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Space Stations

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Marcia S. Smith
Resources, Science, and Industry Division

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SUMMARY

Congress continues to debate NASA's International Space Station (ISS), a permanently occupied facility in Earth orbit where astronauts live and conduct research. Congress appropriated $33.5 billion for the program from FY1985-2004. The FY2005 request is $2.412 billion ($1.863 billion for construction and operation, plus $549 million for research).

The space station is being assembled in Earth orbit. Almost 90 launches of the U.S. space shuttle and Russian launch vehicles were originally planned to take the various segments, crews, and cargo into orbit; more than two dozen have taken place already. ISS has been permanently occupied by successive "Expedition" crews rotating on 4-6 month shifts since November 2000. The Expedition 10 crew is now on board. Cost growth and schedule delays have characterized the program since its inception. The grounding of the space shuttle fleet in the wake of the February 2003 *Columbia* tragedy is further affecting schedule, operations, and cost. Most of the remaining ISS segments are designed to be launched by the shuttle and therefore construction is suspended. President Bush's January 2004 exploration initiative also is expected to affect the ISS program by curtailing the shuttle program in 2010 and changing the focus of U.S. research aboard the facility to only that which supports his goal of returning humans to the Moon and someday journeying to Mars and "worlds beyond."

Canada, Japan, and several European countries became partners with NASA in building the space station in 1988; Russia joined in 1993. Brazil also is participating, but not as a partner. Except for money paid to Russia, there is no exchange of funds among the partners. Europe, Canada, and Japan collectively expect to spend about $11 billion of their own money. A reliable figure for Russian expenditures is not available.

In 1993, when the current space station design was adopted, NASA said it would cost $17.4 billion for construction; no more than $2.1 billion per year. The estimate did not include launch or other costs. NASA exceeded the $2.1 billion figure in FY1998, and the $17.4 billion estimate grew to $24.1-$26.4 billion. Congress legislated spending caps on part of the program in 2000. The cost estimate then grew by almost another $5 billion, leading NASA (at White House direction) to cancel or indefinitely defer some hardware to stay within the cap.

Controversial since the program began in 1984, the space station has been repeatedly redesigned and rescheduled, often for cost-growth reasons. Congress has been concerned about the space station for that and other reasons. Twenty-two attempts to terminate the program in NASA funding bills, however, were defeated (3 in the 106th Congress, 4 in the 105th Congress, 5 in the 104th, 5 in the 103rd, and 5 in the 102nd). Three other attempts in broader legislation in the 103rd Congress also failed.

Current congressional debate focuses on the impact of the space shuttle *Columbia* tragedy on the ISS program and the future of the program in light of President Bush's new exploration initiative.

MOST RECENT DEVELOPMENTS

The "Expedition 10" crew (American Leroy Chiao and Russian Salizhan Sharipov) continues its work aboard the International Space Station (ISS). While the U.S. space shuttle fleet is grounded, Russian Soyuz spacecraft are being used to ferry crews to and from ISS, and Russian Progress spacecraft deliver cargo. NASA hopes to return the shuttle to flight status between May 12 and June 3, 2005.

President Bush announced a new initiative in January 2004 (see CRS Report RS21720) that would focus NASA's efforts on human exploration of space beyond low Earth orbit. The new policy would terminate the space shuttle program after construction of ISS is completed, anticipated in 2010. From 2010 until at least 2014, when a new U.S. Crew Exploration Vehicle is available to take crews to Earth orbit, NASA would be reliant on Russia to take U.S. crews back and forth to ISS. No agreement has been negotiated with Russia as to the terms of Russia providing this service. The cargo capacity of the shuttle, which is much greater than Russia's Progress, also would no longer be available. Cargo would be taken to ISS using U.S. commercial launch vehicles, and other partners' launch vehicles and spacecraft. NASA would redirect its ISS research program to focus on life sciences questions related to sending humans beyond Earth orbit. A NASA budget chart shows NASA ending its involvement in ISS by FY2017.

The FY2005 request for the ISS is $2.412 billion ($1.863 billion for construction and operations, plus $549 million for research). The $1.863 billion includes a new $140 million line item, ISS Crew/Cargo Services, to fund alternatives to the shuttle for taking crew and cargo to and from ISS. NASA's total FY2005 budget request is $16.2 billion. The House Appropriations Committee's version of the FY2005 VA-HUD-IA appropriations bill (H.R. 5041, H.Rept. 108-674), which includes NASA, cut NASA's total request by $1.1 billion. Among the cuts are $190 million from ISS construction and operations (including $70 million from Crew/Cargo), and $103 million from bioastronautics research. The Senate Appropriations Committee (S. 2825, S.Rept. 108-353) cut $260 million (including all $140 million from Crew/Cargo), although it increased the total NASA budget to $16.4 billion. The Senate Commerce Committee ordered reported a FY2005-2009 NASA authorization bill (S. 2541) that includes the requested level of funding for ISS.

BACKGROUND AND ANALYSIS

Introduction

NASA launched its first space station, Skylab, in 1973. Three crews were sent to live and work there in 1973-74. It remained in orbit, unoccupied, until it reentered Earth's atmosphere in July 1979, disintegrating over Australia and the Indian Ocean. Skylab was never intended to be permanently occupied. The goal of a permanently occupied space station with crews rotating on a regular basis was high on NASA's list for the post-Apollo years. In 1969, Vice President Agnew's Space Task Group recommended a permanent space station and a reusable space transportation system (the space shuttle) to service it as the core of NASA's program in the 1970s and 1980s. Budget constraints forced NASA to choose to

build the space shuttle first. When NASA declared the shuttle "operational" in 1982, it was ready to initiate the space station program.

In his January 25, 1984 State of the Union address, President Reagan directed NASA to develop a permanently occupied space station within a decade and to invite other countries to participate in the project. On July 20, 1989, the 20th anniversary of the first Apollo landing on the Moon, President George H. W. Bush gave a major space policy address in which he voiced his support for the space station as the cornerstone of a long-range civilian space program eventually leading to bases on the Moon and Mars.

President Clinton was strongly supportive of the space station program, and dramatically changed its character in 1993 by adding Russia as a partner to this already international endeavor. Adding Russia made the space station part of the U.S. foreign policy agenda to encourage Russia to abide by agreements to stop the proliferation of ballistic missile technology, and to support Russia economically and politically.

President George W. Bush made a major space policy address on January 14, 2004 in which he said that NASA would shift its focus to human exploration of space beyond low Earth orbit. Included in the new plan is termination of the space shuttle program after construction of the space station is completed, now anticipated for 2010, and refocusing the space station research program to support that goal. The President said the United States would fulfill its commitments to its partners in the ISS program, although the details of how that will be accomplished without the space shuttle have not been announced.

The Space Station Program: 1984-1993

NASA began the current program to build a space station in 1984 (FY1985). In 1988, the space station was named *Freedom*. Following a major redesign in 1993, NASA announced that the *Freedom* program had ended and a new program begun, though NASA asserts that 75% of the design of the "new" station is from *Freedom*. The new program is simply referred to as the International Space Station (ISS). Individual ISS modules have various names, and the entire facility is informally referred to as ISS or "Space Station Alpha." ISS is a laboratory in space for conducting experiments in near-zero gravity ("microgravity"). A broadly based research program had been planned for ISS, but President Bush's January 2004 exploration initiative would limit U.S. research on ISS to that which is needed to support the goal of returning human to the Moon and someday sending them to Mars and "worlds beyond." From FY1985 through FY2004, Congress appropriated approximately $33.5 billion for the space station program (see table later in this report).

Space Station *Freedom*

When NASA began the space station program in 1984, it said the program would cost $8 billion (FY1984 dollars) for research and development (R&D — essentially the cost for building the station without launch costs) through completion of assembly. From FY1985-1993, Congress appropriated $11.4 billion to NASA for the *Freedom* program. Most of the funding went for designing and redesigning the station over those years. Little hardware was built and none was launched. Several major redesigns were made. A 1991 redesign evoked

concerns about the amount of science that could be conducted on the scaled-down space station. Both the White House Office of Science and Technology Policy (OSTP) and the Space Studies Board (SSB) of the National Research Council concluded that materials science research could not justify building the space station, and questioned how much life sciences research could be supported, criticizing the lack of firm plans for flying a centrifuge, considered essential to this research. NASA subsequently agreed to launch a centrifuge.

Cost estimates for *Freedom* varied widely depending on when they were made and what was included. *Freedom* was designed to be operated for 30 years. As the program ended in 1993, NASA's estimate was $90 billion (current dollars): $30 billion through the end of construction, plus $60 billion to operate it for 30 years. The General Accounting Office (GAO) estimated the total cost at $118 billion, including 30 years of operations.

In 1988, after three years of negotiations, Japan, Canada and nine European countries under the aegis of the European Space Agency (ESA) agreed to be partners in the space station program. A government-to-government Intergovernmental Agreement (IGA) was signed in September, and Memoranda of Understanding (MOUs) between NASA and its counterpart agencies were signed then or in 1989. The partners agreed to provide hardware for the space station at their own expense, a total of $8 billion at the time.

1993 Redesign — the Clinton Administration Restructuring

In early 1993, as President Clinton took office, NASA revealed $1 billion in cost growth on the *Freedom* program. The President gave NASA 90 days to develop a new, less costly, design with a reduced operational period of 10 years. A new design, *Alpha,* emerged on September 7, 1993, which NASA estimated would cost $19.4 billion. It would have used some hardware bought from Russia, but Russia was not envisioned as a partner. Five days earlier, however, the White House announced it had reached preliminary agreement with Russia to build a joint space station. Now called the International Space Station (ISS), it superseded the September 7 *Alpha* design. NASA asserted it would be a more capable space station and be ready sooner at less cost to the United States. Compared with the September 7 *Alpha* design, ISS was to be completed one year earlier, have 25% more usable volume, 42.5 kilowatts more electrical power, and accommodate 6 instead of 4 crew members.

In 1993, President Clinton pledged to request $10.5 billion ($2.1 billion a year) for FY1994-1998. NASA said the new station would cost $17.4 billion to build, not including money already expended on the *Freedom* program. That estimate was derived from the $19.4 billion estimate for the September 7 *Alpha* design minus $2 billion that NASA said would be saved by having Russia in the program. The $2.1 billion and $17.4 billion figures became known as "caps," though they were not set in law. (See **Cost Caps** below).

The International Space Station (ISS): 1993-Present

The International Space Station program thus began in 1993, with Russia joining the United States, Europe, Japan, and Canada. The 1993 and subsequent agreements with Russia established three phases of space station cooperation and the payment to Russia of $400

million, which grew to $473 million. (NASA transferred about $800 million to Russia for space station cooperation through this and other contracts.)

During Phase I (1995-1998), seven U.S. astronauts remained on Russia's space station *Mir* for long duration (several month) missions with Russian cosmonauts, Russian cosmonauts flew on the U.S. space shuttle seven times, and nine space shuttle missions docked with *Mir* to exchange crews and deliver supplies. Repeated system failures and two life-threatening emergencies on *Mir* in 1997 raised questions about whether NASA should leave more astronauts on *Mir*, but NASA decided *Mir* was sufficiently safe to continue the program. Phases II and III involve construction of the International Space Station itself, and blend into each other. Phase II began in 1998 and was completed in July 2001; Phase III is underway.

ISS Design, Cost, Schedule, and Lifetime

ISS is being built by a partnership among the United States, Russia, Europe, Japan, and Canada. The 1988 Intergovernmental Agreement was renegotiated after Russia joined the program. The new version was signed in 1998. The IGA is a treaty in all the countries except the United States, where it is an Executive Agreement. The IGA is implemented through Memoranda of Understanding (MOUs) between NASA and its counterpart agencies. Brazil and NASA have a bilateral agreement. Boeing is the U.S. prime contractor.

NASA originally stated that ISS would be operated for 10 years after assembly was completed, with a possibility for 5 additional years if the research was considered worthwhile. Using the original schedule, assembly would have been completed in 2002, with operations at least through 2012. The completion of assembly slipped to 2006, but President Bush restructured the space station program in 2001, and it was not clear when assembly would be "completed." NASA briefing charts in March 2003 showed space station operations possibly continuing until 2022. In January 2004, President Bush made a major space policy address in which he called for NASA to redirect its human space flight program towards returning humans to the Moon and going to Mars. A NASA budget chart released in connection with the speech shows NASA ending its space station activities in FY2017.

ISS segments are launched into space on U.S. or Russian launch vehicles and assembled in orbit. The space station is composed of a multitude of modules, solar arrays to generate electricity, remote manipulator systems, and other elements that are too numerous to describe here. Details can be found at [http://spaceflight.nasa.gov/home/index.html]. Six major modules are now in orbit. The first two were launched in 1998: Zarya ("Sunrise," with guidance, navigation, and control systems) and Unity (a "node" connecting other modules). Next was Zvezda ("Star," the crew's living quarters) in 2000. Destiny (a U.S. laboratory), Quest (an airlock), and Pirs ("Pier," a docking compartment) arrived in 2001. Among the other modules that will be added are laboratory modules built by Russia, Europe, and Japan, and two more "nodes" built by Europe. (Zarya counts as a U.S. module because NASA paid Russia to build it. Some of the European- and Japanese-built modules count as U.S. modules because they are built under barter agreements with NASA where Europe and Japan produce hardware NASA needs instead of paying cash to NASA for launch and other ISS-related services.) Ordinarily, the U.S. space shuttle takes crews and cargo back and forth to ISS. As noted elsewhere, the shuttle system is currently grounded. Russian Soyuz spacecraft also take crews to and from ISS, and Russian Progress spacecraft deliver cargo, but cannot return

anything to Earth (the spacecraft is not designed to survive reentry into the Earth's atmosphere). A Soyuz is always attached to the station as a lifeboat in case of an emergency.

The schedule for launching segments and crews is called the "assembly sequence" and has been revised many times. At the end of the Clinton Administration, the assembly sequence showed completion of assembly ("assembly complete") in April 2006. The most recent assembly sequence is being revised because of the *Columbia* tragedy. Space station construction is suspended until the shuttle returns to flight.

"Expedition" crews have occupied ISS on a 4-6 month rotating basis since November 2000. Originally the crews had three members (two Russians and one American, or two Americans and one Russian), with an expectation that crew size would grow to six or seven once assembly was completed. Crew size is temporarily reduced to two (one American, one Russian) while the U.S. shuttle is grounded in order to reduce resupply requirements. The number of astronauts who can live on the space station is limited in part by how many can be returned to Earth in an emergency by lifeboats docked to the station. Currently, only Russian Soyuz spacecraft are available as lifeboats. Each Soyuz can hold three people, limiting crew size to three if only one Soyuz is attached. Each Soyuz must be replaced every six months. The replacement missions are called "taxi" flights since the crews bring a new Soyuz up to ISS and bring the old one back to Earth. Therefore, under normal conditions, the Expedition crews are regularly visited by taxi crews, and by the space shuttle bringing up additional ISS segments or exchanging Expedition crews. During the current period of no shuttle flights, Expedition crews are taken back and forth on the "taxi" flights.

NASA planned to build a U.S. Crew Return Vehicle (CRV) for at least four more crew members. The CRV would have had a lifetime of three years, instead of six months like the Soyuz, reducing operational costs. NASA also planned to build a Habitation Module to accommodate the larger crew, and a Propulsion Module to provide fuel in case Russia was not able to provide all the Progress spacecraft it promised. Europe also was to provide Node 3, another connection point between modules. As discussed below, the Bush Administration canceled or deferred these ISS elements in 2001, then decided to build an enhanced CRV called the Orbital Space Plane (OSP), but later canceled it. Node 3 was restored to the program in 2004.

September 1993-January 2001: the Clinton Administration.

Cost Growth. From FY1994-FY2001, the cost estimate for building ISS grew from $17.4 billion to $24.1-26.4 billion. The $17.4 billion (called its "development cost," "construction cost," or "R&D cost") covered FY1994 through completion of assembly, then scheduled for June 2002. It did not include launch costs, operational costs after completion of assembly, civil service costs, or other costs. NASA estimated the program's life-cycle cost (all costs, including funding spent prior to 1993) from FY1985 through FY2012 at $72.3 billion. A more recent, comparable, NASA life-cycle estimate is not available. In 1998, GAO estimated the life-cycle cost at $95.6 billion (GAO/NSIAD-98-147).

Cost growth first emerged publicly in March 1996 when then-NASA Administrator Daniel Goldin gave the space station program manager control of money allocated for (and previously overseen by) the science offices at NASA for space station research. Congress gave NASA approval to transfer $177 million from those science accounts to space station

construction in the FY1997 VA-HUD-IA appropriations act (P.L. 104-204). A similar transfer was approved for FY1996 ($50 million). NASA changed its accounting methods so future transfers would not require congressional action, and transferred $235 million from space station science into construction in FY1998. ("Space station science" funding is for scientific activities aboard the space station. It is separate from NASA's other "space science" funding, such as Mars exploration, astrophysics, or earth sciences.)

One factor in the cost growth was schedule slippage related to Russia's Zvezda module. As insurance against further Zvezda delays, or a launch or docking failure, NASA decided to build an "Interim Control Module" (ICM). To cover cost growth associated with the schedule delay and ICM, NASA requested permission to move $200 million in FY1997 from the space shuttle and payload utilization and operations accounts to the space station program, and to transfer $100 million in FY1998 from unidentified NASA programs to the space station program. The appropriations committees approved transferring the $200 million in FY1997, but not the FY1998 funding.

In March 1998, NASA announced that the estimate for building the space station had grown from $17.4 billion to $21.3 billion. In April 1998, an independent task force concluded that the space station's cost through assembly complete could be $24.7 billion. Mr. Goldin initially refused to endorse the $24.7 billion estimate, but by 2000, NASA's own estimate had grown to $24.1-$26.4 billion.

Cost Caps. The $2.1 billion per year figure the White House and Congress agreed to spend on the space station, and NASA's $17.4 billion estimate to build the station, became known as "caps," although they were not set in law. Both were exceeded in 1997-1998. As costs continued to rise, Congress voted to legislate caps on certain parts of the ISS program in the FY2000-2002 NASA authorization act (P.L. 106-391). The caps are $25 billion for development, plus $17.7 billion for associated shuttle launches. The act also authorizes an additional $5 billion for development and $3.5 billion for associated shuttle launches in case of specified contingencies. The caps do not apply to operations, research, or crew return activities after the space station is "substantially" complete, defined as when development costs consume 5% or less of the annual space station budget. GAO reported in April 2004 that it could not verify whether NASA is complying with the caps because NASA cannot provide the data GAO requires, and NASA did not comply with the law's reporting requirements in its FY2005 budget request documentation (GAO-04-648R).

2001-Present: the George W. Bush Administration.

Cost Growth. As President Bush took office, NASA revealed substantial additional cost growth. In 2000, NASA's estimate of the remaining cost to build ISS was $8 billion (FY2002 to FY2006). In January 2001, however, it announced that an additional $4.02 billion was needed. That figure grew to $4.8 billion by June, and the IMCE task force (discussed below) said another $366 million in growth was discovered between August and October. Those increases would have raised the cost to over $30 billion, 72% above the 1993 estimate, and $5 billion above the legislated cap. NASA explained that program managers had underestimated the complexity of building and operating the station. The Bush Administration signaled it supported the legislated cap, would not provide additional funds, and NASA would have to find what it needed from within its Human Space Flight account.

"Core Complete" Configuration. In February 2001, the Bush Administration announced it would cancel or defer some ISS hardware to stay within the cap and control space station costs. It canceled the Propulsion Module, and indefinitely deferred the Habitation Module, Node 3, and the CRV. The decision truncates construction of the space station at a stage the Administration calls "core complete." The Administration said that "enhancements" to the station might be possible if NASA demonstrates improved cost estimating and program management. In 2001, NASA estimated that it would cost $8.3 billion from FY2002-2006 to build the core complete configuration, then described as all the U.S. hardware planned for launch through Node 2 plus the launch of laboratories being built by Europe and Japan. NASA subsequently began distinguishing between "U.S. Core Complete" (the launches through Node 2, which, prior to the *Columbia* tragedy, was scheduled for February 2004) and "International Partner (IP) Core Complete" which includes the addition of European and Japanese laboratory modules (then anticipated in 2008).

An "ISS Management and Cost Evaluation (IMCE) Task Force" created by NASA in July 2001 concluded that the $8.3 billion estimate was not credible. Chaired by former Lockheed Martin executive Tom Young, IMCE determined that NASA should make significant management and cost estimating changes (see CRS Report RL31216). NASA Headquarters directed the space station program office (at Johnson Space Center) to reassess its estimate, and had two independent groups conduct their own estimates. A July 2002 GAO report (GAO-02-735) concluded that NASA's focus on managing annual budgets resulted in NASA's failure to heed indicators of future program cost growth. Following those reviews, in November 2002, the Administration submitted an amended FY2003 budget request that shifted $706 million into the ISS program from FY2004-2007: $660 million to boost program reserves to ensure sufficient funds to finish the core complete configuration, and $46 million in FY2004 for "long-lead" items to preserve the option of increasing crew size beyond three. The amended request also proposed another potential enhancement, an Orbital Space Plane (see below), and increasing the annual shuttle flight rate to ISS to five per year beginning in FY2006. At a December 2002 "Heads of Agency" meeting in Japan, the international partners agreed on a process for selecting a final ISS configuration by December 2003. The *Columbia* tragedy delayed the process, and President Bush's January 2004 announcement of new exploration goals changed NASA's own plans for construction and use of ISS, including cancellation of the Orbital Space Plane, and termination of the space shuttle program after ISS construction is completed. At a July 2004 Heads of Agency meeting, the partners endorsed a final configuration of ISS, although final endorsement is not expected until the next meeting, in 2005.

Concerns of the Non-U.S. Partners and U.S. Researchers. The non-U.S. partners, and U.S. scientists who planned to conduct research on ISS, expressed deep concern with the core complete configuration (see CRS Report RL31216). Concerns focused on the decision to indefinitely defer a Crew Return Vehicle (CRV), which would limit the space station to three permanent crew members, not seven as planned. Since NASA estimated that 2 ½ crew members were needed to operate and maintain the station, that would leave only one-half of one person's time to conduct research. Research is ostensibly one of the major reasons for building the space station. For U.S. researchers, another issue was that NASA also reduced the space station research budget by 37.5% over the FY2002-2006 period, necessitating a reassessment of U.S. research priorities on ISS. On July 10, 2002, a Research Maximization and Prioritization (ReMaP) task force reported to the NASA Advisory Council on its efforts to reprioritize NASA's ISS scientific research program. ReMaP recommended

that the ISS research plan be reconfigured with an interdisciplinary approach, identified research priorities, reemphasized the need for a centrifuge, and stressed the need for a strategy for conducting research. In September 2002, the National Research Council released a study of how the ISS program restructuring would impact scientific research. Its overall conclusions paralleled those of ReMaP. Both NRC and ReMaP emphasized that the negative impact on science is due not only to inadequate crew time, but to limits on the amount of "upmass" (e.g., scientific equipment and experiments) that can taken to ISS because NASA had proposed limiting shuttle flights to four per year. For Europe, Canada, and Japan, the "core complete" configuration also poses problems because the additional four permanent crew member slots were to be allocated, in part, to their astronauts. Without those positions, European, Japanese, and Canadian astronauts could work aboard ISS only for short durations as part of visiting crews on the U.S. space shuttle or Russian Soyuz "taxi" missions. As noted, President Bush's exploration initiative eliminates U.S. research on ISS other than that related to long duration human space flight. The U.S. research plan therefore is being restructured again.

Crew Rescue and Return: CRV, CTV, OSP, and CEV. As noted, ISS crew size is limited in part by the number of occupants that can be accommodated in a "lifeboat" or "crew return vehicle" in an emergency. One Soyuz spacecraft, which can accommodate three people, is always docked at ISS today to fulfill this function. To increase crew size, one option is to procure additional Soyuzes, so two could be docked simultaneously, allowing crew size to expand to six. What price Russia would charge is not known. Whether NASA could pay for them is complicated by the Iran Nonproliferation Act (see below).

NASA deferred its own plans to build a Crew *Return* Vehicle (CRV) in the wake of the cost growth revealed in 2001. The CRV was envisioned only for returning crews to Earth (it would have been taken into orbit, unoccupied, via the space shuttle). A Crew *Transfer* Vehicle (CTV), by contrast, could take people both to and from the space station. In November 2002, NASA proposed building a CTV, which NASA called an Orbital Space Plane (OSP), but the OSP program was terminated after President Bush announced his new exploration initiative in January 2004. Instead, NASA plans to build a "Crew Exploration Vehicle" (CEV) whose main function would be taking crews to the Moon. NASA plans to have the CEV available to take crews to Earth orbit by 2014, but it is not clear to what extent it will be designed to service ISS. Thus, the future of U.S. crew transportation to and from ISS after 2010 is unclear. At a minimum, between 2010 when the shuttle would be phased out, and 2014, U.S. astronauts would have to rely on Russia for passage. The policy implications of this "4-year gap" are discussed below.

In the existing international ISS agreements, Russia agreed to have one Soyuz (replaced every six months) docked to ISS through the lifetime of the station. A 1996 "balance agreement" between the United States and Russia stipulates that through assembly complete, the three seats on Soyuz would be available for crew rotation and emergency return of U.S.-Russian ISS crews. Eleven Soyuz spacecraft were specified for this purpose. According to NASA, the 11th Soyuz will be launched in the fall of 2005 and return to Earth in the spring of 2006. The U.S. CRV was expected to be available by assembly complete, allowing crew size to increase to seven. If the U.S. CRV was not available, the agreement simply calls on the parties to "discuss appropriate action." Since there will be no U.S. CRV, without further agreement, Americans could be limited to residency aboard ISS only when the U.S. space shuttle is docked. Russia presumably would continue to have one Soyuz docked at the

station, but would control who could use it, with no guarantee that Americans would be included. Russia is interested in selling opportunities to fly on the Soyuz to help finance its space program, so might choose to limit those opportunities to paying customers. As noted below, the Iran Nonproliferation Act prevents NASA from paying to use Soyuz unless Russia does not proliferate certain technologies to Iran.

NASA therefore is facing two deadlines in terms of assured access to ISS for U.S. astronauts: spring 2006, when Russia no longer will be required to provide a "lifeboat" for U.S. astronauts, meaning U.S. astronauts could be aboard ISS only when the shuttle is docked; and 2010, when the shuttle is expected to be retired, and U.S. astronauts would be completely reliant on Russia for access to ISS at least until the new Crew Exploration Vehicle is available — scheduled for 2014. (China also can launch people into space, but is not an ISS partner.) This "4-year gap" is discussed below.

Risks and Benefits of Russian Participation, and the Iran Nonproliferation Act (INA)

For many years, controversy over the ISS program focused on Russia's participation in the program. Among the issues were the extent to which successful completion of ISS is dependent on Russia, Russia's financial ability to meet its commitments, and whether the United States should provide funding to Russia if it proliferates missile technology to certain countries. While there is no exchange of funds among the other ISS partners, the United States (and other partners) have provided funding to Russia. By 1998, the United States had paid approximately $800 million to Russia for space station cooperation.

Following the Clinton Administration's decision to bring Russia into the program, Congress stated that Russian participation "should enhance and not enable" the space station (H.Rept. 103-273, to accompany H.R. 2491, the FY1994 VA-HUD-IA appropriations bill — P.L. 103-124). The current design, however, can only be viewed as being "enabled" by Russian participation. It is dependent on Russian Progress vehicles for reboost (to keep the station from reentering Earth's atmosphere), on Russian Soyuz spacecraft for emergency crew return, and on Russia's Zvezda module for crew quarters (which allows ISS to be permanently occupied). Since the *Columbia* accident, access to ISS has been completely dependent on Russia, which ferries crews back and forth on the Soyuz spacecraft, and takes cargo to the station on Progress spacecraft. President Bush's exploration initiative would increase U.S. dependence on Russia vis a vis the space station.

Russia's financial ability to meet its commitments is an ongoing issue. The launch of Zvezda, the first module Russia had to pay for itself, was more than two years late. (Zarya was built by Russia, but NASA paid for it.) Since Zvezda's launch in 2000, Russia has met its commitments to launch Soyuz and Progress spacecraft, but is reassessing what other modules and hardware it will build at its own expense. Russian space agency officials have repeatedly expressed concern about whether they can provide the needed number of Soyuz and Progress spacecraft because of budget constraints.

The overall relationship between the United States and Russia is another factor in the ISS equation, including Russian adherence to the Missile Technology Control Regime (MTCR), which is designed to stem proliferation of ballistic missile technology. Getting Russia to adhere to the MTCR appears to have been a primary motivation behind the Clinton

Administration's decision to add Russia as a partner. The United States wanted Russia to restructure a contract with India that would have given India advanced rocket engines and associated technology and know-how. The United States did not object to giving India the engines, but to the technology and know-how. Russia claimed that restructuring the contract would cost $400 million. The 1993 agreement to bring Russia into the space station program included the United States paying Russia $400 million for space station cooperation. At the same time, Russia agreed to adhere to the MTCR. The question is what the United States will do if Russia violates the MTCR. Some Members of Congress believe Russia already has done so. The Clinton Administration sanctioned 10 Russian entities for providing technology to Iran. Neither Rosaviakosmos nor any major Russian ISS contractors or subcontractors were among those sanctioned.

On March 14, 2000, President Clinton signed into law (P.L. 106-178) the Iran Nonproliferation Act (INA). The law, *inter alia*, prohibits NASA from making payments after January 1, 1999 in cash or in kind to Russia for ISS unless Russia takes the necessary steps to prevent the transfer of weapons of mass destruction and missile systems to Iran and the President certifies that neither the Russian space agency nor any entity reporting to it has made such transfers for at least one year prior to such determination. Exceptions are made for payments needed to prevent imminent loss of life by or grievous injury to individuals aboard ISS (the "crew safety" exception); for payments to construct, test, prepare, deliver, launch, or maintain Zvezda as long as the funds do not go to an entity that may have proliferated to Iran and the United States receives goods or services of commensurate value; and the $14 million for hardware needed to dock the U.S. ICM (see above). President Clinton provided Congress with the required certification with regard to the $14 million on June 29, 2000, but no certification was forthcoming for the remaining $24 million. Without such a certification, NASA may only spend more money in Russia for ISS by meeting one of the remaining exceptions — maintenance of Zvezda (further defined in the law) and crew safety. At a House International Relations Committee hearing on October 12, 2000, Members sharply criticized NASA's legal interpretation of the crew safety exception. H.R. 1001 (Lampson) would amend the INA to allow payments to Russia any time the space shuttle fleet is grounded.

Clinton Administration and NASA officials asserted repeatedly that Russian participation in the space station program would accelerate the schedule by two years and reduce U.S. costs by $4 billion. That was later modified to one year and $2 billion, and an April 1, 1994 letter to Congress from NASA said 15 months and $1.5 billion. NASA officials continued to use the $2 billion figure thereafter, however. GAO concluded (GAO/NSIAD 94-248) that Russian participation would cost NASA $1.8 billion, essentially negating the $2 billion in expected savings. In 1998, a NASA official conceded that having Russia as a partner added $1 billion to the cost. Other benefits cited by the Clinton Administration were providing U.S. financial assistance to Russia as it moves to a market economy, keeping Russian aerospace workers employed in non-threatening activities, and the emotional impact, historic symbolism, and potential long term significance of the two former Cold War adversaries working together in space.

One benefit that is being realized is that the space station can be serviced with Russian as well as American spacecraft, providing redundancy in case either side must ground its fleet due to an accident, for example. This is an important advantage now that the U.S. space

shuttle fleet is grounded. Russia is providing both crew and cargo flights to the space station, enabling it to continue operation without the shuttle.

Congressional Action

FY2004

For FY2004, NASA requested $2.285 billion for ISS: $1.707 billion for construction and operations, and $578 million for scientific research. In addition, it requested $550 million for the Orbital Space Plane (OSP). Note that NASA's FY2004 budget reflects full cost accounting, where personnel and facilities costs are now included in the program's budget, instead of separately, as had been done in the past. Hence FY2004 NASA funding figures are not directly comparable to previous NASA figures. In the FY2004 VA-HUD-IA appropriations bill (H.R. 2861), the House made no change to the space station or OSP programs pending release of the report on the *Columbia* accident investigation. The Senate cut ISS by $200 million. No change was made to OSP funding, but the Senate Appropriations Committee report (S.Rept. 108-143) said the committee did not believe OSP was the only approach for taking astronauts to and from ISS, and directed NASA to create an independent oversight committee to examine the OSP program. The FY2004 VA-HUD-IA appropriations bill was incorporated into the FY2004 Consolidated Appropriations bill (H.R. 2673, P.L. 108-199). The conference report (H.Rept. 108-401) cut ISS by $200 million. OSP is part of the Space Launch Initiative program, which was cut by $70 million. OSP is being restructured into a different program in the FY2005 budget, so may or may not be considered part of the space station program.

FY2005

The FY2005 request for the ISS program is $2.412 billion — $1.863 billion

Table 1. U.S. Space Station Funding
(in $ millions)

Fiscal Year	Request	Appropriated
1985	150	150
1986	230	205
1987	410	410
1988	767	425
1989	967	900
1990	2,050	1,750
1991	2,430	1,900
1992	2,029	2,029
1993	2,250	2,100
1994	2,106	2,106
1995	2,113	2,113
1996	2,115	2,144
1997	2,149	2,149
1998	2,121	2,441*
1999	2,270	2,270
2000	2,483	2,323
2001	2,115	2, 115
2002	2,114	2,093
2003	1,839	1,810**
2004***	2,285	2,085
2005	2,412	

The numbers here reflect NASA's figures for "the space station program." Over the years, what is included in that definition has changed.
* NASA's FY1999 budget documents show $2.501 billion on the expectation Congress would approve additional transfer requests, but it did not.
**Adjusted for 0.65% rescission.
***Reflects shift to full cost accounting.

for construction and operations, including $140 million in a new "ISS Crew/Cargo Services" line to pay for alternatives to the shuttle for taking crew and cargo to and from ISS; and $549 million for research. The House Appropriations Committee's version of the FY2005 VA-HUD-IA appropriations bill (H.R. 5041, H.Rept. 108-674) cut $190 million from ISS construction and operations (including $70 million from ISS Crew/Cargo Services), and $103 million from bioastronautics research. The Senate Appropriations Committee (S. 2825, S.Rept. 108-353) cut $260 million (including all $140 million from Crew/Cargo), although it increased the total NASA budget to $16.4 billion. The Senate Commerce Committee ordered reported a FY2005-2009 NASA authorization bill (S. 2541) that includes the requested level of funding for ISS.

International Partners

The Original Partners: Europe, Canada, and Japan

Canada, Japan, and most of the 15 members of the European Space Agency (ESA) have been participating in the space station program since it began. Formal agreements were signed in 1988, but had to be revised following Russia's entry into the program, and two more European countries also joined in the interim. The revised agreements were signed on January 29, 1998, among the partners in the ISS program: United States, Russia, Japan, Canada, and 11 European countries — Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom. Representatives of the various governments signed the government-to-government level Intergovernmental Agreement (IGA) that governs the program. (The United Kingdom signed the IGA, but is not financially participating in the program so the number of European countries participating in the program is variously listed as 10 or 11.) NASA also signed Memoranda of Understanding for implementing the program with its counterpart agencies: the European Space Agency (ESA), the Canadian Space Agency (CSA), the Russian space agency (Rosaviakosmos at that time, now the Federal Space Agency), and the Japanese Science and Technology Agency. The IGA is a treaty in all the countries except the United States (where it is an Executive Agreement).

Canada is contributing the Mobile Servicing System (MSS) for assembling and maintaining the space station. In February 1994, the new prime minister of Canada had decided to terminate Canada's role in the program, but later agreed to reformulate Canada's participation instead. The first part of the MSS (the "arm") was launched in April 2001; development of another part, the Special Purpose Dextrous Manipulator (referred to as the Canada Hand), is complete, and launch was scheduled for 2005.

ESA is building a laboratory module called Columbus, and an Automated Transfer Vehicle (ATV) to take cargo to ISS. The ATV will be launched on Europe's Ariane launch vehicle. The first ATV launch is expected in 2005. The major contributors to Columbus are Germany, France, and Italy. Budgetary difficulties over the years led ESA to cancel other hardware it was planning. ESA also is building a cupola (a windowed dome) and two of the three "nodes" (Node 2 and Node 3) for NASA in exchange for NASA launches of Europe's module and other services. Node 2 is completed and is at NASA's Kennedy Space Center (KSC) undergoing integration testing. Columbus and the cupola also are completed. NASA had canceled plans for Node 3, but now has revived them. NASA also has a bilateral

agreement with Italy under which Italy built three "mini-pressurized logistics modules" (MPLMs). Already in use, they are launched via the shuttle, attached to ISS while cargo is transferred to the station, filled with refuse or other unwanted material, placed back into the shuttle's cargo bay, and returned to Earth.

Japan is building the Japanese Experiment Module, named Kibo (Hope). One part of is pressurized and the other is not (called the "back porch," it will be exposed to space for experiments requiring those conditions). The pressurized section is completed and is undergoing integration testing with Node 2 at KSC; the unpressurized section is in development. Japan also is building a large centrifuge and a Centrifuge Accommodation Module ("CAM") for NASA in exchange for shuttle flights to launch Kibo. CAM was scheduled for launch in 2007, but is experiencing delays in its development.

CSA reported in February 2004 that Canada's total ISS spending is expected to be $1.4 billion (Canadian), of which $1.3 billion (Canadian) was spent by that time. ESA reported in March 2004 that its estimated funding for ISS is 5.1 billion Euros, of which 4.1 billion Euros were spent as of the end of 2003. (In March 2004, 1 Canadian dollar = 0.75 U.S. dollar and 1 Euro = 1.2 U.S. dollars.) In February 2004, the Japanese space agency reported that Japan expects to spend $4.8 billion on ISS, of which $4 billion was spent by the end of March 2003. (A bilateral agreement was signed with Brazil in October 1997 for Brazil to provide payload and logistics hardware. Brazil is restructuring its agreement in light of financial constraints, however. The level of their funding contribution is unclear.)

Russia

Issues associated with Russia's participation in ISS are discussed elsewhere. This section explains Russian space station activities from 1971 to the present. The Soviet Union launched the world's first space station, Salyut 1, in 1971 followed by five more *Salyuts* and then *Mir*. At least two other *Salyuts* failed before they could be occupied. The Soviets accumulated a great deal of data from the many missions flown to these stations on human adaptation to weightlessness. The data were often shared with NASA. They also performed microgravity materials processing research, and astronomical and Earth remote sensing observations. Importantly, they gained considerable experience in operating space stations. Russia's most recent space station, *Mir*, was a modular space station built and operated between 1986 and 2001. Crews were ferried back and forth to *Mir* using Soyuz spacecraft.

Crews occupied *Mir* from 1986-2000. For almost ten of those years (1989-1999), *Mir* was continuously occupied by crews on a rotating basis. Although occasionally crews stayed for very long periods of time to study human reaction to long duration spaceflight, typically they remained for 5-6 months and then were replaced by a new crew. From 1995-1998, seven Americans participated in long duration (up to six month) missions aboard *Mir*, and nine space shuttle missions docked with the space station. Individuals from Japan, Britain, Austria, Germany, France, and the Slovak Republic also paid for visits to *Mir*. Russia deorbited *Mir* into the Pacific Ocean on March 23, 2001.

Key Issues For Congressional Consideration

Increased Dependence on Russia and Other Impacts of the *Columbia* Tragedy and the President's Exploration Initiative

Current Operations. The grounding of the space shuttle system following the *Columbia* accident is affecting the schedule for assembly of ISS, and temporarily reducing the size of Expedition crews from three to two. Crews are being taken to and from ISS using Russian Soyuz spacecraft on the same six-month schedule already planned, and Russian Progress spacecraft are used to resupply the crew. Construction of ISS is suspended until the shuttle returns to flight. This arrangement can continue as long as funding is available to build and launch Soyuz and Progress spacecraft. Russia is obligated to provide two Soyuz and a certain number of Progress spacecraft each year, but has cautioned its partners that funding to provide those spacecraft is not assured. Under the Iran Nonproliferation Act (INA), NASA is prohibited from paying Russia for ISS-related activities unless the President certifies that Russia is not proliferating certain technologies to Iran. NASA officials have testified to Congress that there are no plans to request a waiver from INA. H.R. 1001 would amend the INA to permit payments to Russia for ISS any time the space shuttle is grounded.

If the shuttle is grounded for an extended period, the decision to keep crews on ISS may need to be reassessed. The Russians operated seven space stations using only Soyuz and Progress, so it is possible to keep ISS operating without the shuttle. In this case, however, not only would questions remain about how to fund the requisite Soyuz and Progress spacecraft, but ISS was designed to take advantage of the crew- and cargo-carrying capacity of the U.S. space shuttle. For example, NASA earlier stated that 2 ½ crew members are needed to operate ISS. With only a two-person crew, less time may be available for scientific experiments, and there are fewer experiments to conduct since many cannot be transported to the station without the shuttle. If little science can be accomplished, some may question the wisdom of asking astronauts and cosmonauts to accept the risks inherent in human spaceflight simply to maintain ISS systems. Conversely, how long ISS could continue to function with no one aboard is unknown. Progress spacecraft could dock with ISS automatically to reboost it and keep it at the proper altitude, but a major system malfunction that could not be remedied by ground-based controllers could imperil the station.

Another issue is Russia's March 2004 proposal to extend the duration of Expedition missions to one year instead of six months. In the 30 years that Russia operated its own space stations, only three cosmonauts remained in space continuously for a year or more. Typically, Russian *Mir* crews remained in orbit for 5-6 months. Therefore, the physiological and psychological aspects of year-long missions are not well understood. Doubling the length of the ISS missions could therefore add risk, but would allow additional research on the effects of spaceflight conditions, which could be relevant to eventual human trips to Mars. NASA responded to the Russian proposal by saying it was not ready to approve one-year missions for its crews.

Changes Due to the Exploration Initiative, Including the "4-year Gap". President Bush's January 2004 exploration initiative could affect the ISS program in several ways. The President said the shuttle would be retired in 2010 after construction of ISS is completed, and ISS research would be restricted to only the life sciences research needed

to support the goal of human missions to the Moon and Mars, instead of the broadly-based research program that was expected. According to the NASA budget chart, NASA would complete its utilization of ISS by FY2017. NASA Administrator O'Keefe, however, stated at a February 12, 2004, House Science Committee hearing that NASA may continue using the station after that, and there is no plan to "turn out the lights." The budget projections for achieving the President's exploration initiative assume that funding for ISS (and the shuttle and other NASA programs) ends, so that it can be redirected to the new program. If Mr. O'Keefe's statement is correct, then it is not clear how the goals can be achieved on the announced schedule without additional funds, the source of which is not evident. Mr. O'Keefe also stated that the other partners might continue using ISS, but the extent to which ISS can be utilized without the space shuttle is not clear. Soyuz spacecraft can take crews back and forth, but the shuttle's cargo capacity — both for taking cargo to ISS, and back to Earth (e.g. the results of scientific experiments, or hardware that needs repair) — could be expensive to replicate. No other partner has a spacecraft able to bring material back to Earth today. Europe reportedly now is considering adding a return capsule to its Automated Transfer Vehicle, and NASA is exploring the possibility of U.S. commercial companies developing a return capability. None of those plans is firm, though, and the size and mass of what could be returned is likely to be less than what can be carried in the shuttle's cargo bay. NASA has spent more than $30 billion to build ISS. If its utilization is heavily restricted, as envisioned in the exploration initiative, questions may arise as to whether the expenditure was worthwhile, which could impact future decisions about NASA funding.

One aspect of the policy that has been largely overshadowed by attention on the prospect of returning humans to the Moon is the decision to end assured access to space for U.S. astronauts. The "4-year gap" between 2010 (termination of the space shuttle) and 2014 (availability of the Crew Exploration Vehicle) is discussed above. It must be emphasized that no decision has been made as to whether the CEV will, in fact, be designed to service ISS. It main purpose is lunar transportation. From a policy perspective, some find the decision surprising, especially because that is a period when life sciences research aboard ISS ostensibly is needed to help fulfill the Moon/Mars vision. The only other ISS partner with the ability to launch astronauts is Russia, but no agreement has been negotiated about the terms and conditions Russia would require. Such an agreement does exist today (the balance agreement, discussed earlier), but Russia is expected to complete those obligations in 2006. After that, Russia can charge whatever price it likes to transport U.S. astronauts or provide a "lifeboat" capability for them, or it could choose not to carry Americans at all. It could decide to rotate crews at whatever intervals it chose. As long as the shuttle is operating, U.S. astronauts would still be able to visit ISS whenever the shuttle is there, but retiring the shuttle forecloses that option. One issue that arises is whether the United States should terminate the shuttle before a replacement capability is available. Another is whether ground-based alternatives to conducting the life sciences research should be explored in case Americans cannot access ISS, a situation that could evolve if Russia declines to take Americans, charges too high a price, NASA continues to be prohibited by the INA from making payments to Russia, or Russia makes operational decisions with which NASA disagrees.

Cost and Cost Effectiveness

Cost effectiveness involves what can be accomplished with the facility that is ultimately built versus its cost. In 1993, NASA said it would cost $17.4 billion to build the U.S. portion of the space station. That rose to $24.1-$26.4 billion by early 2000, with $5 billion more in

cost growth announced in 2001. A current cost estimate is not available since construction is suspended awaiting the shuttle's return to flight. Cost estimates for the earlier *Freedom* design rose significantly as the years passed, and with each *Freedom* redesign, the amount of science diminished. Scientific research is often cited as a major reason for building the station. Many wondered whether *Freedom*'s fate awaited ISS, and now believe it has. In FY1996, FY1997, and FY1998 NASA transferred $462 million from the space station science accounts into space station construction. In response to the cost growth revealed in 2001, NASA reduced the ISS research budget by 37.5% (FY2002-2006) and indefinitely deferred building hardware that would enable a larger crew to live aboard the station, meaning that the amount of research that can be conducted may be sharply reduced. President Bush's January 2004 announcement would limit the types of research to be conducted to life sciences research to support human missions to the Moon and Mars rather than the multi-disciplinary research earlier envisioned, which may further reduce the station's scientific pay-off.

Operations and Commercialization Issues

Prior to President Bush's January 2004 policy directive, attention was being given to who should operate ISS and how to encourage commercial use of it. Congress declared economic development of Earth orbital space as a "priority goal" of ISS in the 1998 Commercial Space Act (P.L. 105-303). NASA supported space station commercialization, both in terms of getting the private sector to use research facilities on ISS, and assuming space station operations. According to its ISS commercialization website [http://commercial.hq.nasa.gov], NASA is committed to setting aside approximately 30% of the U.S. share of ISS's research capacity for economic development. NASA wanted to create a non-governmental organization (NGO) to oversee research on the space station that would be modeled after the Space Telescope Science Institute, which operates the Hubble Space Telescope. The NGO would report to NASA. Others want the private sector, not the government, to manage and operate the space station. As noted earlier, it is not clear what the fate of the space station after FY2017 will be under President Bush's new plan and what role, if any, the private sector would play in operations or utilization.

LEGISLATION

H.R. 1001 (Lampson). Amends the Iran Nonproliferation Act to allow payments to Russia in connection with ISS for safety and maintenance purposes any time the space shuttle fleet is grounded. Introduced February 27; referred to House International Relations and House Science Committees.

H.R. 5041 (Walsh)/S. 2825 (Bond). FY2005 VA-HUD-IA appropriations (includes NASA). Reported from House Appropriations Committee September 9, 2004 (H.Rept. 108-674). Reported from Senate Appropriations Committee September 21 (S.Rept. 108-353).

S. 2541 (McCain). FY2005-2009 NASA authorization bill. Ordered reported from the Senate Commerce, Science and Transportation Committee September 22, 2004.