HISTORICAL SURVEY AND EVALUATION OF THE SPACE STATION PROCESSING FACILITY, JOHN F. KENNEDY SPACE CENTER, BREVARD COUNTY, FLORIDA

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TABLE OF CONTENTS

Page

1.0 INTRODUCTION 1
1.1 Purpose and Objectives 1
1.2 Methods 1
1.3 Acknowledgements 1

2.0 HISTORICAL CONTEXT 3
2.1 Introduction 3
2.2 Early Space Station Concepts 3
2.3 The First Manned Space Stations 6
2.4 Prelude to the International Space Station 9
2.5 Development of the International Space Station 11

3.0 THE SPACE STATION PROCESSING FACILITY 20
3.1 History 20
3.2 Facility Description 22
3.3 Functions and Operations 25

4.0 EVALUATION OF SIGNIFICANCE 28

5.0 REFERENCES 29

APPENDICES
APPENDIX A: Chronology of ISS Assembly and Supply Missions
APPENDIX B: FMSF Forms
APPENDIX C: NRHP Nomination Form
APPENDIX D: Survey Log Sheet

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LIST OF FIGURES

Page

Figure 1. Location of the Space Station Processing Facility in the Industrial Area of KSC. 2

Figure 2. Layout of the ISS showing all major components. 14

Figure 3. Major functional areas of the SSPF. 26

LIST OF PHOTOGRAPHS

Page

Photo 1. Wernher von Braun's 1952 space station concept. 4

Photo 2. Model of the Manned Orbital Research Laboratory, 1966. 6

Photo 3. Skylab seen from low Earth orbit during Skylab 3 mission. 7

Photo 4. Shown with the Japanese Experiment Module attached. 10

Photo 5. Space shuttle *Atlantis* (STS-71) as it prepares to dock with the *Mir* space station. 12

Photo 6. ISS as seen from space shuttle *Endeavour* (STS-97), December 2, 2000. 15

Photo 7. ISS as seen from space shuttle *Atlantis* (STS-110), April 17, 2002. 16

Photo 8. ISS as seen from space shuttle *Discovery* (STS-116), December 9, 2006. 16

Photo 9. ISS as seen from space shuttle *Discovery* (STS-119), March 25, 2009. 17

Photo 10. ISS as seen from space shuttle *Atlantis* (STS-132), May 16, 2010. 18

Photo 11. Aerial view showing construction of SSPF, January 1992, facing northeast. 21

Photo 12. The Multi Element Integrated Testing second phase (MEIT II) in the SSPF. 22

Photo 13. North and partial east elevations of SSPF, facing southwest. 23

Photo 14. SSPF High Bay, facing east. 24

Photo 15. SSPF I-Bay, facing southwest. 24

Photo 16. SSPF Control Room, facing southeast. 25

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1.0 INTRODUCTION

1.1 Purpose and Objectives

In April 2010, Archaeological Consultants, Inc. (ACI) conducted an historical survey and evaluation of the Space Station Processing Facility (SSPF; M7-0360) at the John F. Kennedy Space Center (KSC) in Brevard County, Florida. This work was performed on behalf of the KSC Environmental Management Branch under contract to Innovative Health Applications, LLC (IHA) (Task Order No. 011, Basic Ordering Agreement No. IHA-BOA-09-009A). The purpose of the survey, conducted in accordance with Section 110 of the National Historic Preservation Act of 1966, as amended, was to evaluate the significance of the SSPF in terms of the criteria of eligibility for listing in the National Register of Historic Places (NRHP) (36 CFR Section 60.4).

1.2 Methods

The historical survey and assessment of the SSPF at KSC entailed three tasks: research and context development, field survey, and preparation of draft and final reports. Archival research and historical context development were accomplished between April and June 2010. Research was conducted at the KSC Archives Department, the KSC Technical Library, the KSC Engineering Documents Center, and various NASA center websites. Based upon the research findings, a historic context for the International Space Station Program was prepared.

The field survey of the facility, conducted during the week of April 19, 2010, included guided tours of all portions of the SSPF, as well as interviews with the facility manager and other personnel regarding the history and uses of the SSPF. Descriptive information was recorded on site, including construction materials and distinguishing structural features, and digital photographs were taken of exterior elevations and selected interior views.

Following the collection of data through research and field survey, the SSPF was evaluated for its significance in terms of the eligibility criteria for listing in the NRHP. Guidance in applying the criteria was provided by reference to a number of U.S. Department of the Interior, National Park Service (NPS) publications, including *Guidelines for Applying the National Register Criteria for Evaluation* (NR Bulletin 15); *Guidelines for Completing National Register of Historic Places Forms: How to Complete the National Register Registration Form* (NR Bulletin 16A); and *Guidelines for Evaluating and Nominating Properties that Have Achieved Significance within the Last Fifty Years* (NR Bulletin 22).

1.3 Acknowledgements

The historic survey of the SSPF benefited from the cooperative efforts of many individuals. Special thanks are extended to KSC Historic Preservation Officer Barbara Naylor, and to IHA Cultural Resource Specialist Shannah Trout for coordinating access to the facility and personnel providing informational materials. We gratefully acknowledge the generous assistance of John Jackson, KSC ISS Transition Manager, Patty Powell, SSPF Facility Manager and to Rob Mayer for providing a tour of the facility, as well as historic photographs. ACI would also like to thank the many individuals who shared their knowledge of the history and use of the facility, including

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Figure 1. Location of the Space Station Processing Facility in the Industrial Area of KSC.

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Matt Galloway, Lori Hillenbrand, Monica Hopkins, Ira Kight, Curt Lander, Terry Matthews, Johnny Middleton, Bryan Onate, Jay Solomon, Greg Stadthagen, and Ron Woods. Elaine Liston, KSC Archivist, is thanked for providing archival source materials, including historic photographs. ACI is also grateful to Jane Provancha, IHA, for contract and logistical support.

2.0 HISTORICAL CONTEXT

2.1 Introduction

On January 25, 1984, in his State of the Union address, President Ronald Reagan directed NASA to build a space station within a decade, and to invite other countries to join in the endeavor. Building upon the successes of Russia's *Salyat* and *Mir* stations, and the U.S. Skylab program, and following many designs, redesigns, and delays, the first Russian and American built elements of the International Space Station (ISS), the world's ninth inhabited space station, were launched from Kazakhstan in November 1998, and on-orbit assembly began. Once completed in 2010, the ISS will measure 361 feet end to end, and will incorporate contributions from the U.S., Canada, Japan, Russia, Brazil, Belgium, Denmark, France, Germany, Italy, Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. Since arrival of the station's first resident crew in November 2000, 25 expedition crews representing the U.S. and all international partner nations have visited, lived, and worked on the orbiting outpost. Since gravity is virtually eliminated on the station, it provides an opportunity for unequalled study in various fields of research, including the effects of long-term space habitation on humans. Presently, the ISS is scheduled to function as an international platform for advances in scientific research, until at least the year 2020.

2.2 Early Space Station Concepts

The earliest known written proposal for a manned satellite (1869) was published by American writer and critic, Edward Everett Hale, in an *Atlantic Monthly* short story entitled "The Brick Moon," which was soon followed by a sequel, "Life on the Brick Moon." In these stories, Hale described an orbital brick satellite that was meant to be used as a navigational aid to ships at sea, but was inadvertently launched into space with 37 people on board. These travelers eventually form a new civilization that lives in and on the brick moon, raising its own crops (NASA 2009; Launius 2003:5-6). Roughly 10 years later, Konstantin E. Tsiolkovsky, a Russian schoolteacher, published a set of three fictional short stories that described a wheel-shaped space station. In 1898, he began to author several articles for scholarly journals, which outlined many of the principles of modern space flight. Prior to his death in 1935, Tsiolkovsky had authored over 500 works on space travel, discussing a wide variety of topics, such as rockets with steering thrusters, multi-stage boosters, and space stations. In *Beyond the Planet Earth,* for example, Tsiolkovsky described an orbiting space station where humans live and eventually explore and settle the Moon, Mars, and asteroids. His concepts would provide an important basis for the Soviet space program (NASA JSC 1997b; Launius 2003:7-11).

During the 1920s and 1930s, several theorists expanded on the concept of an orbiting space station. Romanian Herman Oberth believed space stations would be necessary for human travel to other planets; in 1923, he coined the term "space station" as a concept for a wheel-like orbiting facility that would serve as a point from which space travel could proceed (NASA JSC 1997a). Another theorist was the Austrian engineer, Herman Potochik, who used the pen name Hermann

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Noordung to publish his works. Noordung's book *Befahrung des Weltraums: Der Roketenmotor* (*The Problem of Space Travel: The Rocket Motor*), published in 1929, offered engineering details for a space station, color illustrations, ideas for biological and physical experiments, and included concepts that are used on today's ISS, such as the solar array and airlocks (Launius 2003:11-23).

Following World War II, the concept of an orbiting space station gained widespread interest among the American public, due in large part to the efforts of German rocket scientist, Wernher von Braun. After leading the V-2 ballistic missile program in Hitler's Germany, von Braun and many of his coworkers immigrated to the U.S. where his name quickly became associated with human space exploration. He authored several articles for *Collier's* magazine, appeared on popular television variety and talk shows, and was a frequent guest on Walt Disney television specials. He used all of these mediums to detail his ideas for space travel, which would ultimately lead to the construction of a permanently inhabited space station to be used to conduct scientific experiments and to serve as a base camp for launching missions to the Moon, Mars, and eventually other planets (Launius 2003:25-29).

In an article for the March 1952 issue of *Collier's*, von Braun further expounded on his concepts for a space station, enlisting the help of artist Chesley Bonestell to create visual images of his plans (Photo 1). In the article, he not only detailed a design for a wheel-shaped station that specified materials and dimensions, but also suggested methods for constructing the orbiting laboratory. He used the image of western frontier forts, which Americans still associated with adventure and exploration of unknown territory, to capture the imagination of the public. His ideas also inspired young engineers, such as Heinz H. Koelle, Darrell C. Romick, and Krafft A. Ehricke, to develop their own concepts for space stations, some of which would later be considered for space station construction. Koelle, for example, conceived of prefabricated modules that could be mated in orbit; Romick's designs were self-contained modules that could be launched and placed in operation immediately after attaching to an existing station. Ehricke "advocated a flexible space station effort in which engineers tailored specific pieces of equipment to the need of the mission and then placed the station into the most useful orbit for its purpose" (Launius 2003:32-37).

Photo 1. Wernher von Braun's 1952 space station concept.
(NASA Image Exchange, MSFC-9132079).

In the aftermath of Sputnik, Ehricke, with the support of his employer, General Dynamics, proposed a "Minimum Manned Satellite" to the U.S. Air Force. The plan called for the use of three Atlas rockets (a product of General Dynamics) to build a small station in orbit. The empty fuel tank of the first rocket would become the base of the station, while the second rocket would deliver supplies, and the third would bring two capsules to serve as living quarters, as well as four astronauts to man the station. Another early proposal for a space station came from von Braun's team stationed at the Army Ballistic Missile Agency in Huntsville, Alabama. Project Horizon, like most conceptual designs, featured a large wheel-like station that would serve as a refueling point for Moon-bound vehicles (Launius 2003:37-38). These concepts and designs, among others, were soon overshadowed by the work at Langley Research Center (LaRC) in Virginia, an outpost of the newly-created National Aeronautics and Space Administration (NASA).

Less than one year after the formation of NASA, LaRC engineers held an in-house conference (July 1959), with the aim of "concentrating research efforts on developing the technology to build, launch and operate" a space station (Newkirk and Ertel 1977). In April 1960, NASA co-sponsored a national "Manned Space Stations Symposium" with the Rand Corporation, and the Institute of Aeronautical Sciences, which featured presentations by leading aerospace scientists and engineers. They examined several topics, including the engineering feasibility of a space station, operational techniques, costs, and utilitarian considerations. Additionally, several conceptual designs were introduced, including that of an inflatable habitat and an artificial gravity habitation module powered by a nuclear-powered system mounted at one end of the module (Launius 2003:40-41; Newkirk and Ertel 1977).

Throughout the early 1960s, Langley engineers researched six different station concepts, ultimately developing a design for a modular space station that included large rigid modules linked by inflatable connectors. Using a low rotational velocity to simulate gravity, the outer portions of a non-rotating hub would provide a place for shuttle docking and a laboratory for experimentation (Launius 2003:40-43). In the meantime, von Braun's group in Huntsville, which became the George C. Marshall Space Flight Center (MSFC) in 1960, continued to develop his idea of a giant-wheeled space station, an image long-accepted by the public through its exposure to von Braun's televised discussions; it would even provide the basis for the station in Stanley Kubrick's 1968 movie *2001: A Space Odyssey* (Launius 2003:45-50). However, due to President John F. Kennedy's challenge to land a man on the Moon by the end of the decade, that goal took precedence over a space station. This, however, did not deter proponents of a space station, but shifted their emphasis to developing a smaller and more economical station that built on the technological systems developed for Apollo.

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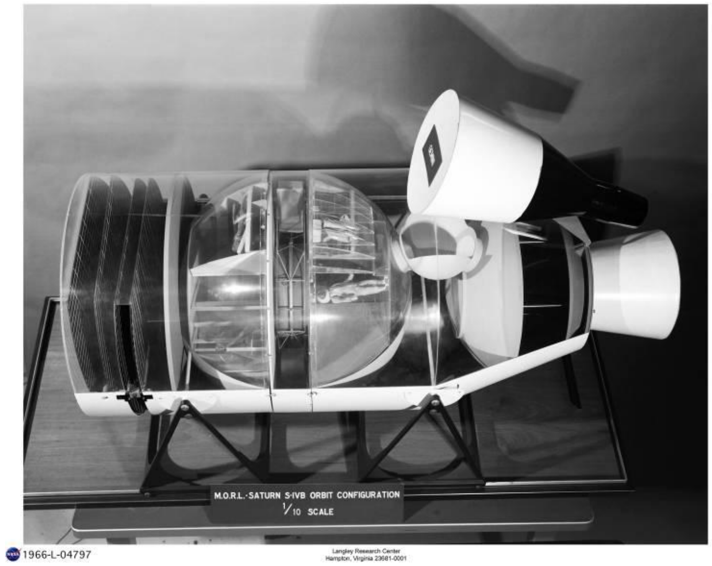

Photo 2. Model of the Manned Orbital Research Laboratory, 1966.
(NASA Image Exchange, L66-4797).

Engineers at LaRC proposed a station concept named the Manned Orbital Research Laboratory (MORL, Photo 2). Designed as a "minimum size laboratory to conduct a national experimental program of biomedical, scientific, and engineering experiments" (Launius 2003:58), MORL would support one astronaut full time for a year, with other crewmembers joining for shorter periods. The proposed zero gravity (weightless conditions) aboard the station distinguished it from previous designs (Launius 2003:50-66). At the Manned Spacecraft Center (later renamed the Lyndon B. Johnson Space Center [JSC]) in Houston, Texas, engineers proposed a Large Orbiting Research Laboratory (LORL), or Olympus, which was roughly seven times the size of MORL and could carry a crew of 24 astronauts. Outside of NASA, other groups also pursued the idea of a manned orbiting satellite, including the U.S. Air Force, whose proposed Manned Orbiting Laboratory (MOL), was very similar to the MORL (Launius 2003:67-69).

By 1968, development of a space station was NASA's leading post-Apollo goal, and in 1969, after the successive Apollo 11 Moon-landing mission, NASA's new space station paradigm, Space Base, was conceived. This permanent space station, envisioned as a home port to launch people and supplies to the Moon, was to be a laboratory for scientific and industrial experiments (NASA JSC 1997a). Scheduled for completion in 1975, it was designed for a 10-year operating life staffed by from 50 to 100 engineers and technologists of varying background and nationality. However, given the projected project costs, especially those associated with using expendable rockets to resupply the station, NASA turned to an alternate plan - the development of a reusable spacecraft, which became the space shuttle. However, while development of the shuttle proceeded, NASA continued research into a scaled-down version of a space station.

2.3 The First Manned Space Stations

The U.S. Skylab Program

The seeds for Skylab, a post-Apollo first-generation space station, were planted as early as 1964. In 1965, NASA established a Saturn-Apollo Application Program Office tasked with promoting

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the use of Apollo hardware for future applications. Skylab was one such application of this program. Among the objectives of the Skylab program were the observation of the Earth from space, the advancement of scientific knowledge of the sun and stars, and the effects of weightlessness. Between 1967 and 1969, concepts were developed for both a “wet” and a “dry” space station. The “wet” concept involved astronauts refurbishing a Saturn upper stage for habitation while in orbit, by purging the hydrogen and replacing it with a life-supporting atmosphere. However, it was the “dry” concept, which entailed ground assembly of the workshop prior to launching into orbit, that was selected in 1969. Much of the design and manufacture for Skylab was conducted under contract by McDonnell Douglas Aircraft Corporation, Martin Marietta, and North American Rockwell (Launius 2003:71-73).

Skylab was launched on May 14, 1973, atop a Saturn V rocket. With 12,700 cubic feet of work and living space, it was the largest habitable structure ever placed in orbit, at the time. Skylab hosted three crews, each with three astronauts, for stays of 28, 56, and 84 days. When the last occupied Skylab mission concluded in February 1974, several objectives had been achieved, including astronomical, space physics, and biological experiments in Earth orbit, and Earth and solar observations. Skylab also proved that humans could live and work in space for extended periods of time. Although it was originally believed that Skylab would orbit the Earth for several years, it was not designed for resupply, refueling or independent reboost (NASA JSC 1997a). Skylab remained in orbit until July 11, 1979, when it re-entered the Earth’s atmosphere over the Indian Ocean and Western Australia after completing 34,181 orbits (NASA 1994:91). Following Skylab, NASA deferred any further plans for a permanent space station until after the space shuttle was flying. In the interim, the Agency explored the potentials of international cooperation in space.

Photo 3. Skylab seen from low Earth orbit during Skylab 3 mission.
(NASA, http://heasarc.gsfc.nassa.gov/docs/heasarc/missions/images/skylab_images.html).

The Apollo-Soyuz Test Project (ASTP) of July 1975, the final application of the Apollo program, marked the first international rendezvous and docking in space, and was the first major cooperation between the only two nations engaged in manned spaceflight. As the first meeting of two manned spacecraft of different nations in space, first docking, and first visits by astronauts and cosmonauts into the others’ spacecraft, the ASTP was highly significant. The program

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established workable joint docking mechanisms, taking the first steps toward mutual rescue capability of both Russian and American manned missions in space (NASA 1994:96).

The Russian Salyut Program

The first-generation Russian space stations, ca. 1964-1977, were designed for short duration stays, with one main compartment, one docking station, and no means to refuel or resupply the spacecraft. Although there were two kinds of stations, the *Almaz* military stations and the *Salyut* civilian stations, all were publicly dubbed *Salyut*. On April 19, 1971, *Salyut* 1, the first space station in world history, reached orbit after being launched by a Proton rocket. The three-man crew lived aboard the station for three weeks, but tragically died on their return to Earth due to air escaping from their vehicle. As a result of this tragedy, the program was stalled for two years, and then suffered further delays when *Salyut 2*, the first *Almaz* military station, failed to reach orbit in April 1973. The last of Russia's first generation space stations, *Salyut* 3 (military), *Salyut* 4 (civilian), and *Salyut* 5 (military), collectively supported five crews between 1974 and 1977. During these missions, the crews performed military surveillance, conducted scientific and industrial experiments, and completed engineering tests to help develop the second generation stations (Launius 2003:99-101; NASA JSC 1997b).

The second generation Russian space stations, *Salyut* 6 and *Salyut* 7, were designed to support longer duration missions, with two docking ports on each station to permit refueling and resupply by automated Russian Progress vehicles. The extra docking port also provided the capability for short-term crews to visit the station, often exchanging their Soyuz spacecraft for the one already docked at the station. *Salyut* 6 (1977-1982) received 16 cosmonaut crews, of which six remained for longer-duration missions; the longest stay was 185 days. Although all of the long-term crews were comprised of Russian cosmonauts, several of the visiting crews included cosmonauts from Soviet-friendly countries, such as Czechoslovakia, Hungary, Poland, Romania, Cuba, Mongolia, Vietnam, and East Germany. A total of 12 deliveries by Progress vehicles provided supplies (Launius 2003:101-105; NASA JSC 1997b).

Salyut 7 received 10 crews between 1982 and 1986, before it was abandoned and reentered the Earth's atmosphere over Argentina in 1991. Six of the crews stayed for long durations that ranged from 112 days to 237 days. Astronauts from France and India were included in the short-term crews. Thirteen supply missions supported the station (Launius 2003:105; NASA JSC 1997b). Overall, throughout the 15-year program, six *Salyut* stations were successfully placed in orbit, and more than 60 dockings with various types of spacecraft were completed (Zak 2008). The end of the *Salyut* program in 1986 corresponds with the initial operation of *Mir*, Russia's first long-duration space station.

The Russian Mir Program

In February 1986, the Soviet Union launched space station *Mir*, ushering in the third generation of Russian space stations. Designed for a five-year stay in space, it remained in orbit until March 2001 when its fragments splashed down in the South Pacific. The core module of *Mir* resembled *Salyut* 7, except that it had six docking ports (one forward, one aft, and four radial) instead of only two. Additional modules were attached to the aft and radial ports in 1987 (*Kvant*), 1989 (*Kvant* 2), 1990 (*Kristall*), 1995 (*Spektr*), and 1996 (*Priroda*).With the exception of two brief periods, during its long life, *Mir* provided for a permanent human presence in space. The longest duration was 366 days by cosmonauts Vladimir Titov and Musa Manarov (Launius 2003:159-173).

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The station outlasted the country from which it was launched, the Soviet Union, and has been described as combining the "bluster of former Soviet Union premier Nikita Khrushchev, the grace of Russian-American ballet dance Mikhail Baryshnikov, the genius of Russian author and historian Aleksandr Solzhenitsyn, the paranoia of former Soviet Union leader Joseph Stalin, and the brilliance of Russian nuclear physicist Andrei Sakharov to create a weird, ugly, and highly successful space vehicle" (Launius 2003:151). In 1999, the Russian government stopped financing *Mir* operations in order to concentrate its limited resources on the ISS, and in October 2000, top Russian space officials officially terminated the *Mir* Program. The station reentered the Earth's atmosphere on March 23, 2001 (Launius 2003:172-173; Zak 2000).

2.4 Prelude to the International Space Station

Two key events occurred within U.S. politics between November 1980 and July 1981, which would ultimately set the country toward the goal of a permanent space station. First, while Ronald Reagan was preparing to take over as President of the U.S. following the 1980 election, George M. Low, a former NASA administrator and head of Reagan's space policy transition team, reported that NASA was "in an untenable position. . . . This unhealthy state of affairs can only be rectified by a conscious decision. Continuation of the prior administration's low level of interest and lack of clear direction would result in an unconscionable waste of human and financial resources" (Launius 2003:117). The second key moment came on June 1, 1981, when James M. Beggs was nominated by the President to be the new NASA administrator and officially entered the office on July 10. Although Low did not directly advocate for a space station, Beggs firmly stated during his confirmation hearings, "it seems to me that the next step is a space station" (Launius 2003:114).

Beggs, and many of his chief lieutenants, spent the next three years laying the foundation work for the approval of a space station program. He first tried to convince the administration's Senior Interagency Group for Space of the value of a station, but found that the majority of the members would not support it. Beggs then turned to the President and had the issue placed on the agenda for the December 1983 Cabinet Council on Commerce and Trade meeting. By circumventing the standard political channels, Beggs effectively appealed to Reagan's well known belief that the Soviet Union, or "evil empire," was a serious threat to the U.S. and democracy. Subsequently, in his January 25, 1984, State of the Union Address, President Reagan directed NASA to develop a permanently manned space station, and to do it within a decade. As a result, the U.S. Space Station Program officially began in January 1984. The program would be managed by a Space Station Program Office at JSC, established in April 1984, and overseen by the NASA Office of Space Station in Washington, D.C. (Launius 2003:118-121).

While the space program had the approval of the President, others, including the Secretary of Defense, had reservations about the cost and the impact the diversion of funds would have on the Space Shuttle program. Cost estimates for the new space station program ranged from highs of $12 to $20 billion. However, Beggs responded with an $8 billion dollar figure noting that since the program was modular, once the necessary pieces were in place, other sections of the station could be added as funds became available. While NASA was directed to stay within the budget, it was unable to do so, and within five years the projected program costs had more than tripled (Launius 2003:121-123).

Although pressure from Congress to reduce the budget was constant, and the funds were never fully sufficient to support the project, designs for a space station were developed. Out of several

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initial design concepts, in April 1984, the Space Station Program Office at JSC produced the first baseline configuration, called the "Power Tower" (Photo 4). It featured a central keel with a cluster of five modules at the lower end and a set of solar arrays at the upper end (Smith 2001:9-12). According to Launius, this concept "offered the most latitude to design a workable space station given political, funding, and technical limitations. [It also satisfied] the broadest range of scientific requirements, and it offered the potential to minimize development costs" (Launius 2003:124). The formal design work was divided between MSFC, JSC, Goddard Space Flight Center in Greenbelt, Maryland, and Lewis (later renamed Glenn) Research Center in Cleveland, Ohio with each center responsible for designing specific elements of the station (*Spaceport News* 1984).

Photo 4. Artist's conception of the proposed "Power Tower" space station configuration shown with the Japanese Experiment Module attached.
(NASA GPN-2003-00109, June 19, 1985)

In April 1985, NASA let four contract work packages to be managed by the field centers, to begin the development of a space station. As a result, in less than one year, the baseline design was revised and replaced with the dual-keel design, which moved the modules to the central truss, and increased the amount of truss structure with two large keels. Between 1984 and 1993, the space station underwent seven major redesigns which were never built. "Despite the redesigns, NASA and contractors produced a substantial amount of hardware" (NASA JSC 1997a).

During the design modification period, the international partnerships that would be fundamental to the ISS program were being formalized. By the spring of 1985, Japan, Canada, and the European Space Agency (ESA) each signed a Memorandum of Understanding with the U.S. for

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participation in a space station program. Subsequently, the partners reached agreement on their hardware contributions (NASA JSC 1997a). Canada was responsible for studying a space construction and servicing system, a solar array for a platform or as a potentially auxiliary power source, and a remote sensing facility (*Spaceport News* 1985a). Japan agreed to conduct studies for an experimental module (*Spaceport News* 1985b), and the ESA was responsible for a laboratory module and polar platform (*Spaceport News* 1987b). In September 1988, the U.S. signed a formal agreement with its international partners. It was also during this year that President Reagan named the station *Freedom*.

As program costs continued to rise, and a broad public, scientific, and governmental consensus in support of the program still failed to be achieved, Congress directed NASA to redesign the space station. Although the new design cut $8.3 million from the cost estimate, the U.S. House of Representatives held its first floor vote on whether to terminate the program in 1991; it survived, as it would for 21 additional Congressional votes held through the year 2000 (Smith 2001).

Following a directive to develop a simplified version of the space station *Freedom*, in 1993 NASA completed a 90-day redesign effort which was evaluated by the Clinton administration's blue ribbon advisory committee, and by teams at JSC, MSFC, and Langley (Humphries 1993:1 and 4). The redesign program, at the time, was expected to save more than $4-6 billion over the next five years and $18 billion over the 20-year life of the program (*Spaceport News* 1993). The Alpha design, a medium-sized, modular station using *Freedom*'s systems and components, as well as Russian hardware alternatives, was selected by the White House as a replacement for the *Freedom* space station. This design, in the words of President Clinton, was chosen to "enhance and expand the opportunities for international participation in the space station program, so that the space station can serve as a model of nations coming together in peaceful cooperation" (Launius 2003:179).

At a Vancouver summit in September 1993, President Clinton invited Russia to participate as a partner in the space station program. The previous year, 1992, NASA received approval to negotiate a study contract with NPO Energia, a Russian space system design agency, to determine whether the Soyuz might serve as an interim crew return vehicle for space station *Freedom* (Deason 1992). At the time, NASA was under pressure to stay within budget, be more efficient, and reduce overlap between its major activities. Many believed that *Freedom* would be restructured, and possibly cancelled (*Space News Roundup* 1993a; Welch 1992). On September 2, 1993, the U.S. and Russia signed an agreement which instructed NASA and the Russian Space Agency to develop by November 1, 1993 a detailed plan of activities for an international space station (ISS) (*Space News Roundup* 1993c). After the Russians agreed to supply major hardware elements, the station became known as the International Space Station (NASA JSC 1997a).

2.5 Development of the International Space Station

One of the results from the summit, was a proposed three-phase approach for the new ISS Program. Phase I (1994 to 1997) was set as a joint Space Shuttle/*Mir* program. In Phase II (1998-2000), a station core was to be assembled using a U.S.-built node, lab module, central truss and control moment gyros, and an interface for the shuttle. Russia was to build the propulsion system, initial power system, and an interface for Russian vehicles, as well as to provide crew-return vehicles. Canada was given responsibility for the construction of a remote manipulator arm. Phase III (2001-2004) called for the completion of the station with the addition of U.S. modules, power system, and attitude control, and Russian, Japanese, and ESA research modules and equipment (Launius 2003:176-181).

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The Shuttle-Mir Program

In 1991, President George Bush and Russian Premier Mikhail Gorbachev agreed that an American astronaut would reside on *Mir* and a Russian cosmonaut would fly on the space shuttle as part of the Manned Flight Joint Working Group (Launius 2003:155, 158-159). The following year, a second agreement was made between the two countries' space agencies, which outlined a plan for a U.S. space shuttle to dock with *Mir*, and leave an American astronaut on board the station for a set period of time. Subsequently, after the Vancouver summit in 1993, this agreement was extended to include up to 10 shuttle-*Mir* rendezvous missions (NASA 2004).

In February 1994, the joint U.S./Russian, shuttle-*Mir* program was initiated with NASA's STS-60 mission, when Sergei Krikalev became the first Russian cosmonaut to fly on a shuttle. The first approach and flyaround of *Mir* took place on February 3, 1995, with cosmonaut Vladimir Titov aboard *Discovery* (STS-63) (NASA KSC n.d.a); the first *Mir* docking was in June 1995 (STS-71) (NASA KSC n.d.b; Photo 5). That same year, in November, *Atlantis (*STS-74) delivered and permanently attached a Docking Module to the *Kristall* module's androgynous docking unit, thus serving to improve clearance between the shuttle and the station for subsequent docking missions.

During the three-year shuttle-*Mir* program, from June 27, 1995 to June 2, 1998, the space shuttle docked with *Mir* nine times. In 1995, Norman E. Thagard, M.D. became the first American astronaut to live aboard the Russian space station. Arrriving aboard the Russian Soyuz TM-21, Dr. Thagard stayed on *Mir* for 115 days. Over the next three years, six more U.S. astronauts served tours on *Mir*. In 1998, the last NASA astronaut to reside on *Mir* returned to Earth aboard *Discovery* (STS-91). The space shuttle served as a means of transporting supplies, equipment and water to the space station; shuttle astronauts performed a variety of mission tasks, many of which involved earth science experiments. The shuttle-*Mir* program acclimated the U.S. astronauts to living and working in space with Russian engineers and cosmonauts on long-duration missions. Many of the activities carried out were types they would later perform on the ISS, including spacewalks outside the station, as well as crew exchanges.

Photo 5. Space shuttle *Atlantis* (STS-71) as it prepares to dock with the *Mir* space station. (NASA, http://spaceflight.nasa.gov/history/shuttle-mir/multimedia/m-photo.htm).

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ISS Assembly

In 1994, the first component of the ISS, the Functional Cargo Block (FGB) dubbed *Zarya*, was initially scheduled for launch in November 1997; the date for completion of on-orbit assembly of the ISS was scheduled for June 2002. At a program review in March 1994, participants included representatives of the U.S., Canada, Europe, Italian, Japanese and Russian space agencies, as well as prime contractor Boeing and "tier I subcontractors" Rocketdyne and McDonnell Douglas. After review and evaluation of the overall configuration, technical requirements, and detailed specification for the station design, it was concluded that all station systems had a "high degree of design maturity," meaning they were close to completion (*Spaceport News* 1994b).

While most international participants contributed research modules and non-essential components, Russia was responsible for critical station modules that would derail the program if not delivered on time. Concern about Russia's stability was expressed both politically and economically, and NASA entered into an agreement where Russian-made components were built by the Russian Space Agency (Roscosmos), acting as a contractor to Boeing (Launius 2003:181-182). On February 5, 1995**,** NASA and the Russian Space Agency signed a protocol "complementing an agreement reached between Lockheed Missile and Space Company and Russia's State Research and Production Space Center (Khrunichev) for the U.S. purchase of the Russian Functional Energy Block (FGB)" which was launched as the first element of the ISS. The protocol guaranteed, with no additional cost to NASA, the launch of the FGB on a Russian Proton booster. The Lockheed agreement with Khrunichev called for the design, development, manufacture, test, and delivery of the FGB at a price of $190 million (*Spaceport News* 1995). As the critical Russian components costs increased over budget and failed to meet the schedule, the timeframe for the ISS was delayed.

On-orbit assembly of the ISS officially began in November 1998 (see Figure 2 for a layout of the ISS), when *Zarya*, built by Russia and financed by the U.S., was launched by a Russian Proton rocket from the Baikonur Cosmodrone, Kazakhstan, (Launius 2003:185-187; NASA JSC 1999d). This pressurized module provided orientation control, communications, and electrical propulsion for the station until the launch of additional modules. The late delivery of this initial element delayed the launch of subsequent ISS modules. The U.S.-built *Unity* Node 1 connecting module, along with two pressurized mating adapters (PMAs), was launched from KSC aboard *Endeavour* (STS-88) in December 1998. Built by The Boeing Company at the MSFC, the six-sided *Unity* connector module supplied essential ISS resources such as fluids, environmental control and life support systems, as well as electrical and data systems, to the working and living areas of the station (NASA JSC 1999c). *Unity* was connected to the orbiting *Zarya* by the *Endeavour*'s crew on December 6, 1998. As noted by Williamson, delivery of the first U.S.-built element to the station marked, "at long last the start of the Shuttle's use for which it was primarily designed – transport to and from a permanently inhabited orbital space station" (Williamson 1999:191).

A 19-month hiatus followed the mating of *Zarya* and *Unity* because of Russian delays in building the *Zvezda* Service Module. Until delivery and installation of this key module, the ISS could not be inhabited without a shuttle present. *Zvezda* was launched from Kazakhstan by an unmanned Russian Proton booster on July 25, 2000. It docked with *Zarya* and *Unity* via ground control and a Russian automated rendezvous and docking system. The 42,000 pound module is similar in layout to *Mir* and provides living quarters, life support systems, electrical power distribution, data processing systems, and flight control and propulsions systems, including remote control capabilities (NASA JSC 1999b). In October 2000, the Z-1 Truss and the third PMA were

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Figure 2. Layout of the ISS showing all major components.

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delivered and connected during the *Discovery* (STS-92) mission; the ISS was then officially declared ready for occupancy.

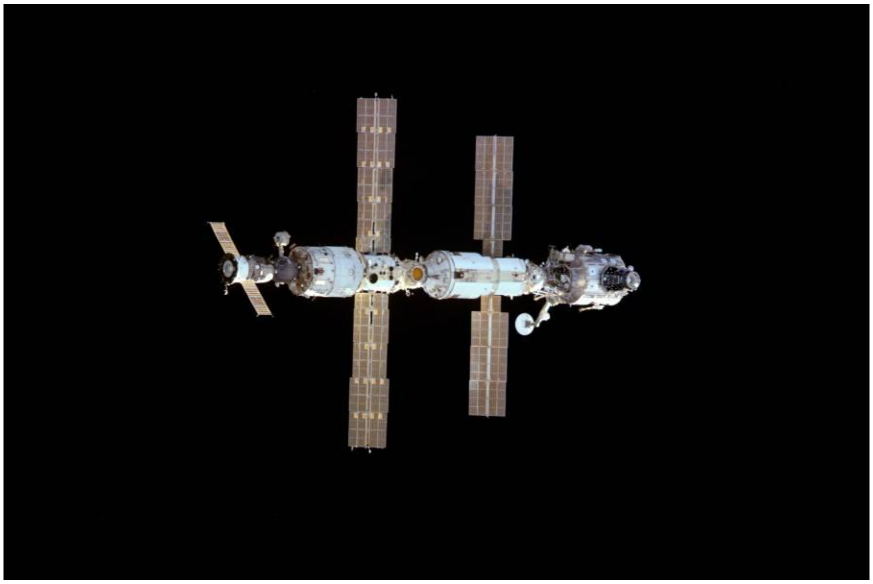

Photo 6. ISS as seen from space shuttle *Endeavour* (STS-97), December 2, 2000. (spaceflight.nasa.gov, S97-E-5009).

The next major ISS component, the U.S.-built *Destiny* Laboratory Module, arrived in February 2001 aboard *Atlantis* (STS-98). Built by Boeing at MSFC, the *Destiny* module is used for research in life sciences, microgravity sciences, and Earth and space science research. The astronaut crew arriving aboard *Discovery* (STS-102) in March 2001attached and unloaded the first Multi-Purpose Logistics Module (MPLM), *Leonardo*. *Leonardo* and two other MPLMs, *Donatello*, and *Raffaello*, were built by the Italian Space Agency (ISA) at the Alenia Aerospazio factory in Turin, and are owned by the U.S. ISA's role in MPLM construction was independent of Italy's membership in the ESA; the modules were built in exchange for Italian access to U.S. research time on the ISS. The three pressurized modules are filled with racks that carry equipment, experiments, and supplies to and from the station aboard the shuttle. They are mounted in the shuttle's cargo bay and are berthed to the station using the shuttle's robotic arm. The MPLMs have components that provide limited life support, as well as fire detection and suppression, electrical distribution, and computer functions.

The shuttle *Endeavour* (STS-100) delivered the Canadarm 2 to the ISS in April 2001. Three months later, the Joint Airlock *Quest* arrived, which enabled the U.S. astronauts to perform spacewalks without the space shuttle present. *Quest* is comprised of two sections – a crew lock that is used to exit the station and begin a spacewalk, and an equipment lock used for storing gear and for overnight "campouts" by the crew. On September 15, 2001, the Russian *Pirs* Docking Compartment, launched aboard a Progress spacecraft, provided the ISS with additional spacewalking support and docking capabilities.

On November 30, 2000, the Port 6 (P6) Truss, fitted with the first set of solar arrays, were launched by *Endeavour* (STS-97). P6 was temporarily installed on top of the Z1 Truss to provide power to the station while the remainder of the integrated truss system, which forms the backbone of the ISS, was completed. The P6 Truss remained in its temporary location until October 2007, when the crew from the STS-120 mission moved the segment to its designated location.

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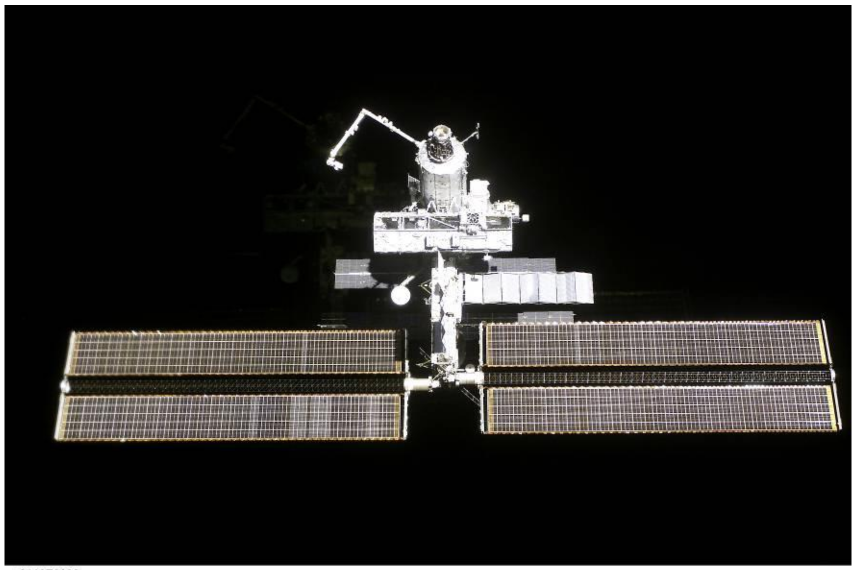
Starboard Trusses (S0 and S1) were delivered aboard *Atlantis* (STS-110 and STS-112) in April and October 2002, respectively, followed by the P1 Truss in November 2002. After the addition of the P1 Truss during the *Endeavour* (STS-113) mission, the configuration of the outpost "froze" at this stage for years. At this point, approximately 45 percent of the station had been delivered and assembled. In the aftermath of the *Columbia* accident, the space shuttle fleet was grounded and construction on the ISS was placed on hold. All access to and from the station was by way of the Russian-built Soyuz capsule. During the two-year period spanning 2003 to 2005, Russia flew 14 resupply and crew rotation missions until *Discovery's* STS-114 Return to Flight mission launched on July 26, 2005 (Launius 2003:214-216).



S110E6006

Photo 7. ISS as seen from space shuttle *Atlantis* (STS-110), April 17, 2002.
(spaceflight.nasa.gov, S110-E-6006).

Photo 8. ISS as seen from space shuttle *Discovery* (STS-116), December 9, 2006.
(NASA, http://www.nasa.gov/mission_pages/station/structure/iss_assembly_1291.html)

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On March 2, 2006, the international partners approved a new assembly sequence which dedicated 16 remaining shuttle flights to launching ISS elements. Truss segments P3/P4 and P5, as well as S3/S4 and S5 were delivered in 2006 and 2007. *Discovery* (STS-120) launched on October 23, 2007 carrying the Italian-built *Harmony* Node 2. This module increased crew living and working space; provided connecting ports for supply vehicles and the shuttle; and provided a passageway between the U.S. *Destiny* lab, the Japanese *Kibo* Experiment Module, and the ESA-built *Columbus* Laboratory. The *Kibo* and *Columbus* modules, as well as the Canadian-built robotic device *Dextre* arrived at the station in early 2008.

The last major U.S. truss segment, S6, and the final pair of power-generating solar array wings, were delivered to the station aboard *Discovery* (STS-119) in March 2009. The same year, the *Kibo* Japanese Experiment Module (JEM) Exposed Facility (EF) and Experiment Logistics Module (ELM) Exposed Section (ES) were delivered aboard *Endeavour* (STS-127). The module provides an environment in which astronauts conduct microgravity experiments. The exposed facility is a platform outside the module where Earth observation, communication, scientific, engineering, and materials science experiments are performed (NASA 2007a).

Photo 9. ISS as seen from space shuttle *Discovery* (STS-119), March 25, 2009. (spaceflight.nasa.gov, S119-E-009765).

In February 2010, the *Tranquility* Node 3 and its cupola were delivered aboard *Endeavour* (STS-130). The node and viewing port were built by the Italian company Thales Alenia Space and commissioned by the ESA (Thales Group 2010). The *Tranquility* node provides needed space and a centralized home for the station's environmental control equipment, as well as other essential services. The cupola allows a view of robotics operations on the station's exterior.

By April 2010, following the conclusion of *Discovery's* (STS-131) mission, the non-Russian segment of the ISS was virtually complete. In May, *Atlantis* (STS-132) delivered the Russian-built Mini-Research Module 1 (MRM1) *Rassvet*. MRM2 *Poisk* was delivered earlier, in November 2009, aboard a Russian Progress M spacecraft. The MRM1 is used for science research and cargo storage. It also provides an additional docking port for Russian Soyuz and Progress vehicles (NASA MSFC 2010). Despite their identification as research modules, the primary function of both MRMs was to provide docking ports for the Russian segment of the station, needed to receive the Soyuz and Progress transport ships.

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Photo 10. ISS as seen from space shuttle *Atlantis* (STS-132), May 16, 2010. (spaceflight.nasa.gov, S132-E-007808).

The ISS Support Fleet

An international fleet of space vehicles supports the ISS by delivering components; bringing and returning crews; providing logistical support; replenishing supplies and equipment (e.g., food, water, air, propellants, experimental equipment, hardware and spare parts); returning experiment results to Earth; plus removing trash and waste. In addition to the three American space shuttle vehicles *Discovery*, *Atlantis*, and *Endeavour*, logistics and resupply missions are supported by the Soviet Soyuz, Proton, and Progress spacecraft; the ESA's ATV-1; and the JAXA's HTV-1. The Progress, ATV-1, and HTV cargo ships commonly remain at the station for a period of several months. They undock from the ISS loaded with a cargo-load of trash, which subsequently burns up, along with the vehicle, as they re-enter into the Earth's atmosphere.

Upon the final completion of the ISS, the three **U.S. space shuttles** will have delivered all but three of the major station elements, *Zarya*, *Zvezda*, and *Nauka* (which were or will be delivered by the unmanned Russian Proton spacecraft). Additionally, the shuttles have been used to transport the three MPLMs, *Leonardo*, *Raffaello* and *Donatello*, to and from the ISS. These modules are carried in the shuttle's payload bay, and are transferred to the station using the shuttle's robotic arm. In addition, four of the first five Expedition crews to the space station were delivered by shuttle vehicles between March 2001 (Expedition 2) and June 2002 (Expedition 5). Since then, the shuttles have worked in conjunction with the Russian Soyuz spacecraft to carry entire or partial crews to and from the ISS. After NASA retires the Space Shuttle program, it will seek commercial providers of launch and return logistical services (Commercial Orbital Transportation Services, or COTS) to support the ISS.

The **Russian Soyuz** launched the first Expedition crew to the ISS on October 30, 2000. Between then and June 2010, numerous Soyuz missions have carried Expedition crews to and from the space outpost, including astronauts and cosmonauts, international participants (non-professional astronauts) and space tourists. Following the grounding of the space shuttle fleet in February 2003, the Soyuz vehicle became the only means of transport to and from the ISS. Upon delivery of the crew, the three-seat Soyuz spacecraft remains docked to the station, providing an emergency lifeboat. It is changed out with another spacecraft every six months to maintain the emergency crew return capability. After 2009, when the outpost crew was increased from three to six people, at least two Soyuz vehicles have to be docked to the station at all times to serve as a lifeboat for all crew members.

The **Russian Progress**, an automated, unpiloted version of the Soyuz spacecraft, is used to bring supplies and fuel to the station. An earlier model of the Progress was used to supply the *Salyut* space station in the late 1970s and *Mir*, beginning in the late 1980s. The Progress is equipped to dock using the *Zvezda* Service Module or the *Pirs* Docking Compartment (NASA 2007b). Its first cargo supply mission was launched on July 12, 2000. Subsequently, it made two more trips in 2000 and four more in 2001. In the aftermath of the *Columbia* accident, Progress became the only supply vehicle to support the ISS. Between February 2003 and April 2010, it made a total of 28 trips. In addition to its primary function as a resupply vehicle, once docked, Progress can boost the ISS to higher altitudes and control the orientation.

The ESA's Automated Transfer Vehicle (**ATV-1**) joined the fleet of supply vehicles in 2008. Launched on an Ariane 5 rocket from Europe's spaceport in Kourou, French Guinea on March 9, 2008, the ATV-1 carried up nine tons of cargo on its maiden voyage. The ATV has about three times the payload capability of the Russian Progress cargo craft. After docking, the ATV can perform space station attitude control and debris avoidance maneuvers; it is also used to boost the station's orbit.
The newest addition to the cargo fleet is JAXA's unpiloted spacecraft **HTV** (H-IIB Transfer Vehicle), which made its inaugural launch atop an H-2A booster rocket from the Tanegashima Space Center in Japan on September 1, 2009. It docked with the *Harmony* node on September 8, and provided supplies for Expedition 19/20.

Expedition Crews and Participants

The Expedition 1 crew, composed of U.S. astronaut commander Bill Shepherd and Russian cosmonauts Yuri Gidzenko and Sergei Krikalev, left Kazakhstan on October 30, 2000 aboard a Russian Soyuz spacecraft. The crew took up residence on the ISS on November 2, and the Soyuz spacecraft remained docked with the station, allowing crew an emergency return to earth if needed (Launius 2003:192-193; NASA JSC 1999a). Since the arrival of Expedition 1, there has been a continuous human presence on the ISS. This first crew stayed aboard the ISS for approximately 120 days, during which time they were visited by *Endeavour's* (STS-97) crew, arriving in December 2000. The Expedition 1 crew was replaced with Expedition 2, who arrived during the STS-102 mission in March 2001, and remained on the station for 163 days. Space shuttles *Discovery* and *Endeavour* carried Expedition crews 3, 4 and 5 between August 2001 (STS-105) and June 2002 (STS-111).

In the aftermath of the *Columbia* accident, the ISS crew size was reduced from three to two, and instead of a three month period of residency, all crew were scheduled to stay for approximately 180 days. Expedition 12, launched on September 30, 2005 aboard Soyuz TMA-7, was the last two-person crew. Expedition 13, launched on March 29, 2006, marked a return to the three-person long duration crew. A major milestone in the ISS program was reached in May 2009 when, for the first time, the permanent crew was increased to six. Russian Soyuz TMA-15 spacecraft carried Russian cosmonaut Roman Romanenko, Canadian astronaut Robert Thirsk, and ESA (Belgium) astronaut Frank DeWinne, who joined three crew members (cosmonaut Gennady Padalkat, NASA astronaut Michael Barratt, and American space tourist Charles Simonyi) who arrived two months earlier on Soyuz TMA-14. With this crew (Expedition 20), all participating space agencies now had a representative on the ISS for the first time.

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Since 2001, the long-duration expedition crews have been visited by professional astronauts who participate in ISS functions for a limited amount of time. In addition, non-professional participants also have visited the ISS. Between 2001 and 2009, Roscosmos flew seven "space tourists" to the ISS. The practice was halted in 2009 when the ISS crew was increased from three to six, and all the places on board the outpost had been reserved for astronauts. Dennis Tito, an American businessman, was the first space tourist in 2001. He launched with two Russian cosmonauts on April 28, 2001. Tito was followed by South African computer millionaire Mark Shuttleworth in April 2002; Gregory Olsen, a U.S. entrepreneur, in 2005; Charles Simonyi, a founder of Microsoft, in 2005 and again in 2009; Anousheh Ansari, a U.S. citizen, in 2006; Richard Garriott, a U.S. games developer and son of an American astronaut, in 2008; and Guy Laliberte, the Canadian founder of the Cirque du Soleil, in October 2009. Each space tourist was transported to the station aboard a Russian Soyuz-TMA spacecraft.

The Legal Framework for the ISS

The rights and obligations of the ISS partner countries are defined in three types of international agreements. On January 29, 1998, the International Space Station Intergovernmental Agreement was signed by the U.S., Canada, Japan, Russia, and 10 member states of the ESA, including Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden and Switzerland. As provided for in Article 1, this agreement established "a long international co-operative frame-work on the basis of genuine partnership, for the detailed design, development, operation, and utilization of a permanently inhabited civil space station for peaceful purposes, in accordance with international law" (ESA 2008). In accordance with Article 5, each partner retains jurisdiction and control over the elements it provides and over personnel in or on the station who are its nationals. Article 9 of the Intergovernmental Agreement, as well as separate Memoranda of Understanding, define utilization rights. The international partners may barter or sell their unused utilization rights among themselves and to other non-participants. For example, an agreement between the ISS partners allocates 8.3 percent of the outpost's resources, including crew time and power, to the ESA, following the arrival of the Columbus Laboratory. This is equivalent to a six-month mission on the station every two years. The ESA has a bartering agreement with NASA to use 51% of the European Columbus Laboratory in exchange for shuttle transportation services (ESA 2008).

The four Memoranda of Understanding between NASA and each cooperating space agency (the ESA, the Canadian Space Agency (CSA), the Russian Federal Space Agency (Roscosmos), and the Japan Aerospace Exploration Agency (JAXA)) describe in detail the roles and responsibilities of each space agency in the design, development, operation and use of the station. These agency-level agreements also establish the management structure and interfaces necessary to ensure the effective use of the ISS (ESA 2008). In addition to the intergovernmental agreement and the Memoranda of Understanding, various bilateral implementing agreements between the space agencies provide concrete guidelines and tasks among the national agencies.

3.0 THE SPACE STATION PROCESSING FACILITY

3.1 History

In 1984, KSC was selected as the location where all space station elements to be flown on the space shuttle would be processed. Early the following year, the Center solicited study proposals to analyze how these ground processing operations would be conducted; these studies continued

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into 1986, and by 1987, the decision was made to construct a building specifically for space station processing (*Spaceport News* 1985a, 1987). Design work on the SSPF was completed by Jacobs Engineering Group, Inc., of Lakeland, Florida; Jose Perez-Morales served as NASA's lead design engineer (Jacobs Engineering Group, Inc. 1989; Grinter 2009).

In February 1991, the Tampa, Florida-based firm, Metric Constructors, Inc, was awarded the contract for construction with the winning proposal of $56.2 million (Varnes 1991:1; Grinter 2009). Construction officially began in April 1991, under the direction of Tommy Mack, NASA's construction manager (Grinter 2009). The final construction cost of the SSPF was approximately $72 million and it was officially dedicated on June 23, 1994 (Grinter 2009). The first occupants of the building, the Test Control and Monitoring System software team, moved into their second floor offices while construction of the SSPF High Bay was still underway. Three years later, 1997, the south wall of the High Bay was fitted with visitor's windows (Kight 2010).

Photo 11. Aerial view showing construction of SSPF, January 1992, facing northeast. (KSC Archives, KSC-392C-326.02).

In the fall of 1994, the Russian-built Mir-2 Docking Module (DM) became the first flight hardware to be processed in the SSPF; it was carried on *Atlantis* (STS-74) in November 1995 with NASA's second docking with the Russian station, *Mir* (*Spaceport News* 1994d; Grinter 2009; NASA KSC n.d.c). In June 1997, the first U.S.-built element for the ISS, *Unity* (Node 1), arrived at the SSPF for processing; it was carried into orbit in December 1998 aboard *Endeavour* as part of ISS Assembly Mission 2A. Since then, all payloads destined for the station, regardless of the sponsoring nation, have been processed through the SSPF, except those delivered via Russian spacecraft (NASA JSC 1997c; NASA 2009).

Additionally, the ISS Programs Multi Element Integrated Testing (MEIT) was performed in the SSPF. It was completed in three phases from December 1998 through September 2003. MEIT was performed on the ISS Flight Hardware that was soft mated on the high bay floor in the same configuration it would have on orbit. The various cabling (C&T, C&DH, EPS, etc), and fluid lines, were connected between the elements, which were then powered up and tested as an

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integrated unit. With the number of countries and U.S. contractors involved in building the hardware, this was the first time the flight elements had been connected and tested as a system in an on-orbit configuration. A Flight Emulator was developed that would simulate the missing elements already on orbit. Many problems were discovered and corrected. Photo 12 depicts MEIT II, the second phase of MEIT. It shows the S0 Truss connected to the S1 and P1 Trusses, the P1 connected to the P3/P4 Trusses. P4 on the far right is tented and has ammonia running through the pressure vessel. The Flight Emulator is adjacent to the S0 Truss.

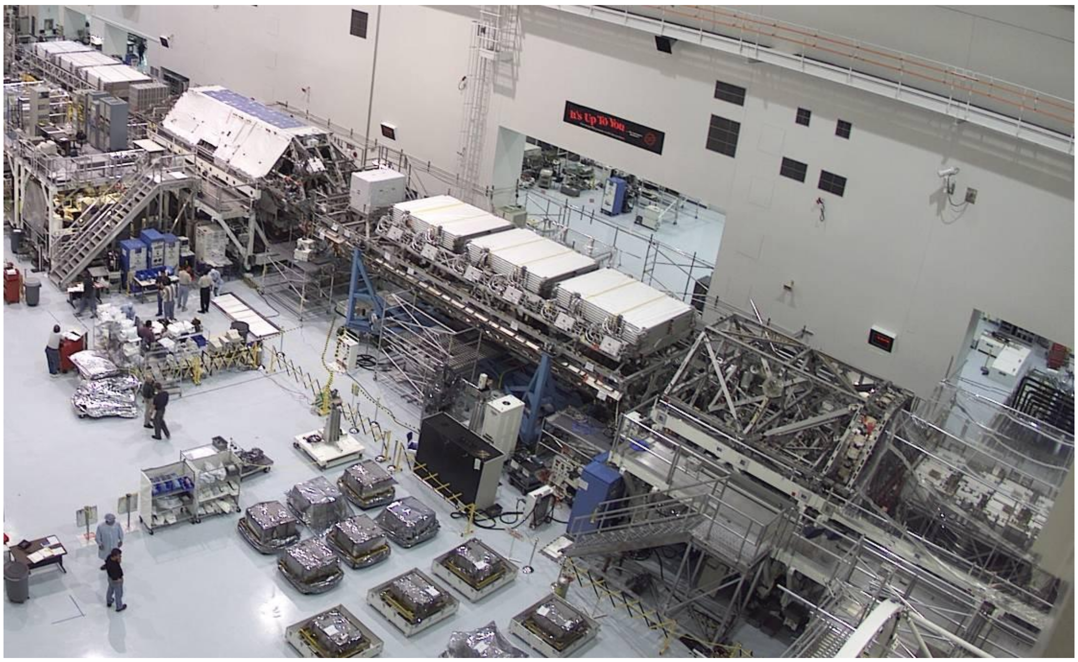

Photo 12. The Multi Element Integrated Testing second phase (MEIT II) in the SSPF.
(Courtesy of John Jackson, NASA KSC)

3.2 <u>Facility Description</u>

The SSPF is a three-story Industrial Vernacular style building with approximate overall dimensions of 671 feet (ft) in length (east-west), 367 ft in width (north-south), and 90 ft in height. The entirety sits on a reinforced concrete slab, which is supported by reinforced concrete piers/footers. Its walls are formed by a combination of concrete block and a steel skeleton faced with both insulated and non-insulated metal sheeting, and composite wall panels. The facility has a flat roof comprised of metal decking, rigid insulation, and a four-ply built-up roof system with gravel topping.

The north elevation of the SSPF is the principal façade of the building. This elevation features pilasters formed with composite wall panels, ribbons of fixed and operable windows, and expanses of corrugated metal paneling with a stepped profile. The main entrance is comprised of two pairs of mechanically-operated glass swing doors framed by fixed-window sidelights and a transom. The ribbons of windows continue along the north half of both the east and west elevations of the SSPF. At the south end of the east elevation, there is one metal rolling door into the High Bay; the south end of the west elevation features a four-section vertical lift door, with a

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personnel opening. The south elevation of the SSPF has a small visitor's gallery near its center, added ca. 1997 (Kight 2010).

Photo 13. North and partial east elevations of SSPF, facing southwest. (Archaeological Consultants, Inc., 2010).

Internally, the SSPF is divisible into two sections: an office/laboratory area to the north and a High Bay area to the south. The office/laboratory area contains three main floor levels; there is also a small first floor mezzanine at the northeast corner. Except for a few rooms located near the Intermediate Bay (I-Bay), the portion of the first floor level to the east of the main entrance contains office and general support rooms. The exceptions are four biological laboratories, the Payload Rack Checkout Unit (PRCU) Room, and the Fluids Processing Room. To the west of the main entrance, the first floor contains spaces devoted to shuttle flight crew equipment and space station equipment, as well as six biological laboratories and three off-line processing laboratories. The mezzanine level, second floor, and third floor consist of office areas, support rooms, and electrical/mechanical equipment rooms.

The High Bay area, which comprises the southern portion of the SSPF, contains one-, two-, and three-floor sections. The first floor level contains the High Bay, the Airlock, the Hardware Inspection Area, the I-Bay, the Low Bay, the Rack Room, five off-line processing laboratories, and part of the shipping/receiving area. The High Bay and Airlock are both full-height spaces. The High Bay sits in the southeast corner, and contains eight designated work areas, called "footprints." To the west of the High Bay is the Airlock, which contains various vacuum hook-ups for cleaning and decontaminating each ISS element. To the north of the Airlock is the Hardware Inspection Area. The I-Bay sits directly to the north of the east end of the High Bay; throughout this bay are various power distribution boxes, work tables, and data testing areas. At the east end of the space is the Hazardous Fluid Servicing Area for working on elements of the ISS that contain ammonia. Directly to the west of the I-Bay is the Low Bay; to its west are the Rack Room and three processing labs (the other two are located within the northwest corner of the High Bay). To the west of the labs is the shipping/receiving area.

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Photo 14. SSPF High Bay, facing east.
(Archaeological Consultants, Inc., 2010).

Photo 15. SSPF I-Bay, facing southwest.
(Archaeological Consultants, Inc., 2010).

Above the Low Bay, Rack Room, labs, and shipping area are two additional floor levels, which align with the second and third floors of the office/laboratory area. On the lower of the two levels are nine Control Rooms, that can be programmed to operate any of the eight footprints in the High Bay. Along the walls of each Control Room are the various console stations; work tables are positioned in the center of the space. The upper level, which also extends over the I-Bay and the Hardware Inspection Area, contains various mechanical equipment rooms.

Photo 16. SSPF Control Room, facing southeast.
(Archaeological Consultants, Inc., 2010)

Ancillary Features

To the east of the I-Bay is the Ammonia Vapor Containment Building (M7-0361A), which is considered a contributing ancillary feature to the SSPF. Built ca. 2000, this facility has approximate dimensions of 75 ft in length, 20 ft in width, and stands roughly 14 ft in height. It is comprised of a poured concrete slab foundation, concrete block walls, and a metal shed roof. It contains a metal rolling door on its east elevation, and a metal swing door on its south elevation. Inside the building are three ammonia storage tanks, two ammonia chilling carts with a corresponding liquid nitrogen tank, and a Flow Control and Instrumentation Cart.

3.3 Functions and Operations

In general, the functional areas within the SSPF support a variety of activities, including the assembly and testing of space station elements, the processing of mechanical and electrical experiments, and the integration of payloads, as well as the shipping and receiving of flight hardware and cargo (Myers 1995:2-4). The five major functional areas, as depicted in Figure 3, are as follows:

1) the Hardware Processing area;
2) the Off-Line Processing Labs;
3) the Biological Labs;
4) the Cargo Mission Contract (CMC) Areas; and
5) the Flight Crew Area.

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Figure 3. Major functional areas of the SSPF.

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The **Hardware Processing Area**, depicted by blue in Figure 3, includes the High Bay, the I-Bay, the Low Bay, the Airlock, the Hardware Inspection Area, the Rack Room, the Fluids Processing Room, the Payload Rack Checkout Unit (PRCU) Room. Nine associated control rooms are located on the second floor level. This area was designed to support the processing of any hardware component or payload destined to travel to the ISS via the space shuttle. Payloads typically enter the SSPF either though the Airlock or through the Hardware Inspection Area. In the Airlock, the equipment is thoroughly cleaned through the use of vacuums; it is checked for damages in the Hardware Inspection Area (Mayer 2010).

The east end of the I-Bay is specially equipped to process ISS elements that contain ammonia, which is used for cooling the ISS. The **Ammonia Vapor Containment Building**, located adjacent to the SSPF, houses the ammonia storage and servicing equipment. Science modules and experiment racks are processed in the Low Bay, the I-Bay, or the Rack Room, prior to installation into a flight element. Payload racks also undergo testing in the PRCU Room to ensure they are operating properly. Once these items have satisfied all test requirements, they are taken into the High Bay and placed in one of the three Italian-built Multi-Purpose Logistics Modules (MPLM) (Mayer 2010; Hopkins 2010).

The High Bay is also used for staging, experiment integration, payload integration and verification, and post-landing deintegration. Additionally, computer modeling is used to conduct a digital pre-assembly of the ISS elements to discover any physical incompatibilities, since the elements are not physically connected prior to meeting in orbit. To assist with all of the activities, the High Bay contains various pieces of specialized equipment, including four Cargo Element Workstands, one Express Logistics Carrier Rotation Stand, one Element Rotation Stand, one Cargo Element Lifting Assembly, one Lightweight Multi-Purpose Experiment Support Structure Carrier, and one Rack Insertion Device. All of these devices were uniquely designed to support the processing of ISS elements and flight support equipment (Mayer 2010; NASA KSC 2006).

The SSPF contains eighteen smaller processing laboratories, which contractors can use to work on their hardware or science experiments destined for the station, prior to officially handing the items over to NASA. Eight of these are referred to as **Off-line Processing Labs** (depicted by yellow in Figure 3) and are used on general hardware items, such as EXPRESS (Expedite the Processing of Experiments to the Space Station) racks. One of these rooms is referred to as the **Multi-Layer Insulation Sew Shop**, which is specifically used to fabricate and repair multilayer insulation blankets for station hardware. The remaining ten rooms are designated as **Bio Labs** (denoted by green in Figure 3), and are equipped with standard biological equipment to support the pre-launch and post-flight off-line processing of experiment-specific hardware (Mayer 2010; Middleton 2010; Galloway 2010).

The **Cargo Mission Contract (CMC) Areas,** denoted by red in Figure 3, include the Tray Processing Room, the Foam Operations Laboratory, the Logistical Room, and the Trash Room. The main purpose of these areas is to prepare cargo, such as food, clothing, tools, and experiments, to be carried to the ISS by the space shuttle. Activities include packing the gear into Cargo Transfer Bags, inspecting pre-packaged bags from a similar facility at JSC or from a partner country, and designing and cutting foam padding to protect sensitive hardware. In addition, these areas are used to unpack and sort cargo that has returned from the ISS on the space shuttle (Hillenbrand 2010).

The **Flight Crew Area**, moved to the SSPF roughly 10 years ago, works in conjunction with the CMC Areas, and typically focuses on items for use by the space shuttle crew. These items can include small pieces of hardware, personal items of the astronauts, extravehicular mobility units,

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crew escape poles, and cameras. Some of the apparatus is prepackaged at JSC and then inspected and stored in this area prior to being placed in the orbiter; other items are assembled and prepared for flight. All packages' dimensions are checked to be sure they fit into the crew compartment as detailed in the configuration plans (Woods 2010).

4.0 EVALUATION OF SIGNIFICANCE

The SSPF is considered eligible for listing in the NRHP in the context of the Space Station program (1984-2020) under Criterion A in the areas of Space Exploration and Science and under Criterion C in the area of Engineering. Because it has achieved significance within the past 50 years, Criteria Consideration G applies. The period of significance for the SSPF is from 1991, when construction of the facility began, through 2011, the anticipated end date for the in-orbit assembly of the U.S. portion of the ISS. It derives its primary significance from the hardware processing areas, specifically the High Bay, the I-Bay, the PRCU Room, and the Airlock, as well as nine associated Control Rooms. In addition, the Ammonia Vapor Containment Building is considering a contributing ancillary feature to the SSPF. Under Criterion A, the SSPF is the only building in the United States that was designed and constructed exclusively for the pre-flight checkout and processing of ISS flight hardware. All but three of the nearly four dozen components that comprise the station were carried into orbit by one of the U.S. space shuttles, and therefore, underwent final preparations at the SSPF. Additionally, the shuttles have been used to transport the three MPLMs, *Leonardo*, *Raffaello* and *Donatello*, to and from the ISS. These three pressurized modules were filled at the SSPF with racks that carry equipment, experiments, and supplies to the station aboard the shuttle, and were unloaded here as well. As such, it is of exceptional importance to the International Space Station program.

Under Criterion C, the design of the SSPF focused on providing "infinite flexibility" within the Hardware Processing Areas. This resulted in the use of a conductive floor throughout the High Bay and I-Bay, which can accommodate air-bearing pallets (used to move processing hardware). This type of floor also prevents the build-up of static electricity. Additionally, the SSPF High Bay contains four Cargo Element Workstands, one Express Logistics Carrier Rotation Stand, one Element Rotation Stand, one Cargo Element Lifting Assembly, one Lightweight Multi-Purpose Experiment Support Structure Carrier, and one Rack Insertion Device, all of which were uniquely designed to support the processing requirements of the hardware. It is this equipment coupled with the specific design features of the High Bay area that facilitate the use of this equipment, which provides the basis for the SSPF's eligibility under Criterion C. The SSPF maintains integrity of location, design, setting, materials, workmanship, feeling and association.

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APPENDIX A: Chronology of ISS Assembly and Supply Missions.

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Assembly Mission No.	**Vehicle**	**Launch Date**	**Payload/comments**
1 A/R	Russian Proton	Nov. 20, 1998	*Zarya* Control Module
2A	*Endeavour* (STS-88)	Dec. 4, 1998	*Unity* Node 1; two Pressurized Mating Adapters (PMA)
2A.1	*Discovery* (STS-96)	May 27, 1999	Logistics delivery. First space shuttle to dock with the ISS.
2A.2a	*Atlantis* (STS-101)	May 19, 2000	Logistics delivery
1R	Russian Proton	July 12, 2000	*Zvezda* Service Module
1P	Progress M1-3	Aug. 6, 2000	Cargo supply
2A.2b	*Atlantis* (STS-106)	Sept. 8, 2000	Logistics delivery
3A	*Discovery* (STS-92)	Oct. 11, 2000	Z-1 Truss, third PMA, Ku-band antenna
2P	Progress M1-4	Nov. 16, 2000	Cargo supply
4A	*Endeavour* (STS-97)	Nov. 30, 2000	P-6 Truss and first set of solar arrays
5A	*Atlantis* (STS-98)	Feb. 7, 2001	*Destiny* Laboratory Module
3P	Progress M-44	Feb. 26, 2001	Cargo supply
5A.1	*Discovery* (STS-102)	March 8, 2001	Supplies, equipment and experiment racks for *Destiny*. First MPLM, *Leonardo*
6A	*Endeavour* (STS-100)	April 19, 2001	Canadarm 2
4P	Progress M1-6	May 21, 2001	Cargo supply
7A	*Atlantis* (STS-104)	July 12, 2001	Joint Airlock *Quest*
7A.1	*Discovery* (STS-105)	Aug. 10, 2001	Supplies, equipment and experiment racks for Destiny
5P	Progress M-45	Aug. 21, 2001	Cargo supply
3R	Progress/DC-1	Sept. 15, 2001	Cargo crane; Russian *Pirs* Docking Compartment
6P	Progress M1-7	Nov. 26, 2001	Cargo supply
UF-1	*Endeavour* (STS-108)	Dec. 5, 2001	Experiment racks for *Destiny*
7P	Progress M1-8	March 21, 2002	Cargo supply
8A	*Atlantis* (STS-110)	April 8, 2002	S0-Truss; Mobile Transporter
UF-2	*Endeavour* (STS-111)	June 5, 2002	Experiment racks for Destiny
8P	Progress M-46	June 26, 2002	Cargo supply
9P	Progress M1-9	Sept. 25, 2002	Cargo supply
9A	*Atlantis* (STS-112)	Oct. 7, 2002	S1 Truss
11A	*Endeavour* (STS-113)	Nov. 23, 2002	P1 Truss; P6 solar arrays deployed
10P	Progress M-47	Feb. 2, 2003	Cargo supply
11P	Progress M1-10	June 8, 2003	Cargo supply
12P	Progress M-48	Aug. 29, 2003	Cargo supply
13P	Progress M1-11	Jan. 29, 2004	Cargo supply
14P	Progress M-49	May 25, 2004	Cargo supply
15P	Progress M-50	Aug. 11, 2004	Cargo supply
16P	Progress M-51	Dec. 23, 2004	Cargo supply
17P	Progress M-52	Feb. 28, 2005	Cargo supply
18P	Progress M-53	June 17, 2005	Cargo supply
LF-1	*Discovery* (STS-114)	July 26, 2005	Supplies and equipment
19P	Progress M-54	Sept. 8, 2005	Cargo supply
20P	Progress M-55	Dec. 21, 2005	Cargo supply
21P	Progress M-56	April 24, 2006	Cargo supply
22P	Progress M-57	June 24, 2006	Cargo supply
ULF-1.1	*Discovery* (STS-121)	July 1, 2006	Supplies and equipment

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Assembly Mission No.	Vehicle	Launch Date	Payload/comments
12A	*Atlantis* (STS-115)	Sept. 9, 2006	P3/P4 Truss structure. Solar arrays and radiator deployed
23P	Progress M-58	Oct. 23, 2006	Cargo supply
12A.1	*Discovery* (STS-116)	Dec. 9, 2006	P5 Truss
24P	Progress M-59	Jan. 18, 2007	Cargo supply
25P	Progress M-60	May 12, 2007	Cargo supply
13A	*Atlantis* (STS-117)	June 8, 2007	S3/S4 Truss; third set of solar arrays
26P	Progress M-61	Aug. 2, 2007	Cargo supply
13A-1	*Endeavour* (STS-118)	Aug. 8, 2007	S5 Truss; External Stowage Platform 3 (ESP3)
10A	*Discovery* (STS-120)	Oct. 23, 2007	*Harmony* Node 2
27P	Progress M-62	Dec. 23, 2007	Cargo supply
28P	Progress M-63	Feb. 5, 2008	Cargo supply
1E	*Atlantis* (STS-122)	Feb. 7, 2008	*Columbus* Laboratory
ATV1	ATV-1	March 9, 2008	Cargo supply
1J/A	*Endeavour* (STS-123)	March 11, 2008	*Kibo* Laboratory; Experiment Logistics Module (ELM)-Pressurized Section; Special Purpose Dexterous Manipulator “Dextre”
29P	Progress M-64	May 15, 2008	Cargo supply
1J	*Discovery* (STS-124)	May 31, 2008	JAXA Pressurized Module; *Kibo* robotic arm
30P	Progress M-65	Sept. 10, 2008	Cargo supply
ULF-2	*Endeavour* (STS-126)	Nov. 14, 2008	Supplies and equipment; spare hardware
31P	Progress M-01M	Nov. 26, 2008	Cargo supply
32P	Progress M-66	Feb. 10, 2009	Cargo supply
15A	*Discovery* (STS-119)	March 15, 2009	S6 Truss; final set of solar arrays
33P	Progress M-02M	May 7, 2009	Cargo supply
2J/A	*Endeavour* (STS-127)	July 15, 2009	*Kibo* Experiment Module Exposed Facility; ELM - Exposed Section
34P	Progress M-67	July 24, 2009	Cargo supply
17A	*Discovery* (STS-128)	Aug. 28, 2009	Life support and science racks; Lightweight Multi-Purpose Experiment Support Structure Carrier
HTV-1	HTV-1	Sept. 10, 2009	Cargo supply
35P	Progress M-03M	Oct. 15, 2009	Cargo supply
4R	Progress M/MIM-2	Nov. 10, 2009	Mini-Research Module 2 *Poisk* (MRM2)
ULF-3	*Atlantis* (STS-129)	Nov. 16, 2009	Equipment; spare gyroscope
36P	Progress M-04M	Feb. 3, 2010	Cargo supply
20A	*Endeavour* (STS-130)	Feb. 8, 2010	*Tranquility* Node 3 and cupola
19A	*Discovery* (STS-131)	April 10, 2010	Equipment for scientific experiments
37P	Progress M-05M	April 28, 2010	Cargo supply
ULF-4	*Atlantis* (STS-132)	May 14, 2010	Mini-Research Module 1 *Rassvet* (MRM1); Integrated Cargo Carrier
ULF5	*Discovery* (STS-133)	TBD (targeted Nov. 2010)	Permanent Multipurpose Module *Leonardo*; Express Logistic Carrier (ELC) 4; spare components
3R	*Endeavour* (STS-134)	TBD (targeted Feb. 26, 2011)	ELC 3; Alpha Magnetic Spectrometer; spare components

Legend: LF=logistics flight; UF=utilization flight; ULF=utilization and logistics flight

APPENDIX B: FMSF Form

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APPENDIX C: NRHP Nomination Form

APPENDIX D: Survey Log Sheet

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