from customs in a matter of hours. It is recommended that alternative methods be used for hardware shipment; contractor to contractor, NASA to embassy, etc. anything to avoid relying upon RSCE to be responsible for getting hardware out.

Integration

Observations:

Systems Integration: Teaming of operations and engineering has been beneficial. We were forced into this because that is how the Russian side operates. Russians hold large margins and don't perform detailed verification level analysis until much later than we do. The fidelity of analysis is less than that of the US side, in some cases. Russians don't do much pre-flight contingency situation planning and analysis. Russians have a completely different philosophy regarding stowage planning and pre-launch stowage timing. Russians only tell us what they think we need to know, when they think we need to know it.

Early delivery of training hardware will improve chances of adequate training (training hardware delivery was impacted by: shipping delays (Christmas rush), loss of hardware during transportation, customs, & possible AT 2).

The Biotechnology department has been integrally involved in several Priroda experiment system reviews. Russian personnel have both participated in reviews in Moscow and in Houston.

In our efforts to complete the STS-74-descent photo book to fly with the Mir 19 procedures and STS-74-descent inventory cards on STS-71, it was discovered that Russian names utilized on the STS-74 inventory cards were not based on flight hardware labels. The STS-71 transfer cards did not use the Russian flight hardware names. This caused confusion.

We learned from the Mir 18 procedure development process that it was absolutely necessary to use the Russian name on the flight hardware label as baselined in the engineering document development process. Variations in translation by different translators create great difficulty on bi-lingual procedures, transfer operations, etc.

The Russians do not like foam for packing items on the Mir because it tends to break down over time and generate particulates which get into the air, systems, etc. The foam we use quite often on shuttle flights, Pyrell, has a 3 + year shelf life. Covering foam with Nomex was acceptable.

The Russians are always looking at the off gasses from an object to find acetic acid, which is one of a few items on their hit list. If a report lists items in a nomenclature such as "acetic acid, methyl ester", we cause ourselves problems because the Russians reviewing the report do not distinguish between that and acetic acid. Therefore, we should report offgases with the accurate nomenclature, such as "methylacetate", which will not cause confusion when reviewed by the Russian side.

Organizational Relationships

Mir Integration group is working with no fewer than a dozen RKK Energia 'departments' responsible for the following principal functions:

- science program definition
- science integration
- biotechnological experiment systems
- technological experiment systems
- medical experiment systems
- safety and materials, including materials experiment systems
- data management systems
- electrical systems
- EVA systems and operational suitability
- vehicle integration
- Test facilities
- Operations

Principle interfaces during the first year of Priroda/Mir integration activities has been primarily with the vehicle integration group. Meetings have been coordinated through the science integration group.

Hardware shipment schedules were arranged beginning in April, 1994 and jointly agreed upon. Despite delays to documentation and drawing agreements by the Russians in October/November, hardware was delays to documentation and drawing agreements by the Russians in October/November, hardware was completed per schedule and shipped to Moscow beginning in November, 1994. No attempt was made by the Russians to retrieve hardware from Customs until testing was actually scheduled to take place in March.

The lack of adequate support has had a direct effect on the failure to establish systems interfaces required to support jointly agreed upon scientific programs.

Meetings and hardware testing in March/April 1995, were poorly coordinated and supported by the Russian side. Although the lack of timely customs support was to be expected based upon Spektr experiences, the further lack of appreciable technical support in understanding the reasons for hardware not being released from Customs may be the result of a new lack of a Spektr/Priroda coordinator resulting from recent organizational changes. In November, 1994, the lead Spektr/Priroda (US program integrator), was promoted into a position with approximately 30 subordinates. Although an assistant was identified during the beginning of the Mir Integration meetings, in March, coordination proved to be difficult for any of the significant activities identified in meeting agendas agreed to prior to the meetings.

The Russian users groups (training, procedures, in-flight ops and stowage) are primarily concerned with ensuring the RUSSIAN labels stay consistent throughout the numerous iterative translations of all "user" documents and the manifest.

Recommendations:

Identify responsibility on US side for operation, maintenance and configuration of training hardware.

Provide all engineering documents (i.e., 100 series) to CTC.

Consult with Russian specialists before finalizing labels.

Ensure that decals and labels on training units are identical to flight units.

Design the hardware to be robust, and perform the full regime of hardware tests recommended by the Russian side whenever possible, because it probably will see the environments specified.

It is absolutely critical that ALL bi-lingual documents which refer to flight hardware use the official RUSSIAN version of the hardware name so crew members will be able to identify transfer items. It is absolutely necessary to avoid situations which occurred with STS-71, where the Russian hardware names called out on the transfer cards did not match the Russian labels on the hardware (and this was NOT new hardware).

It is incumbent on the hardware supplier to make certain that the nomenclature established in the documentation is consistent.

We must call the hardware by its negotiated label name and not some translation of that name. To do otherwise is confusing and somewhat offensive.

Although a primary difficulty continues to be the lack of an established documentation tree for the program, the pecking order for establishing nomenclature should be as follows based upon the order in which, typically, the items are established to be on board:

- LEVEL II: PRCB established Team 0 Manifest / 004 Document

- LEVEL II: PRCB established Team 0 Manifest / 004 Document
- LEVEL III: DIDs/EIDs/100 Series Documents
- LEVEL IV: PNOM, SVD, Procedures, Stowage Verification, and other 'working level', implementation documents
- LEVEL V: Hardware labels

If a piece of hardware was previously developed for another program and the hardware predates all of the higher level documentation, manifests should be required to maintain the actual label nomenclature. It is incumbent on the hardware supplier to make certain that the nomenclature established in the documentation is consistent. Numerous outside organizations are maintaining numerous lower level documents based upon the top tier documents, so trying to backtrack and maintain top programmatic documentation established months or years before an actual hardware label shows up at an AT is difficult.

The OPS IPT needs to have a Russian counterpart from the TsUP working with them on the Stowage Verification Document (SVD). With no Russian counterpart, efforts in developing and trying to maintain the SVD are ludicrous.

Consider whether there are any cultural sensitivity issues we need to be aware of for release of photos or information from ISS that we normally do not worry about.

Meetings

Observations:

At the NITs facility a snack bar upstairs provides good, complete, hot lunches at extremely low prices. It also sells prepackaged foods and drinks.

The role of the jointly signed protocols need to be clearly defined. Some of the Russians do not consider signed protocols binding. The individuals with authority for negotiating and signing should be officially designated. Individuals with responsibility for signing the protocols must be at a level higher than those who generate the documentation and perform the testing.

Recommendations:

It is recommended that a 'pre-protocol' be written prior to the meetings which gives the desired wording for all agreements. In addition to being useful as a guide for use during the meeting, if the meeting should break down in terms of getting adequate Russian attendees/support, it can be used as the basis for further discussion/negotiation with the meeting principals.

Avoid lunches at the RSCE 'main territory,' especially if working at an off site facility such as NITs. Besides the quality and cleanliness being questionable, and the price high by Russian standards, the lunches at RSCE appear to be a deliberate effort by the Russians to waste time so that their own workers can have a major portion of the day to spend in their offices. The typical lunch at RSCE from NITs takes an hour to travel to the main territory, one and one half to two hours at the lunch facility, and one hour to return. Including time to break up and time to regroup, the period allocated to lunch can easily extend from 1 to 4 P.M.

Identify desired sites for tours/visits in advance so that your Russian host can arrange these. Candidate locations include:

- Krunechev
- TsUp
- Star City
- Monino Air Force Museum/Academy

Visiting groups should arrange to provide their own facility support in Russia (copying machines, computers, CAD system, printers, office space, E-mail etc.). Serious consideration should be given to bringing administrative personnel to assist in meeting support, protocol generation, etc.

Adequate preparation and recovery time is required before and after joint meetings. Adequate time must be allowed for closure of all activities of a completed meeting and set-up time for a following meeting.

Mission Control

Observations:

A significant flight plan and crew sleep shifting change was made to get a daylight landing when the launch date of STS-74 was changed. As a result, the dynamics test was inaccurate the first time.

Fewer JISes with the Russians are required. The people on both sides are the same with few exceptions. We will reduce the number of joint SIMs to one or two for STS-76. The RIOs AND CG FAO will support at the SCA. This means they should be plugged into the SIM planning process.

The use of Sergei Krikalov (or other consultant group member) at the CAPCOM console was valuable and should continue.

Recommendations:

Do not change the flight plan after the final flight plan is published (about L-6 weeks). If the launch date changes after this, we should be prepared to accept a dark landing.

We should try and make late changes, even on non interference secondaries.

Discipline needs to be kept to pass official information on Loop 1 and not over the airwaves.

Payload Operations

Observations:

The way the signal conditioning box works, several of the TLM parameters on the DM (and later on the EM) were very unfriendly on SM displays.

Compression of the template made our operations very difficult. The FDF and other documentation was not mature enough.

The DM work got done very late due to the compressed template and the STS-71 work. This was a complicated effort, and the EM will be an equally complicated effort.

The Mir ops procedures folks did not know enough about the DM. We wrote procedures and then got a poor review from the TsUP procedures folks.

poor review from the TsUP procedures folks.

A small error in the PC MPSR display caused a great deal of consternation in Moscow. PC MPSR will not be supported in the future.

Recommendations:

Some program resources can be saved by using PGSC displays for EM rather than SM displays. There are no safety critical parameters on either the DM or the EM that require an SM display.

We should try hard to keep the template on track for future flights.

We should get EM work started one joint meeting (4 months) earlier.

We need to work EM procedures with the engineering group and not operations for procedures. We propose adding annex 3 type procedures to integration's documents.

If we use REM, we will use only certified displays. We will work the requirements on what we are going to supply to Moscow in the future.

Consultant Group

Observations:

Using the Consultant Group as a part of the planning process (FAO functioned as the technical interpreter of preliminary flight plans) worked very well and should continue.

The MCC-H replanning milestones need to be synced with MCC-M replanning personnel. It is planned to use the lead FAO for the next flight as the replanning rep in Moscow.

Consultant group must be ready to go to Russia pre-launch. Must be there 2 days prior to launch.

Operations

In-flight Timeline

Observations:

Multiple iterations of the inflight timeline were required before the mission because of changing science definition, hardware availability (Spektr/Progress launch options), and Mir operational activities.

Russian timelines provide significant personal time that they feel is critical for the mental health of the crewmembers during long-duration flights. Don't expect Shuttle time-lining strategies to be used (timelines accurate to the min).

Timeline: work on Mir is not scheduled for 7 days a week, 12 hours a day for 90 days. In fact, if you look at just how many days we are working over 90 days, it is much less than Skylab and quite leisurely. The whole crew is only scheduled for 5 days a week and has several holidays (including a 4 day Russian holiday).

Changes to the Mir inflight timeline have been relatively easy to accomplish (changes within the next 24 hr period or the entire flight plan have been equally easy to implement -- depending on crew time flexibility for the scheduled activities).

Many activities did not occur as timelined because of apparent lack of communication between TsUP timeliners and Russian engineers. Specifically for Mir 18 science hardware on Spektr, there were several instances of other Russian hardware that blocked the access of several lockers containing hardware for joint science activities. As a result, science that was originally timelined had to eventually be postponed until the hardware was removed/relocated.

The lead timeliner is key to the implementation/scheduling of activities and US representatives need to establish good working relationships with this person.

Discussions with lead timeliner to review changes in priorities and schedules, as a result of changes in Mir activities, proved beneficial to optimizing inflight science activities.

During docked/joint activities, the Mir 18 crew was very confused about the events of any day (i.e., the Russian timeline version said "Joint Science Activities" while the US version said "Baroreceptor/LBNP"). Implementing a daily science conference to review the following days activities helped this situation.

Cosmonauts like to go over their timeline the night before - every evening they review the activities of the next day. This is consistent with their long-term mission, as opposed to our short-term missions where we practice every moment of a day and a morning uplink package is all that is necessary. The daily private science conference during STS-71 worked well.

Crew work day is 8.5 hr/day, typically with 2 hr of scheduled exercise. During the first week of flight the crew work day is less (6.5 hr/day) and exercise is not scheduled (preceding crew is scheduled for end-of-mission countermeasures).

Weekends and holidays are typically not scheduled, however, scheduling of limited crew time on the weekends was possible (particularly for the astronaut and primarily on Saturdays).

EVAs and other Mir operational activities were rescheduled numerous times (preflight as well as during flight), causing numerous rescheduling of science activities.

Inflight changes of the science timeline (whether initiated by the US or Russian side) were discussed and agreed upon (US science representative, TsUP lead timeliner, and in most cases the IBMP science representative) before implementation.

During the mission, the detailed daily timeline has been provided 1-2 days in advance and the 15 day plan provided 3-5 days in advance. For Mir 19, the 15 day timeline was provided only twice during the mission.

Recommendations:

It is quite likely that the first of multiple experiment sessions will take longer in order to collect all the samples, process them and restow than will the successive experiment sessions.

"The first run of each of the three protocols will take longer because we have not had the usual training with all three crewmembers and don't even have a Spektr module to train in. "

with all three crewmembers and don't even have a Spektr module to train in."

Flight Plan for STS-71 tried to track too much. It should show blocks of time and let crew fill them from list. EDV transfers, transfers in general, IMAX are examples. Get status during day but no detailed timeline on these things.

Don't put excessive resources on the multiple iterations in science program before flight (at least not before L-3/4 months).

Don't expect Shuttle time-lining strategies to be used (timelines accurate to the min).

All activities should be scheduled, regardless of how trivial or minor these activities are. Unscheduled activities that are just called up to the crew may be forgotten or go undocumented.

Crew hand over for long duration crews will require similar hand over that Mir crew uses. Long duration crew is not going to be fresh on Shuttle routine.

Be aware that a long duration crew member may not be as fresh and gung-ho about participating in a well choreographed timeline and that we can not expect them to be as familiar with the Shuttle portion of the mission. Should not assign tasks to them unless it is coordinated with them shortly before Shuttle launch.

Replanning of joint activities requires improved coordination.

24 hour shifts not required at TsUP. Discipline required to ensure that RIO is only entity passing flight related data.

Identification of TsUP Main Control Hall crew interface for NASA, such as CIC or APS function.

Strongly recommend NOT share Mir Ops loops with Shuttle-Mir loops (e.g. Mir PI/Sim Sup).

Utilization of joint planning system between TsUP and NASA/JSC was successful.

Identify and communicate reporting procedures to management, such as daily status reports, before the mission. Make an agreement on how reporting will be handled and stick to it.

Document as a requirement that NASA operations be involved in all timeline and procedure development processes, during the pre-flight and on-orbit phases of each mission.

Science activities scheduled for the last day of the docked period should be kept to a minimum. Final day activities tend to be rushed and science may be cut and/or forgotten in the last minute crunch.

A statement made by the ESA folks: "As a consequence of the MIR stowage situation, the planned experimental workload needs to be reduced by approx. 50% in the first and last 3-4 days of the mission."

Plan realistic schedules, with 20% pad.

Be prepared that on landing the VIPs may want some of the crew time, and work this into any post-landing activities.

Transition new representatives into CTC with overlap of current representatives.

In-flight Support at TsUP

Observations:

From 4/4 daily SMR - CR reported that he was instructed in the daily radiogram to use old procedures (from Mir 17) for the "Pilot" experiment. He correctly used the Mir 18 procedures from the flight data file instead. The incident highlights the importance that the US SMSP representatives be given an opportunity to review the radiograms in a timely fashion. It also raises an issue of having outdated procedures on-board and the potential need for inventory management of on-board documentation.

Radiograms have been sent up on a daily basis, but US representatives have not necessarily had a chance to review these before they were sent (negotiations underway to change this). Request signature authority on radiograms. The flight plan generated by the TsUP representatives needs to be coordinated with the FDF representatives in order to assure that experiment names on the radiograms are consistent with the FDF.

Communication time averages 10 minutes with 3-7 sessions/day (some satellite sessions are available).

Communication time can vary depending on specific requirements.

TsUP personnel are responsible for generating the Program of Flight (outlines the activities for the entire mission).

There are TsUP personnel that support both medical and non-medical experiments.

The Medical Support Group personnel are employed by IBMP and act as liaisons between Chief Operator (Capcom) and Russian side and US investigators or science representatives.

Non-medical "Experiment Group" are employed by RSC E and act as the liaison between Chief Operator (Capcom) and RSC E or science representative for technical related topics.

Neither of the experiment support groups appear to be particularly knowledgeable on the experiments, possibly due to the lack of communication between Star City, RSC E and IBMP (IBMP acted as co-investigators, RSC E wrote the Flight Data File and controlled the engineering documents, Star City trained the crewmembers and wrote/verified the flight procedures).

TsUP personnel responsible for uplinking "radiograms", oftentimes send these messages without US approval or review of science related issues (currently under negotiation).

Radiograms consist of 3.5 inch wide paper, so information delivered must be brief, and support only Cyrillic font.

Recommendations:

Require signature authority on radiograms.

Coordinate one-word names for each experiment with TsUP people responsible for the Program of Flight and the RSC E people responsible for the Flight Data File so that the experiment names on the radiograms and the FDF are the same. Do not expect the Russians to do this even though they work for the same organization.

Russian side must identify RSC E TsUP personnel who will be supporting inflight activities well in advance of the actual mission.

TsUP personnel supporting inflight activities must be adequately educated with the experiments (objectives, methodologies, hardware, constraints, experiment approach) prior to the beginning of the mission.

Payload responsibilities and logistics overload require more than one 16 hour-a-day representative (Russian activities during the day, US activities in the evening).

Consider refreshing or updating the crew on the investigations/protocols for which they have provided informed consent. Be aware that PIs like to make a few minor changes that may require new information be provided to the crew (via a private science conference) and perhaps a new consent form. Have a mechanism for this, if necessary.

Sub-floor volume in Spacelab or SpaceHab should be available for foam, unplanned bulky items, etc. Plan to make this volume available and not a safety issue (ignition sources).

Consider developing a passive freezer/refrigerator for short thermal stowage coming to/from ISS.

Crew transfer of resupply, etc. Scheduling 2 people is harder than 1. Use 1 whenever possible.

Keep flight-like hardware in Moscow for any trouble-shooting efforts. If you are using this hardware for training, there may be a scheduling conflict when it comes time for troubleshooting, so 2 units is better.

Rapid safing of the Shuttle is a concern with the return-to-Houston bag concept. They could be too heavy if all the heavy items got placed into 1 bag, resulting in a penetration hazard. Because we have to repack everything once we get the bags onto the Spacelab, there is a period of time where we could be vulnerable. They are also too heavy to tether. Consider a better systems approach to return bags from ISS which fit directly into a stowage location on the Shuttle without repackaging. (NOTE: Collapsible transfer bags were implemented for later flights.)

Cold stowage transfers - have freezers and refrigerators on the ISS be the same shape and volume as the ones on the Shuttle which bring items up and down to simplify transfers, or at least have the sample holder system in the ISS be compatible in some way.

Don't put excessive resources on the multiple iterations in science program before flight (at least not before L-3/4 months).

Launch and on-orbit configurations of Mir vehicles must be clearly identified to investigators and other relevant personnel. Losses in science can best be avoided if current inflight configurations are understood and appropriate actions can be taken to optimize science scheduled.

Improved communications will enhance the success of future missions (increased satellite time/improved Fax/radiogram capability/air to ground in Houston).

Improved communications between Russian support personnel and US support personnel will provide PIs, and other relevant personnel, with a clearer status of inflight activities.

Extended stay (6 months) by US representative essential for efficient interaction with the Russians.

Procedures

Observations:

Procedure and timeline development and verification as part of flight crew training phase

- Flight Plan development (pre-mission)
- Two-week plan development and review
- Daily plan development and review (cyclogram)
- Radiogram development and review

Procedures were developed real-time during the training sessions. This required coordination and joint participation between the Russian trainers, procedure developers, and principal investigators. The procedure redline process needs to be communicated to all participants prior to start of the training session. The joint participation in the process is mandatory.

Identification and functional description of communications and data requirements, including all Russian interfaces, in document form. Protocols not binding.

RSC E Experiment FDF group are:

- Responsible for generating "on-board" experiment documentation from science procedures (Scientific Methodological Notes) and engineering documents (100 series documents)
- The control point for Mir 18 FDF (latest electronic version - Russian)
- Not adequately supported by RSC E (no computer, printer, binder rings)
- Rarely able to attend training sessions (must take train to reach CTC - 3-4 hours one-way time commitment)
- Also assigned work on TsUP console in support of on-going Mir missions
- Also responsible for other science missions (Euromir 95)

Development/Updating Process

Scientific Methodological Notes were not used in the procedures development (even though that was supposed to be one of the major purposes of the document).

100 series documents were not available until very late in some cases and RSC E engineers did not bother to share these documents with the RSC E FDF writers.

Engineering documents were not utilized by RSC for procedures development even though we were told they would be.

Procedures were developed by US investigators in conjunction with Star City trainers.

RSC Energia personnel formatted the electronic copies that were provided to them.

Procedures were verified by a US science representative and translator very familiar with the training hardware and experiment procedures.

Lack of engineering input resulted in inaccuracies and insufficient information in the FDF.

For Mir 18 the Russian FDF was the controlling document, and the English version was verified/formatted based on the Russian version.

Delivery schedule

Majority of FDF development occurred after primary training activities.

Final delivery of FDF was only days before flight.

ALL Russian delivery dates agreed to in protocols were missed.

Role of Investigators

US investigators provided initial procedures.

Russian investigator participation was extremely limited and/or late in arriving.

Role of Trainers

Some Star City trainers were critical in the development of procedures and provided valuable information about interfacing with the Russian hardware and Mir.

Format

Adequate, if provided early enough in the training period to allow for training with the onboard procedures.

Recommendations:

One area for improvement is in the process for procedure development and translation. One master copy, either English or Russian, should be the only one used for the final translation. Agreement on the procedure wording must be reached on one version which is then provided to the translators. Clarification notations to accommodate translation are acceptable in either version. The final translation is acceptable in either version. The final translated versions should match item for item and specifically the numbers for the steps should be the same. Providing independently marked up English and Russian versions of the procedures to the translators is not acceptable practice for future sessions.

Approval authority - team lead essential.

Identify requirements (based on operations concepts and scenarios) in protocols and hash out implementation in documentation. Do not be afraid to repeat requirements. Once established don't change requirements rapidly; Russians won't respond.

Science and Baseline Data Collection

Observations:

It is critical to establish the scientific program and receive Russian side endorsement FIRST. Most Russian side interfaces will not proceed with any planning without a signed science program at Gargarin Cosmonaut Training Center.

Rehabilitation time utilized was significantly less than time allotted, particularly by cosmonauts. Due to science constraints, rehabilitation exercise activities were typically scheduled near the end of the day. This appeared to be a contributing factor to the under-utilization of rehab time.

Cosmonaut compliance with science based diet constraints was inconsistent.

Communication between Russian management team and cosmonauts was insufficient. Cosmonauts were frequently unaware of their daily schedules and program agreements reached at daily management meetings.

Postflight cosmonauts appeared to take daily direction from Russian flight surgeons. Schedule ownership by Russian flight surgeons is essential to completing daily science activities.

Informed consent - after a long time the crew may forget what they agreed to do and what the protocol for the investigation was.

Mir station has concerns about research gases such as SF6 being released into their atmosphere due to high temp of some life support equipment, i.e. perchlorate candle. Also, concern over Halon from fire extinguishers due to same concern. There could be ops impact and science impact if certain gases are excluded from allowable list.

Recommendations:

As you know, the science samples in the ORF and the LSLE refrigerator/freezers were of primary importance on this mission. Like many other missions, it was very important to maintain vehicle power post landing to ensure the preservation of these samples.

BDC - Perform functional tests with BDC hardware in the US prior to sending entire BDC team to CTC.

Cross-train BDC personnel for hardware setup and operation to limit travel for BDC occurring in Russia.

Due to the nature of biological data, multiple collection points are required. Data as close to flight as possible are optimal for comparisons with inflight and postflight data.

The loss of Baro BDC data in January, 1995, was due to a chip fracture (probably from the cold).

In order to optimize science, US/Russian investigators should develop contingency (abbreviated) data collection activities in the event a crewmember is unable to complete the full set of data collection requirements on landing day (or in the early days postflight). These abbreviated data collection sessions could be discussed and agreed upon prior to landing day activities.

Training

Observations:

"We are not oversubscribed on research (applied physiology and engineering), but are under supported by Star City and NPO. The complement of experiments is less than prior Spacelab flights (SL-D1 and USML-1) but we had higher fidelity mockup trainers and better training for Spacelab. You could whittle this flight down to one experiment, but if it is not given the proper resources (e.g. time, power, etc) on orbit, it could fail also."

US payload representative(s) at CTC are critical to successful program implementation.

Joint U.S. and Russian real-time negotiations of scheduled changes/impacts was very effective.

Acceptance testing (AT) and training scheduled in the same location at the same time is unacceptable and is too distracting.

Differences in configuration between the Mir mockup on the ground VS the on-orbit Mir created stowage problems.

For some experiments the training unit was of low fidelity and that on-orbit will be the first time the crew will have really operated the equipment.

Because of either inadequate training on the ground or unfamiliarity with the flight hardware configuration some on-orbit training will be required.

Given the timeline negotiated with the Russians, certain experiment objectives are at risk i.e. it may take more time to do the experiments (impacting experiments down stream on the timeline) and/or a reduction in data/samples obtained. As the crew becomes more familiar with where things are stowed, has run an experiment several times, has adapted to life on the Mir, and has become familiar with the operation of the equipment, then their performance will get better. The point is that the existing timeline seems to assume this peak performance up front and does not allow for a longer learning curve resulting from the above stated conditions and preflight problems.

Research (whether it be basic science, applied science, or applied engineering) is not a high priority training item at Star City or within NPO. There is of course, much talk about the instruments, applications, etc, but when you really probe into "results" and "productivity", it is very difficult to find any meat. They launch the instruments, they are just not utilizing them effectively or are compromising the outputs.

Hardware

Labeling configuration - Acceptance Testing (AT) does not ensure training hardware has flight configuration since significant flight hardware changes were made in AT-1 and 2 (after training hardware AT).

Engineers who performed AT-1 for the training hardware were not the same people responsible for flight hardware.

Trainers take personal responsibility for training hardware (storing, locking in offices, rather than training room). However, at times the trainers did not maintain the hardware sufficiently (depletion of consumables without restocking, minor changes in configuration).

AT-2 for training hardware was never performed.

Jointly signed protocols listing all hardware received at CTC were necessary.

Set-Up/Maintenance - Insufficient US engineering focus and support for training hardware at CTC

Russian side played critical role in electrical set-up of BDC hardware.

Storage - Inadequate furnishings to control, organize and protect training hardware.

Completion of training hardware fabrication was in some cases too late to support crewmember training.

Training hardware that is shared and supports various investigations (i.e., MIPS) must be available at all times, for all relevant experiments. Training on this hardware must be coordinated across disciplines, and led by personnel knowledgeable on the systems, as well as the specific investigations.

Scheduling

Performed at the request of the Russian trainers.

US science representatives requested additional training both upon observation that crewmembers were not receiving adequate training and at crewmember request.

Specific training schedules were developed weekly and released on Friday afternoon of the preceding week.

Training Schedules contain only title, time, place of activity with limited special requirements/constraints.

Trainers often said they would inform crewmembers of requirements/constraints, but this did not often occur.

Training Schedule of activities posted and/or made available to everyone involved.

Real-time changes to the training schedules incorporated and distributed.

Science training easier to obtain further out from flight (Mir 18 training was limited due to late arrival of training hardware and limited time within the L-4 month time frame).

Training: The training from NASA PI's and engineers has been excellent. But these people do not reside in Russia. Because of this and the Star City policy of using their own instructors for experiments, we trained a number of people at JSC from Star City. It has been a mixed bag. The individuals that we trained for LBNP and Anticipatory Posture have been excellent. The individual we trained for Metabolic, one of the most complex, has been disappointing. This problem can only be solved by negotiating more leverage on the part of NASA for evaluating our own experiment training program. At present, only the Russian trainer signs the crew off as "trained". The NASA PI's were not given the option of evaluating the experiment training program provided by Star City and were not notified in advance when the crew would actually receive training from Star City so that they coordinate travel schedules. Not all crew questions can be answered without sending messages across the ocean. Even though the Russians would have us believe from their experience that training is adequate, without our own experience base for training of long-duration crewmembers, it is difficult to know how much training is enough. The truth probably lies between the two perspectives.

The Russians don't normally schedule much training inside three weeks to launch. MIR-18 flight duration is not long by Russian standards but it does fall into their category of lengths for which a pre-flight R&R period should be provided. Requests for BDC and training in that period have to evaluated in terms of impact on the psychological and physiological state of the crew in the immediate pre-launch period.

Trainers (usually one per science discipline)

Have multiple responsibilities (i.e. Flight Surgeons).

Also have extensive vacations (not different from any other CTC employee), often unannounced.

Often lack background knowledge to answer crewmember questions on specific technical/procedure issues.

The real-time changes that the trainers made to procedures during the May training could not be incorporated into translated procedures for the Cosmonauts due to the heavy workload that TTI had.

BDC Approach

Russian roles (for each of the different organizations) in BDC were not clearly defined.

Often involved multiple, unnecessary individuals as session "operators".

Training schedules (particularly in the US due to their intense nature) often changed on a daily, and even hourly, basis. This was in large part due to crewmembers desires to modify schedules.

Schedule of Mir 19 training with available hardware was adequate.

Facilities

Most life science training is performed in Medical Building 3, utilizing available rooms (with desks/chairs) and relevant hardware.

Limited integrated science training in the Mir mock-up.

Mir mock-up is not very flight-like.

Electrical layouts of CTC facilities are not completely understood by RS; interaction with US power converters, conditioners and hardware even less understood.

Priority

Science payload activities are much lower priority than operational Mir training.

Joint Plans

Signed pre-/post-flight plans are treated as guidelines, NOT agreements (pre-flight training/BDC hours allocated were 51% of those requested in baselined documents).

Location

Most successful training occurs in US due to ability to control schedule, increased access to US specialists, and better/more available resources (45% of pre-flight science activities with crewmembers occurred during two 3-week sessions at JSC).

Recommendations:

Training - Establish mechanism involving US CTC representative for ensuring trainers, procedures and hardware are prepared and available.

The lack of training time preflight could also be ameliorated in flight by providing us more time for first performance of an experiment.

Crew requests should be solicited and coordinated in advance (e.g., language training, T-38 flights, CPR refreshers).

Training should not be scheduled over a holiday.

External organization requests for crew training should be scheduled only by the crew scheduler and such requests should be minimized. The primary objectives of the session should be advertised including clarification that the crew is present at JSC for payload training. Time needed for admin and other activities should be negotiated outside of the training weeks. Each 40 hour week allows for 32 hours/week for training, lunch, exercise, limited breaks, and transportation between buildings only and is not sufficient for other demands on crew time.

Prior to the training session, specific instructors (Russian or U.S.) need to be identified for each lesson to avoid scheduling parallel sessions requiring the same instructor.

The number of people in the training area should be limited to only those essential for conduct of the session.

Team meetings and readiness review should be held starting two weeks prior to the session and should include representatives from other IPTs.

Logistics such as security, badges, banking, etc., should occur on the Monday, after arrival, and not impact scheduled training.

More training IPT team involvement and interaction with the Pis should occur prior to training to determine and identify training objectives, lesson duration, constraints, etc.

Some sessions ended early resulting in less efficient scheduling and concern over total training hours provided. Several factors may have influenced the lesson length such as overscoping the time required, crew proficiency, instructor preparedness, crew interest, etc.

Russians (TsUP operations) were only interested in high activity phases. We need to tailor our support appropriately. Reduce the number of long sims and number of sims. Generic sims with -RIOs substituting for Moscow worked well. Do some more for future flights.

- Failures in Mir need to be pressed for sims.
- Work debrief times earlier with FD and Moscow FD.
- With Russian real Mir passes, sims must start on time. Keep up the pressure to do this.
- Keep training telecons separate from main telecons.
- VHF Relay problems are still with us. We need to verify full functions and not just that loops are up.
- MMT meetings, if done for sims need to be carefully coordinated.

A final sit down session directly with the P.I. or their dedicated representative for all of the complex experiments in which we discuss all aspects of the in-flight component of their experiment would be useful in the immediate preflight period.

Have crewmembers cross trained so they can cover for each other, at least for part of the session.

Perform real-time, joint accounting of training accomplished and tie it to a specific contract deliverable (crew training hr/month).

Utilize US sessions with RS participation whenever possible (to optimize procedure development).

Generate realistic expectations for training at CTC, considering resources (i.e., limited RS manpower), schedule control and priority.

Specialize cosmonaut training where possible to optimize total science training per given mission (do not train both cosmonauts as operators for all activities).

Work with CTC schedulers to incorporate constraints into weekly schedule.

Develop a more streamlined method to notify all relevant personnel of changes to the training/BDC schedules (particularly during US training/BDC). This could include Microsoft Mail messages, distribution lists for faxes, coordinated phone messages.

Laboratory and training personnel must be able to support very dynamic changes occurring in schedules and crew participation.

Trainers

Add a mechanism to control the quality of the training (for example, require that the trainers pass a certification test and tie it to a contract deliverable).

Russian Trainers and Investigators must be encouraged to take an active role in preparing for and participating in BDC. This should include working with US colleagues in scheduling of BDC, BDC hardware setup and checkout, data collection, and data analyses.

US representation in Star City should be conducted using the same people during the course of training and the subsequent mission.

When trainers from Russia are involved in training sessions and/or procedures verification it would be valuable to have the trainers in the US a week early. This would allow time for them to make changes to and become familiar with the procedures.

Hardware

Involve engineers/hardware providers early in the training/BDC schedule development process to assure that training hardware will be ready before scheduled training/BDC.

Perform real-time, joint accounting of training accomplished and tie it to a specific contract deliverable (crew training hr/month).

Work with CTC schedulers to incorporate constraints into weekly schedule.

Add a mechanism to control the quality of the training (for example, require that the trainers pass a certification test and tie it to a contract deliverable).

Revise AT process jointly with RS (have EXPERIENCED, qualified personnel work with the appropriate Russian side counterparts to streamline the documentation process).

Upgrade hardware storage, inventory control (cabinets, shelves).

Perform hardware training at CTC with participation of US engineers and Russian side engineers/trainers.

Assure adequate resources are allotted to fabrication and delivery of training hardware.

Allocate some resources in Russia to allow for configuration of flight-like mockups (Spektr, Priroda) with flight-like hardware (assuming it can be done in a timely manner; Phase 1 training will be completed by mid-year 1997).

Logistics activities necessary for successful operations include:

- implementation of travel, lodging and pass logistics for visiting scientists/trainers
- facilitate removal of shipments out of customs
- inventory and maintenance of training/BDC hardware
- schedule of training sessions
- coordination of training schedules with RSC E FDF writers (Star City personnel will not facilitate this)
- shipping and receiving of training/BDC hardware (including manual unloading of all hardware)

Visiting personnel at the Gargarin Cosmonaut Training Center should plan on working to a large degree out of their personal room and bring necessary hardware to do so.

Transfers

Observations:

Shuttle Program vs. Phase 1 Program, interfaces were not clean. Clarify who we listen to in real time.

Use of consultant group/science team to help transfer coordination worked very well.

The Russians would consult with Bill Gerstenmaier prior to uplinking to the Mir crew and this worked very well.

There seems to be some confusion among the Russians as to whether a change to 0005 is required for real-time changes or not (MOD does not think it is required).

The Mir-20 crew was much more ready for transfers than the Mir 18 crew. The reasons are:

- A transfer overview session with the Mir crew prior to their launch
- Crew conferences were highly successful

Adding notes to the transfer cue card reduced the number of joint procedures.

Recommendations:

A more effective means of verifying hardware/sample transfer must be implemented. Mir crewmembers must be fully aware of all hardware/samples to be transferred well in advance of docked activities. Shuttle crewmembers must be briefed on Mir stowage locations of these items, even if Mir crewmembers are assigned to perform transfer activities.

Use large blocks of time and do not schedule specific items.

Do not timeline in priority order. This did not work even when we did prioritize. Do not temporarily stow things, this wastes much time.

Have more crew to crew teleconference. Crew should confirm with Mir crew even if confirmed with TsUP previously.

Transfer list, put names of items in Russian but do not create a separate list.

Do not assume food/clothing will be empty. Plan on where to stow it. Keep some empty lockers in reserve.

Do not build Russian procedures for transfer.

Inventory list and blocks of time worked very well and should continue.

The involvement of the MOST Team should continue.

Changes to transfer on the Russian side are to come through the PRP and RIO. This will be added to the communication and interaction document. A transfer change form (similar to the attitude change form) will be considered.

A change to 0005 should have the authority to change the transfer list (pre-mission). This will be worked at the meeting in December.

Having one crewmember in charge of transfers worked quite well and should continue, in addition to a 30 minute daily tag-up.

We should keep the crew conference time frame the same. Two conferences about two weeks and one week before flight.

Translation and uplink the list of conference list of topics to the Mir crew BEFORE the conference is mandatory.

Travel & Personal Logistics

Observations:

CTC Transportation

Vans

- NASA Ops maintained two vans during Phase 1A for work-related use by NASA representatives at CTC. These were subsequently increased to a fleet of four vans.
- The two initial vans were prioritized for crewmember support.
- Users include crewmembers, crewmember families, Director of Operations, flight surgeons, NASA Ops staff, science trainers, and investigators.

Train

- Station at front gate of CTC, final stop at Moscow Komsomolskaya Metro station
- Runs frequently, 1.5 hr trip each way
- Relatively safe but group travel is recommended

CTC Lodging

Prophylactorium

- Developed for crew quarantine periods
- One floor available, six rooms, for NASA representatives (including DOR, flight surgeons, training representatives)
- Dormitory-like accommodations
- PCN telephones in each room
- Managers only speak Russian
- $40 single, $60 double paid in rubles

Orbita

- Basic, apartment-like accommodations
- Building shared with CTC residents
- Managers and staff only speak Russian
- Restaurant with Star City prices (inexpensive)
- Typically 5-6 rooms available
- Local phones in each room

- Approx. $40 per person (rooms often shared) paid in rubles

Druzba

- Used for Star City overflow
- 20 km outside CTC
- Meals provided
- Hotel-like accommodations
- One phone in lobby
- Isolated
- $40 paid in rubles

Moscow Hotels

- 3-4 hours round-trip commute to CTC is inconvenient
- Expensive
- Significantly limits interface with remainder of CTC team, both US and Russian side

CTC Access

Vehicles

- Entrance restricted
- Vehicle pass must be generated by CTC administration, usually requires at least one day's notice and must have license plate number, name of driver, purpose of visit, sponsorship from Russian side.

Personnel

- Restricted from entering CTC, additional clearance required for training area
- Repeated access (more than a day or two) requires a badge with photo, generated by CTC administration at request of CTC management sponsor
- Infrequent access can be coordinated by a letter placed at security gates, also requires sponsorship of Russian side

The availability of drivers with pagers in the US adds greatly to a smooth running training schedule.

RSA/RSC limits on travel are a problem.

In Russia, RSCE will typically arrange for all airport pickup and delivery if they have been provided proper notification of numbers of individuals and flight times and assuming you are working with them.

Recommendations:

Lodging: Stay at CTC, if possible.

Plan early, coordinate with CTC, NASA DOR to reserve space and make contingency plans if not available.

Self-sufficiency is encouraged.

CTC Access

- Include "alternates" on access list requests
- Allow 8 weeks for hardware shipment (nominal), with a buffer prior to hardware use.
- Select a customs facilitator, submit a content's list to CTC and the custom's facilitator prior to shipment.
- Notify customs facilitator of shipment arrival in Russia, often saves 3-4 days.
- If hand-carrying hardware, be prepared to clear the shipment through customs if it is confiscated at the airport (identical process to clearing standard shipment, normally takes at least a day).

A detailed guide, and briefings or courses are required to define the process, documentation, and tracking required for shipping to Moscow for those individuals that are integrally involved. Confusion and unclear requirements have contributed greatly to the delays in shipping/delivery of hardware to Moscow.

All hardware being shipped should be listed on a joint protocol, which includes information:

- hardware nomenclature
- value
- mass
- quantity
- type - flight, ground, test
- whether hardware is to be returned to US;, when to be returned
- be processed through JSC shipping (B420).

If items are to be hand carried, provide detailed information on flight arrival and provide names of those who will be responsible for carrying the hardware aboard the plane. Request customs clearance organization presence at the airport upon arrival.

If items are to be sent via air cargo, provide copies of air waybill and shipping documents to cognizant technical manager and to the customs clearance organization.

In all cases, verify that all documentation is filled out accurately and price and weight of boxes is included and that ALL documentation is consistent. Follow up on all FedEx or FAX transmittals to ensure that recipients have received all information necessary to process customs documentation.

Involve personnel who will receive the hardware in Moscow in the process of packing equipment once it has been delivered to Building 420.

Shipping crates should be no larger than what can easily be handled manually by 2-3 individuals. No equipment (lifts, tractors, etc.) are available for handling hardware once it arrives at the RSCE facilities.

A permanent person may be needed in Moscow just to expedite the clearance of hardware from customs. It is impossible to work the customs issues from the US.

Always get receipts when paying customs duties. Customs officers and RSCE personnel appear to charge for their own time as well as for real duties.

Russian language introduction needed for all travelers.

Hearing on the Status of the International Space Station Program
6/18/97

before the Subcommittee on Science, Technology and Space
Committee on Commerce, Science and Transportation
United States Senate

HEARING SUMMARY:
6/20/97

Subject: Hearing on the Status of the International Space Station Program.

Members Present Chrm. Frist (R-TN), Senator Hutchison (R-TX), and Full Committee Chrm. McCain (R-AZ)

Chairman Frist conducted the hearing on the current status of the the International Spce Station (ISS) program. He cited his concerns with the program: (1) the recent reallocation of funds from shuttle to station; (2) the Russian portion of the program; and, (3) the contingency plan in case of Russian non-compliance.

Mr. Goldin was the witness in the first panel; his testimony focused on the prograss made at the Heads of Agencies meeting in Japan and the cooperation that has been achieved with our international partners. He also commented on his concerns about the performance of the Station prime contractor, whose costs for the past 22 months for work performed have continued to climb. Questions from Chairman Frist, Senator Hutchison, and Committee Chairman McCain focused on Russian participation and concern for their ability to contirbute as planned, the possibility of legislating a cost cap for ISS, and a possible Congressional review and/or redesign of the ISS program. Mr. Goldin agreed to work with Congress on any reviews that the Congress may feel necessary, but said that he felt the program would not be able to endure another redesign. He stated that he had no disagreement with the Government Accounting Office (GAO) testimony which would be presented in the second panel of the hearing by Mr. Thomas Shulz. Chairman Frist asked if the ISS program costs were crowding out science programs, to which Mr. Goldin responded that NASA hasn't had as strong a science program as it has today in a decade. The Administrator asked that NASA's science program be measured by how robust the science is rather than the amount of dollars being invested. Chairman Frist also asked if there were sufficient reserves in the Station program at this juncture, to which Mr. Goldin responded that the situation is very tight; NASA will be doing an analysis with Boeing over the next month and will have a more accurate assessment sometime in July.

The second panel consisted of Thomas Shulz, Associate Director, National Security and International Affairs for the GAO; Marcia Smith, Specialist in Aerospace and Telecommunications Policy for the Congressional Research Service; and Dr. Larry DeLucas, Director of the Center for Macromolecular Crystallagraphy at the University of Alabama, Birmingham. Tom Shulz testified about the pending update to the GAO report on the ISS program, which concludes that if costs continue to increase, threats to reserves increase, and the Russians don't comply, ISS would have to be delayed and would increase costs. The risks have increased due to the 8 month delay caused by the Service Module delay. He testified that cost controls by the prime contractor have worsened and that unless action is taken, will continue.

Marcia Smith was asked to testify in response to the questions: Why are we building an International Space Station? What are its goals? She cited the following reasons: (1) next logical step in the space program; (2) direct and indirect creation of 40,000 jobs; (3) foreign policy, preeminence in space; and, (4) program; (2) direct and indirect creation of 40,000 jobs; (3) foreign policy, preeminence in space; and, (4) space lab for life science, biomedical, and materials research. She stated that Congress and the international partners continue to support Station and, barring unforeseen catastrophe, we can expect that support to continue. However, the current focus on who has caused the cost overruns diverts attention from the fundemental question, which is where will increased resource requirements for Station come from after FY 1998? She listed 4 possibilities: (1) an increase in the overall NASA budget; (2) money transfer from other NASA programs; (3) stretch in the delivery date; and, (4) a redesign to fit the $17.4 billion cap. She thinks that as long as there continues to be strong support for the program, we should focus on how to budget, not on the $17.4 billion cap.

Dr. DeLucas testified on the benefits for space research, and described how some protein crystals require a month to fully develop, which would require a space station rather than a 10-day shuttle mission to accomplish. He described the Commercial Space Center (CSC) in Birmingham which he runs, funded partially by NASA and partially by industry. He predicted that within one year after ISS is finished, scientific research will exceed everything done on all the shuttle missions to date.

Questions from Chairman Frist for this panel focused on the commercial aspects of the CSC and the future commercialization of the Station, the possibility of a cost cap, and the savings to the program by Russian participation. Tom Shulz described NASA's budgeting process as having "gimmicks" and recommended a review of all costs in order to develop a realistic cap. He stated that "earlier is better" and that this hearing helped in reaching that goal. Chairman Frist concluded the hearing by thanking the witnesses for their work in reaching the same common goal.

Statement of
Daniel S. Goldin
Administrator
National Aeronautics and Space Administration

before the

Subcommittee on Science, Technology and Space
Committee on Commerce, Science, and Transportation
United States Senate
June 18, 1997

Mr. Chairman and Members of the Subcommittee: I am pleased to present my statement for the record regarding the current status of the International Space Station program.

We have overcome many challenges since President Clinton asked NASA, in the spring of 1993, to redesign the Space Station. Development progress has steadily and aggressively advanced toward the on-orbit assembly of this unprecedented international orbital research facility. Our steps have taken us far, and we are nearing the doorway to the future of human space exploration.

With fifteen international partners, twenty-six collective hardware providers, launch sites in Tanegashima, Japan; Kourou, French Guiana, Baikonur, Kazakhstan; and the Kennedy Space Center here in the U.S., the Space Station program rivals the complexity of any the Agency or Government has ever undertaken. This is a very large program with a very demanding and challenging task of building, testing, outfitting, launching, assembling in orbit and operating a 900,000 pound engineering marvel. The journey hasn't been easy. We have overcome many challenges internationally, as well as here in the U.S. But, as we approach the two-thirds completion mark of the development program, I am happy to say that our international partnership remains solid, our development activities are largely on track, and our research capabilities upon completion of assembly are being enhanced.

Phase 1

While the first phase of preparation for International Space Station (ISS) assembly and operation is still underway at this time, I can already state with confidence that we will certainly meet the objectives set originally for this joint undertaking with our Russian partners.

As you will recall, the Phase I program objectives intended for us to capitalize on existing U.S. and Russian space assets and know-how by (a) learning to work with the Russians; (b) reducing the risk on the ISS program in areas of technology and assembly/operation procedures; and, (c) utilizing the space station Mir for conducting early science research requiring longer duration than provided by Shuttle missions. By exercising crew exchanges, science research, hardware delivery, on-board repairs and servicing, and operational testing, we have in all of these categories gained much more from our collaboration with Russia than many experts expected at the outset.

Since the flight of Dr. Norman Thagard to Mir on a Soyuz launcher in March 1996, American astronauts at this time have maintained a continuous presence in space for over 430 days. With the rendezvous and docking of Space Shuttle Atlantis/STS-84 on May 16, we have now successfully conducted six of nine planned Shuttle/Mir docking missions, in addition to one earlier rendezvous mission. Both on the ground and in space, U.S. and Russian engineers and spaceflyers, as a result of performing joint operations, have developed mutual understanding in spite of historically dissimilar design philosophies, and established close rapport despite cultural differences. Through the Shuttle/Mir program, we have accomplished more days with U.S. astronauts in space that we were able to accumulate over the last 10 years in the Shuttle program. It is this long-duration flight experience that is so valuable in preparing us for the ISS and further human exploration of the universe.

The important lessons that we have learned from Phase I derive from the fact that Mir, unlike the Shuttle and its relatively short-duration operations in space, has circled Earth for well over eleven years (Mir Core launched: February 20, 1986). The difference is notable, comparable to the operation of a airplane versus that of a ship at sea. If a problem on a plane develops, one lands for servicing as soon as possible, On a ship, corrective actions and necessary maintenance, including the change out of faulty equipment can generally be conducted at sea. Only in an extreme emergency would one make use of the lifeboats to evacuate. The International Space Station will be very similar to operation of a ship. The manner in which research is conducted follows similar lines. The Shuttle science is task-oriented; we conduct science for two weeks at a time in space, and spend an enormous time in preparation. Hence, we have developed procedures to address specific tasks scheduled to be performed on a mission or which might occur in-flight. The Russian cosmonauts train to be skill-oriented, and have used their advantage in long-duration missions to learn how to live and work effectively in space. This difference makes the Mir an excellent early model for building and using the ISS. Starting from the very beginning of a typical Shuttle mission to a space station, we have gained experience in preparing and stowing cargo for efficient unloading and transferring, proved the feasibility of maintaining the critical 5-to-7 minute Shuttle launch window, verified rendezvous and docking operations of massive space vehicles using newly developed technology and procedures, and gathered experience in joint ground and mission control operations.

Other major lessons, taught us by the joint missions to date, pertain to the intravehicular transfer of life support and consumables supplies, delivery of science equipment, transfer of bulky repair and servicing apparatus and tools, such as the Elektron oxygen generator or the vacuum cleaner on STS-84, and the development of joint EVA techniques, including the first-time use of a new Russian spacesuit by an American crewmember. Along with successfully conducted joint science experiments, the mutual development of detailed multilingual design and operations documentation, the joint resolution of safety and acceptance testing differences, and the performance of special risk mitigation experiments in support of the ISS, such as a demonstration of the Active Rack Isolation System, these accomplishments place us into an excellent position for initiating and conducting the assembly and subsequent operation of the ISS with richer experience, reduced risk, greater confidence and in all likelihood reduced learning-curve expenditures in time and costs.

Thanks to the Phase I program we have been able to test schedules for long duration (Mir) and short duration (Shuttle) crew work-rest cycles during the docked and undocked phases of missions. Based on our Mir experience, we are adjusting our training protocols to focus on skill development rather than focusing on specific tasks as we have in the past, and we are improving and expanding our capacity for in-flight training on long-duration missions. We have learned some very important lessons in human factors and the importance of cultural support and have modified our operations accordingly. We have sharpened our criteria and work procedures for safety, hardware, and personnel issues, and we have cooperated to establish international health care requirements. We are using Mir to investigate how to maintain the health of crews living in space over extended periods, and how to manage readaptation to gravity on return to Earth. We are learning about reliability, maintenance and unforeseen repairs of onboard systems, as well as long-term aspects of crew safety considerations, identifying risks and developing remedial procedures.

Let me dwell a moment longer on the crucial subject of onboard repairs. Mir is an aging spacecraft that has long exceeded its original design life and is exhibiting an increasing number of in-flight anomalies. We have assured ourselves that these equipment malfunctions, which may reoccur in the future, generally do not constitute a safety of flight concern. While the reliability of several Mir systems has been observed to be degraded, Mir itself has, over the last several years, actually grown in its robustness due to redundancy added by the newer modules. Problems such as an in-flight anomalies in a gyrodyne attitude control unit, the failure of a carbon dioxide scrubber and of an oxygen generator, or coolant loop leaks due to corrosion in the aluminum alloy pipes do present operational challenges. They are certainly not insignificant and require remedial attention, but they do not pose major safety concerns. In fact, since this type of equipment deterioration can be expected to also occur on the ISS during its later stages of operation, dealing with it on board Mir provides us an early learning experience in handling such emergencies and developing procedure for repairs, containment, control and, if necessary, evacuation to protect the health and safety of the crew. Even a real emergency situation like the onboard fire in the secondary solid-fuel oxygen generator on February 23, 1997, proved to be easily manageable by the cosmonauts because they were well trained and equipped for such an eventuality, with a nominal, reliable way to return to Earth remaining available at all times.

Let me assure you that no one is more concerned about the safety and well-being of our astronauts than myself and our NASA and industry team. And I might add that our joint experiences with our counterparts at the Russian Space Agency (RSA) and its industrial suppliers indicate that they share that concern to no lesser degree. NASA and RSA flight surgeons and systems experts are monitoring the Mir missions from Houston and Moscow day and night, just as we do Shuttle missions, and they feel keenly responsible for protecting the health and safety of the humans on board. And let me repeat that the crew has the means to come home at any time, should a serious safety concern make it necessary, just as it will be able to do during ISS assembly and operation, using the Russian Soyuz spacecraft in the early years and the planned Crew Return Vehicle (CRV) after completion of the assembly.

The Mir is not one hundred percent safe. Space exploration is dangerous by its vary nature and the safety of the crew can not be guaranteed. However, their safety will always be maintained within an acceptable level of risk.

The mechanical problems have been, or are in the process of being addressed. Prior to our decision to launch astronaut Mike Foale to Mir on STS-84 this May, the NASA Shuttle-Mir Program Manager, Astronaut Frank Culbertson, conducted his own internal safety review, as did my Associate Administrator for Safety and Mission Assurance, Astronaut Fred Gregory. Lieutenant General Tom Stafford was also asked to lead an independent assessment of the Mir's safety. Their assessments all validated the continued U.S. presence on Mir, clearly indicating that the crew transfer to replace Jerry Linenger with Mike Foale should proceed as planned. In addition to delivering Astronaut Foale, the Shuttle delivered a replacement oxygen generation system and other equipment to enhance the Mir's life support capability.

Both the U.S. and the Russian side have grown through this continuing process of joining our space activities in Phase I to an ever-increasing degree of effectiveness. The problems which we have jointly overcome have increased our confidence in each others decision-making and action-taking ability. Thus, as intended by the Phase I program objectives, we have strengthened our capability to deal with on-orbit situations which will undoubtedly arise with the ISS and for which we, unlike the Russians, have had not much experience before. I am therefore greatly pleased to call, as of now, our Shuttle/Mir cooperation with the Russians an unequivocal success.

As a precursor to ISS development and operations, the Shuttle-Mir program has been essential. But it has provided much to the scientific research community as well, demonstrating that future ISS science will support space missions while helping to improve the quality of life for our citizens here on Earth.

We continue to develop and test our medical countermeasures using data and experience on Mir. Long-term observations on Mir are helping to shed light on the mechanisms behind space-induced bone loss. Bone loss in space flight is similar to bone-loss associated with aging and osteoporosis, but researchers have yet to determine if the underlying mechanisms are the same. Continued study of accelerated bone loss in space may lead to valuable insights into the treatment of conditions like osteoporosis that affect millions of people on Earth.

New technologies demonstrated on Mir have substantially increased the number and quality of crystals grown in protein-crystal growth experiments. Researchers grow protein crystals on orbit in order to define the structures of proteins. They use structural information for developing drugs. Major drug companies are already using information from protein crystals grown in space (though not necessarily on Mir) to develop drugs for improved treatment of diabetes, to reduce inflammation associated with open-heart surgery, and even to help treat influenza. Many important proteins take weeks or longer to crystallize, so long-duration platforms like Mir and the International Space Station are ideal for that type of research.

Astronauts have planted and harvested dwarf-wheat crops using Russian/NASA equipment on Mir, improving our understanding of what will be needed to grow food in orbit or to integrate plants into life support systems. Plant research in space promises to help us better understand plant growth and development here on Earth as well. For example, studying plant growth on orbit is helping researchers to identify and understand the process by which plants produce lignin, the primary constituent of wood, in response to gravity and other source of mechanical stress. This information may be applied to future efforts to develop more productive plants for forest products and agriculture.

NASA has developed a revolutionary system for culturing cells by suspending them in a rotating bioreactor to simulate the effects of low gravity. On the ground, this system has enabled researchers to grow much more realistic tissue samples for research including cancer tumors, cartilage, and tissues from the lymphatic system used in the study of AIDS. (Traditional methods for culturing these tissues generally produce thin films of cells that do not reproduce any of the three dimensional structure of the original tissue.) The full potential of this bioreactor technology for growing tissues outside the body is now being achieved on Mir as researchers have completed the first long- duration experiments in low gravity. This research may lead to deeper understanding of how cancer tumors grow and develop, how diseases like AIDS infect the tissues of the body, or even how tissues like cartilage for transplant surgery may be grown. An overview of this work appears in the May/June 1997 issue of Science and Medicine.

BION

Cooperation with the Russian Space Agency includes life sciences research conducted aboard Russia's uncrewed Bion spacecraft. Bion satellites, developed by the Russians, fly biological experiments with primates, rodents, insects, and plants in near-Earth orbits. In very general terms, the major objectives of the Bion biosatellite investigations are to study the biological effects of low gravity and the space radiation environment on the structure and function of individual physiological systems and the body as a whole.

U.S. participation in the last nine Bion missions has provided a major source of space flight opportunities for the U.S. science community and has complemented the Space Shuttle program. The Bion program has resulted in the flight of more than 100 U.S. scientific experiments and the publication of more than 90 peer-reviewed scientific papers. It has accounted for one half of all U.S. Life Sciences flight experiments accomplished with non-human subjects.

As a result of the unexpected post-flight death of a Rhesus monkey following the successful flight and landing of Bion 11, NASA has suspended its participation in primate research on the next planned Bion mission, Bion 12. NASA's decision was based on the recommendations of an independent review board. The board found that there was an unexpected mortality risk associated with anesthesia and surgical procedures (biopsy of bone and muscle) on the day following return from space. NASA determined that this risk is unacceptable and has therefore discontinuing its participation in the primate portion of the BION Program.

The use of non-human primates is a small but important part of NASA's overall research program that provides valuable and important biomedical and behavioral data. This research will continue. NASA is deeply concerned with the welfare of its animals and is fully committed to conducting its animal research programs in conformance with accepted standards. NASA has an outstanding policy on animal research with official "ethical" standards. This was recently recognized by the National Institutes of Health Office for Protection from Research Risks (OPRR). On May 30, 1997, the OPRR issued a statement saying:

We are pleased to call your attention to an important new development in the ethical consideration of animals in research from the National Aeronautics and Space Administration (NASA).
In March 1997, NASA promulgated the enclosed document, "NASA Principles for the Ethical Care and Use of Animals." It is intended to guide careful and considered discussion of the ethical challenges that arise in the course of animal research under NASA's auspices. You may find it useful in your endeavors, as well.

NASA will continue studying the effects of post-flight anesthesia and surgery. Bion 11 created profound implications for clinical care in-flight and post-flight. The need for additional research and new technologies is imperative to address these important questions. Some of that research will include biocomputation and appropriate subjects including primates when such experimental models are scientifically justified. I would like to underscore that NASA's decision to withdraw from primate research in Bion 12 was not the result of any external pressure.

With the exception of Skylab, our thirty-six year old Space Program has consisted of relatively short-duration flights. Medical capabilities on board those flights have consisted primarily of equipment, medications, and techniques almost identical to standard Earth-bound medical care. We have focused primarily on first aid and temporizing measures and an emergency return capability. The NASA's stringent astronaut physical selection process, exhaustive training, and superior engineering have kept the number of in-flight medical events to a minimum and of a benign nature only. However, these short-duration flights have not allowed the full impact of the physiological adaptation process on the human body to become manifest.

As has been true throughout the history of medicine, the unanticipated death of a biological subject, in this case the primate of Bion 11, has taught us, as most biological research does, an invaluable medical lesson, now highlighted by our sense of urgency to understand and learn from this infrequent but medically catastrophic event. We highly value the contribution it will make to the future of medical science for the space program. This unanticipated anesthesia-related death on the first day after return from space has spurred us on to measures which we feel will enhance the health and safety of our flight crews in Space and upon return to Earth, a priceless lesson learned. We have analyzed all prior events with primates and rodents, reviewed all the biological specimens from our data archives and worked very closely with the experts at the Armed Forces Institute of Pathology. We also requested that medical experts conduct an independent review of the above findings and existing procedures of medical care to recommend future directions, both in research and medical practice, to take care of astronauts returning from Space.

With the help of the Aerospace Medicine and Occupational Health Advisory Subcommittee, chaired by Dr. Ronald C. Merrell, Chief of Surgery at Yale University Medical School, we have outlined changes to the monitoring and rehabilitation program of returning long-duration flyers, beginning with Dr. Jerry Linenger, who just returned from an extended and challenging stay onboard the Mir. In addition, should Dr. Linenger or any other returning long-duration flyer require anesthesia in the immediate post-flight period, we will now treat them, not as anesthesia Level One risks, as their outward health might suggest them to be, but as anesthesia Level Four risks, similar to patients with autonomic dystrophy (failure of nervous system control) and myocardial impairment (advanced diabetics for example). Such patients are routinely and successfully managed in operating rooms all over our country.

In addition to the immediate changes made to the post-flight health care regime, and going beyond the excellent fundamental research still slated to look closely at the physiological changes which I alluded to above, we also must ascertain if medications and techniques which we use for certain illnesses on Earth are adequate for related conditions in space. Will the proper antibiotic to treat pneumonia on Earth be similarly absorbed, distributed through the body and successfully address an infection in an astronaut whose immune system may be altered by space flight? Will critical care techniques for patients whose infections may have progressed to sepsis succeed in microgravity?

The challenges for developing an adequate space medicine capability for long-duration missions are substantial. Modifying Earth-based models of clinical care for application in space is not a simple process. To adequately address clinical care, we must have an adequate knowledge base for dealing with the classical triad of medicine: prevention, diagnosis, and treatment. Clinical equipment must also be developed and proven to function in the space environment. Finally, the skills to practice medicine in space must be developed, maintained, and constantly improved upon.

A key to the success of the process of establishing this capability is to develop an ongoing program utilizing human subjects, animals, and computer models (biocomputation) as well as to establish a group of properly credentialed physicians and other paramedic equivalent providers with appropriate knowledge, skills, and training in the practice of medicine in the extreme environment of space, as well as post-flight here on Earth, and on the surfaces of other planets. In order to assure that medical risks are addressed, medical errors are avoided, and no life is lost due to negligence, this group of health care providers must have experience in space flight. They must understand the space environment more fully and must be able to apply and attempt to validate the treatments devised. Our medical operations team at Johnson Space Center is hard at work developing a plan of medical research and training. This plan, which will also involve other NASA Centers, such as the Ames Research Center, will define the best methods to seek this new knowledge and how best to utilize the time and capabilities of those health care providers once in space.

Now America, along with our international partners, is preparing to undertake long-duration space flights. Much valuable research has been, and will continue to be directed toward understanding the physiological changes the human body undergoes during space flight. That research will answer those significant unanswered questions which remain. Despite the physiological adaptation process, this work will allow modified Earth-like medical treatment and medications to achieve usefulness in space and upon the return of an astronaut to Earth, and ultimately achieve medical autonomy on missions beyond low-Earth orbit, where rapid return to Earth is not possible. We are also proceeding to establish a formal review process to provide periodic accreditation for our standard of medical practice and care. To achieve this goal, we are working with the American Medical Association and the Joint Commission for Accreditation. (International).

International

I have just recently returned from a meeting in Tsukuba, Japan, with the heads of the other space agencies involved in the International Space Station. This was our first meeting since 1994, when early progress on incorporation of Russia was the primary focus of discussion. The heads of agencies acknowledged the major achievements and progress made, emphasized the importance of the utilization potential, and reconfirmed the significance of the International Space Station for the future of humankind. The heads of agencies also agreed that the necessary plans are in place to move ahead, unanimously affirming their resolve and commitment as a partnership to make the International Space Station a reality.

Canada, Europe and Japan have proven their commitment to this international venture for humankind, investing nearly $6 billion to date for design and development of their hardware contributions.

In late 1995, the European Space Agency (ESA) confirmed its commitment to a three-component ISS contribution: the Columbus Orbital Facility (COF), the COF utilization plan and the Automated Transfer Vehicle which will be launched by Ariane 5 and provide pressurized or unpressurized logistic-services and reboost activities for Station. In March 1996, the ESA entered into the largest single contract in ESA history for development of the Columbus Orbital Facility (COF). In exchange for Shuttle launch services for the COF, NASA and ESA have reached an agreement in principle on the provision of Nodes 2 and 3 and utilization facilities. ESA and NASA are also currently studying joint participation on the development of a crew return vehicle.

The Japanese program is solid and on track with its contributions of the Japanese Experiment Module (JEM), the JEM Exposed Facility, and the JEM Experimental Logistics Modules. The JEM Pressurized

Module Engineering Model and the Qualification Test Article arrived at the Tsukuba Space Center in late April from Mitsubishi Heavy Industries' Tobishima Plant in Nagoya. Post-delivery activities, including ground support equipment setup, hookups and connections, have began and will continue through mid-June. The JEM Exposed Facility engineering model system test is continuing at IHI Mizuho. Preparations have been completed for system level testing for the JEM robotics systems over the next several weeks. NASDA is also working with NASA to offset the Shuttle launch services costs associated with the JEM assembly flights through the provision of the Centrifuge and associated hardware and services. We expect to sign an agreement in principle shortly. NASDA also desires to use its H-2 Transfer Vehicle (HTV) to offset common operations obligations and is engaged in discussions with NASA in this regard.

Canada's key contribution to the ISS is the Mobile Servicing System (MSS). The MSS, consisting of a mobile base system, two manipulators(the Space Station Remote Manipulator System (SSRMS), the Special Purpose Dexterous Manipulator (SPDM)) and a Canadian Space Vision System will be used in the construction and maintenance of the International Space Station. The SSRMS will be a new-generation manipulator featuring seven motor driven computer controlled joints. The SPDM, having the fidelity of a human hand, will augment the robotics system already being provided by Canada with additional capabilities to carry out on-orbit maintenance and operation of the Space Station. Canada is making good progress across the board, with Canadian Government approval of funding for the Special Purpose Dexterous Manipulator (SPDM) having just been recently secured in spite of constrained budgets. This underscores their commitment to this program.

The Russians, in the face of tremendous economic challenges, have experienced serious difficulties in meeting their commitments. They have missed a number of development milestones for their ISS contributions, including the delivery of the Service Module (SM) which has been delayed from April to December 1998. This issue was addressed at the highest levels of both U.S. and Russian Governments and top-level Russian officials committed that adequate funds would be provided in 1997 to keep Russian elements on track.

NASA initiated contingency plans to provide an Interim Control Module last December to protect for further Service Module delays. Prior to the Space Station Control Board (SSCB) held on May 14th, NASA and its partners agreed on the need to baseline a single assembly sequence to bring stability to the program and avoid the costs and inefficiencies of parallel paths. Russia was informed that baselining the Service Module launch for December 1998 was NASA's preferred approach, but that decision would be made only if Russia met the following criteria: Russian contractors' receipt of Russian Government funding in April and May 1997; completion of a Service Module General Designer's Review; and, satisfactory progress by Service Module subcontractors to support a December 1998 launch.

RSA's total funding for ISS in CY 1997 is to total 1.8 trillion rubles. This is to be comprised of 300 billion rubles through RSA's normal budgetary processes. In addition, 1.5 trillion rubles in supplemental funding to the RSA budget for its Space Station contributions has been approved through the Ministry of Economic Development. The 1.5 trillion rubles in supplemental funding was to be provided in two increments -- 800 billion rubles by the end of May, with another 700 billion rubles to be provided later. RSA expects the process for obtaining the additional 700 billion to be defined by the end of June 1997.

Prior to the SSCB, RSA had received over 900 billion rubles in CY 1997 funding for the ISS. Of this amount 188 billion rubles was through the normal RSA budgetary process, the rest coming from the supplemental funding. RSA had distributed 217 billion rubles to Energia and 217 billion rubles to Khrunichev, the primary two Russian companies supporting the RSA. The remainder of the funding is being distributed to other enterprises according to contracts approved at the General Designer's Review.

The Service Module General Designer's Review, held on April 24, 1997, with RSA, RSC-Energia, Krunichev and all major subcontractors (over 40 companies) reconfirmed that there were no known technical impediments to completion of the Service Module in support of a December 1998 launch. NASA senior managers were in attendance during this open and candid review which focused on technical issues. Schedule milestones were reviewed in detail and all Russian parties stated that the current Service Module schedule for a December 1998 launch is feasible. They then committed to the schedule execution necessary to hold this launch. As a result of the GDR, we now have a signed overall Service Module schedule and detailed delivery schedules for the subcontractors.

At the May 14 SSCB meeting , in conjunction with all of our international partners, we officially rescheduled the launch of the first element, the Functional Cargo Block, to June 1998. This was done in order to work around the Service Module delay to December 1998. The reason for this action was that the U.S.-owned Functional Cargo Block (FGB) is designed to perform critical control and stability functions for only the first several assembly flights. The Service Module, upon its delivery to orbit, then takes over these functions until arrival of the U.S. Laboratory Module. Unfortunately, as currently designed, the FGB cannot adequately provide control functions for the assembly sequence beyond the arrival of the U.S. Node. The FGB's on-orbit avionics and fuel reserves would also be stretched beyond acceptable limits, if we were to continue to hold its scheduled November 1997 launch date. As we will not expose flight hardware to unnecessary risks, the first element launch was delayed.

The assembly sequence baselined at the May 14 SSCB provides for the Service Module launch in December 1998, in lieu of a U.S.-developed interim control module. This decision reflected a renewed confidence by all the international partners that Russia will deliver its commitments on schedule. There were many factors that the U.S. and the other partners considered in making this decision, but, it was ultimately based on a visible and concrete demonstration by Russia of their resolve. This doesn't mean NASA will slow down work in an Interim Control Module. We will continue its development to support a December 1998, reviewing Russia's progress this fall to determine whether the Service Module remains on track.

The Service Module delay imposed slips in launch dates for all the partners. While a six-person permanent habitation capability is still scheduled for the year 2002, the delay has now pushed the completion of assembly into 2003. We have spread the schedule impacts as equitably as possible. The partners are in agreement with the new assembly sequence and International commitment to the program remains solid.

At the Tsukuba Heads of Agencies meeting, the outcome the SSCB meeting was discussed and endorsed. While acknowledging that the program delay embodied in the new assembly sequence had adverse impacts on each of the participating nations, the heads of agencies collectively confirmed that moving to the new assembly sequence was a logical and necessary decision. A broader strategy to mitigate assembly delays and other impacts from recent program developments was also endorsed, including consideration of collaboration on additional utilization missions to minimize the impacts to on-orbit research programs resulting from the assembly schedule slippage. All expressed the determination to strive for long-term stability in the program and to accomplish the International Space Station without further delay.

U.S. Development

The largest international, scientific research facility in history is rapidly becoming a reality. The ISS Program has now passed the 60% milestone completion mark, having built nearly 200,000 pounds of U.S flight hardware. As testing of more design units is completed, we are seeing production runs of hardware and software increase. The final quarter of CY1996 marked the largest increase in the amount of flight hardware built since the Program's inception, over 30,000 pounds. Design and fabrication of flight elements for the first six American flights are almost complete. Qualification testing is well underway across the program and flight hardware is being assembled and checked out. Integrated test and verification planning is progressing well and steps are being taken to provide even more integrated testing at the Kennedy Space Center. The NASA/industry team has worked long hours and demonstrated a true commitment to the American people in delivering the International Space Station. It is important to note that despite manufacturing and testing difficulties, the US Node and Payload Mating Adapters would have been ready to support their originally planned launch in December of this year. Now, the delay in the Service Module and our subsequent deferral of the first two missions until next summer, provides ample time for the final development, testing and check-out of those modules for launch. The additional time also allows us to perform full integration and verification on the ground of flight elements for the first five U. S. flights.

The Space Station Program continues to demonstrate a high level of performance, completing approximately 97% of scheduled work at approximately 104% of budgeted cost. Given the breadth and complexity of the ISS Program, and taking into account the experiences of other major Government development programs, we are convinced that we have demonstrated strong performance.

Nevertheless, the performance of the ISS prime contractor is of significant concern. For 22 months now, the cost for work performed has continued to climb. For the last six months, Boeing and its subcontractors have spent about twenty percent more than planned to perform the contracted scope of work. Boeing is addressing the technical problems identified to date and continues to work hard to solve the myriad of challenges encountered as the program moves through the qualification testing and production phase of the development cycle. They are continuing to make progress in the process. However, the individual product groups and their subcontractors have had higher than anticipated technical and schedule performance problems associated with the delivery of both hardware and software products. This is a complex and difficult undertaking. But, we believe they can improve their planning, scheduling, control process and their execution of their systems integrator responsibilities, bringing and keeping the right level of management experience and tools on the program. Recovery plans will mitigate cost and schedule variances, but the continued cost growth and performance problems have strained near-term reserves and will continue to require the use of reserves in the future. We are not faulting the people at Boeing and its subcontractors for lack of dedication, they have provided outstanding support. We will continue to work closely with Boeing corporate management to ensure that required corporate assets are available to this critical program and that the necessary levels of management experience and tools are applied. Although Boeing has had some performance problems in the past, I am encouraged by recent discussions I have had with the Chairman of the Board and Chief Executive Officer of Boeing.

As we approach the Congressional Budget decisions for FY 98, we recognize our challenge to manage within our available resources will be greater than ever before. We have just agreed to a new assembly sequence that addresses the Russian Service Module delay. While the assembly schedule has slipped, we are attempting to hold many delivery schedules to their original dates. This should allow us to transition people of the program or onto other tasks. It should also allow us to achieve hardware-to-hardware integration and verification tests at the Kennedy Space Center for the first flights. But, not all the details, including the total cost of these changes has been worked out. We are also in a critical phase where a considerable amount of hardware is being assembled and tested, and software is being developed, integrated and checked out. Further, peak manufacturing and testing activity is occurring through 1998, the same year when we will now start on-orbit assembly. The potential for unforseen challenges to our cost and schedule targets is extremely high. We have at the close of fiscal years before, faced financial challenges which we have fortunately overcome. Our management flexibility will again be challenged, but there is less certainty that we can meet all of the cost, schedule & technical goals for FY 98. As we proceed over the next few months and develop a better understanding of the funding situation, we will continue to keep you fully informed.

It is certain that the program does not have adequate reserves built into the total development estimate to address Russian contingencies, which I will address later. There is also the issue of the impact the Russian delay has had in pushing completion of the assembly sequence beyond 2002, which must be addressed. Clearly, the drawn out timeframe for development and assembly will increase program cost. The exact extent of this cost is being worked. NASA has made decisions independent of the Russian delays that must be considered in determining cost accountability. The delay also requires adjustment of the schedule for achieving full operational capability, for which it is too early to determine all the financial implications.

Alternative Research Flight Opportunities

The schedule changes resulting from the eight-month delay of the Russian Service Module have impacted both assembly and utilization flights. We are evaluating the addition of up to three Shuttle missions for the purposes of bridging the utilization gap created by the delay. These utilization missions would provide a continuing opportunity for our research and private sector communities in the areas of commercial space product development, life sciences and microgravity research. They would also provide opportunities to continue to test some of the capabilities to be deployed later on the ISS, including more extensive teleoperations and telescience. For the first mission, the Research theme would be biotechnology with specific research efforts in protein crystal growth/structure-based drug design, cell culture and plant studies. The two additional missions would focus on the areas of microgravity research and life sciences with contributions from other disciplines, including commercial research. The theme of the microgravity research will be an extension of the Microgravity Spacelab mission objectives in combustion, fluid physics and biotechnology, while the theme for the life sciences would be a better understanding of the aging process. Both missions will have the possibility for contributions from other disciplines including commercial payloads. The missions would be shared with our international partners, but nominally on a cost sharing basis. We are also looking at increased access to the Space Shuttle middeck for small payloads and studying the feasibility for additional flights using robotic missions. In the event such opportunities emerge, we intend to invite international and commercial participation in order to minimize cost impacts.

Contingency Planning

The events that have taken place in Russia over the last few months have resulted in an increased confidence in their ability to meet ISS commitments, specifically, the delivery of the Service Module. They have begun to demonstrate through concrete actions what it will take to deliver on their commitments. In turn, we, along with our International partners have baselined the Russian Service Module for launch in December 1998. This does not mean that we now have complete confidence in Russia's ability to deliver the Service Module. What it does mean, is that the risk to its delivery schedule has been sufficiently lowered, to the extent that it is now within an acceptable margin. While it appears that FY 1997 funding for the Service Module is being applied, continued uncertainties regarding Russia's long-term ability to maintain necessary funding will exist for some time. We are not so confident in Russia's ability to secure funding that we will chance further Russian delays, without having a reasonable fallback to protect schedule.

Quite frankly, contingency development has been extremely difficult for NASA because we have confronted, in effect, a moving Russian baseline for over a year. While I am certainly not pleased with the delay in the delivery of the Service Module, the experience of the last year and a half has taught us quite a lot about working with our partners to mitigate the impact of funding problems. In the process, we were able to fund some contingency activities, but, until a few months ago, we had neither sufficient insight into the status of Russian funding nor did we have confidence in the true arrival date of the Service Module. As a result, it was only recently that we were able to determine a clear course of action, in close consultation with our international partners, that would minimize the impact on the partnership caused by the delay of the Service Module. I have instilled in my management team the need to maintain close scrutiny on the Russian situation in order to act quickly should the Russians again have difficulty in meeting their commitment to the ISS. With limited near-term reserves available and with our focus on meeting schedule commitments, it is imperative that we continue to refine our contingency plan. Let me assure you, contingency planning for the case of potential problems among our partners is receiving constant attention. To ensure that the partnership moves forward in the event of unforeseen problems on the part of any partner, we have developed a contingency strategy that will allow the program to continue the assembly phase under a variety of circumstances, including renewed Russian funding shortfalls.

In April, I informed the Congress of NASA's plan to reallocate $200 million in FY 97 funds within the Human Space Flight account to a new budget line item -- "Russian Program Assurance" -- at no change to NASA's total budget. This new line is the source of funds to reduce the cost and schedule risk resulting from Russian uncertainties. This reallocation enables NASA to support the initial steps of contingency plans addressing the Russian uncertainties. Of the $200 million reallocated to the "Russian Program Assurance" line, $190 million is drawn from available program reserves within Space Shuttle Program and $10 million from the Payload and Utilization line. Implementation of these contingency plans is prudent, will not impact the planned Shuttle activities or Shuttle safety, and will likely need to be built upon.

There are those that question why NASA has not come forward with a plan to remove the Russians from the Program. If NASA were to follow through with this suggestion, it would likely result in an increase of billions of dollars for a less capable space station. NASA has no desire to assume the responsibilities of another partner, and has every intention to minimize the cost to the U.S. taxpayer, while at the same time maximizing the return on investment. To realize this, NASA is taking an approach to contingency planning that is similar to the procurement of insurance. For example: one could look at the $200 million being reallocated for Russian Program Assurance as an incremental payment on a risk reduction policy. With it, the United States procures necessary hardware and software to continue the assembly sequence should Russia have further problems delivering the Service Module, reducing the schedule and costs impacts should they not succeed. Thus, we reduce, but do not eliminate, the risk to the program. We continue to carry certain risks, but the onus to deliver remains with the partner.

Rather than take on another ISS partner's responsibility, we incrementally fund only those activities that will allow us to move forward without them. It is a process based on the identification of risks, development of contingency plans to reduce these risks, the establishment of decision milestones and the criteria by which action will be taken, and further implementation of contingencies as necessary. Our ISS partnerships are based on mutual benefits. Should a partner not meet its commitments, a readjustment could be made in the sharing of resources. Ultimately, it is in each partner's interest to meet its commitments. Our approach of setting criteria which need to be achieved, then taking the necessary action to move forward, allows us to maintain the pressure on the other partners to produce. I believe this method has been instrumental in leveraging Russian funding for the Service Module.

Our approach, to some, may appear reactive rather than proactive. Let me assure you, NASA has assessed, and will continue to assess, many possibilities in the development of its plans. The risks and ramifications change with time and with progress in the development of hardware. As such, the specifics of our contingency plans evolve, but there does exist a top level set of decision points, correlating to phased increases in the level of contingency implementation that I would like to lay out for the Committee.

The first step in our contingency planning is already being implemented. This step protects as against a potential further delay in the Service Module up to December 1999. However, we do carry certain risks forward by not baselining the ICM rather than the Service Module for the December 1998 launch. These will increase with time to a point, this fall, when we will need to reevaluate Russia's development progress. We will fully implement the ICM into our baseline plans if Russia's performance on the Service Module is not up to expectations. The cost for this first step is up to $250 million. These additional funds are not going to Russia to have the U.S. taxpayer fund what the Russian government has committed to contribute to the program. These funds will largely be spent in the United States. Work performed in Russia will go to modify the U.S.-owned FGB, and the procurement of an additional docking adapter to assure the Interim Control Module can be accommodated in the assembly sequence.

We may want to make some initial decisions relative to the second step in our contingency plan the early fall. It is important to understand that the ICM provides us only temporary relief should Russia falter. If we do not have either a Service Module or follow-on propulsion supply module in orbit approximately a year after launch of the ICM, we will be worrying about the loss of millions of dollars of hardware already in orbit -- not a mere schedule delay. At this point in time, if there is not certainty as to whether Russia will ultimately deliver the Service Module, it may be prudent to incrementally fund this additional step, thus, buying down the risk inherent with non-delivery of the Service Module. Costs to fully implement the second step of NASA's contingency plan are estimated at three quarters of a billion dollars. However, the funding could be applied incrementally. That way, if the risk of Russian nonperformance diminishes through concrete actions, we can retain the option to discontinue some of this activity.

We now have access to the Russian Space Agency's detailed development milestones. It is my intention to provide an assessment of the risks associated with the delivery of Russian contributions as NASA identifies funding requirements for further Russian contingency activities. It is essential that the Congress be involved in these decisions to either carry forward or reduce the risks to the program.

Beyond the issue of hardware development is the potential that Russia may not be able to fully support, the currently planned number of Russian-funded logistics flights to ISS. Contingency plans to reduce the risks from this threat are forthcoming. We are working with our international partners to determine the extent that the Japanese H2 launch vehicle and the European Space Agency's Automated Transfer Vehicle can be accelerated, as well as developing other options. The availability of these offsets is enabling us to respond in part to changes to the basic infrastructure driven by Russian funding shortfalls. As you are aware, we are entirely reliant on the Russian Soyuz for three person crew return capability until a permanent six person Crew Return Vehicle can became available. A solution to the crew return requirement is being addressed if the Soyuz is not available. We are and will continue studying further options which can be taken as circumstances warrant action.

Shuttle Safety

Let me emphasize the commitment of the entire NASA team to the Safety of the Shuttle as the Agency's highest priority. I am convinced, as are the Shuttle program managers that the reallocation of these funds will have no effect on the safety of the Shuttle Program or on activities planned for FY 1997. The funds are available as the result of careful and efficient performance by the entire Shuttle team, and have been carried separately in the Program Manager's reserves for program changes from the beginning of the fiscal year.

NASA remains unwavering in our commitment to improving Shuttle safety. It has been our highest priority. In 1991, the probability of catastrophic loss on ascent for the Shuttle was one in 78. Today, is one in 248. NASA has achieved a 50% reduction in the number of flight anomalies per flight since FY 1993 from 14.3 to 6.8. The Agency has also reduced the number of monthly mishaps during Shuttle processing at the Kennedy Space Center by almost 50%, from 0.9 on FY 1993 to 0.5 in 1996. At the same time we have worked diligently to reduce Shuttle operating costs. Since FY 1993, the amount of Shuttle processing overtime has been reduced by 37%. This means our teams are not overworked and thus susceptible to making mistakes, and that we are meeting budgetary commitments.

Space Station Utilization

In our intense focus on the day-to-day issues of schedules, budgets, international cooperation and contingency plans, it is easy to lose sight of the ultimate objective of our efforts. We are leading the world in the construction of a space station of unprecedented size, complexity and capability. Upon completion of the assembly phase the research program will enter into a period of steady-state operations with resources of unprecedented magnitude. Research power will range from 26 to 45 kw (compared to 2.5 kw on Spacelab). There will be at least 2 dedicated crew for research operations 365 days per year (compared to 14 days per year on Spacelab). The laboratory volume will house at least 26 payload racks for the U.S. (compared to 7 racks on Spacelab). A 50 Megabits per second communications downlink with simultaneous uplink for teleoperations will be available (efforts are underway to upgrade to 150 Mbps). Finally, five shuttle flights per year are planned for periodic resupply of research samples and equipment. These capabilities will be "on-line" 365 days per year to support continuous research. The international nature of the program will lead to truly premier research, drawing upon the best scientists, engineers, and entrepreneurs from around the globe to engage in the exploration and development of the space frontier and the expansion of human knowledge.

The Research Plan for the International Space Station summarizes the overall objectives and content of the scientific, technological and commercial research program that will utilize the multidisciplinary laboratories, technology testbeds and observatories. The plan enumerates six goals for the research program:

- on an international scale establish an unprecedented microgravity research program in gravitational biology, chemistry, and physics with applications benefiting both life on Earth and development of space;
- facilitate the development of an international industrial collaborative test bed program in engineering and space operations to enable the study of infrastructure and technology for human research & development;

- increase the knowledge base of biomedical responses of humans living and working in the space environment on a routine basis, in order to enable the next generation of space travelers to pursue exploration and development of space and to improve medicine hear on the ground;
- foster private sector investment and utilization of space, either on-orbit or using knowledge gained from the unique environment of space, for terrestrial applications;
- establish the station as a unique vantage point for conducting Earth science, space physics, astrophysics and planetary research programs on an international scale to further civilization's understanding of our world and the universe; and
- bring together the world community in this historic endeavor through government, academic, and private sector cooperation to revolutionize the approach to exploration and development of the space frontier.

International Space Station research will provide research benefits including: improving industrial processes on Earth, providing a better understanding of health and the aging process, and helping us to develop concepts for innovative new materials of the future. Orbital research is a source of technological innovation for application both on Earth and in Space. The Space Station will also be a platform for engineering research and for learning how to live and work in Space. We will learn how to assemble and sustain large structures in space and vastly improve our capabilities for providing medical care and support for long duration space crews. Orbital research on controlling the physiological effects of space flight and providing regenerative life support systems is a prerequisite to future human missions of exploration.

Biomedical Research:
"The Space Station is not a luxury any more than a medical research center at Baylor College of Medicine is a luxury." "Present technology on the shuttle allows for stays in space of only about two weeks. We do not limit medical researchers to only few hours in the laboratory and expect cures for cancer. We need much longer missions in space--in months to years--to obtain research results that may lead to the development of new knowledge and breakthroughs." Dr. Michael DeBakey, Chancellor and Chairman of the Department of Surgery, Baylor College of Medicine

The human body has evolved to operate in ordinary Earth gravity (1g). When people orbit the Earth, they experience a new gravitational environment which is unanticipated by our evolutionary history. Nearly every system in the body is affected. For example, when the body is released from the downward pull of gravity its fluids shift upward toward the head. This shift causes changes in hormones and nervous system responses and causes red blood cell production to change and the heart, lungs, and kidneys to make adjustments. Eventually, the number of red blood cells in the body begins to decrease. Meanwhile, the organs and systems that the body uses to balance and orient itself are receiving conflicting signals from the environment. Later in flight, muscles begin to atrophy and bones begin to weaken as the body continues to adjust to its new, weightless condition. NASA is still seeking to understand the long term implications of changes that occur in the immune system, in how the body absorbs and distributes drugs and nutrients, and a host of other issues associated with exposing humans to low gravity environments.

NASA seeks to understand and control these phenomena in order to ensure the safety and efficacy of humans living and working in Space. In addition, the medical knowledge this research creates can be applied to improve treatments here on Earth. For example, research on orbit provides a unique perspective on bone remodeling (the process by which bone is renewed and changes composition over time) which may be directly relevant to the study of osteoporosis. In cooperation with investigators at Genentech, Inc., NASA researchers have demonstrated that muscle atrophy can be reduced in experimental animals using a combination of exercise and growth hormone. This approach opens new therapeutic avenues for rehabilitation, as well as for preventing some of the changes that accompany aging.

Many of the changes experienced in microgravity are at least superficially very similar to changes that occur during the aging process. Research on the international space station holds the potential for elucidating the underlying causes of both sets of changes.

Gravitational Biology
The International Space Station will allow biologists to exploit the unique environment of space to address basic biological questions. Areas of study include Plant Biology, Developmental Biology, Evolutionary Biology, Population Dynamics, Chronobiology, Cell and Molecular Biology and Radiation Biology. The Space Station will provide researchers with the ability to isolate and control gravitational stimuli using a centrifuge. The knowledge generated from these studies will be broadly applicable to medical and agricultural research on Earth as well as to increasing our ability to live and work effectively in space. For example, preliminary experiments appear to have established a firm link between exposure

to gravity during fetal development and the control of movement later in life. Future research may lead to a deeper understanding of human development and neuronal renewal processes throughout life. Studying adaptation to microgravity over generations in different living species including cells, plants, and animals will have profound implications for our understanding of the evolution of life and importance of planetary environments for the genesis of life.

Advanced Human Support Technology:
Scientific, technological and engineering research on the Space Station will address future life support systems. Work on advanced human support technology will be used to evaluate advanced life support systems for their effectiveness in the Space Station environment in preparation for full regenerative life support systems for exploration missions. Advanced life sustaining technologies will combine physical, chemical and biological processes to safely increase the duration and self sufficiency of future human space missions. These technologies will have numerous applications in environmental and agricultural settings here on Earth, including vastly improved air and water quality sensors and analyzers, air revitalization systems and means to capture and dispose of airborne particulates. NASA research has already resulted in a prototype "electronic nose" that can detect a broad range of chemicals in spacecraft atmospheres. The electronic nose is based upon advanced electronic "neural networks" and draws upon NASA's new millennium technology. The nose will be an invaluable technology for monitoring the air quality of spacecraft, aircraft, submarines or any enclosed vessel or space. It can be used to monitor important gases aboard the space station, detect chemical leaks, or possibly act as an early detection system for fires.

Microgravity Science:

"As is usually the case in the physical and biological sciences, discoveries are made when a new area or novel parameter space is explored. Microgravity research, despite its relative infancy, is no exception. Increasingly, fundamental processes that were though to be well understood under terrestrial (1-g) conditions have, in fact, proved to behave in altered and even startlingly unfamiliar ways when observed and measured in reduced gravity environments. Space experiments in areas such as combustion, fluid flow and transport, phase separation fundamental physics, and biology have revealed new phenomena and have demonstrated new and occasionally unpredicted behavior." (page 24, Microgravity Research Opportunities for the 1990s, National Research Council)

The International Space Station will give researchers control over a series of phenomena that obscure or mask more subtle phenomena on Earth. On Earth, gravity acts on density differences that are present in almost any fluid to drive materials resulting in mixing or settling phenomena that can disturb and obscure more subtle processes. For example, the intricate process by which atoms arrange themselves into crystals is difficult to study when gravity creates nearly imperceptible swirling currents of liquid that push and pull on the growing crystal and disturb the orderly aggregation of atoms. Similarly, the processes that influence the burning of even a simple flame cannot be fully studied and understood until gravity can be excluded and the underlying process exposed for study in the absence of the swift currents of air that gravity and heat combine to create. Orbital research provides low gravity conditions that reduce the confounding effects of gravity. It allows scientists to lift the veil of gravity and study phenomena such as solidification, crystal growth and combustion with an unprecedented clarity.

Biotechnology:

"I view the space shuttle program as a stepping stone to the ultimate program that will guarantee prolonged efforts in microgravity. . . .Ultimately our hope is to be able to crystallize proteins in microgravity, conduct all x-ray data collection experiments in Space and transmit the data to Earth for

processing. This can only be done in a Space Station." Dr. T.L. Nagabhushan, Ph.D. -- Vice President of biotechnology Development, Schering-Plough Research Institute

In the discipline of biotechnology, the low gravity environment available on the International Space station will allow researchers to expand on work conducted on Mir and the Space Shuttle to grow three-dimensional tissue samples, including cancer tumors, that are much better models for research than the best available samples grown on Earth. NASA's bioreactor, developed to simulate low gravity, has already proven dramatically successful as an advanced cell culturing technology. This success has led to an extensive collaboration with the National Institutes of Health. Work with NASA bioreactors at the NIH has already produced advanced cultures of lymph tissue for studying the infectivity of HIV. Initial results of tissue culture research on the Mir Space Station are very positive and suggest the possibility of major advances in tissue culturing once the International Space Station becomes available.

Biotechnology researchers will also use the International Space Station to produce protein crystals for drug research that are superior to crystals that can be grown on Earth. Already researchers have produced superior protein crystal samples for proteins important to the study of AIDS , emphysema, influenza, diabetes and other diseases as part of NASA's protein crystal growth efforts. Commercial researchers at BioCryst pharmaceuticals have used space-grown crystals of the protein *neuraminadase* to design a drug to stop the spread of the flu virus.

Combustion Science

"Almost every chapter in the combustion textbooks will be rewritten as a result of the microgravity work."
Prof. Howard Palmer, Prof. Emeritus, Penn State University

Combustion scientists seek comprehensive understanding of the physics and chemistry of combustion. They study how fires begin, spread and die. They study how fires produce pollution and how various fuels burn in different configurations (e.g., the combustion of liquid fuel droplets dispersed in air). Research has shown that combustion is a highly complex process involving many factors, such as: the physical flow of fuel and oxygen; the chemical conversion of fuel and oxygen into heat and chemical products —some of which may be pollutants; and the transfer of heat (for example, between flames and unburned fuel). In many cases, combustion processes are so complex that scientists have difficulty developing accurate, complete models of them. By significantly reducing gravity's effects, scientists can study subtle aspects of combustion that gravity hides. For example, in the near-absence of gravity's effects, scientists can study how fuel and heat are transported into and out of flames during combustion at the molecular level. Microgravity combustion research could produce knowledge that will allow us to improve the efficiency of combustion processes in converting fuel into heat. Such knowledge from microgravity research could be used on Earth to redesign burners for both home and industrial use to improve fuel efficiency and reduce pollution. In 1996, Dr. Robert Cheng and Dr. Larry Kostiuk, combustion science researchers at Lawrence Berkeley National Laboratory under contract to NASA, were awarded a patent for a Ring Flame stabilizer which significantly reduces pollution from natural gas burners. Fitted into an off-the-shelf home heating furnace, the device reduced nitrogen oxide emissions by a factor of 10, while increasing efficiency by 2%. The device can be readily sized to industrial scales. Academic Press, a major publisher of scientific and engineering texts, recently asked a NASA Lewis Research Center senior scientist to edit and co-author the first textbook dedicated strictly to microgravity combustion science. Several internationally recognized academicians active in microgravity research were selected by this editor and have already agreed to write chapters in the book. A first draft would be due next year.

Fluid Physics

For these reasons, a research program on fluid physics, aimed at primarily fundamental studies of fluid mechanics and transport phenomena that are partly or completely masked at 1 g, has been under way for the past several decades, and the committee recommends that this program be continued. (page 51 Microgravity Research Opportunities for the 1990s, National Research Council)

International Space Station research promises to produce new insights into the behavior and properties of fluids. One of the most significant forces affecting fluid behavior on Earth is gravity. Gravity causes heavier, more dense materials to settle to the bottom of a container and lighter, less dense materials to rise. Thus, the force of gravity gives rise to disturbing fluid flows whenever a fluid is heated or cooled unevenly, when two non-mixing liquids are contained together (such as oil and water) or when a liquid contains suspended solid particles (such as flour and water paste). On the International Space Station, where gravity's effects will be greatly reduced, scientists will observe aspects of fluid behavior that are difficult or impossible to understand in normal gravity. Space Station research will deliver a deeper understanding of fluids not only to advance physical research, but also to improve a broad range of economically important processes and procedures. Aspects of fluid behavior are critically important in a variety of situations. The stability and performance of a power plant depends on the flow characteristics of vapor-liquid mixtures. Oil recovery from partially depleted reservoirs depends on how liquids flow through porous rocks. Safe engineering of buildings in earthquake-prone areas requires an understanding of the fluid-like behavior of soils under stress. Perhaps most significantly, advances in materials engineering require a better grasp of how fluid behavior determines the structure of a solid material during solidification. Space Station research will allow fluid physics researchers to open a new window on the underlying physics behind these important phenomena.

Fundamental Physics

Microgravity allows researchers to design physics experiments that achieve a measurement accuracy not possible in the gravity environment of the Earth. International Space Station research will test physics theories at levels of resolution that will serve as a new standard. Areas of investigation will include research on general relativity, critical phenomena, laser cooling for ultra-precise measurement of atomic electronic properties, as well as other thermophysical measurements of interest in condensed-matter physics. Scientific results from the highly successful Lambda Point Experiment, flown aboard the Space Shuttle, were published in the prestigious journal Physical Review Letters in February, 1996 by John Lipa of Stanford University. The Lambda Point Experiment confirmed the validity of a Nobel prize- winning theory describing the conditions under which matter will change between different states, such as from liquid to gas or from conductor to superconductor. This theory constitutes one of the greatest achievements of theoretical physics of the past 30 years and has very broad application. This theory is very important to scientists seeking to develop better models for how water seeps through soil, how frost heaving occurs in arctic climates, and how turbulent weather systems evolve.

Materials Science:

The microgravity environment, by reducing these gravity driven phenomena, clearly offers new opportunities to metallurgists to develop and enhance control of materials processing. (page 77 Microgravity Research Opportunities for the 1990s, National Research Council)

Materials science is an extremely broad field, encompassing systems as diverse as multi-ton ingots of steel for the automotive industry, super alloys for advanced aerospace applications, precision electronic materials for computers and medical instruments and exotic glasses for high-speed optical communications. Production of these materials includes, as part of the production sequence, processes affected by gravity. In each case, an increase in the fundamental understanding of the underlying physics and chemistry of the processes could allow researchers to improve their control over the microstructure of materials during fabrication and thus improve the properties of the final product. Microgravity is an important tool for exploring the details of many important materials processes because microgravity allows researchers to study important phenomena that are normally obscured by gravity. The Space environment can be used to study how gravity influences the formation of defects in materials which can affect the properties of that material. For example, Dr. David J. Larson of the State University of New York at Stony Brook has reported that cadmium zinc telluride (CdZnTe) crystals grown on Space Shuttle missions have 50 times lower levels of a key defect than the best commercially available crystals. Dr. Larson has used space flight to verify his mathematical models for semiconductor crystal growth which can now be applied to improve semiconductor fabrication on Earth.

Earth Observation and Space Science:
The International Space Station will be a unique platform with multiple exterior attach points from which to observe the Earth and the Universe. Conceptualized by Nobel prizewinning scientist Dr. Sammuel Ting of MIT, the Alpha Magnetic Spectrometer experiment will search the universe for antimatter and "dark" matter in an attempt to prove cosmological theory with direct evidence. The Stratospheric Aerosol and Gas Experiment, SAGE-III will obtain global profiles of aerosols, ozone, water vapor, and oxides in order to determine their role in climatological processes.

Researchers from academia, industry, and government look forward to conducting scientific research on the International Space Station which simply cannot be accomplished on the ground. Cooperation in Space will help the nations of the world forge closer relationships and enhance international stability and security. We will use the Space Station to learn how to live and work in Space and how to capture the unique resources of the space environment for human benefit. At the same time, the knowledge and experience we gain on the International Space Station will reduce the risks faced by those humans who eventually leave Earth orbit for destinations beyond. The International Space Station challenges us. It is a step into the unknown. When we, as a people have found the courage, the resources and the faith to venture into the unknown we have always found rewards their that have justified our efforts. We are doing everything that we can to keep surprises to a minimum, yet, it is precisely to the surprises that we look forward as we begin this new phase in the exploration and development of the space frontier.

Conclusion

NASA is meeting its commitments to the Congress and the American people in building the ISS. The ISS program continues to identify ways to maximize program efficiencies and leverage investments to enhance the capabilities of the Space Station. NASA, the Administration and the Congress recognized the risks and challenges involved in undertaking a partnership on the International Space Station with the Russian Federation, but agreed that the risks were outweighed by the tremendous benefits. We have already learned much from the Shuttle/Mir Program. The International Space Station remains a much more capable and robust laboratory facility than it would be without the Russian contributions -- we will gain incredible scientific capabilities; we will develop cutting-edge technology. As I have said earlier, the American taxpayer has gained by the Russian involvement, and would stand to lose a great deal if Russia does not continue as part of the program. The Russian funding shortfalls have presented challenges. Now, in conjunction with our international partners, we have developed the necessary plans to move ahead, while still providing the opportunity for the Russians to participate in the program. With the support of this Committee and the Congress, we can enhance program stability and adapt to the realities that have come with Russia's involvement.

The International Space Station is an initiative of significant size and complexity, offering enormous returns. It is a demonstration of America's leadership in the development of peaceful cooperative ventures entering the 21st century. Humankind's thirst to expand its knowledge and desire to explore the unknown are essential elements to our continued growth as a Nation and as a world community. The Space Station is our opportunity to prove America's commitment to lead the way. This is a partnership based on mutual benefits. With Russia, we receive the benefits of a mature and experienced space program. However, their financial commitment must be maintained. It is important to remember that before the Russians joined the partnership, the cost of the space station was $2 billion more and would have started a year later, even with the current change in the first element launch. We continue to believe it is important that Russia remain a partner in the International Space Station; however, we will continue to monitor the situation and make appropriate adjustments to our baseline assembly sequence, per our contingency plan, as required based on Russia's ability to continue to meet their commitments. We must not be overly dependent on them, or any of our other partners.

Last updated 6/27/97 by Julie Meredith

APPENDIX G

Ulf Merbold Briefing
December 20, 1994
John Graf

Ulf Merbold is a german astronaut who has flown on two space shuttle spacelab missions. He has recently completed a 30 mission on board the MIR. Euromir 94 was launched October 3, 1994, was up for 30 days, and after a period of "confinement" in Moscow with restricted diet, sleep, and careful medical observation, he has come to JSC to answer questions about habitability on the MIR. Frank Brizzolara hosted his visit, the 90 minute presentation was videotaped. Here are my notes.

Mission and crew:
The MIR 16 crew; Yuri Malenchenko, Valery Polyakov, and Talgat Mussabayev was joined by the MIR 17 crew; Ulf Merbold, Elena Kondakova, and Aleksandr Viktorenko. A young esa astronaut named Pedro (don't have last name) was Ulf's backup, and served as his cap com. Pedro was at the JSC briefing. Polyakov is the Russian cosmonaut who has already stayed in orbit for more than 400 days, and Merbold has real admiration for this strong, motivated, spirited person.

Transportation:
There are two russian vehicles that dock with the MIR. The Soyuz has an upload payload of 10^2 kg. The Soyuz cabin is tiny. The phasing is complicated and it takes 34 orbits and 2 days to reach the MIR. The progress has an upload of 10^3 kg. There are two ways to take things down. There is a very small (10 kg) payload on an unmanned vehicle. Most of the vehicle burns up, but there is a small payload. The g load is "Not that far away from a car crash." The Progress vehicle also has a limited downweight, ESA was only allowed to take 18 Kg down, and Merbold wants NASA to take some of his experiments and data tapes down when they dock. There is a 4-5 hour dedock, then when they are farther away from the MIR, there is a de-orbit burn. Maximum g load is 4+ on deorbit. "The shuttle is very smooth by comparison." Merbold considers the limited downweight capabilities a real problem that the shuttle may be able to fix.

Communications:
The MIR flys without any sort of TDRSS, only communications link is when over russia. There was one relay satellite, but NPO Energia has to pay to use this satellite and they can't afford it, so they stopped using it. Many parts of the day there is no telemetry, and no communications at all. Merbold says that if is very hard to do science this way. The PI's don't know anything, they record data onto a diskette, and don't see any results until post-flight. Often there was a problem, and nobody detected it, and the experiment failed. There is a very limited Austrian data packet for ESA science payloads.

It sounded like Merbold's docking event was quite exciting. Merbold's vehicle was performing close proximity operations, they were just over 100 meters from MIR and the ground called up and told the commander, "You are three minutes from a communications blackout, and you'll lose telemetry. The automatic docking system is too slow, perform a manual docking maneuver and do it in less than 3 minutes." The commander took the stick and performed a hard, but successful dock.

Power:
A power comes directly or indirectly from the solar cells. During the day, the cells generate about 10 kW of power, some is used to charge the batteries. At night, 3-4 kW is the battery load. Power is limited and if Ulf wanted to use the furnace for his experiments, they would turn of the water elctrolysis unit (for O_2 gen).

On day 9 there was a complete loss of power. Six crew on board is a stress on the system, lots of power use. On day 8 there was a PR event with Ulf talking to Helmut Kohl on live television. Heavy power use, extra transmitter, camera, lights. The next day, there was an alarm that battery voltage was below minimum. In the preflight briefing, Merbold was told that in low power situations, turn off electrolysis unit, he thinks a russian cosmonaut did this. The next night cycle there was a complete loss of power, fans went off, lights went out, gyros went off, attitute control gone, computers quit, radio quit, no backups, no separate battery, MIR was dead. The whole station started to precess (and the solar panels became misaligned). When they got to the next day cycle, power returned, but with MIR misaligned, solar panels generated much less electricity. Next night cycle everything went dead again. The crew turned everything off, focused on life support and gyros, swapped new fresh batteries from all parts of MIR into the gyros and life support, realigned the MIR, and slowly recharged the batteries. They could not immidiately realign MIR, because with no TDRSS, they had to wait until it was daylight over Russia, to have both power and communications. For the next two days they intermittently lost power during the night cycle. After two days power was restored to nominal condition.

Merbold didn't say if LiOH backups were used during the two days, but even if they were, the fans were periodically going out. He said after everything was restored to nominal and the CO2 monitor was turned on it measured 8 mmHg. He said it probably was higher in cabins with lots of crew and no ventillation, but he said he had no headaches or any other symptoms, and didn't seem to be very concerned about air quality.

Merbold is an amazing person, he said his first thought when power went out was, "damn, that's the end of my flight." His second thought was that a rapid evacuation with fluids in pipes etc, would mean that the MIR would suffer so much damage the whole spacecraft would be shut down and never used again. He was impressed with the russians who fixed things quickly and calmly, he never thought his safety was in danger, and he trusted his commander to make the right decision. He said the two cosmonauts who worked on the hardware really saved the day.

Habitability - Water:
There are two separate water systems. The humidity condensate is collected and treated for drinking water. Merbold said he drank this water whenever possible and it was of good quality. Urine is collected and separated much like the shuttle. The urine is distilled in 0g with a semi permeable membrane (VCD?). It is really distilled water, and potable, but for psychological reasons urine distillate is the feed for the electrolysis unit. Dump the H_2 and use O_2 as makeup gas.

Habitability - Air:
Merbold doesn't know the chemistry of the CO2 scrubber, but it has an adsorbent bed, and when heated and exposed to vacuum, vents CO2 to space. Sounds like solid amine. There are LiOH backups. O2 is supplied with an electrolysis unit. Backup O2 supply is a potassium permanganate cartridge that supplies 600 liters of O2 per cartridge. Total pressure is 680 mmHg (equivalent to 2000-3000 foot elevation) with 150 mmHg O2 partial pressure He didn't talk about perturbations.

When they docked with MIR and first opened the hatch, he was expecting to notice an old, musty, or unpleasant smell. He was surprised to find the odor "fresh and pleasant". Rember, Merbold was in a tiny capsule for 2 days getting to the MIR and he may have been used to spacecraft odor.

Habitability - Microbiology:
The MIR has been up for 9 years now. It is used and worn, like an old house, but it is not dirty. It is cleaned once a week, and there is a regular procedure for monitoring microbiology. "There are all kinds of stories about mold and fungi growing on the walls of MIR, this is bullshit. There is no fungi growing on the walls."

Habitability - Thermal:
There are flexible ventillation ducts between modules, but the pictures he showed did not illustrate any active fans between modules. Merbold said he slept in the Kvant 2 module because it is quieter, cooler, and there are windows there.

Habitability - Radiation:
At 400km + this is the biggest safety and habitability issue. He received 3 REMs in 30 days. German nuclear workers are allowed 5 REMs per year. The real issue is people like Polyakov. He sleeps in a spot where there are batteries on both sides of him.

Habitability - Noise:
Merbold said the MIR was very noisy, much noisier than shuttle. Many ventillators running, and most MIR cosmonauts slept with earplugs (he did not). You have to negotiate a quiet place to sleep, and he considers the MIR to be poorly organized. A future station should have a quiet place to sleep, a noisy place for excercise, etc. The noise seemed to be Merbold's most troublesome envrionmental factor.

A Real Thermal Vacuum Test:
Merbold trained in a full scale training mockup of the MIR at a military base somewhere. This entire mockup was inside a thermal vacuum chamber, and one of the training exercises was to cause a leak somewhere, and have the crew find and isolate the leak while they were losing pressure. Merbold said this was not a real simulation, because the trainer was very clean with no ducts or wires and the MIR would need to have ducts and wires clipped in a hurry if there were a loss of cabin pressure.

In Flight Maintenance:

duties during later International Space Station phases. *Atlantis* will pick up two Russian cosmonauts and U.S. astronaut Dr. Norman Thagard, all launched to *Mir* in the Russian *Soyuz-TM 21* spacecraft on March 14, 1995, and will drop off two Russian cosmonauts for a three-month stay on the station.

On STS-74 (October 1995), *Atlantis* will deliver a Russian-built docking module that will improve clearance between the orbiter and *Mir's* solar arrays, making additional shuttle-*Mir* dockings easier. Beginning on STS-76 (April 1996), *Atlantis* will carry four U.S. astronauts to live on *Mir* in succession, so for eighteen months there will always be at least one American on the Russian station. On STS-86 (September 1997), the last planned flight of Phase I, U.S. astronauts and Russian cosmonauts will conduct a spacewalk to deploy outside *Mir* a solar dynamic energy module jointly developed by U.S. and Russian engineers. The module will test for possible use on the International Space Station a new kind of solar power system in which the Sun heats a working fluid to drive a turbine, generating more electricity than current photovoltaic solar arrays.

International Space Station Assembly Begins: Phase II (1997-1999)

Phase II Milestones

Assembly begins/first Phase II flight	November 1997
First shuttle assembly flight	December 1997
First Russian assembly flight	April 1998
Soyuz crew transfer vehicle added; 3-person permanent human presence capability	May 1998
First truss segment added	June 1998
First U.S. solar power	September 1998
U.S. laboratory module added	November 1998
Last Phase II flight	February 1999

Phase II consists of six U.S. and six Russian assembly flights, beginning with a Proton rocket launch from Baikonur Cosmodrome in central Asia in November 1997. The unpiloted rocket's cargo will be an automated spacecraft known by the Russian acronym FGB. The 20-ton FGB provides attitude control and propulsion during early assembly, plus solar power and berthing ports for additional modules. The FGB is a proven design sharing its ancestry with the *Kvant 2* and *Kristall* modules attached to *Mir*.

On STS-88, the shuttle will haul station hardware into space for the first time. *Endeavour* will berth Resource Node 1 at the front end of the FGB. Resource Node 1 will provide storage space for supplies and equipment, berthing ports and attachment points for modules and the station's large truss, and a docking port for shuttle orbiters. The Russian and U.S. segments of the International Space Station will be permanently linked through Resource Node 1 and the FGB.

On the first Russian assembly flight, a service module with living and working space for three crew members will dock with the FGB's aft port. The service module is proven hardware closely resembling the *Mir* core module. Russian automated *Progress* freighters will periodically dock at the service module's aft docking port, delivering supplies, fuel, and equipment.

With the second Russian assembly flight, the fourth flight of Phase II, the International Space Station will achieve three-person permanent human presence capability. Crews will be able to live and conduct research on the station for long periods. A *Soyuz* crew transfer vehicle will dock, providing assured return to Earth for three people when no orbiter is present. The *Soyuz* crew transfer vehicle design is based on the *Soyuz-TM* transport used in the *Mir* space station program.

On the next U.S. flight, STS-91, *Endeavour's* crew will attach the first truss segment, designated Z1, to the top of Node 1. The next U.S. flight will attach the P6 truss segment and a solar power module to truss Z1, providing the first U.S. solar power to the station. (For more on the truss, see below.)

The last Phase II milestone is delivery of the U.S. laboratory module on STS-94, the fifth U.S. assembly flight. Fully outfitted, the U.S. laboratory carries 13 racks of experiment equipment, plus life support, maintenance, and control systems. *Atlantis*' crew begins outfitting the U.S. laboratory on STS-95 and puts it to work on STS-96, the first U.S. Space Station utilization flight.

Utilization Flights Begin and Assembly Concludes: Phase III (1999-2002)

Phase III Milestones

First utilization flight/start of Phase III	February 1999
Airlock module added	March 1999
First Russian research module added	August 1999
First Japanese/U.S. assembly flight	January 2000
First Japanese assembly flight (possible launch on Japanese H-II rocket)	March 2000
First European assembly flight (launch on European Ariane 5 rocket)	February 2001
U.S. centrifuge module added	October 2001
Truss complete/full electrical power capacity achieved	December 2001
U.S. habitation module added	February 2002
6-person permanent human presence capability	June 2002
Assembly complete	June 2002

Phase III includes 13 U.S., eight Russian, two European, one Japanese, and two Japanese/American assembly flights. The first flight of Phase III is not an assembly flight, however. STS-96 is the first of six Space Station utilization flights in Phase III. During utilization flights, crews of astronauts will work in the U.S. laboratory module for more than two weeks at a time while a docked shuttle orbiter provides assured Earth return capability. Utilization flights are designed to start U.S. research on the International Space Station as early as possible.

The first assembly milestone takes place on the the next U.S. flight, STS-97. *Endeavour's* crew will berth an airlock module on Resource Node 1. The airlock will permit U.S. astronauts and Russian cosmonauts to perform routine spacewalks when the shuttle orbiter is not present (contingency spacewalks are possible as early as three-person permanent human presence capability–April 1998–by using hatches on the Russian service module). Addition of the airlock makes easier the limited number of spacewalks required to assemble the International Space Station.

Addition of new international laboratories constitutes most of the rest of the Phase III assembly milestones. The first Russian research module, similar to the science modules on the *Mir* space station, will be added in August 1999. Russian research modules will also be added in June 2000 and May 2001. The Japanese experiment module (JEM) and Europe's attached pressurized module will be added over the course of five assembly flights in 2000-2001. Robotic equipment inside the European laboratory will aid human experimenters, lessening demands on their time. The JEM laboratory has a special "front porch" for exposing experiments and equipment to space conditions. Europe plans to launch the attached pressurized module on its Ariane 5 rocket, while Japan is considering using its H-II rocket to launch portions of the JEM.

The U.S. will add the centrifuge module on STS-116 in October 2001. The centrifuge will for the first time permit studying the effects of sustained partial gravity on living things. For example, the centrifuge will be able to simulate a stay on the surface of Mars, where the gravitational pull is only one-third as strong as on Earth.

The largest single element of the International Space Station, the truss, grows segment by segment during Phase III, with the tenth and last segment added during the 15th U.S. assembly flight, STS-117, in January 2002. The completed truss, measuring more than 350 feet in length, will hold systems requiring exposure to space, such as communications antennas; external cameras; mounts for external payloads; and equipment for temperature control, transport around the station's exterior during spacewalks, robotic servicing, and stabilization and attitude control.

The truss will also support eight Sun-tracking solar array pairs. Combined with the arrays on the Russian segment, they will provide the station with 110 kilowatts of electrical power–twice as much power for experiments as the old *Freedom* design and more than 10 times as much as *Skylab* or *Mir*.

In February 2002, a second *Soyuz* crew transfer vehicle will dock, enabling six people to return to Earth when the shuttle orbiter is absent and signaling achievement of six-person permanent human presence capability. Later in the month, on the STS-119 mission, *Atlantis* will deliver the U.S. habitation module. Once outfitted, the habitation module will provide a crew of four with dining, personal hygiene, sleep, conference, and recreation facilities during their long stays in space.

Completion of U.S. habitation module outfitting in 2002 on Shuttle mission STS-121, the 16th U.S. assembly flight, signals the end of Phase III. International Space Station will be complete in 2002 and ready to provide unprecedented space research capability in the new millenium.

International Space Station

National Aeronautics and Space Administration

International Space Station
The International Space Station Program is Underway

Introduction

The International Space Station has three phases, each designed to maximize joint space experience and permit early utilization and return on our investment. In Phase I, Americans and Russians will work together in laboratories on *Mir* and the shuttle. They will conduct joint spacewalks and practice space station assembly by adding new modules to *Mir*. American astronauts will live and work on *Mir* for months beside their Russian counterparts, amassing the first U.S. long-duration space experience since *Skylab* (1973-1974).

International Space Station Phase I began with Russian cosmonaut Sergei Krikalev's flight aboard the Space Shuttle *Discovery* in February 1994 on STS-60. In February 1995, on the STS-63 mission, *Discovery* flew around the Russian *Mir* space station with Vladimir Titov on board as a mission specialist. During the flyaround, *Discovery* stopped 37 feet from *Mir*–a rehearsal for the first docking between Space Shuttle *Atlantis* and *Mir* in May or June 1995. In March 1995, U.S. astronaut Dr. Norman Thagard flew to *Mir* for a three-month stay with two Russian cosmonauts.

Phase I Impact on Phases II and III

The goal of Phase I is to lay the groundwork for International Space Station Phases II and III. Phase II will place in orbit a core space station with a U.S. Laboratory module, the first dedicated laboratory on the station. The U.S. Laboratory will be put to work during utilization flights in Phase III, while assembly continues. Phase III ends when assembly is complete (scheduled for mid-2002) and astronauts and cosmonauts from many countries commence a planned 15 years of research on the International Space Station.

Phase I is contributing to the success of Phases II and III in four major areas:

- Operations–learning to work together on the ground and in space
- Risk reduction–mitigation of potential surprises in hardware exchange, working methods, spacecraft environment, and spacewalks
- Long-duration stays on a space station–amassing experience
- Science–early initiation of science and technology research

Space Station *Mir*–Shuttle's Partner in Phase I

Mir represents a unique capability–an operational long-term space station which can be permanently staffed by two or three cosmonauts. Visiting crews have raised *Mir's* population to six for up to a month.

Mir is the first space station designed for expansion. The 20.4-ton core module, *Mir's* first building block, was launched in February 1986. The core module provides basic services (living quarters, life support, power) and scientific research capabilities. *Soyuz-TM* manned transports and automated *Progress-M* supply ships dock at two axial docking ports, fore and aft. Expansion modules dock first at the forward port then transfer to one of four radial berthing ports using a robot arm (except for the expansion module, Kvant–see below).

Up to 1990, the Russians added three expansion modules to the *Mir* core:

- *Kvant*. Berthed at the core module's aft axial port in 1987, the module weighs 11 tons and carries telescopes and equipment for attitude control and life support. Kvant blocked the core module's aft port, but had its own aft port which took over as the station's aft port.
- *Kvant 2*. Berthed at a radial port in 1989, the module weighs 19.6 tons and carries an EVA airlock, two solar arrays, and science and life support equipment.
- *Kristall*. Berthed opposite *Kvant 2* in 1990, *Kristall* weighs 19.6 tons and carries two stowable solar arrays, science and technology equipment, and a docking port equipped with a special androgynous docking mechanism designed to receive heavy (up to about 100

tons) spacecraft equipped with the same kind of docking unit. The androgynous unit was originally developed for the Russian *Buran* shuttle program. The Russians will move *Kristall* to a different radial *Mir* port to make room for the new *Spektr* module in May 1995. *Atlantis* will use the androgynous docking unit on *Kristall* for the first shuttle-*Mir* docking in June 1995.

Three more modules, all carrying U.S. equipment, will be added to *Mir* in 1995 for International Space Station Phase I:

- *Spektr*. Launch on a Russian Proton rocket from the Baikonur launch center in central Asia is currently set for May 1995. The module will be berthed at the radial port opposite *Kvant 2* after *Kristall* is moved out of the way. *Spektr* will transport four solar arrays and scientific equipment (including more than 1600 lbs of U.S. equipment).
- Docking Module. The module will be launched in the payload bay of *Atlantis* and berthed at *Kristall's* androgynous docking port during STS-74 in October 1995. The docking module makes shuttle dockings with *Mir* easier and will carry two solar arrays–one Russian and one jointly developed by the U.S. and Russia—to augment *Mir's* power supply.
- *Priroda*. Launch on a Russian Proton rocket is scheduled for November 1995. *Priroda* will berth at the radial port opposite *Kristall* and will carry microgravity research and Earth observation equipment (including 2200 lb of U.S. equipment).

In late 1995, after *Priroda* is added, *Mir* will mass more than 100 tons. The station will be made up of seven modules launched separately and brought together in space over ten years. Experience gained by Russia during *Mir* assembly provides valuable experience for International Space Station assembly in Phases II and III.

Phase I Shuttle Mission Summaries

STS-60 (February 3-11, 1994)

This mission inaugurated International Space Station Phase I. Veteran Russian cosmonaut Sergei Krikalev served as a mission specialist aboard *Discovery*. He conducted experiments beside his American colleagues in a Spacehab laboratory module carried in *Discovery's* payload bay.

STS-63 (February 3-11, 1995)

Discovery maneuvered around *Mir* and stopped 37 feet from the *Kristall* module's special androgynous docking unit, which *Atlantis* will use to dock with *Mir* on the STS-71 mission. Cosmonauts on *Mir* and *Discovery's* crew–which included veteran Russian cosmonaut Vladimir Titov–beamed TV images of each other's craft to Earth. For a time it appeared that minor thruster leaks on *Discovery* might keep the two craft at a preplanned contingency rendezvous distance of 400 feet. However, mission control teams and management in Kaliningrad and Houston worked together to determine that the leaks posed no threat to *Mir*, so the close rendezvous went ahead. The minor problem became a major builder of confidence and joint problem-solving experience for later International Space Station phases. Titov served on board *Discovery* as a mission specialist, performing experiments beside his American colleagues in a Spacehab module in the orbiter's payload bay.

STS-71 (May-June 1995)

Atlantis will be launched carrying five astronauts, two Russian cosmonauts, and, in its payload bay, a Spacelab module and an orbiter docking system for docking with *Mir*. The STS-71 orbiter docking system is designed for use on this mission only–subsequent shuttle-*Mir* docking missions will use a Multimir orbiter docking system. The STS-71 and Multimir orbiter docking systems are outwardly identical–they consist of a cylindrical airlock with a Russian-built androgynous docking mechanism on top. For STS-71, *Atlantis* will dock with an identical androgynous unit on *Mir's Kristall* module. The shuttle will be used for the first time to change a space station crew, a task which will become a routine part of its duties in later International Space Station phases. *Atlantis* will drop off cosmonauts Anatoli Solovyev and Nikolai Budarin, and pick up Vladimir Dezhurov, Gennadi Strekalov, and U.S. astronaut Norman Thagard for return to Earth. They were launched from Russia in the *Soyuz-TM 21* spacecraft on March 14. Thagard and his Russian colleagues will be completing a three-month stay on *Mir*, the first long-duration space mission involving an American since the last U.S. *Skylab* mission in 1974. The joint crew will carry out experiments similar to those planned for International Space Station Phases II and III. *Atlantis* will remain docked to *Mir* for five days.

STS-74 (October-November 1995)

Atlantis will carry the Russian-built docking module, which has androgynous docking mechanisms at top and bottom. During flight to *Mir*, the crew will use the orbiter's remote manipulator system robot arm to hoist the docking module from the payload bay and position its bottom androgynous unit atop *Atlantis'* orbiter docking system. *Atlantis* will then dock to *Kristall* using the docking module's top androgynous unit. After three days, *Atlantis* will undock from the docking module's bottom androgynous unit and leave the docking module permanently docked to *Kristall*, where it will improve clearance between the shuttle and *Mir's* solar arrays during subsequent dockings. The docking module also carries two solar arrays, one Russian and one U.S.-Russian, which will increase power available on *Mir* for experiments. No crew exchange is scheduled, but on board *Mir* will be an astronaut from the European Space Agency (ESA), halfway through a four-month stay on the station, and on board *Atlantis* will be a Canadian astronaut. The European long-duration mission is part of the Euromir space research program, which included a month-long stay on *Mir* by ESA astronaut Ulf Merbold in 1994. Canada built the shuttle's robot arm and will provide robotics systems for the

International Space Station in Phase II, while Europe will provide a laboratory module for the station in Phase III. On this and subsequent flights *Atlantis* will deliver water, supplies, and equipment to *Mir* and will return to Earth experiment samples, dysfunctional equipment for analysis, and products manufactured on the station.

STS-76 (March-April 1996)

Atlantis will deliver astronaut Shannon Lucid to *Mir* for a five-month stay. The orbiter will carry a single Spacehab module in its payload bay, and will remain docked to the Russian station for five days. While docked, astronauts Linda Godwin and Michael R. "Rich" Clifford will perform a spacewalk to transfer three experiments from *Atlantis* to *Mir's* exterior and evaluate International Space Station hardware.

STS-79 (August 1996)

Astronaut Shannon Lucid, delivered to *Mir* on STS-76, will be picked up and astronaut Jerry Linenger will be dropped off for a planned four-month stay on the Russian station. U.S. astronauts will perform a spacewalk during the five-day docked phase. *Atlantis* will carry a Spacehab double module.

STS-81 (December 1996)

Astronaut Jerry Linenger, delivered on STS-79, will be returned to Earth and astronaut John Blaha will take up residence on *Mir* for four months. *Atlantis* will also delive U.S. and Russian equipment for spacewalks to take place o this and subsequent missions. Two Russians or an America and a Russian will perform U.S. experiments as part of a spacewalk during or after the five-day docked phase. *Atlantis* will carry a Spacehab double module.

STS-84 (May 1997)

Astronaut John Blaha, delivered on STS-81, will be picked up and astronaut Scott Parazynski dropped off for a four-month stay on *Mir*. *Atlantis* will carry a Spacehab double module, and will remain docked to *Mir* for five days.

STS-86 (September 1997)

Atlantis will pick up astronaut Scott Parazynski, dropped off on STS-84, and will deliver a joint U.S.-Russian solar dynamic energy module. As many as two spacewalks by U.S. astronauts and Russian cosmonauts will be needed to deploy the energy module outside *Mir*. The solar dynamic system will heat a working fluid which will drive a turbine, generating more electricity than current photovoltaic solar arrays. The *Mir* solar dynamic energy module will test the system for possible use on the International Space Station. In addition, developing the solar dynamic energy module will provide joint engineering experience. The astronauts and cosmonauts will also retrieve and deploy experiments outside *Mir*.

International
Space Station

National Aeronautics and Space Administration

International Space Station
U.S. Space Station History

Introduction

Space stations have long been seen as a laboratories for learning about the effects of space conditions and as a springboard to the Moon and Mars. In the United States, the Apollo lunar program preempted early station efforts in the early 1960s, and changing priorities in the U.S. deferred post-Apollo station efforts to the 1980s. Since 1984, space station design has evolved in response to budgetary, programmatic, and political pressures, becoming increasingly international in the process. This evolution has culminated in International Space Station, orbital assembly of which will begin in 1997.

The Beginning (1869-1957)

The concept of a staffed outpost in Earth orbit dates from just after the Civil War. In 1869, American writer Edward Everett Hale published a science fiction tale called "The Brick Moon" in the *Atlantic Monthly*. Hale's manned satellite was a navigational aid for ships at sea. Hale proved prophetic. The fictional designers of the Brick Moon encountered many of the same problems with redesigns and funding that NASA would with its station a century later.

In 1923, Hermann Oberth, a Romanian, coined the term "space station." Oberth's station was the starting point for flights to the Moon and Mars. Herman Noordung, an Austrian, published the first space station blueprint in 1928. Like today's International Space Station, it had modules with different functions. Both men wrote that space station parts would be launched into space by rockets.

In 1927, American Robert Goddard made a major breakthrough by launching the first liquid-fueled rocket, setting the stage for the large, powerful rockets needed to launch space station parts into orbit. Rocketry advanced rapidly during World War II, especially in Germany, where the ideas of Oberth and Noordung had great influence. The German V-2 rocket, a missile with a range of about 300 miles, became a prototype for both U.S. and Russian rockets after the war.

In 1945, renowned German rocket engineer Wernher von Braun came to the U.S. to build rockets for the U.S. Army. In the 1950s, he worked with *Collier's* magazine and Walt Disney Studios to produce articles and documentaries on spaceflight. In them, he described a wheel-shaped space station reached by reusable winged spacecraft. Von Braun saw the station as an Earth-observation post, a laboratory, an observatory, and a springboard for Moon and Mars flights.

On October 4, 1957, the Soviets launched Sputnik 1. This triggered the Cold War competition between the U.S. and Soviet Union in space which characterized the early years of the Space Age—competition replaced today by cooperation in assembly of the International Space Station. In response to Sputnik, the U.S. established the National Aeronautics and Space Administration in 1958 and started its first man-in-space program, Project Mercury, in 1959.

Apollo and Space Stations (1958-1973)

Project Mercury had hardly begun when NASA and the Congress looked beyond it, to space stations and a permanent human presence in space. Space stations were seen as the next step after humans reached orbit. In 1959, A NASA committee recommended that a space station be established before a trip to the moon, and the U.S. House of Representatives Space Committee declared a space station a logical follow-on to Project Mercury.

In April 1961, the Soviet Union launched the first human, Yuri Gagarin, into space in the Vostok 1 spacecraft. President John F. Kennedy reviewed many options for a response to prove that the U.S. would not yield space to the Soviet Union, including a space station, but a man on the moon won out. Getting to the moon required so much work that the U.S. and Soviet Union were starting the race about even. In addition, the moon landing was an unequivocal achievement, while a space station could take many different forms. Kennedy's choice proved wise–in January 1969, *Soyuz 4* and *Soyuz 5* docked in Earth orbit, the first time two piloted spacecraft came together in space, and the Soviet Union declared that they constituted the first space station. Few accept the claim today, but the *Soyuz 4/Soyuz 5* docking might have been a blow to U.S. prestige had Kennedy picked the wrong goal.

Space station studies continued within NASA and the aerospace industry, aided by the heightened interest in spaceflight attending Apollo. In 1964, seeds were planted for *Skylab*, a post-Apollo first-generation space station. Wemher von Braun, who became director of NASA's Marshall Space Flight Center, was instrumental in *Skylab's* development.

By 1968, a space station was NASA's leading candidate for a post-Apollo goal. In 1969, the year *Apollo 11* landed on the moon, the agency proposed a 100-person permanent space station, with assembly completion scheduled for 1975. The station, called Space Base, was to be a laboratory for scientific and industrial experiments. Space Base was envisioned as home port for nuclear-powered tugs designed to carry people and supplies to an outpost on the moon.

NASA realized that the cost of resupplying a space station using expendable rockets would quickly exceed the station's construction cost. The agency also foresaw the need to be able to return things from a space station. A reusable spacecraft was the obvious solution. In 1968, NASA first called such a spacecraft a space shuttle.

Skylab (1973-1974)

In May 1973, the U.S. launched the *Skylab* space station, our only experience with long-duration microgravity research to date. *Skylab* was launched atop a Saturn V rocket similar to those that took astronauts to the Moon. The rocket's third stage was modified to become an orbital workshop and living quarters for three-person crews. Non-reusable Apollo spacecraft originally designed for Moon missions ferried astronauts to and from the station. *Skylab* hosted three different crews for stays of 28, 56, and 84 days. *Skylab* astronauts conducted medical tests and studied microgravity's influence on fluid and material properties. The crews also made astronomical, solar, and Earth observations. Long-duration microgravity research begun on *Skylab* will continue and be refined on the International Space Station.

Skylab proved that humans could live and work in space for extended periods. The station also demonstrated the importance of human involvement in construction and upkeep of orbital assets–the first *Skylab* crew performed an emergency spacewalk to free a solar array jammed during the station's launch.

Skylab was not designed for resupply, refueling, or independent reboost. When the last *Skylab* crew headed home in February 1974, NASA proposed sending a space shuttle to boost *Skylab* to a higher orbit or even to refurbish and reuse the station. But greater than expected solar activity expanded Earth's atmosphere, hastening *Skylab's* fall from orbit, and shuttle development fell behind schedule. *Skylab* reentered Earth's atmosphere in 1979.

NASA Responds to Changing Priorities (1974-1979)

Shuttle was originally conceived as a vehicle for hauling people and things back and forth between Earth and a space station. People and the supplies they needed for a long stay in space would go up, and people and the industrial products and experiment samples they made on the station would come down. But economic, political, social, and cultural priorities in the U.S. shifted during the Apollo era. Despite Apollo's success, NASA's annual budgets suffered dramatic cuts beginning in the mid-1960s. Because of this, NASA deferred plans for a permanent space station until after the space shuttle was flying, and explored international cooperative space projects as a means of filling in for a permanent station.

The U.S. invited Europe to participate in its post-Apollo programs in 1969. In August 1973, Europe formally agreed to supply NASA with Spacelab modules, mini-laboratories that ride in the space shuttle's payload bay. Spacelab provides experiment facilities to researchers from many countries for up to two weeks–an interim space station capability. Spacelab 1 reached orbit in 1983, on the ninth space shuttle flight (STS-9). European contributions to International Space Station, a laboratory module and a supply module, are based on Spacelab experience and technology.

U.S. and Soviet negotiators discussed the possibility of a U.S. shuttle docking with a Soviet *Salyut* space station. This was an outgrowth of the last major U.S.-Russian joint space project, *Apollo-Soyuz*, the first international spacecraft docking in 1975. The shuttle's ability to haul things down from space complimented *Salyut's* ability to produce experiment samples and industrial products–things one would want to return to Earth. NASA offered the shuttle for carrying crews and cargo to and from *Salyut* stations and in return hoped to conduct long-term research on the *Salyuts* until it could build its own station, but these efforts ended with the collapse of U.S.-Soviet detente in 1979.

Defining the Goal and Building Support (1979-1984)

By 1979, space shuttle development was well advanced. NASA and contractor engineers began conceptual studies of a space station that could be carried into orbit in pieces by the space shuttle. The Space Operations Center was designed to serve as a laboratory, a satellite servicing center, and a construction site for large space structures. The Space Operations Center studies helped define NASA expectations for a space station.

The space shuttle flew for the first time in April 1981, and once again a space station was heralded as the next logical step for the U.S. in space. NASA founded the Space Station Task Force in May 1982, which proposed international participation in the station's development, construction, and operations. In 1983, NASA held the first workshop for potential space station users.

NASA Gets the Go-Ahead (1984-88)

These efforts culminated in January 1984, when President Ronald Reagan called for a space station in his State of the Union address. He said that the space station program was to include participation by U.S. allies.

With the presidential mandate in place, NASA set up the Space Station Program Office in April 1984, and issued a Request for Proposal to U.S. industry in September 1984. In April 1985, NASA let contracts on four work packages, each involving a different mix of contractors and managed by a separate NASA field center. (This was consolidated into three work packages in 1991.)

This marked the start of Space Station Phase B development, which aimed at defining the station's shape. By March 1986, the baseline design was the dual keel, a rectangular framework with a truss across the middle for holding the station's living and working modules and solar arrays.

By the spring of 1985, Japan, Canada, and the European Space Agency each signed a bilateral memorandum of understanding with the U.S. for participation in the space station project. In May 1985, NASA held the first space station international user workshop in Copenhagen, Denmark. By mid-1986, the partners reached agreement on their respective hardware contributions. Canada would build a remote manipulator system similar to the one it had built for the space shuttle, while Japan and Europe would each contribute laboratory modules. Formal agreements were signed in September 1988. These partners' contributions remain generally unchanged for International Space Station.

In 1987, the dual keel configuration was revised to take into account a reduced space shuttle flight rate in the wake of the Challenger accident. The revised baseline had a single truss with the built-in option to upgrade to the dual keel design. The need for a space station lifeboat–called the assured crew return vehicle–was also identified.

In 1988, Reagan gave Space Station a name–*Freedom*. Space Station *Freedom*'s design underwent modifications with each annual budget cycle as Congress called for its cost to be reduced. The truss was shortened and the U.S. Habitation and Laboratory modules reduced in size. The truss was to be launched in sections with subsystems already in place. Despite the redesigns, NASA and contractors produced a substantial amount of hardware. In 1992, in moves presaging the current increased cooperation between the U.S. and Russia, the U.S. agreed to buy Russian *Soyuz* vehicles to serve as *Freedom*'s lifeboats (these are now known as *Soyuz* crew transfer vehicles) and the shuttle-Mir program (now International Space Station Phase I) got its start.

International Space Station (1993-2012)

In 1993, President William Clinton called for the station to be redesigned once again to reduce costs and include more international involvement. To stimulate innovation, teams from different NASA centers competed to develop three distinct station redesign options. The White House selected the option dubbed Alpha.

In its new form, the station uses 75% of the hardware designs originally intended for the *Freedom* program. After the Russians agreed to supply major hardware elements, many originally intended for their *Mir 2* space station program, the station became known as International Space Station. Station assembly will begin with the launch of the Russian-made FGB, a propulsion module which will provide guidance, control, and orbit maintenance for the station as it grows, permitting expansion to basic operational capability much earlier than *Freedom*. This offers new opportunities to all the station partners by permitting early scientific research.

Program management also underwent redesign. The three-work-package system was scrapped in favor of a simpler, more straightforward host center/prime contractor arrangement. This streamlined management and reduced program costs and red tape. Johnson Space Center became host center for the space station program, and Boeing became prime contractor. NASA and Boeing teams were housed together at JSC to increase efficiency through improved communications.

JSC's strong experience in both engineering and spaceflight operations means efficient evolution from station development to station operations—important in part because operations will begin early in the International Space Station assembly sequence. Boeing was selected for its experience in integrating and outfitting *Freedom* modules, and for its successful application of the concept of integrated product teams (IPTs) to its federal government contracts—for example, in the development and manufacture of the 767 AWACS airplane and the Comanche helicopter for the Department of Defense.

Individual IPTs are charged with overseeing various aspects of the complex station program. They contain representatives from all the major groups involved in station development and operations, such as engineering, the flight crew, and mission operations personnel. If a problem arises during development, all the major groups have inputs to its solution. This prevents any one group from solving a problem on its own in a manner that creates new problems for other groups, streamlining the development process. The effective team relationships resulting from these practices are producing space station operations plans and designs faster and cheaper than ever before.

The International Space Station program is divided into three phases. Phase I, an expansion of the shuttle-Mir program begun in 1992, is giving Russian and U.S. engineers, flight controllers, and astronauts experience in working together and U.S. astronauts long-duration space experience aboard the *Mir* space station. Hardware is being tested and validated. This experience and hardware will be applied in Phases II and III, when the International Space Station is assembled in Earth orbit. Phase II begins in late 1997, with a core station assembled in Earth orbit by mid-1999. During Phase III, assembly flights will be interspersed with flights dedicated to research on the station. International Space Station operations are planned to continue for 10 years after assembly is completed in mid-2002.

Phase I of the International Space Station program kicked off in February 1994 with STS-60, the first Phase I flight, when cosmonaut Sergei Krikalev worked beside American astronauts in Space Shuttle *Discovery*, and continued in February 1995, when *Discovery* rendezvoused with *Mir* during the STS-63 mission with cosmonaut Vladimir Titov aboard. In March 1995, U.S. astronaut Dr. Norman Thagard lifted off in the Russian *Soyuz-TM 21* spacecraft with two Russian cosmonauts for a three-month stay on Mir. In June 1995, on the STS-71 mission, Space Shuttle *Atlantis* will dock with the *Mir* station for the first time and pick up Thagard and his colleagues, plus experiment samples and other items from the station, for return to Earth. Six more shuttle-*Mir* dockings and four more long-duration stays by U.S. astronauts aboard *Mir* are planned in Phase I.

APPENDIX F

APPENDIX J

Houston Chronicle Interactive

Section: World

Lights In the Sky.

HCI's World forum

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- August 7: Mir repairs begun before arrival of new crew
- August 6: Russian rocket heads for Mir
- August 5: New Russian crew heads to Mir
- August 5: U.S., Russia prepare for missions in space
- August 1: American may do Mir spacewalk
- July 31: Mir's commander defends action leading up to collision of June 25
- July 31: NASA: Astronaut not tall enough for Mir

7:28 PM 8/13/1997

Cosmonauts pocket large cash bonuses for hazardous duties

Manual dockings, spacewalks boost pay

MOSCOW (AP) -- Cosmonaut Anatoly Solovyov switched his Soyuz capsule to manual control as he approached the Mir space station, then guided the ships into a gentle embrace -- and earned himself a cash bonus.

The Russian space program has an elaborate bonus system that includes not only general hazardous-duty pay, but specific payments for such tasks as spacewalks and manual dockings.

By switching from the automated docking system to manual, Solovyov should pocket an extra $1,000 when he returns to Earth in 6 1/2 months, according to the Russian daily Kommersant, one of several Russian news outlets that have reported specific amounts.

Russian and U.S. space officials agreed that Solovyov's decision to go manual last week was the best way to get the job done. But the episode highlights the unusual reward system, which Russian news media say also pays $1,000 for each spacewalk.

The average pay for cosmonauts is about $3,000 per month in orbit. The new Russian crew, Solovyov and Pavel Vinogradov, could earn as much again in bonuses and finish their mission with a $40,000 paycheck, media reports say. The bonus money is in performing up to six spacewalks and vital repair work on the Mir's damaged Spektr module.

The sums involved may not sound like much, but Russians earn only about $200 a month on average. Also, Russian media report all the figures in U.S. dollars, suggesting the astronauts will be paid in U.S. currency, which is much preferred to rubles.

NASA astronauts, who are considered U.S. government employees, earn between $48,000 and $103,000 a year, depending on their years with the government and past promotions. Astronauts on Mir receive only their regular 40-hour-a-week pay -- no overtime, comp time or bonuses, according to NASA spokeswoman Eileen Hawley.

For the cash-strapped Russian space program, the bonuses reflect the importance placed on the mission to fix the ailing, 11-year-old Mir.

The Russians want to keep it aloft two more years, partly out of pride and partly because it generates cash from the Americans and other countries that send up space visitors. The Americans are paying the Russian space program $473 million over five years, with much of the money going to rent space on the Mir for U.S. astronauts.

Perks are not limited to the space program in Russia or other former Soviet republics, where official salaries always have been low and special benefits and privileges plentiful for the elite.

Spokesmen for the Russian Space Agency and Mission Control Center refused to discuss the money issue.

"The contracts are confidential and it would be unethical to reveal their contents," said Sergei Gromov, spokesman for RKK Energia, a state-run company that built the Mir and has overseen it since its 1986 launch.

Gromov, however, did not dismiss the figures published in the Russian media, saying the newspapers apparently "got them from some cosmonaut."

The last time the money question attracted public attention was 1995, when space officials stripped Mir commander Gennady Strekalov of some benefits for refusing to make a spacewalk.

Strekalov, who cited safety concerns and the lack of necessary equipment, went to arbitration after his return from space and won the money back.

There's no word on whether the outgoing Mir crew -- Vasily Tsibliyev and Alexander Lazutkin -- would be subject to financial sanctions for any of the woes that have plagued the station in recent months. They are scheduled to return to Earth today.

Last month, the Mir lost all power temporarily after a crew member inadvertently unplugged a key cable. And the Mir's June 25 space collision occurred while the crew was practicing a manual docking with a Progress cargo ship.

Russian newspapers have blamed Tsibliyev for the June crash. Russian space officials have not assigned blame, saying only that the cause was under investigation. President Boris Yeltsin, however, said last week that the collision apparently was caused by human error.