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Progress on the International Space Station – We're Part Way up the Mountain

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The first phase of the International Space Station construction has been completed, and research has begun. Russian, U.S., and Canadian hardware is on orbit, and Italian logistics modules have visited often. With the delivery of the U.S. Laboratory, Destiny, significant research capability is in place, and dozens of U.S. and Russian experiments have been conducted. Crew members have been on orbit continuously since November 2000. Several "bumps in the road" have occurred along the way, and each has been systematically overcome.

Enormous amounts of hardware and software are being developed by the International Space Station partners and participants around the world and are largely on schedule for launch. Significant progress has been made in the testing of completed elements at launch sites in the United States and Kazakhstan. Over 250,000 kg of flight hardware have been delivered to the Kennedy Space Center and integrated testing of several elements wired together has progressed extremely well. Mission control centers are fully functioning in Houston, Moscow, and Canada, and operations centers Darmstadt, Tsukuba, Turino, and Huntsville will be going on line as they are required.

Extensive coordination efforts continue among the space agencies of the five partners and two participants, involving 16 nations. All of them continue to face their own challenges and have achieved significant successes. This paper will discuss the contributions of the International Space Station partners and participants, their accomplished milestones, and upcoming events. The International Space Station program, the largest and most complicated peacetime project in history, has progressed part way up the mountain, and the partners are continuing their journey to the top.

PROGRESS ON THE INTERNATIONAL SPACE STATION—WE'RE PART WAY UP THE MOUNTAIN

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Abstract

The International Space Station (ISS) is unprecedented in its technological, engineering, and management complexity, and is one of the largest international collaborations ever undertaken. The ISS is a dramatic example of the ability of nations to work together as a team toward common goals and dreams. The challenges encountered and overcome by the international ISS team have been likened to climbing a mountain. Construction of the ISS has progressed rapidly in the past year. ISS is now a functioning microgravity laboratory in space hosting a permanent human presence, prompting the characterization that we are "part way up the mountain, and the team continues its climb."

Introduction

The ISS Program draws on the resources and expertise of 16 nations: the United States, Russia, Japan, Canada, Italy, Belgium, Denmark, France, Germany, the Netherlands, Norway, Spain, Sweden, Switzerland, the United Kingdom, and Brazil. The development, integration, and operation of the contributions of each partner in a single integrated Station—with all of its associated supporting systems, facilities, and personnel—has been characterized as the most complicated and difficult international peacetime effort ever undertaken. This challenge is being met by individuals and teams around the world who are dedicated to contributing the technical expertise and operational experience of their nations to the International Space Station.

The U.S. acts as overall integrator responsible for developing and operating major elements and systems aboard the Station. At assembly complete, the U.S. will provide integrated ISS services for all international partners including electrical power generation, storage, and distribution; communications; data storage and distribution; thermal control; environmental control and life support; crew health maintenance; and attitude control. Russia provides the Zvezda Service Module, the Soyuz spacecraft for emergency crew return, and Progress resupply vehicles. Three Japanese research elements and the European Columbus laboratory will be linked to the front of the U.S. modules. Three Italian-built, U.S.-owned Multi-Purpose Logistics Modules (MPLMs) are used to transport experiments and supplies to and from ISS. The Canadian robotic arm, mounted on a mobile base, will traverse the truss structure, which holds the solar arrays. Brazil is contributing various single items.

To date, there have been a total of 20 Flights (11 Space Shuttle, 9 Russian) to the ISS for the purpose of assembly, outfitting and resupply, and crew delivery. These successful flights have demonstrated that the ISS Program has developed a safe, stable integration, operations, and logistics capability. Approximately 190,000 pounds of ISS hardware is currently on orbit, with another 84,000 pounds planned for launch in 2002. Of the remaining hardware, over 40 percent has been shipped to Kennedy Space Center (KSC) for integrated testing and final preparations for launch.

The first crew of three was launched in October 2000, and early research began with the delivery of the U.S. Destiny Laboratory in March 2001. The ISS is now a functioning space station supporting its third long duration crew, with research increasing in scope and assembly operations ongoing.

Expedition Crew 1 - Sergei Krikalev, Bill Shepherd, and Yuri Gidzenko

Expedition Crew 2 - James Voss, Yury Usachev , and Susan Helms

Expedition Crew 3 - Mikhail Tyurin, Frank Culbertson, and Vladimir Dezhurov

Program Flight History

The assembly of ISS began with the launch of the Zarya Module on a Proton booster from the Baikonur Cosmodrome in Baikonur, Kazakstan, on November 20, 1998. Zarya (meaning "dawn" in Russian) provided early propulsive and guidance capability for the ISS until the arrival of the Zvezda Service Module. The Zarya Module was built by Russia's Khrunichev Industries Company under subcontract to Boeing.

The first fully U.S. module, the Unity node, was launched aboard the Space Shuttle (ISS Flight 2A/ Shuttle Mission STS-88) on December 4, 1998. During this mission, Unity was successfully mated to the orbiting Zarya. Unity is a connecting module with six docking ports to which other modules are attached.

In May 1999, ISS logistics and maintenance flight 2A.1/STS-96, carrying a double SpaceHab Module in the Orbiter's payload bay, transported supplies and equipment to outfit the Zarya and Unity Modules.

Following the STS-96 flight, ISS assembly was delayed almost a year due to several unrelated issues. The Space Shuttle fleet was discovered to have wiring damage and was grounded until all wiring could be inspected and replaced as necessary. Also, in June and September 1999, the Russians lost two Proton booster rockets following launch, but before reaching orbit. The Russians conducted an investigation of the Proton rockets, established corrective actions, and conducted several Proton launches prior to Zvezda's launch. Zvezda (the Russian word for Star) itself also had experienced delays in final outfitting due to funding shortages.

Because of the delay in the Zvezda's arrival on orbit, the next ISS logistics and maintenance flight was split into two missions. The first flight, designated 2A.2a/STS-101, was launched on May 19, 2000, carrying the items necessary to extend the life of Zarya's electrical systems until Zvezda's arrival, as well as equipment and supplies for outfitting Zarya. The second flight, 2A.2b/STS-106 launched on September 8, 2000 (following the Zvezda launch), carrying a SpaceHab double module with supplies and equipment to outfit Zvezda in preparation for the arrival of the First Expedition Crew.

The Zvezda Service Module was successfully launched from Baikonur Cosmodrome on July 12, 2000, opening the way to the continued assembly and utilization of ISS by providing the living quarters for a three-person crew. Zvezda's arrival was followed shortly thereafter by the first Progress resupply ship to ISS, which docked on August 8, 2000, carrying crew equipment and supplies such as clothing, food, water, and computers. Figure 1 shows the ISS configuration one year ago.

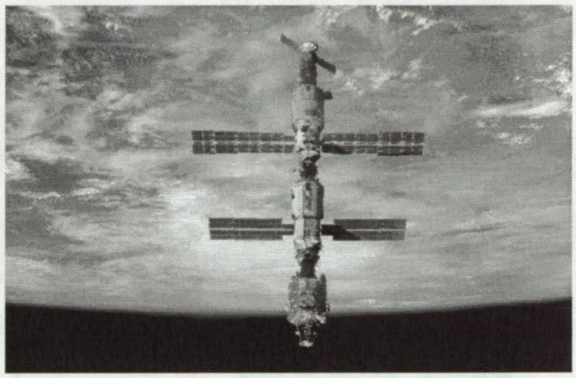


Figure 1. ISS - September 17, 2000

The next flight to ISS, 3A/STS-92, launched on October 11, 2000, and delivered the Z1 Truss Segment and a Pressurized Mating Adapter, both of which were mated to the Unity Module. The Z1 Truss contains four Control Moment Gyroscopes (CMGs) that are used to provide nonpropulsive attitude control for ISS, as well as the KU-Band and S-Band antenna systems.

A major milestone in the evolution of ISS followed the 3A mission. The First Expedition Crew launched in a Soyuz spacecraft from the Baikonur Cosmodrome on October 31, 2000, beginning a permanent human presence in space that is planned to continue for the remainder of the station's lifetime. The First Expedition was commanded by U.S. Astronaut William (Bill) Shepherd, and included Sergei Krikalev, Flight Engineer; and Yuri Gidzenko, Soyuz Commander.

During their mission, Flight 4A/STS-97, launched on November 30, 2000, and delivered the P6 Truss, the main keel of the truss system, and the first set of large U.S. Solar Arrays. The Expedition 1 Crew also experienced the arrival of the Destiny Laboratory, launched on Flight 5A/STS-98, on February 7, 2001, and was responsible for its checkout and activation. The 16-ton Destiny rode to orbit in the payload bay of the Space Shuttle and was lifted out and attached to the Unity Node by the Space Shuttle's robotic arm. At this point in the assembly, the Payload Operations Integration Center in Huntsville, Alabama became operational to supplement the Mission Control Centers in Houston and Moscow.

The Russian Soyuz spacecraft which carried the Expedition 1 Crew to orbit remained docked to ISS during their stay to provide emergency crew escape capability when a Space Shuttle was not docked. The life of a Soyuz spacecraft on orbit is approximately 6 months, this time limitation being primarily a factor of propellant system lifespan. On April 30, 2001, a Russian Soyuz was launched from Baikonur, Kazakstan, on a taxi flight to provide a fresh Soyuz crew return vehicle for ISS. The crew, Commander Talgat Musabaev, and Flight Engineers Yuri Baturin and Dennis Tito (the first "space tourist"), spent 1 week on ISS and returned to earth on the Soyuz, which had launched Expedition 1. This flight received much notoriety, due to the fact that Mr. Tito was not previously an astronaut or cosmonaut, but rather an American businessman who paid Russia $20 million to fly to ISS. Mr. Tito received cosmonaut training in Russia prior to the flight, and although many concerns were voiced, ultimately the mission was successful and without incident.

Flight 5A.1/STS-102, launched on March 8, 2001, carrying the Expedition 2 crew, Commander Yuri Usachev, and Flight Engineers Jim Voss and Susan Helms. This flight was also the maiden voyage of the MPLM Leonardo, carrying systems racks and the first payload rack, the Human Research Facility, for installation in the Destiny Laboratory. MPLMs provide a pressurized environment with power, data, and fluid interfaces for racks being transported to orbit. Leonardo was lifted from the Space Shuttle payload bay and mated with ISS using the Space Shuttle's robotic arm, then the hatch was opened and the combined Shuttle and Expedition crews began the transfer of equipment and supplies to the ISS. The Leonardo was loaded with items being returned to Earth and placed back in the Shuttle's payload bay for the trip back to KSC where it would be processed for its next flight. The Expedition 1 crew also returned to earth on the Space Shuttle, completing their mission of 138 days on orbit.

The next flight to ISS, Flight 6A/STS-100, launched on April 19, 2001, was a mission to deliver and install the ISS robotic arm known as the Space Station Remote Manipulator System (SSRMS). A Canadian contribution to ISS, SSRMS (or Canadarm2) was installed with the aid of Canadian astronaut Chris Hadfield, who was the first Canadian to conduct an EVA. Also delivered on this mission was the MPLM Raffaello, containing supplies and equipment as well as the first two Expedite the Processing of Experiments to Space Station (EXPRESS) Payload Racks.

Two on orbit anomalies, one during the 6A/STS-100 flight and one approximately a month later, proved the ability of the on orbit and ground crews to work together to identify and resolve issues with fight hardware and software on orbit. On April 24, the ISS experienced a failure of the Command and Control (C&C) Computer 1, which is one of three redundant C&C computers onboard. The second anomaly involved the SSRMS, which experienced a problem in the elbow braking system during on orbit checkout. The next assembly flight, which would use the SSRMS to mate the Quest airlock to ISS, could not proceed until the SSRMS issue was resolved. The systematic troubleshooting and analysis of data by the on orbit and ground crews resulted in the causes of both incidents being fully understood and resolved in a timely manner, allowing the next mission to proceed with little delay. The SSRMS issues were resolved by up linking a software patch. The C&C Computer problem was temporarily resolved using software uplinks and the use of a spare payloads computer, facilitating nominal operations until spare parts could be delivered by Flight 7A.1. An upgrade to solid-state mass memory devices, scheduled to launch on FlightUF1/STS-110 in November 2001, will further enhance the C&C Computers..

Flight 7A/STS-104, launched July 12, 2001, delivered the U.S. Quest Airlock to the ISS. All of the previous Space Shuttle missions to ISS included from one to four extravehicular activities (EVAs) by crewmembers to accomplish assembly tasks such as connecting power and data cables between modules and installing equipment. But, prior to installation of the Quest, ISS EVAs in NASA space suits known as Extravehicular Mobility Units (EMUs) could only be conducted from the Space Shuttle and were, therefore, restricted to when the Shuttle was present. The Quest provides the on-orbit crew with a continuous ability to perform EVAs in NASA EMUs and in Russian Orlan space suits. Quest has two rooms that total approximately 950 cubic feet, the equipment lock and the crew lock, which are separated by a hatch that can be closed. The equipment lock provides space for donning and doffing of space suits, as well as a storage area for suits that are not in use. The crew lock is the area which the crew moves into prior to depressurizing the airlock and opening the hatch to space. The Quest Airlock is designed to recover over 90 percent of the gases that were previously lost when airlocks were vented to the vacuum of space. Figure 2 shows the ISS configuration after the addition of Quest.

On August 10, 2001, the Expedition 3 Crew was launched to ISS aboard the 7A.1/STS-105 flight. Expedition 3 is commanded by U.S. Astronaut Frank Culbertson, and includes Russian Cosmonauts Vladimir Dezhurov and Mikhail Tyurin. This flight was the second flight of the MPLM Leonardo which delivered two more EXPRESS racks to ISS as well as supplies and equipment. A Russian Progress vehicle

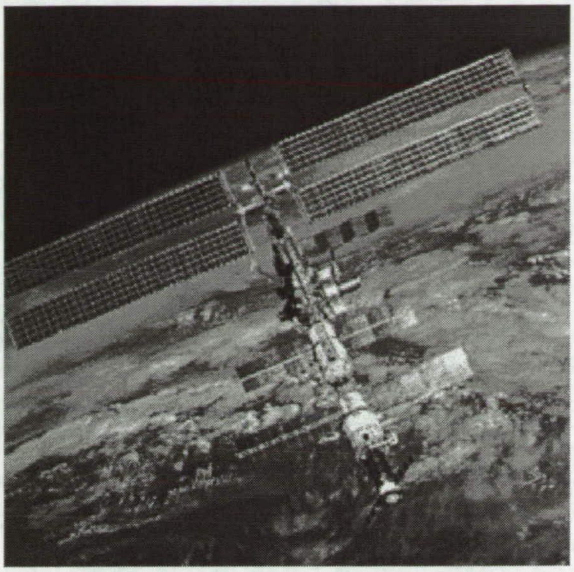
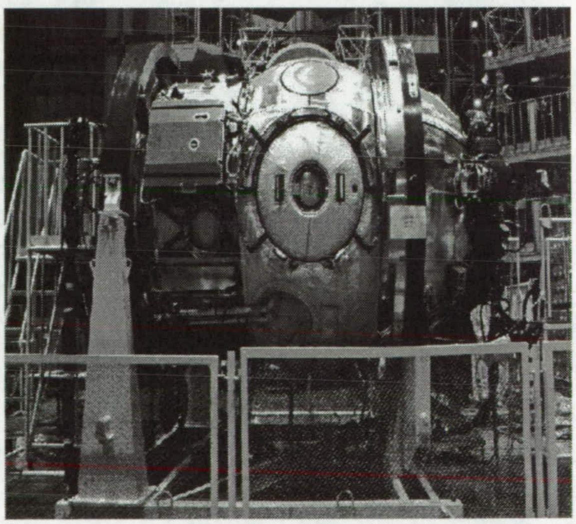


Figure 2 - ISS, August, 10, 2001

arrived shortly after the beginning of their mission, and they also expect the arrival of the Russian Docking Compartment. The "Pirs" (Russian for pier) Docking Compartment provides ISS with EVA capabilities in Russian Orlan spacesuits, as well as an additional docking port for Soyuz and Progress vehicles.

A Soyuz taxi flight is scheduled for October, to provide a fresh Soyuz vehicle for ISS. The Soyuz crew will include two Russian Cosmonauts and French Flight Engineer Claudie Andre-Deschays of CNES. They will spend a week onboard ISS conducting research before returning to earth in the Soyuz which has been docked to ISS since April 2001. The Space Shuttle is not planned to visit ISS during Expedition 3 until the UF1/STS-110 Mission, scheduled for November 29, 2001, arrives to deliver Expedition 4 and return Expedition 3 to Earth.

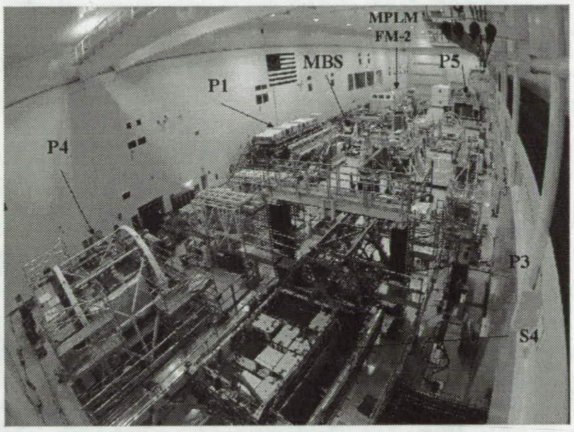


Pirs Docking Compartment

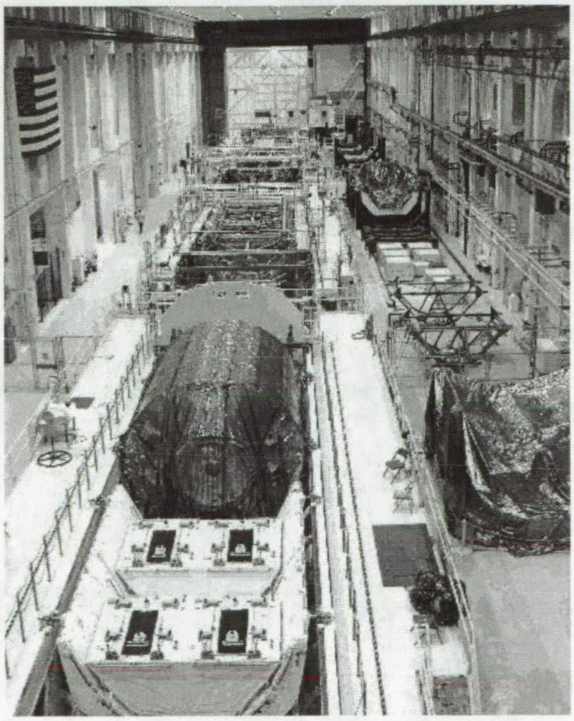
International Partner Participation

United States

The U.S. is poised to begin the building up of the ISS integrated truss system and solar arrays. This hardware is currently undergoing multi-element integrated testing at KSC. The S0 truss, the central segment for the remaining truss components, is scheduled to launch on Flight 8A/STS-110 in February 2002. Assembly of the truss system and solar arrays will continue into 2003, followed by the delivery of Node 2, thus preparing the ISS to receive International Partner elements beginning in 2004.



Space Station Processing Facility, KSC



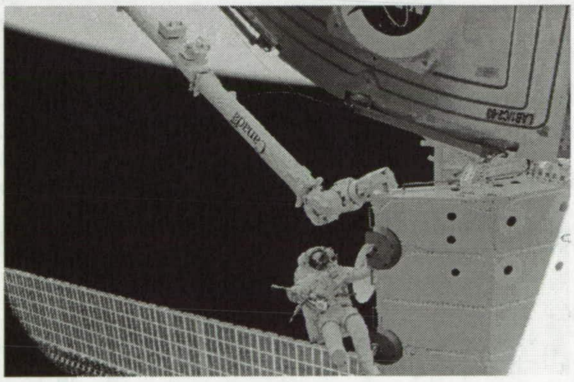
Operations and Checkout Building, KSC

Russian Aviation and Space Agency (Rosaviakosmos)

Funding pressures brought work on the Science Power Platform (SPP) to a standstill, and a similar situation exists with the Russian Research modules. Russia is currently working on a modified design for the SPP to reduce its complexity and cost, with an assessment scheduled for completion by October 2001. The supply of Soyuz and Progress modules appears adequate, with 2 Soyuz and 4 Progress flights to ISS scheduled for the next 12 months. Russia successfully deorbited the Mir Space Station in March 2001, bringing an end to its 15-year mission.

Canadian Space Agency

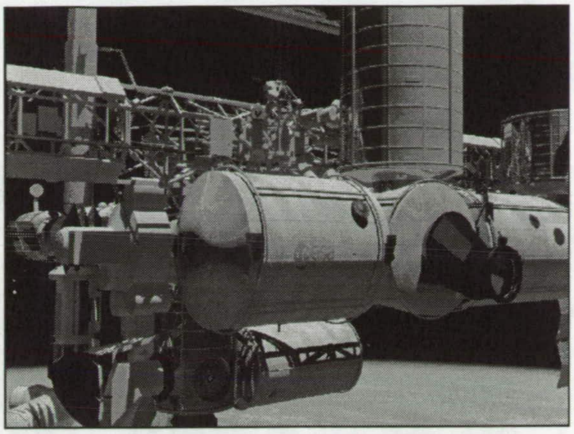
Canada's contribution to the ISS is the Mobile Servicing System (MSS) and its associated ground elements. The 58-foot-long SSRMS robotic arm, which can handle masses up to 255,000 pounds, was successfully attached to ISS during the 6A/STS-100 flight. Canada played a key role in the resolution of the on orbit anomaly involving the SSRMS. Also included in the MSS is a Mobile Base System that will allow the arm to move along the Space Station truss system, and a robot with two 11-foot arms called the Special-Purpose Dexterous Manipulator (SPDM), that is attached to the end of the SSRMS. The Mobile Base is the next Canadian element scheduled for launch to ISS on the UF2/STS-111 flight in April 2002.



CanadaArm2 on ISS

European Space Agency (ESA)

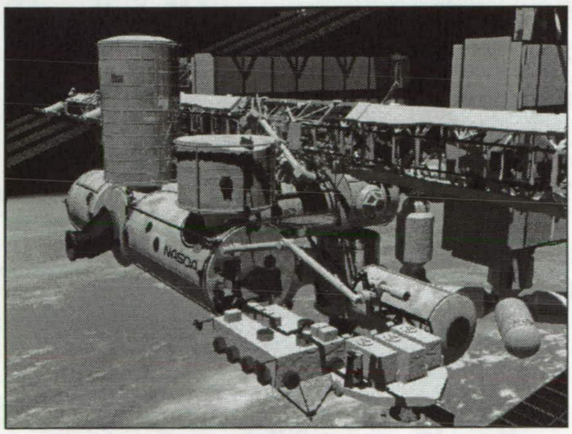
ESA's Columbus laboratory, with accommodations for 10 standard research racks is undergoing final integration at Alenia with shipment to Astium scheduled for September 2001. Columbus processing is on schedule for launch in 2005. A preliminary design review for the ESA's Automated Transfer Vehicle was completed in December 2000, and its first launch is scheduled for 2004.



Columbus Module

National Space Development Agency of Japan (NASDA)

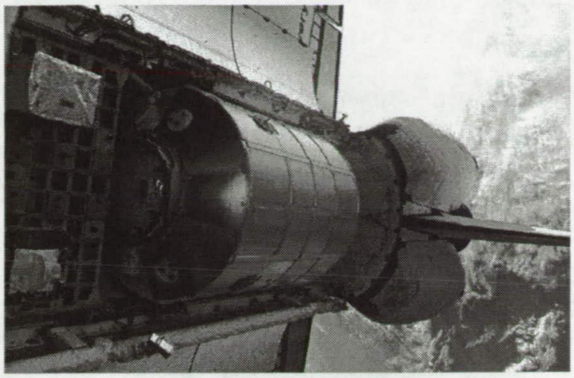
NASDA will provide the Japanese Experiment Module (JEM), named Kibo, which will include the pressurized laboratory, an exposed facility (external) platform for up to 10 unpressurized experiments, a 32-foot remote manipulator system robotic arm, and an Experiment Logistics Module (ELM) for logistics resupply. JEM Laboratory integrated system testing is scheduled to begin in October 2001. The launch of the JEM pressurized laboratory module is currently scheduled for 2004. Japan will also provide the H-II Transfer Vehicle (HTV), a logistics resupply vehicle. On August 29, 2001, NASDA conducted a successful test launch of the H-IIA rocket, the rocket which will be used to transport the HTV to ISS. The Centrifuge Accommodations Module to be provided by Japan has slipped approximately 2 years due to integration issues with the centrifuge rotor.



Kibo

Italian Space Agency (ASI)

Italy has completed building and has shipped to KSC three MPLMs for ISS, in addition to its contributions as a member of ESA. The first two MPLMs, "Leonardo"



Leonardo MPLM in Shuttle Bay on orbit

and "Rafaello" have already flown successful missions to ISS. Node 2 (built by ASI under an arrangement with ESA) completed its Critical Design Review in March 2001 and is on track for a February 2004 launch.

Brazilian Space Agency (AEB)

Brazil is providing the following items to the International Space Station: Expedite the Processing of Experiments to Space Station (EXPRESS) Pallets, Unpressurized Logistics Carriers (ULCs), Cargo Handling Interface Assemblies (CHIAs), Technology Experiment Facility (TEF), Window Observational Research Facility Block 2 (WORF-2), and the Z1-ULC-Attach Site (Z1-ULC-AS). Currently, the focus is on the design of the EXPRESS Pallet, however flight hardware development has been impeded by significant funding issues.

Research is Underway

The goals of the ISS research program are to conduct research to enable safe and productive human habitation of space; to use the space environment as a laboratory to test the fundamental principles of physics, chemistry and biology; and to enable and promote commercial research in space. The majority of ISS flight experiments are selected from responses to regularly released NASA Research Announcements.

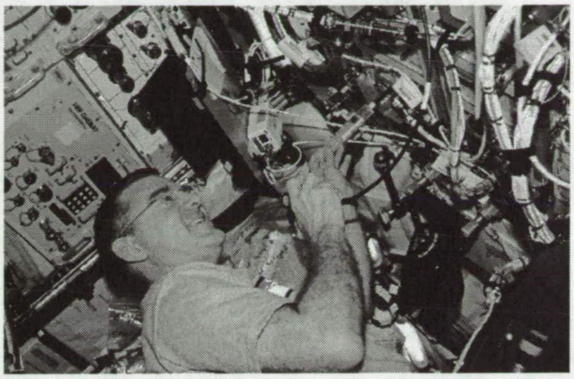
The standardized rack concept was developed as the most efficient means to house, transport, and change out research payloads on ISS. The racks are housed in the Italian MPLMs on their trip to and from orbit. Following Space Shuttle docking with ISS, the MPLM is mated with the ISS using the Space Shuttle robotic arm, and crewmembers transfer the payload racks to the laboratories. The Destiny Laboratory can accommodate 13 standardized payload racks, the Columbus Laboratory 10 racks, the JEM Laboratory 10 racks, and the Centrifuge Accommodation Module 4 Racks. At assembly complete, there will also be 38 external attached accommodations for nonpressurized payloads.

The first two Expedition Crews were very involved with assembly operations and installation, startup, and troubleshooting of new equipment, although they did conduct some research. The delivery and activation of the Destiny Laboratory set the stage for the expansion of ISS research activities. The Human Research Facility EXPRESS Racks 1 and 2 were delivered and began operating Expedition 2's mission.

EXPRESS Racks 3 and 4 were delivered by the 7A.1/STS-105 flight, bringing the total number of payload racks on ISS to 5, and Expedition 3's planned number of experiments to 18. The Expedition 3 Crew is conducting experiments in the fields of human life sciences, biotechnology, education, and video technology. They also conduct an ongoing program of Earth observation and photography.

In spite of the many assembly activities, 41 research investigations have already been completed or are underway. Table 1 lists the investigators and their investigations.

The ISS research program will continue to expand, with the number of experiments planned for Expedition 4 increasing to 28. Additional research racks are currently undergoing development and testing. By the end of 2002, the number of payload racks operating on ISS will have grown to 10 with about 60 experiments begun or completed.



James Voss conducting research on ISS

Table 1 - ISS RESEARCH HAS BEGUN!
U.S.- Sponsored Investigators on ISS thru October 2001

Principal Investigator	Institution	Investigation
G Badhwar	Johnson Space Center	Organ Dose Measurements Using a Phantom Torso
M. Baumstark	University of Freiburg, Germany	Crystallization of Human Low Density Lipoprotein (LDL) Subfractions in Microgravity
J. Becker	University of South Florida	Evaluation of Ovarian Tumor Cell Growth and Gene Expression
G Bushnell	The Boeing Company	Characterizing the Active Rack Isolation System
D. Carter	New Century Pharmaceuticals	Facility-Based Hardware Science and Applications
W. de Grip	University of Nijmegen, the Netherlands	Crystallization of Rhodopsin in Microgravity
R. DeLombard	Glenn Research Center	Microgravity Acceleration Measurement System
R. DeLombard	Glenn Research Center	Space Acceleration Measurement System II
L. DeLucas	University of Alabama, Birmingham	Commercial Protein Crystal Apparatus
L. DeLucas	University of Alabama, Birmingham	Dynamically Controlled Protein Crystal Growth
A. Gabrielsen	National University Hospital, Copenhagen	Effect of Microgravity on the Peripheral Subcutaneous Veno-Arteriolar Reflex in Humans
R. Giege	CNRS Strasbourg, France	Effect of Different Growth Conditions on the Quality of Thaumatin and Aspartyl-tRNA Synthetase Crystals Grown in Microgravity
T. Goka	National Space Development Agency of Japan	Bonner Ball Neutron Detector
T. Hammond	Tulane University Medical Center	Renal Cell Differentiation and Hormone Production from Human Renal Cortical Cells
T. Hammond	Tulane University Medical Center	Bioprocessing Research
J. Jessup	University of Texas	Use of NASA Bioreactor to Study Cell Cycle Regulation Mechanisms of Colon Carcinoma Metastasis in Microgravity
N. Kanas	University of California and Veterans Affairs Medical Center, San Francisco	Crewmember and Crew-Ground Interactions During ISS Missions

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U.S.- Sponsored Investigators on ISS thru October 2001

H. Keshishian	Yale University	Bioprocessing Research
W. Kinard	Langley Research Center	Materials on International Space Station Experiment
D. Klaus	BioServe Space Technologies Antibiotic Production	Commercial Generic Bioprocessing Apparatus -
C. Kundrot	Marshall Space Flight Center	Improved Diffraction Quality of Crystals
T. Lang	University of California San Francisco	Sub-regional Assessment of Bone Loss in the Axial Skeleton in Long-Term Space Flight
P. Lelkes	Drexel University	PC12 Pheochromocytoma Cells: A Proven Model System for Optimizing 3-D Cell Culture Biotechnology in Space
H. Levine	Dynamac Corporation	Soybean and Corn Seed Germination in Space
K. Lulla	Johnson Space Center	Crew Earth Observations
J. Martial	University of Liege, Belgium	Crystallization of the Next Generation of Octarellins.
B. Mason	Dreamtime Holdings, Inc	Long Duration HDTV Camcorder Experiment
A. McPherson	University of California Irvine	Protein Crystal Growth-Enhanced Gaseous
R. Ninneman	Air Force Research Laboratory	Middeck Active Control Experiment-Reflight Program
F. Otalora	University of Granada, Spain	Testing New Trends in Microgravity Protein Crystallization.
G Reitz	German Aerospace Center Institute of Aerospace Medicine	Dosimetric Mapping
S. Ride	University of California San Diego	Earth Knowledge Acquired by Middle Schools
L. Stodieck	BioServe Space Technologies	Effects of Spaceflight on Fruit Fly (Drosphila Melanogaster) neural Development
D. Watt	McGill University, Montreal	Effects of Altered Gravity on Spinal Cord Excitability
S. Weinkauf	Technical University Munich, Germany	Solution Flows and Molecular Disorder of Protein Crystals: Growth of High Quality Crystals, Motions of Lumazin Crystals, and Growth of Ferritin Crystals
D. Weitz	Harvard University	Physics of Colloids in Space
J. West	University of California San Diego	The Effects of EVA and Long-term Exposure to Microgravity on Pulmonary Function
L. Wyns Camelids	Free University Brussels Belgium	Extraordinary Structural Features of Antibodies from
P. Whitson	Johnson Space Center	Renal Stone Risk During Space Flight: Assessment and Countermeasure Validation
A. Zagari	University Naples, Italy	Protein Crystallization in Microgravity, Collagen Model (X-Y-Gly) Polypeptides: the case of (Pro-Pro-Gly) 10
W. Zhou	Wisconsin Center for Space	Microgravity Impact on Plant Seed-to-Seed Automation and Robotics, Production University of Wisconsin -Madison

Conclusion

The ISS Program continues to face significant challenges including budgetary constraints; overcoming cultural and national differences; building and operating the ISS on schedule; and maintaining global interest, excitement, and commitment to the Program. This widespread Program is producing hardware in different countries, operating various control centers; providing multinational crews and integrating all of these efforts into the most advanced space vehicle ever constructed. When the ISS is completed, it will truly be recognized as a significant historical accomplishment.

Because of the limited resources available to individual nations today and the expanded expertise possessed by larger numbers of countries, future activities will be conducted by necessity on a cooperative basis. After the ISS is successfully built, it will serve as a catalyst and pathfinder for international cooperative scientific ventures in all fields. The ISS will also increase our knowledge and technology development leading to the extension of human exploration beyond low Earth orbit.