Paper Session II-B - The International Space Station: Background and Current Status

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INTRODUCTION

The International Space Station Program is the largest scientific cooperative program in history. It draws on the resources and expertise of 13 nations: the United States, Canada, Italy, Belgium, the Netherlands, Denmark, Norway, France, Spain, Germany, the United Kingdom, Japan, and Russia. The development, integration and operation of the contributions of each partner into a single integrated Station, with all of its associated supporting systems, facilities, and personnel, is arguably the most complicated and difficult international peacetime effort ever undertaken. In order to deal with a task of this complexity, new systems of management, new international relationships, new types of partnerships, and new funding mechanisms had to be developed. The critical factors in meeting these challenges are the dedication of the people involved in all the nations who are participating and the relationships those people have formed with each other. A tremendous amount of credit for the continuing success of this Program goes to those people of all nationalities.

BACKGROUND

The current International Space Station (ISS) was born from the Space Station Freedom Program. During the redesign effort in Crystal City, Virginia, in 1993, Freedom became the International Space Station Alpha (ISSA), which remains the basis for our efforts today. The groundrules for the development of the Alpha option included

- the use of as much Space Station Freedom hardware and systems as possible (approximately 75% of Freedom designs were incorporated in ISSA);
- the continued involvement of all international partners with as little impact as possible (CSA, ESA and Japan remain partners);
- and a design that could be implemented within strict, flat budget constraints.

In September 1993, a Program Implementation Plan (PIP) was developed and baselined for the new ISSA. Based on this PIP, NASA reached agreement with the Clinton Administration and with Congress that the ISSA would be implemented with a flat budget of $2.1 billion per year, for a total of $17.4 billion. To accomplish these goals, NASA formed a new Space Station Program Office, located at the Johnson Space Center.

RUSSIAN INVOLVEMENT

During the Crystal City redesign effort, an expanded relationship between the U.S. and the newly-formed Russian Republic was evolving in ways that would have dramatic impacts on the ISSA still under formation. At the Bush/Gorbachev summit in July 1991, the U.S. and the Soviet Union agreed to expand their civil space cooperation in a number of areas, including an agreement in principle for the first time to exchange crew members, with a U.S. astronaut aboard the Soviet space station Mir and a Soviet cosmonaut on a Space Shuttle mission. This agreement in principle was codified in the June 1992 five-year agreement in civil space cooperation between the U.S. and the newly-formed Russian Federation. On October 5, 1992, the Implementing Agreement on Human Space Flight Cooperation was concluded. The program outlined in the Agreement was at

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that time the largest U.S./Russian or Soviet cooperative space venture since Apollo/Soyuz in 1975. The activities under this agreement included the long-duration flight of a U.S. astronaut aboard the Russian space station Mir, flight of a Russian cosmonaut on a Space Shuttle mission, a joint Shuttle/Mir docking mission, and a joint science program.

In September 1993, while planning for these activities was still ongoing, and at the same time that the Crystal City redesign effort was completing the ISSA PIP, Vice-President Gore and Prime Minister Chernomyrdin chaired the first meeting of the U.S./Russian Joint Commission on Economic and Technological Cooperation. They called for further expansion of the human space flight cooperation between the U.S. and Russia, in three phases. Phase One greatly expanded the current activities. Instead of a single crew exchange and a single Shuttle/Mir docking, Phase One would now last through 1997 with multiple missions.

The second and third phases culminate in the construction of an international space station involving the U. S., its current partners, and Russia. The Crystal City redesign team, fresh from completing the PIP for ISSA, began immediately to meet with a Russian team to develop anew PIP that could incorporate Russia into the International Space Station program. Upon completion of the new PIP, NASA consulted with its Space Station Partners on its intentions to add Russia to the Partnership. A Station Readiness Review was then held at Johnson Space Center later that month to develop a new baseline for the ISSA.

Concurrently with these discussions, an amendment or protocol to the October 5, 1992, Agreement was negotiated between NASA and RSA to cover:

- two cosmonaut flights on-board the Shuttle
- a Shuttle rendezvous and close approach to Mir
- up to two years astronaut stay time onboard Mir
- up to ten Shuttle/Mir docking missions
- a joint science mission
- joint development of new technology

The Protocol mentioned reimbursable financial arrangements between NASA and RSA to cover the costs of the expanded Phase One and selected Phase Two activities, at a rate of $100 million per year for four years; $400 million total. Both the Protocol to the October 5, 1992, Human Space Flight Agreement and the NASA/RSA $400 million Letter Contract were signed at the second meeting of the Gore/Chernomyrdin Commission in Washington on December 16, 1993.

NASA and RSA began to definitize the Letter Contract during the Spring of 1994. The definitized Contract was signed by the negotiators on June 21, 1994 and by the NASA Administrator and RSA General Director the following day in Washington. During this same period, NASA and RSA developed an Interim Agreement for Russian involvement in the ISSA. The Interim Agreement allowed Russia to begin work with NASA and the other Partners on the development of the ISSA while negotiations were ongoing for a formal Memorandum of Understanding that would make Russia an official Space Station Partner. The Interim Agreement was signed on June 24, 1994.

**INTERNATIONAL PARTNER CONTRIBUTIONS**

**MOU and IGA Negotiations**

With each original Space Station Partner, the U.S. Government signed an Intergovernmental Agreement (IGA) with the Partner’s government and NASA signed a Memorandum of Understanding (MOU) with the Partner’s space agency. (In the case of Europe, ESA signed the MOU on behalf of all ESA member states supporting ISS activities.) Russian officials have indicated that they recognize that they are joining an existing partnership, with certain understandings and procedures already in place, and that they want to participate within this framework. Negotiations for the IGA and MOU are underway.
As negotiations with Russia proceed, NASA and the U.S. Government are negotiating modifications to the existing MOUS and IGA with the existing Partners to reflect: 1) the new Partnership roles and responsibilities with Russia as a Partner, and 2) the evolving contributions of the existing Partners. The major issues being discussed during these negotiations are:

- the transition from “Shuttle only” support of the ISS to a mixed fleet to include Russian, European and Japanese vehicles
- streamlined program management structures and requirements resulting from the redesign
- new Partner contributions and responsibilities
- system for allocation of Station accommodations, resources and crew flight opportunities, in proportion to the common operations requirements that each partner provides or funds.
- sharing of common operations costs and methods of meeting obligations

The goal is to complete an original IGA and MOU with Russia and to sign protocols, or modifications, to the existing IGA and MOUs at the same time, so that all ISS Partners can move forward in a consistent and complementary manner.

**Canadian Space Agency**

Canada’s contribution to the ISS is the Mobile Servicing System (MSS) and its associate ground elements. The MSS will provide a second-generation robotic arm similar to the Canadarm developed for the Shuttle, and consists of the 58-foot long Space Station Remote Manipulator System (SSRMS) that can handle masses up to 220,000 pounds, a Base System, and a 12-foot robotic arm called the Special Purpose Dexterous Manipulator (SPDM) that attaches to the SSRMS. CSA will also develop a Space Operations Support Center, MSS Simulation Facility and Canadian MSS Training Facility. The first consoles of the Operations Support Center have already been installed and were used to monitor operations during the STS-74 Shuttle mission to Mir in November 1995, which included the flight of a Canadian mission specialist and Canadian experiments.

In 1994, CSA experienced budgetary cuts and informed NASA that the Canadian contribution needed to be restructured. In May 1994, NASA and CSA signed the “Arrangements for Enhanced Cooperation in Space.” The Arrangements refined NASA/CSA cooperation in a broad spectrum of areas and contained the following provisions concerning the Canadian contributions to the ISS:

- CSA would no longer provide the MSS Maintenance Depot for storage of on-orbit spares.
- CSA could delay the decision to manufacture the SPDM until April 1997.
- the role of operating the MSS would be maintained in Canada by CSA.
- NASA has increased responsibility for repair and overhaul of CSA elements.
- CSA’s utilization allocation would be decreased from 3.0% to 2.7%; or 2.3% if Canada does not develop the SPDM.

Although CSA has until April 1997 to make a final decision concerning provision of the SPDM, NASA recognizes the importance the SPDM plays in the on-orbit construction and operation of the ISS. The SPDM is necessary to perform the dexterous robotic functions required for these activities and therefore critical for ISS completion. Therefore, NASA asked CSA to make an early decision on the SPDM so that alternatives can be pursued if Canada decides not to produce it. Throughout 1995, CSA investigated lower cost versions of the SPDM and potential partnerships for its manufacture. CSA/industry discussions are currently underway to determine the feasibility of a joint activity. CSA should inform NASA of its final decision in the next 2-3 months. If CSA does not pursue a SPDM program, NASA is prepared to provide an alternative system.

**Japan**

The Japanese contribution to the ISS has remained stable and unchanged since the original MOU was signed between NASA and the GOJ. The National Space Development Agency of Japan
(NASDA) will provide the Japanese Experiment Module (JEM), which consists of a number of different components, including the following elements:

- Pressurized Module (PM) - pressurized laboratory, providing 77% of the utilization capability of the U.S. laboratory and can accommodate 10 racks
- Exposed Facility (EF) - external platform for up to 10 unpressurized experiments
- Remote Manipulator System - 32-foot robotic arm used for servicing system components on EF and changing out attached payloads.
- Experiment Logistic Module - carriers for both pressurized and unpressurized logistics resupply

All of the JEM elements are scheduled for launch on the Space Shuttle. The PM will be the primary payload for one Shuttle mission. The remaining JEM elements will be delivered on another three shared Shuttle missions.

The Japanese completed a feasibility study of the H-II Transfer Vehicle in March 1995 and have requested that NASA include the use of the NASDA Logistics System in the ISS baseline for logistics resupply. It consists of the H-II Transfer Vehicle (HIV), the H-IIA launch vehicle and the ground segment. NASA and NASDA are currently working together to explore the types of missions the HTV could perform and NASA is providing the information necessary for NASDA to assure the HTV is compatible with the ISS baseline. The Japanese have also proposed use of their planned Data Relay and Tracking satellite for complementary communication support to the ISS. NASA will also develop and operate a Space Station Operations Facility at Tsukuba Space Center in Japan. It is located at the Space Station Integration and Promotion Center, which also includes a test building, astronaut training facility and weightless-environment test building.

The JEM program is on schedule and on budget. A Joint program Review with NASA and Japanese top officials was held in August 1995. A major milestone was achieved in October 1995 when the JEM Pressurized Module structural test article underwent structural qualification testing. This was the first ISS pressurized module for any Partner to undergo qualification structural testing. The first JEM Critical Design Review was held in February 1996 to confirm requirement traceability to the hardware design; the second CDR is scheduled for May 1997. Most of the components and assemblies have been manufactured. System integration of the engineering model is underway. Manufacturing of the proto-flight model components and assemblies have begun. The JEM Pressurized Module is scheduled for launch to the ISS several months past the original date of March 2000, followed by another shared assembly mission for the unpressurized elements a year later.

**European Space Agency**

After 5 years of considerable political maneuvering and negotiations, ESA legally and financially committed to its current complement of contributions to the ISS during the October 18-20, 1995, ESA Ministerial Meeting in Toulouse, France. NASA welcomed this positive decision, as the loss of the COF would have had implications for the research programs of all ISS Partners. The approved ESA contributions are:

- the Columbus Orbital Facility (COF, formerly the APM), providing 77% of the utilization capability of the U.S. laboratory
- the Automated Transfer Vehicle (ATV) for ISS logistics resupply and propellant resupply and reboost missions, to be launched by the Ariane 5 launch vehicle.

The COF will accommodate 10 international standard payload racks, 5 of which are allocated to European users. The ESA program includes a utilization preparation program to plan for eventual use of these racks and to develop microgravity facilities for operation on the ISS. The program also includes definition studies of a potential future Crew Transfer Vehicle (CTV). The studies will take place between 1996 and 1998, with a recommendation for pursuing full development put forth in late 1997.
ESA will begin development of the COF in January 1996 and of the ATV in September 1996. The launch date of the COF is scheduled for November 2002. An ATV demonstration flight is scheduled for March 2002 with the first flight of an ATV to the ISS in early 2003.

ESA has also made separate arrangement with the Russian Space Agency for 2 contributions to the Russian elements: the European Robotic Arm (ERA) on the Russian Science and Power Platform and the Data Management System (DMSR) for the Service Module.

**Italian Space Agency**

In 1991, NASA and the Italian Space Agency (ASI) entered into an agreement whereby Italy would develop two Mini Pressurized Logistics Modules (MPLMs) in addition to being a member of ESA. Italy is not a full-fledged Partner because ASI will not continue to operate and maintain a facility onboard the ISS. Instead the MPLMs will be turned over to NASA after delivery to Kennedy Space Center and NASA will own and operate them.

Following the Crystal City redesign effort, NASA and ASI decided to amend and renegotiate certain aspects of the agreement to reflect changes in requirements and to add a third MPLM. Those negotiations are still underway. In addition to providing the modules, ASI will develop a sustaining engineering center, the MPLM Technical Center, in Turin, Italy. The Center will also be used to receive data from the modules and to control Italian utilization experiments on ISS.

As a member of ESA, Italy will also provide the structure for ESA’s COF module, using the same module design as the MPLMs. In return, Italy will use the European life support, or ECLSS, system developed for the COF as the ECLSS system aboard the MPLM.

**Russian Space Agency**

The Russian contributions to the ISS will not be formally confined until the conclusion of the MOU negotiations. However, work within the ISS program is proceeding with the following Russian hardware baselined: service module, universal docking module, solar power platform, docking compartment, life support module, and research modules. This is approximately a third of the mass of the completed assembly of the ISS and will provide nearly half of the pressurized volume of the ISS. The service module will provide early sleeping and living quarters for crew members. Russia will also provide logistics resupply and station rebooting capability with the Progress and other vehicles, as well as crew transfers aboard the Soyuz vehicle.

NASA is also obtaining the Functional Energy Block, or FGB, module from Khrunichev, a Russian company, under a contractual arrangement. RSA may provide the launch of the FGB as a Partner contribution; therefore, the launch of the FGB, which will be the first element launch of the ISS, will be considered a joint U.S./Russian launch. The FGB is being procured for NASA by Boeing. Boeing and Khrunichev signed the contract for the FGB in August 1995.

RSA approached NASA in December with a proposal to consider utilizing the existing Russian Mir space station in the early assembly stages of the ISS. RSA said that recent examinations showed that Mir would last longer than originally projected and should continue to be used. After discussions in December and January, NASA and RSA agreed to augment the Phase I Program by extending use of Mir and to modify some Russian contributions to the ISS. For example, the solar power platform will now be launched aboard the Shuttle, not a Proton, and Progress logistics flights may be provided by a new FGB cargo vehicle instead. RSA also recommitted to providing the FGB and Service module as designed on schedule. These arrangements were confined at the Gore/Chemomyrdin Commission meetings in Washington in January. Further discussions to finalize the technical and managerial details are scheduled for March. Negotiations to complete the IGA and MOU will begin after these discussions and be completed this summer.
ACCOMPLISHMENTS

Management

NASA announced in February of this year that the management of the NASA Space Station Program will be centralized at the Space Station Program Office (SSPO) at Johnson Space Center. The Program Manager will continue to be located at JSC and will report to the Center Director. The Program Director at NASA Headquarters will maintain a small staff and will be responsible for relations with Congress and external organizations.

NASA and Boeing are completely integrated in the ISS Program management. Each major Integrated Product Team, the functional work unit within the ISS structure, has a NASA and a Boeing lead. One is designated as the Team Lead with some teams being led by NASA and some by Boeing.

The current staffing level for the NASA SSPO is 334, with the projected level at 339. This is fully consistent with the earlier Vest Committee recommendation that the Program Office be staffed at 300-400 people. NASA centers have been tasked to provide additional matrixed personnel and appropriate goods and services, again consistent with the Vest Committee recommendations. The staffing level at the Program Office for the prime contractor is about 370, with approximately 920 subcontractor employees. Approximately 3500 additional personnel are employed by the Tier 1 subcontractors of McDonnell Douglas, Rocketdyne and Boeing/Huntsville.

The Space Station Program has had outstanding performance for the last two years, with progress toward milestones on target for schedule and cost. A number of major milestones have been accomplished during the past year. In March, the second Incremental Design Review (IDR) was completed. The purpose of an IDR is to ensure that the design of all elements, systems and subsystems included in the increment that is the subject of the review has been completed, as well as all actions and open items associated with that increment. The IDR is considered to be an in-process event, with activities throughout the previous year directed toward closure by the time of the IDR completion date.

The first IDR reviewed the first increment of the ISS, which includes missions up through flight 6A. The IDR was very successful. Of 431 assessments planned for completion at the IDR, 402 or 93% were completed. Of almost 5000 issues identified for work, over 4500 were successfully resolved by the time of the IDR, and of 239 products planned for the IDR, 201 were delivered on time. All of the items not completed on time are being addressed and will be completed. IDR #1 was an extremely important event for the ISS Program, being the first integrated systems engineering approach design review.

Whereas IDR #1 covered Flight Group 1 at a Preliminary Design Review, or PDR, level of maturity, IDR #2 will cover Flight Group 1 at a Critical Design Review, or CDR, level of maturity. IDR #2 will also conduct a first order assessment of the entire preliminary assembly sequence for the ISS. IDR #3 is scheduled for March 1997, and IDRs #4, 5, and 6 will continue reviews through Assembly Complete.

Hardware

NASA has remained ahead of schedule for completed flight hardware since 1994. Over 80,000 pounds of flight hardware had been manufactured by the end of last year, almost 5,000 pounds more than projected at this point. The exterior structures of the U.S. components are almost complete. Machining of Nodes 1 and 2 were completed last year. Node 2, which serves both as the structural test article and as a flight article, underwent pressure and leak testing in February. Node 1 will undergo testing after Node 2 and will begin final assembly and checkout in June, including the installation of floors, equipment racks, life support systems, power and communication systems. It is scheduled for launch in November 1997. Machining of the laboratory and habitation modules has also been completed. Interior mechanical installation is
underway and pressure testing will be completed this summer. The machining of the airlock is due to be finished in May. This will complete construction of the exterior of all the U.S. pressurized elements for ISS.

Completion of the first production of the International Standard Payload Rack, the pressurized adapter for the FGB, a photovoltaic array assembly, and the Integrated Electronics Assembly structure framework was also achieved in 1995.

Testing on a number of major components will be completed in 1995 as well. The JEM Pressurized Module structural test article underwent structural qualification testing in October and passed. This was the first ISS flight hardware to be fully tested in this manner and was a major milestone for the ISS Program. Dynamic, static and pressure testing of the FGB module has also been completed. The S1 Truss and Radiator Orbital Replacement Unit underwent underwater testing in the WETF in May. Qualification test on the Pressurized Module 2 weld was completed in June. In September, engineering tests were finished on the Battery Charger/Discharge Unit.

This is tremendously encouraging and demonstrates the effectiveness of the new organization and management structure and particularly the dedication and hard work of the employees working on this program. These accomplishments would not have been possible without the commitment and ingenuity of those involved. However, the main challenge is yet to come. Scheduled hardware completions in 1998 jump to 223,200 pounds, as compared to 70,100 pounds in 1997. Even with the improvements made thus far, extreme diligence, continuous improvement, and dedication will be required to meet this goal.

**Phase One Missions**

The Phase One Program Office operates separately from but in close coordination with the Space Station Program Office. The objectives of the Phase One Program include: 1) the U.S. and Russian space programs learning to work together on joint projects; 2) risk mitigation activities for ISS; 3) long-duration space experience and studies; and 4) science and research.

A number of historic and dramatic Phase One events were accomplished last year, including:

The STS-63 mission in February, a rendezvous and close-approach mission to the Mir space station. The second Russian cosmonaut to fly aboard the Shuttle was on this mission and was able to see and communicate with his fellow cosmonauts aboard Mir.

The first NASA astronaut aboard a foreign launch vehicle, Dr. Norman Thagard launched on a Russian Soyuz vehicle in March from Baikonur, Kazakhstan. Thagard spent the next 115 days aboard Mir with his two cosmonaut hosts.

On May 20, the Russian Spektr module was launched to Mir carrying 1000 kg of U.S. scientific hardware. The module was docked with Mir on June 1.

STS-71 in June/July, the first Shuttle/Mir docking mission. Aboard Atlantis were two Russian cosmonauts who would replace the two Russian cosmonauts already aboard Mir. Those cosmonauts, along with Thagard returned to earth onboard Atlantis after five days of docked activities.

STS-74, the second Shuttle/Mir docking missions, in November 1995 and delivered to Mir the Docking Module built in Russia, which will provide a docking port for the future Shuttle/Mir missions that will take place through 1998.

In March, the third Shuttle mission visited Mir and docked using the Docking Module left by STS-74. This mission transported astronaut Shannon Lucid to Mir, who is still will remain on Mir longer than Dr. Thagard, until the next Shuttle mission.
The Phase One Program is now making plans for the additional Shuttle flights to Mir that were agreed to in January. Currently, two additional flights are planned in 1998. They will be utilized for logistics support and science, but specific details are still being worked out.

CONCLUSION

The changes in structure, organization, and management in the ISS Program since the redesign effort in 1993 have been accompanied by new opportunities and approaches for our International Partners. The benefits have been multiple, visible, and positive for all involved. Rather than a single route to the ISS, there is now multiple access to the Station, including the Shuttle and Soyuz vehicles for crew members and the Shuttle, Progress and possibly the Ariane Transfer Vehicle and H-II Transfer Vehicle for logistics support. Distributed operations and utilization control centers are now possible. Canada will establish an MSS Control Center in Saint Hubert near Montreal. Europe and Japan will establish centers to operate and receive data from their experiment payloads aboard the Station. Russia will of course operate TsUP, or Mission Control Center, in Moscow to support the Russian elements aboard the Station, their transportation vehicles, and to serve as backup Station Mission Control.

The addition of the Russian space program to the Space Station partnership has added

- Larger volumes onboard the Station.
- Larger crews accommodated.
- Permanent habitation earlier.
- Greater science capability earlier.
- Automatic docking systems.
- Greater exposure to earth’s surface.
- Use of proven technologies.

The ISS program faces significant challenges. We must live within our budgetary constraints, overcome cultural and national differences, build and operate the ISS on schedule, and maintain a global interest, excitement, and commitment to the program. But if one has doubts that these will be accomplished, then he or she should spend time with the experienced, capable people supporting this program in the United States and abroad. The thousands of individuals who, worldwide, make up the work force of the ISS program come from varied backgrounds, areas of expertise, and cultures. However, they all share commitment, competence, and dedication to an ultimate goal.

This widespread program will produce hardware in different countries, operate various control centers, provide multinational crews, and all the other work that goes into producing a Space Station. When this is all integrated into a single functional, productive and inspirational entity, the International Space Station, it will be recognized as a historical accomplishment and will serve as a tribute to the workforce who produced it.

The International Space Station Program is currently creating the mechanisms and processes that will be used by future international civil cooperative activities in all fields. Because of the limited resources available to individual nations today and the expanded expertise possessed by larger numbers of countries, large projects conducted on a unilateral basis will be phenomena of the past. Future activities will by necessity be conducted on cooperative bases. We are currently defining the management methods for those projects. To a large extent, we will also determine whether many of those projects will occur at all. If the International Space Station Program does not succeed, international civil cooperation in all fields will be stunted for the foreseeable future. On the other hand, if the International Space Station is the success we are working toward, it will pave the way for even bigger, more far-reaching, and more inspiring joint achievements than would have been possible before.

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