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

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Introduction

The International Space Station, as the largest international civil program in history, features unprecedented technical, managerial, and international complexity. Seven international partners and participants encompassing fifteen countries are involved in the ISS. Each partner is designing, developing and will be operating separate pieces of hardware, to be integrated on-orbit into a single orbital station. Mission control centers, launch vehicles, astronauts/cosmonauts, and support services will be provided by multiple partners, but functioning in a coordinated, integrated fashion. A number of major milestones have been accomplished to date, including the construction of major elements of flight hardware, the development of operations and sustaining engineering centers, astronaut training, and seven Space Shuttle/Mir docking missions. International partner contributions and levels of participation have been baselined. Astronauts and cosmonauts are in training. In short, the International Space Station is well on its way to its first launch and being a fully-operation program.

Background

The current International Space Station (ISS) was born from the Space Station Freedom Program. In his State of the Union Message to Congress in January 1984, President Ronald Reagan officially established the goal of developing a permanently inhabited station in orbit. Invitations were issued to Canada, Europe and Japan to join in this effort and agreements with the Canadian Space Agency (CSA) and the European Space Agency (ESA) were reached in September 1988, and with the Government of Japan (GOJ) in March 1989.

However, in response to additional budget constraints, complaints about an unwieldy management structure, and concerns about the ability of the program to meet schedule milestones, the Clinton administration and NASA Administrator Dan Goldin called for a redesign of the station in the Spring and Summer of 1993. This was the so-called Crystal City activity. By September 1993, a Program Implementation Plan (PIP) had been developed and baselined for the new International Space Station Alpha (ISSA).

However, 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 in September. They issued a joint statement calling

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for further expansion of the human space flight cooperation between the U.S. and Russia. The activities would take place in three phases.

The Phase One Program greatly expanded the activities under the 1992 Human Space Flight Agreement to exchange an astronaut and cosmonaut. 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 complete a new redesign and then develop a new PIP that could incorporate Russia into the International Space Station program. This effort entailed the merging of two distinct stations, the U.S. ISSA and the Russian Mir 2. Components of both would have to be integrated and assembled, piece by piece, so that the total station could be operated and maintained as a single vehicle, not only when completed, but also at each point during assembly.

ISS International Partner Cooperation

MOU and IGA Negotiations

NASA and RSA reached an *ad referendum* agreement on a Memorandum of Understanding (MOU) between NASA and RSA in July 1996, following the signing of a NASA/RSA agreement in June on the sharing of ISS accommodations, resources, responsibilities and costs. This agreement resolved many outstanding technical and managerial issues, such as the sharing of common operations costs, utilization rights on board the ISS, crew makeup, and provision of logistics and other services.

The other International Partners and participants reached *ad referendum* agreement on the multilateral Intergovernmental Agreement (IGA) between their governments in December 1996. Having reached agreement on the IGA and the MOU with RSA, NASA updated the MOUs with the other Partners. The IGA and all the updated MOUs were signed in Washington, D.C. on January 29, 1998.

ISS Construction Phases

The ISS Phase 2 (with the NASA/Mir Program being Phase 1) begins in June 1998 with launch of the Russian-built FGB on a Russian Proton rocket. Phase 2 creates an advanced orbital research facility with early human-tended capability using hardware developed by U.S., Russian, Italian, European, and Canadian resources. A number of U.S. and Russian systems are shared across the station design. Russian hardware provides nominal propulsion, guidance, navigation, attitude control, and power during early Phase 2 operations. As U.S. hardware is launched, data management and electrical power will be added and navigation and pointing functions will be transitioned from the Russian systems. Canadian and Italian hardware is also utilized during Phase 2.

Phase 3 completes ISS construction, readying the Station to support a permanent human presence with a minimum operational lifetime of 10 years. Phase 3 begins with delivery of the Russian Docking Compartment and includes delivery of the Japanese Experiment Module, the Columbus Orbital Facility, and two Italian-built nodes, and concludes with delivery of the U.S. Habitation Module in 2003. Capability is increased incrementally by adding modules and systems. Phase 3 also completes the truss, provides additional U.S. power modules and research facilities, and additional Russian science modules, and completes the outfitting for full science utilization.

Canadian Space Agency

Canada's contribution to the ISS is the Mobile Servicing System (MSS) and its associated ground elements. The MSS provides a second-generation robotic arm similar to the Canadarm developed for the Shuttle and consists of a 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 robot called the Special Purpose Dexterous Manipulator (SPDM) that attaches to the SSRMS. After additional negotiations were completed in 1997, the SPDM became an offset to CSA's common system operating costs, reducing Canada's cost of utilizing ISS.

CSA has developed a Space Operations Support Centre, MSS Simulation Facility and Canadian MSS Training Facility. The first consules of the Operations Support Center 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. One such experiment was the Space Vision System, an advanced camera system that will be used to assist astronauts as they manipulate the SSRMS during Station assembly.

The most recent major milestone for CSA was the SSRMS Acceptance Review, held in October 1997. The SSRMS was conditionally accepted, and a pre-shipment SSRMS review will be held in August 1998 to assure that all issues and actions are closed. The SSRMS is scheduled for launch to the ISS in June 1999, with the SPDM following in January 2002.

National Space Development Agency of Japan

The National Space Development Agency of Japan (NASDA) will provide the Japanese Experiment Module (JEM), which consists of a number of different components:

- 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 (ELM) - carriers for both pressurized and unpressurized logistics resupply

All of the JEM elements are scheduled for launch on the Space Shuttle. The delivery of the JEM elements to the ISS will commence in May 2001 with the launch of the JEM ELM-PS on a shared flight that also contains U.S. elements. In August 2001, the JEM PM will be the primary payload for one Shuttle mission. A subsequent shared flight in February 2002 will deliver the JEM EF and ELM-ES with external payloads.

The majority of the component and assembly engineering models have been manufactured. System integration of the engineering model is underway and expected to conclude in April 1998. Manufacturing of the proto-flight model components and assemblies began in 1996, and the Pressurized Module is expected to undergo checkout in late 1998.

In addition, to support its participation in the ISS, NASDA has constructed and outfitted a number of facilities. A Weightless Environment Test System (WETS) began operations in 1994. NASDA also constructed an astronaut training facility to support ISS crew selection and training, health care, and human space flight technology development. In July 1996, NASDA completed construction of its Space Station Operations Facility, which will be used for JEM operations. These facilities join the already completed Space Experiment Laboratory and Space Station test building to comprise the Space Station Integration and Promotion (SSIP) center at Tsukuba Space Center.

The Japanese completed a Systems Requirements Review of the H-IIA Transfer Vehicle in October 1997. It consists of the H-II Transfer Vehicle (HTV), the H-IIA launch vehicle and the ground segment. The Japanese have also proposed use of their planned Data Relay and Tracking satellite for complementary communication support to the ISS. In addition, NASA and NASDA have signed an Agreement in Principle about the provision of the Centrifuge Accommodation Module (CAM), the centrifuge rotor, and the Life Science glove box, as a partial offset to the costs of launch JEM on the Shuttle. NASA and NASDA are now working to complete the hardware specifications and develop an implementing arrangement to effect the program.

European Space Agency

ESA formally committed to its current complement of contributions at the ESA Ministerial Meeting in Toulouse, France, October 1995, after several years of internal political and economic discussions. The approved contributions are:

- the Columbus Orbital Facility (COF, formerly the APM), with accommodations for 10 standard racks, 5 of which are allocated to European users. The COF provides 77% of the utilization capability of the U.S. laboratory. Development of the COF began in January 1996 and is scheduled to be launched in late 2002.
- the Automated Transfer Vehicle (ATV) for ISS logistics resupply, propellant resupply and reboost missions, to be launched by the Ariane 5 launch vehicle. An ATV demonstration flight is scheduled for March 2002 with the first flight of an ATV to the ISS in early 2003.
- Cooperation on the X-38, which is the protoflight vehicle for the ISS Crew Return Vehicle (CRV). ESA is considering participation on the CRV as well.

In addition to this contribution to the ISS partnership, ESA will receive early utilization access to the ISS and two astronaut opportunities prior to the launch of the COF in exchange for ESA provision of capabilities to support early utilization functions and ground facilities. Specifically, ESA will provide a microgravity glovebox, a minus-80 degree freezer, a scientific instrument pointing system, and ground software to support the Mission Build Facility.

ESA has also made separate arrangement with the Russian Space Agency for two contributions to 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 for Italy to develop two Mini Pressurized Logistics Modules (MPLMs) in addition to being a member of ESA. In exchange for providing the MPLMs, ASI receives a portion of NASA's ISS utilization capability. Because ASI will not continue to operate and maintain a facility onboard the ISS, ASI is designated an International Participant. 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. In addition to providing the modules, ASI will develop a sustaining engineering center, the MPLM Technical Center, in Turin, Italy. The Center will 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 system, or ECLSS, developed for the COF as the ECLSS system aboard the MPLM.

The first MPLM unit will be delivered to Kennedy Space Center in June 1998 and launched in June 1999. The second unit will be delivered mid 1998 and launched in February 1999. The third unit will arrive at KSC in October 2000 and be launched in September 2001.

The ESA COF Barter Arrangement was officially signed in October 1997. As part of this arrangement and as a member of ESA, ASI will deliver two nodes to NASA. One node would serve as Node 2 on the Station, in place of the Node Structural Test Article (provided by Boeing). The second node will be the Habitation Module 1. This will replace the Boeing-built U.S. Hab by housing the ECLSS functions, until the Habitation Module 2 arrives later in the assembly sequence. NASA/ASI are still in negotiations regarding the configuration of Hab 1. These are expected to be complete by February 1998.

Russian Space Agency

The currently-planned Russian contributions to the ISS include: service module, universal docking module, science 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 reboosting 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. Because this capability was a NASA requirement, NASA has procured the FGB for $190M and providing it as a U.S. contribution.

In the Fall of 1996, RSA formally informed NASA that sufficient funding had not been received from the Russian Government to support the development of the Service Module (SM) and follow-on elements and that the SM would be at least 8 months late. NASA and Russian space organizations held a number of meetings in November and December of 1996 and January 1997 to discuss methods for accommodating the delay of the SM and other changes. During this time, the Russian Government finally approved the budget for RSA for 1997 to support their continuing work for ISS and to meet the new schedules. A Joint Program Review was held in Moscow on January 24, 1997 to finalize and confirm these arrangements and to agree upon a new assembly sequence schedule.

In Spring of 1997, RSA began receiving budget payments from the Russian government. Russian contractors began to work at full speed again and considerable progress was made throughout 1997. NASA took advantage of the additional time allowed by the schedule slip to have modifications made to the FGB module to add additional robustness. The FGB module has been completed, with modifications, by Khrunichev, and was shipped from the factory to the Baiknour launch site in January 1998. It will undergo additional tests and integration at Baikonur in preparation for launch in June. Work is progressing on the Service Module and

Progress vehicles, as well. Energia is currently 2-3 months behind schedule, but state that they can catch back up. However, RSA did not receive the promised additional funding in late 1997, and a 1998 budget is not yet in place. Discussions between NASA and RSA will be held on this and other issues at General Designer's Reviews and Joint Program Reviews in January and again in March.

Brazilian Space Agency

NASA and the Brazilian Space Agency (AEB) signed an agrement October 14, 1997, outlining Brazil's participation in the ISS. Brazil will provide six items in return for research and astronaut opportunities on the ISS:

- Expedite the Processing of Experiments to Space Station (EXPRESS) Pallet. The pallet serves as an interface mechanism which will be utilized to attach small payloads to the U.S. truss segment.
- Unpressurized Logistics Carrier (ULC). A platform for transportation of unpressurized cargo and will be attached to U.S. truss segment P3.
- Technology Experiment Facility (TEF). A facility designed to provide long-term exposure to the low-Earth-orbit space environment for active and passive experiments.
- Window Observation Research Facility 2 (WORF-2). Intended to be an ISS capability devoted to observational science and remote sensing development.
- Cargo Handling Interface Assembly (CHIA). Flight support equipment which provides a method of attaching cargo to ULCs and allows for on-orbit handling of cargo.
- Z1-ULC Attach System (Z1-ULC-AS). System which provides mounting accommodations for external passive payloads and experiments at the Z1 location.

Brazil will retain ownership of the TEF and WORF-2. NASA will take ownership of the other elements. In return, NASA will receive 0.45% of the non-Russian ISS research capabilities and a percentage of the utilization of the TEF and WORF-2. Brazil will also receive at least one astronaut flight on ISS and an astronaut flight on the Shuttle.

U.S. Contributions

The U.S. is the initiator, integrator, and leader of the International Space Station Program. The U.S. hardware contributions begin at the start of the assembly phase with the first launch of the FGB control module mentioned above. The FGB provides initial propulsion, propellant storage, attitude control, and data links for the station. Other U.S. hardware added to the station in Phase 2 includes:

- Node 1, linking the FGB to the U.S. Lab Module
- Pressurized Mating Adapters
- U.S. Laboratory Module containing 13 Integrated Standard Payload Racks
- Truss segments Z1 and P6
- A pair of large solar arrays for generating about 19 kilowatts of electrical power
- Airlock for spacewalks using Russian and U.S. space suits

U.S. hardware contributions in Phase 3 include:

- Node 2, linking the Lab to the Centrifuge, the JEM, and Europe's Columbus Orbital Facility (COF) modules

- Habitation Module, providing living quarters for U.S. and international crew members
- Centrifuge Module, a unique biomedical space laboratory providing artificial gravity
- Cupola for viewing robotic operations used in assembling and maintaining the Station
- Remaining segments of the 310-ft-long truss
- Three additional pairs of large solar arrays

At the end of the assembly phase in 2002, the U.S. segment will provide almost half of the station's pressurized volume. The U.S. will also provide integrated ISS services for all the international partners, including:

- Electrical power generation, storage, and distribution
- Communications
- Data storage and distribution
- Thermal control
- Environmental control and life support
- Crew health maintenance
- Attitude control using control moment gyroscopes

All power for the U.S., Japanese, and European modules (about 88 kilowatts) will be generated by four pairs of large, truss-mounted U.S. solar arrays and will be routed through U.S. power storage and conditioning systems. The U.S. communications contribution will include the U. S. Space Flight Tracking and Data Network on the ground and the Tracking and Data Relay Satellite System in space.

The U.S. also provides the Space Shuttle, a vital transportation link for station assembly and operations. In addition to U.S. station components and astronauts, the Shuttle will deliver hardware and ferry crew members and their supplies for all the other international partners. The Shuttle is also the only spacecraft in the world capable of returning to Earth large quantities of equipment and experiment results.

To provide for a contingency against further delays in the Russian SM and to increase the redundancy and robustness of the ISS, NASA is developing an Interim Control Module (ICM). The ICM will provide additional propulsion capabilities for the ISS. The design is a derivative of a past propulsion bus developed at the Naval Research Laboratory. Once docked and activated, the ICM can provide full function for guidance, navigation, and control (GN&C) to the ISS. If the ICM is not required to support SM contingency, it will be reconfigured to protect against interruptions in Progress propellant delivery flights.

Current Status

Technical Management

Besides the accomplishments of the Partners and Participants described above, a number of major U.S. milestones have been accomplished in 1997. In July, the first Stage Integration Review (SIR) covering flights 1A/R and 2A was completed. The purpose of an SIR is to evaluate Stage products and demonstrate readiness to proceed toward final integration and certification of the Stages being reviewed. The Program has recently commenced SIR #2 which covers flights 1R, 2A.1, 3A, 2R, and 4A.

Approximately 200,000 pounds of U.S. flight hardware has been manufactured as of mid 1997. Node 1, which will be launched aboard the first Shuttle assembly flight, was delivered to

Kennedy Space Center (KSC) in June, and Phase 1 acceptance testing is currently 85% complete. Phase 2 testing began in mid-September and is scheduled to run through October. Pressurized Mating Adapter (PMA)-1 arrived at KSC in July, and acceptance testing resumed in August. Node 1 and PMA-1 are scheduled to be hard mated in late October. Final assembly is complete on PMA-2, and it is scheduled to arrive at KSC in early October. Both PMA 1 and 2 will be launched on Flight 2A with Node 1 (see figure 3). PMA-3 is preparing for proof pressure testing at the Boeing facility in Huntington Beach, CA while the Avionics Rack 1 and the Laboratory Module are both undergoing testing at the Boeing facility in Huntsville, AL. Welding is complete on the MPLM flight module 1, and it is scheduled for shipment to KSC in April 1998. The Space Station Remote Manipulator System (SSRMS) is undergoing functional acceptance testing and is scheduled to be on-dock at KSC in March 1998. Proof pressure and leak rate tests were completed on the Airlock in July. The Z1 Qual article completed modal testing in September.

Scheduled hardware completions in 1998 jump to an additional 240,000 pounds. Even with the accomplishments achieved thus far, extreme diligence, continuous improvement, and dedication will be required to meet this goal.

Payload Management

The Space Station Program Office has always been responsible for the development and implementation of payload utilization and operations, but has also been tasked to expand that scope to include the cost, schedule, and technical aspects for the design, development and operations of major facility class payloads. The ISS Payloads Office revised the plans for outfitting the research laboratories on station in support of the changes in assembly milestones and on-orbit capabilities. They baselined the Pressurized Interface Requirements Document, which is critical for payload developers in meeting their schedules. The Payloads Office has made great strides in identification and implementation of telescience requirements to be implemented starting around the June 2002 timeframe to facilitate payload operations. Significant progress has also been made on consolidating U.S. payload crew training to provide the required time for the crew to adequately train on the complement of payloads manifested. Also, the Program conducted extensive discussions with NASDA and ESA, regarding the partners providing specific payload hardware. Tentative agreements are in place with the international partners, and detailed implementation arrangements are being made for delivery of the hardware.

Conclusion

The ISS Program continues to face 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.

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 experienced and capable workforce who produced it. It will also provide the gateway to the international exploration of deep space and other planets.