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CREW TRAINING FOR INTERNATIONAL SPACE STATION: PLANS, CONCEPTS AND ISSUES ON THE EVE OF FIRST ELEMENT LAUNCH

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Within months of the presentation of this paper, there will be a new star in the night sky. Traveling in low earth orbit at 17,000 miles per hour, it will consist of the first elements of the International Space Station (ISS). Built through the cooperative efforts of 7 international space agencies representing almost every spacefaring nation on the planet, astronauts and cosmonauts are scheduled to begin construction of the 470 ton orbiting laboratory later this year. To prepare for this endeavor, a multi-lateral team must train the crew members to assemble, operate, utilize and maintain this new spacecraft using experience from current and past programs, as well as new concepts and technologies. This paper describes the training program that is preparing astronauts and cosmonauts for ISS and laying the groundwork for future multi-national space missions.

Overview

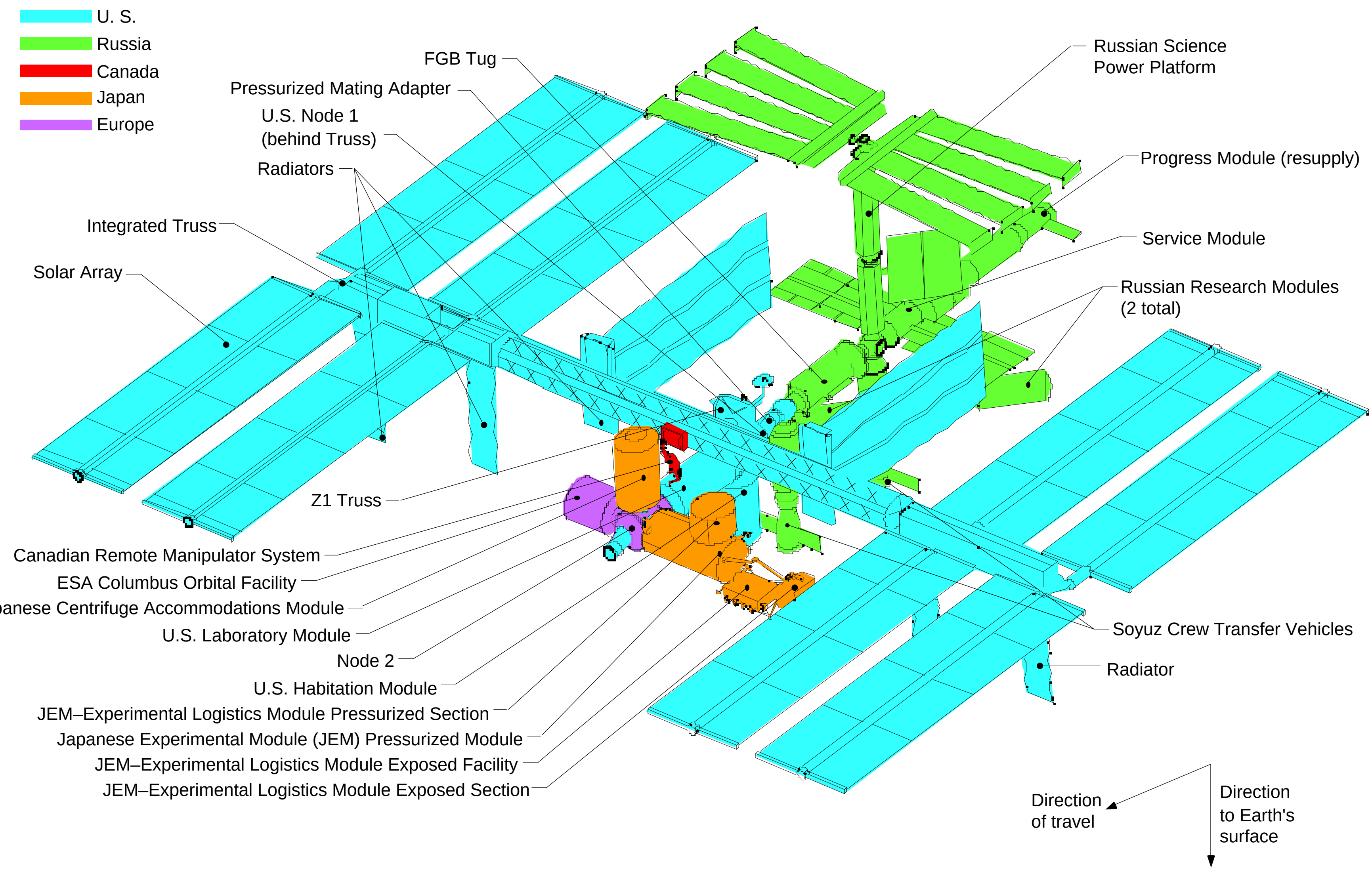
Background

Crew training for the International Space Station presents a unique set of goals and challenges. As the largest peacetime cooperative effort ever undertaken, assembly will involve 16 nations, represented by 5 Partner and 2 Participant agencies (Figure 1). Partners are the National Aeronautics and Space Administration (NASA), the Russian Space Agency (RSA), the Canadian Space Agency (CSA), the National Space Development Agency of Japan (NASDA) and the European Space Agency (ESA). Participant agencies are the Italian Space Agency (ASI) and Brazilian Space Agency (AEB). Construction will require 28 Space Shuttle flights, 10 Russian assembly flights, and additional Soyuz and Progress vehicles to ferry crew members and supplies. During the half decade assembly phase beginning mid-1998, teams of 3 crew members will perform robotic deployment, extravehicular activities (EVAs), system activation and checkout, and experiment operations. The criticality, complexity and time constraints of these operations, coupled with the limited number of crew members, dictate that crews must be highly trained to handle a wide variety of tasks. The multi-national aspect of the ISS lends a great deal of technical expertise and political support to the program. It also results in integration and communication difficulties within and among the multi-national crews and their training support personnel. These factors drive the ISS to a hybrid training concept which takes lessons learned from US programs (Apollo, Skylab, Shuttle), Russian programs (Soyuz, Salyut, Mir) and the joint NASA-Mir program.

Key Operations and Training Drivers

The era of manned space flight began with Yuri Gagarin's launch from the Baikonour Cosmodrome on April 12, 1961. Since then, there have been over 200 manned missions, the overwhelming majority of which have been successes, with several tragic failures. Much of the success of these missions has been due to the training programs developed to ensure safe and efficient operations. The ISS training program has its roots in the current and past programs of its Partners, but has been modified significantly due to some unique driving factors: distributed

International Space Station Partner Participation



Not Shown:
Italian Mini Pressurized Logistics Module (attaches to Node 2)

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versus centralized training and operations; multi-cultural and multi-lingual crew members and flight controllers; criticality and complexity of assembly on every mission; changing ISS configurations with every flight; and a crew size of only 3 until assembly complete in 2003.

Unlike previous programs, the ISS employs **distributed operations and training**. Specifically, there are 6 control centers and 7 training sites scattered around the globe (Figure 2). Each Partner is responsible for ground control and crew training of its orbital elements. NASA, as the program integrator is responsible for overall command & control and multi-segment training. This differs from the single, centralized control centers and training sites of past programs.

Many **multi-cultural issues** have arisen, although none have been insurmountable and some have been a bit humorous. One example is the allocation of on-orbit holidays. When a solicitation for potential on-orbit holidays was issued several years ago, the Partners responded with a total of 44 candidate days! Some holidays were even the same, but celebrated on different days in different countries. Christmas, for example, is celebrated December 25 in the US and Europe, but January 7 in Russia. The agreement was reached for 10 on-orbit holidays, to be prorated based on the on-orbit stay time of each crew. The crew commander and flight planning team will determine which are celebrated depending on the crew nationalities represented on each flight.

Language of operations and training is an issue that requires additional work, but there are interim agreements to provide Russian language training to astronauts and English language training to cosmonauts. There is a large dependence on interpreters at the beginning of the program, with the intent to wean the program by the time the Japanese and European elements are launched. The Russian Space Agency position is that ISS should evolve to a dual language program with both Russian and English used for training and operations. NASA's position is that this will complicate training and lead to onboard safety and efficiency concerns. Without resolution of this issue, Japanese and European astronauts will be required to know English and Russian in addition to their native language — a significant crew selection constraint. The non-Russian Partners have previous agreements that English is the official language. This is similar to the agreements for a single, common language in international aviation. Discussions are ongoing to resolve this sensitive topic.

During its half decade assembly, the space station will **change configurations** virtually every mission. That dictates a great deal of flexibility and adaptability for each crew and their training facilities. During their 3-6 month stay, each crew will support one or more assembly flights. That means that the configuration upon their arrival will change, sometimes several times, prior to their departure. Furthermore, due to the interdependencies among flights, assembly may come to a halt if the planned deployment tasks are not completed. This makes a flexible, adaptable training program a necessity.

Due to **small, 3-member crews** onboard station, each astronaut and cosmonaut must be trained to handle a wide variety of tasks. Within each crew, there must be primary and backup crew members for each task: flying the Soyuz, operating the 5 robotic arms built by 3 different countries, performing extravehicular activities (EVAs) on any of the 5 segments in either of two EVA suits (Russian Orlan or American Extravehicular Mobility Unit), performing system activation and checkout, operating dozens of payload experiments and maintaining the expansive space station. At assembly complete, this will still be a challenge, but will ease due to steady state (versus assembly) operations and the ability to specialize on a 7-person crew.

Together, these factors resulted in a training flow that was initially over 4.5 years — longer than it takes to start and finish most undergraduate programs. The International Training Control Board (ITCB), the multi-lateral controlling body for ISS training, has made significant progress in shortening this template to 2.5 years, with the ultimate goal of reducing the flow to 18 months. This was accomplished through a number of means: setting target allocations for each Partner; using

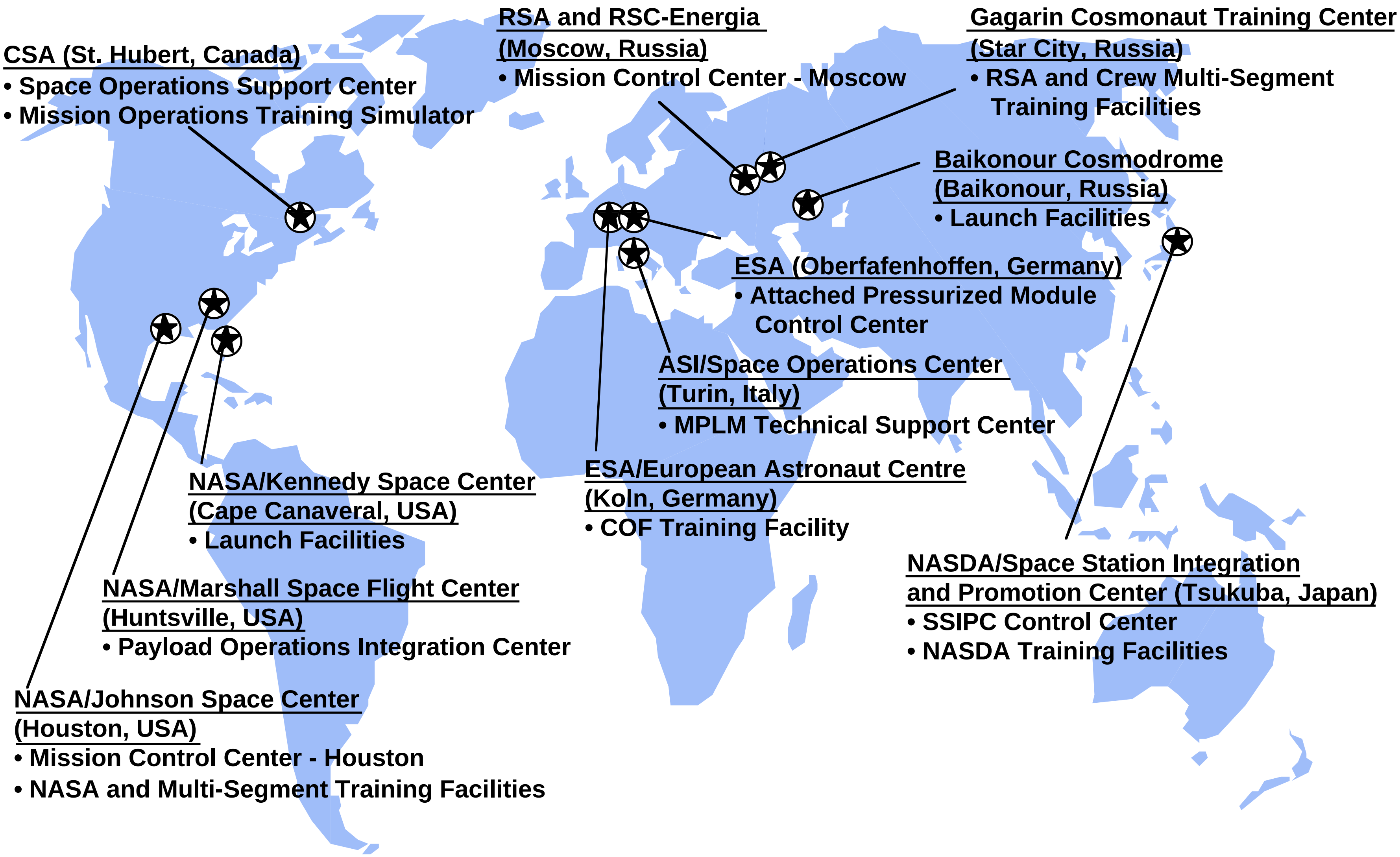

Figure 2: ISS Control Centers and Training Sites

advanced technology, both for simulators on the ground and computer-based trainers onboard; adopting approaches taught in education theory; using skills-based versus timeline-based training; taking lessons learned from the joint Shuttle-Mir program; and involving astronauts and cosmonauts early in the development and evaluation of the training curriculum.

Training Plans and Concepts

International Space Station training plans and concepts have been negotiated among the Partners since the inception of the Program. Crew training is divided into 4 major phases: Basic, Advanced, Increment Specific and Onboard. Detailed descriptions of crew and mission controller training agreements are documented in the “Station Program Implementation Plan, Volume VII: Training”, National Aeronautics and Space Administration (SSP 50200-07).

Basic Training is provided to newly selected crew members by their respective agencies. This phase emphasizes background knowledge including general space science, Shuttle, Soyuz, and ISS systems briefings, engineering, physiology, psychology and survival training. Much of the curriculum consists of classroom instruction, training manuals, video taped lessons and computer based training (CBT) lessons. Upon completion, these astronaut and cosmonaut candidates may be assigned to the Shuttle, Mir or ISS program.

Upon completion of Basic Training, crew members assigned to ISS begin **Advanced Training**. During this phase, crew members receive generic training on the Soyuz return vehicle, space station systems, EVA, robotics, medical operations and experiment operations. In this phase, 9-12 crew members representing a group of 3-4 missions undergo the training together. Their training includes travel to each of the Partner sites to learn nominal and malfunction operations from the developers of the respective elements.

Increment Specific Training marks the beginning of training for increment-assigned crews. It is a full-up dress rehearsal, providing a flight-like environment for crew members to work with their flight control teams. In the Space Station Training Facility (SSTF), trainers provided by each of the Partners will be connected to practice multi-segment systems and payload operations. This type of training exercises station-wide interactions and team training (air-to-ground, ground-to-air, and ground-to-ground). This is important based on experience and statistical data showing that 70% of all errors in a technical environment are due to a lack of situational awareness, communication skills and decision making abilities.

Due to the length of onboard stays and the complexity of ISS, **Onboard Training** will be crucial for ISS. Crew members must have robust means to practice the skills and knowledge acquired on the ground, particularly for robotics, EVA and docking operations. The 5 robotic devices on station are built by three different agencies, each with somewhat different modes and interfaces. On any particular mission, EVA may be required on multiple segments using either space suit, the American Extra-Vehicular Mobility Unit (EMU) or Russian Orlan. Crews also depend on docking operations for fuel, food and other provisioning. Without proficiency training for manually docking the Progress resupply ship, a critical leg of redundancy is lost. More critical yet is the ability to manually pilot the Soyuz in case of emergency departure from ISS. Maintenance training also presents an interesting dilemma. In the Space Shuttle program, the vehicle travels to space for 1 to 2 week missions, then returns to Earth and is serviced by a team of hundreds at the Kennedy Space Center prior to the next mission. For ISS, once each element launches, it must be maintained by the team of 3 crew members onboard. Given the thousands of orbit replaceable units onboard, it is not feasible to train all repairs or replacements pre-flight. To accomplish the requisite onboard training, several training devices are planned. These include the Crew On-orbit Support System (COSS), a high-end laptop with CD-ROM capability currently in use on NASA-Mir missions and a Soyuz docking simulator. Others will follow as technology allows us to place high fidelity simulators onboard.

Training Facilities

The complex and incremental nature of ISS assembly drives a unique set of requirements for training facilities. These facilities must maintain the capability to change as the ISS evolves through assembly and remain flexible enough to adapt to off-nominal configurations that cannot be predicted in advance. They must also have the capability to provide multi-segment and interface training for elements which are trained at other Partner sites. The fidelity of these facilities is driven by training for the complex, time-/safety-critical operations which occur during assembly.

Each ISS Partner plans to provide training on its elements to all astronauts and cosmonauts. RSA will train the Russian Segment and Soyuz using a suite of existing and planned simulators in Star City. CSA will train the robotic Mobile Servicing System (MSS) operations at the MSS Operations and Training Simulator (MOTS) in St. Hubert. NASDA will train Japanese Experiment Module and Exposed Facility operations at the Space Station Integration and Promotion Center in Tsukuba. ESA will train Columbus Orbiting Facility operations at the European Astronaut Centre in Cologne, Germany. Finally, NASA will provide US Segment, Multi-Segment, and Shuttle training at the Johnson Space Center in Houston. A description of the NASA-provided training facilities and media follows.

Computer Based Trainers take advantage of advancing technology by providing crew members with self-paced training accessible from most personal computers. The capabilities of these computers and the large capacity of CD-ROMs allows storage of simulations and extensive data archives for training and reference. Agreements have been made among all Partners for the free and open exchange of lessons and the use of compatible hardware and software. This reduces costs, avoids duplication and makes any Partner's lessons available to crew members at virtually any time — at their desk, on an airplane or onboard.

Part Task Trainers are Silicon Graphics-based trainers which, for any particular simulation, will simulate Command & Data Handling, Electrical Power System and any other station system (Guidance, Navigation and Control, Structures and Mechanisms, Thermal Control System, Communications and Tracking, or Environmental Control and Life Support). They can also be configured to simulate system operations for either onboard crew training or flight controller training. There are four PTTs, each with a crew laptop, virtual panels, Mission Control Center workstation, instructor station, and the necessary computational equipment. The PTTs are currently on-line, supporting display development, procedure verification and mission controller training.

The **Multi-use Remote Manipulator Development Facility** is a 57-foot long, full scale, hydraulic robotics trainer. It provides realistic hardware interactions and accurate closed-circuit television viewing of Space Station Remote Manipulator System (SSRMS) operations. It will contain a cupola workstation and representative Shuttle payload bay mockup. Hardware training in the MRMDF augments the dynamic software simulations available in the SSTF and the Canadian MOTS. It is the only facility which can provide contact training for tight tolerance assembly and maintenance tasks. Additionally, it is the only facility which provides night operations training. The MRMDF is scheduled for completion in March 1999.

The **Neutral Buoyancy Laboratory** will be used for simulated micro-gravity training of Shuttle and ISS EVA assembly and maintenance. At 202'x102'x40' and containing 6.2 million gallons of water, it will be capable of accommodating two training sessions simultaneously. The capacity is driven by the large size of ISS and the number and complexity of EVAs for assembly. The NBL has been in operation since January 1997 and is currently supporting EVA training for Space Shuttle flights and engineering tests for ISS.

The **Space Station Mockup and Training Facility** is used for flight crew and mission controller training and procedure verification for payloads, stowage, maintenance, medical operations, habitability and emergency operations. This facility emphasizes the hardware aspects of the ISS, and contains selected high-fidelity mockups of NASA (US Laboratory, Habitation Module, Node 1 and Airlock), RSA (Service Module, Functional Cargo Block and Soyuz), ESA (Columbus Orbiting Facility and Nodes 2 and 3), NASDA (Japanese Experiment Module and Element Logistics Module), and ASI (Mini Pressurized Logistics Module) modules. Most mockup elements are already fabricated and will be upgraded depending on specific mission objectives.

The **Space Station Training Facility** is the full-task simulator for ISS. It is the only facility which can simulate "inter-system" and "inter-payload" effects, integrate International Partner simulators for Multi-Segment Training, and provide connectivity to the Mission Control Center - Houston, the Payload Operations Integration Center, the Space Shuttle simulator and other facilities for team training. It can run 2 simultaneous, real-time simulations with dynamic command and telemetry capability. It uses actual flight software and emulated flight computers to produce a high-fidelity simulator for crew and mission controller training and procedure verification. Instructor workstations allow control of the simulations and insertion of malfunctions. The SSTF is located next to the Shuttle Mission Training Facility to take advantage of shared equipment and personnel. Initial simulation capability was delivered in October 1997, with incremental deliveries throughout station assembly.

Early Crew Training Status

As of January 1, 1998, four International Space Station Crews have been assigned. They are designated Expeditions 1 - 4. These first crews are at the leading edge of the development of the new space station. As such, they must deal with the problems inherent in most large program start-ups. The crews and their respective launch dates are listed below.

<u>Expedition 1</u>:
Crew: William Shepherd (Commander), Yuri Gidzenko, Sergei Krikalev
Scheduled Launch: 1/26/99 via Soyuz
Training Began: 10/15/96
NASA Training: 134 hours completed, 589 remaining
RSA Training: 167.5 hours completed, Soyuz 345 hours completed, 920.5 remaining

<u>Expedition 2</u>:
Crew: Yuri Usachev (Commander), James Voss, Susan Helms
Scheduled Launch: 6/30/99 via Flight 6A/STS-99
Training Began: 9/15/978

<u>Expedition 3</u>:
Crew: Ken Bowersox (Commander), Vladimir Dezhurov, Mikhail Turin
Scheduled Launch: 12/4/99 via Soyuz 3
Training Began: September 15, 1997

<u>Expedition 4</u>:
Crew: Yuri Onufrienko (Commander), Carl Walz, Dan Bursch
Scheduled Launch: 1/13/00 via UF-1/STS-104
Training Began: September 15, 1997

Expedition 1, as the "pathfinder" crew for ISS is experiencing significant problems. Being the first mission, its schedule is severely impacted by late deliveries of flight software and engineering data. This impacts training facility and curriculum development, creating a bow wave of training activity just prior to flight. The crew members are also undergoing intense language training to raise their proficiency to the level required for space flight. Early on, there was a heavy reliance on interpreters — a crutch that will not be available onboard. RSA is also delinquent in delivering simulations of the Russian segment to be used in the Space Station Training Facility in Houston. This may impact the ability to provide multi-segment training before launch of the first crew. Other training facilities are experiencing technical and budgetary challenges as vehicle designs change and simulator development problems arise.

Even with these problems, significant progress has been made. The International Training Control Board has been established to oversee training plans and policies. The Neutral Buoyancy Laboratory has been supporting simulations and tests since January 1997. The Space Station Training Facility and Mission Control Center were connected for the first ISS simulation in October 1997. Most of the hardware mockups have been fabricated and are being readied for training. Other training facilities are progressing with major deliveries expected in 1998. Most of the US training curriculum has been developed and NASA instructors are working with their counterparts at the Gagarin Cosmonaut Training Center to complete development of Russian lessons. There is also an increasing reliance on distance learning, using high bandwidth, two-way video conferences. Two additional video conferencing facilities are being installed in Star City to decrease crew travel and increase flexibility in training scheduling. For training objectives that cannot be met in the training facilities, the early crews are being sent to contractor sites and the launch sites (Kennedy Space Center and Baikonour Cosmodrome) to view the flight hardware.

Critical issues still remain, but much of the framework for training in the early phase is in place. Perhaps the best indication that the joint training team has progressed is the fact that we now debate the objectives and content of every *hour* of training. This contrasts with discussions at the beginning of the program when the sides argued over "ownership" of entire *months and years* in the training template. Both sides have had to significantly change their paradigms to create a joint training concept. It will continue to evolve throughout the life of ISS as actual missions are flown and our experience base expands.

Summary

On the eve of First Element Launch, most of the training facilities, curricula and joint agreements are in place. Remaining issues are being vigorously worked. The first 4 ISS crews are well into their training at the Johnson Space Center and Gagarin Cosmonaut Training Center. The ISS training program, and indeed many of the onboard vehicle systems, will serve as testbeds for future programs that will take us back to the Moon and on to Mars. For the long missions to the Red Planet, training may even occur en route instead of pre-flight. Either way, those missions will almost certainly be multi-national and will be based on the concepts and agreements developed for ISS. Perhaps, future historians will regard the International Space Station as a significant stepping stone in the new era of international cooperation.

Bibliography

Covault, Craig. *Aviation Week & Space Technology: Challenges, Promise Mark Station Debut*. December 8, 1997.

Dethloff, Henry C. *Suddenly, Tomorrow Came . . .* Houston, Texas: NASA SP-4307, Library of Congress Catalog Card No 93-86012, 1993.

Feng, Ven C. and Shawn L. Linam. *International Space Station Training Overview: A NASA Perspective*. Star City, Russia: Gagarin Cosmonaut Training Center Cosmonautics Conference, 1995.

Hart, Douglas. *The Encyclopedia of Soviet Spacecraft*. Greenwich, Connecticut: Brompton Books Corporation, 1983.

McDowell, Jonathan. *Jonathan's Space Home Page*. Internet address: http://hea-www.harvard.edu/QEDT/jcm/space/jsr/jsr.html, 1997.

Precourt, Charles. *International Space Station Phase I Shuttle-Mir Program: Lessons Learned for Joint Operations*. Star City, Russia: Third Annual International Scientific Practical Conference on Manned Space Flight, 1997.

Station Program Implementation Plan, Volume VII: Training (SSP 50200-07). Houston, Texas: National Aeronautics and Space Administration, 1997.