Order Code RL33568

CRS Report for Congress
Received through the CRS Web

The International Space Station and the Space Shuttle

Updated October 2, 2006

Carl E. Behrens
Specialist in Energy Policy
Resources, Science, and Industry Division

The International Space Station and the Space Shuttle

Summary

The International Space Station (ISS) program began in 1993, with Russia joining the United States, Europe, Japan, and Canada. Crews have occupied ISS on a 4-6 month rotating basis since November 2000.

The U.S. Space Shuttle, which first flew in April 1981, has been the major vehicle taking crews and cargo back and forth to ISS, but the shuttle system has encountered difficulties since the *Columbia* disaster in 2003. Russian Soyuz spacecraft are also used to take crews to and from ISS, and Russian Progress spacecraft deliver cargo, but cannot return anything to Earth, since they are 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.

President Bush, prompted in part by the *Columbia* tragedy, made a major space policy address on January 14, 2004, directing NASA to focus its activities on returning humans to the Moon and someday sending them to Mars. Included in this "Vision for Space Exploration" is a plan to retire the space shuttle in 2010. The President said the United States would fulfill its commitments to its space station partners, but the details of how to accomplish that without the shuttle were not announced.

The shuttle *Discovery* was launched on July 4, 2006, and returned safely to Earth on July 17. This was the first of 16 *post-Columbia* flights to the ISS that NASA plans to complete before retiring the shuttle in 2010. The shuttle *Atlantis* followed with a September 9 launch that resumed construction of the International Space Station before returning to earth September 21.

On June 29, 2006, the House passed the FY2007 Science, Justice, Commerce and Related Agencies appropriations bill (H.R. 5672), which includes funding for NASA. The bill would fund the Exploration Capabilities account, which includes the shuttle and the ISS, at $6.194 billion in FY2007. The Senate Appropriations Committee reported its version of H.R. 5672 (S.Rept. 109-280) on July 13, 2006, recommending $6.235 billion for Exploration Capabilities.

This report replaces CRS Issue Brief IB93017, *Space Stations* and CRS Issue Brief IB93062, *Space Launch Vehicles: Government Activities, Commercial Competition, and Satellite Exports*. It will be updated as needed.

Contents

List of Tables

The International Space Station and the Space Shuttle

Most Recent Developments

The crew of the space shuttle *Atlantis,* launched September 9, resumed construction of the International Space Station, including a large new solar array to increase power to the station. *Atlantis* completed the mission, STS-115, and returned to earth September 21. The National Aeronautics and Space Administration (NASA) plans to launch the shuttle *Discovery* on STS-116 in early December.

On June 29, the House passed H.R. 5672, which includes funding for. The bill would fund NASA's Exploration Capabilities, which includes the shuttle and ISS programs, at $6.194 billion for FY2007. The Senate Appropriations Committee reported its version of H.R. 5672 (S.Rept. 109-280) on July 13, 2006, recommending $6.235 billion for Exploration Capabilities.

The International Space Station (ISS)

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, but the goal of a permanently occupied space station with crews rotating on a regular basis, employing a reusable space transportation system (the space shuttle) was high on NASA's list for the post-Apollo years following the moon landings. Budget constraints forced NASA to choose to build the space shuttle first. The first launch of the shuttle was in April 1981. 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 join. On July 20, 1989, the 20th anniversary of the first Apollo landing on the Moon, President George H. W. Bush 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. That "Moon/Mars" program, the Space Exploration Initiative, was not greeted with enthusiasm in Congress, primarily due to budget concerns, and ended in FY1993, although the space station program continued.

President Clinton dramatically changed the character of the space station program in 1993 by adding Russia as a partner to this already international endeavor.

That decision 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 as it transitioned from the Soviet era. The Clinton Administration strongly supported the space station within certain budget limits.

The International Space Station program thus began in 1993, with Russia joining the United States, Europe, Japan, and Canada. An Intergovernmental Agreement (IGA) established three phases of space station cooperation. The IGA is a treaty in all the countries except the United States, where it is an Executive Agreement. It is implemented through Memoranda of Understanding (MOUs) between NASA and its counterpart agencies.

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. (*Mir* was deorbited in 2001.) 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.

President George W. Bush, prompted in part by the February 2003 space shuttle *Columbia* tragedy, made a major space policy address on January 14, 2004, directing NASA to focus its activities on returning humans to the Moon and eventually sending them to Mars. Included in this "Vision for Space Exploration" is a plan to retire the space shuttle in 2010. The President said the United States would fulfill its commitments to its space station partners, but the details of how to accomplish that without the shuttle were not announced.

ISS Design, Cost, Schedule, and Lifetime

Under the original ISS schedule, assembly of the station would have been completed in 2002, with operations at least through 2012. President Bush restructured the space station program in 2001, and left it unclear when assembly would be completed. NASA briefing charts in March 2003 showed space station operations possibly continuing until 2022. Under President Bush's January 2004 "Vision for Space Exploration," however, NASA plans to complete its utilization of ISS in 2016 (though the other partners may continue to use it after that time).

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. (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," a Russian-built, U.S.-owned, module with guidance, navigation, and control systems) and Unity (a U.S. "node" connecting other modules). Next was Zvezda ("Star," a Russian module that serves as the crew's living quarters) in 2000. Destiny (a U.S.

laboratory), Quest (a U.S. airlock), and Pirs ("Pier," a Russian docking compartment) arrived in 2001. Among the other modules awaiting launch 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. The European-built nodes and Cupola count as U.S. components because they were built under barter agreements where Europe produces hardware NASA needs instead of paying cash to NASA for launch and other ISS-related services. Japan was to build a centrifuge and its Centrifuge Accommodation Module under such a barter arrangement, but NASA terminated that activity in 2005.)

The U.S. space shuttle has been the major vehicle taking crews and cargo back and forth to ISS, but the shuttle system has encountered difficulties since the *Columbia* disaster. Russian Soyuz spacecraft are also used to take crews to and from ISS, and Russian Progress spacecraft deliver cargo, but cannot return anything to Earth, since it 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.

"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 was temporarily reduced to two (one American, one Russian) while the U.S. shuttle was 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. 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. NASA planned to build a U.S. Crew Return Vehicle (CRV) to provide lifeboat capabilities for at least four more crew. The Bush Administration canceled those plans due to cost growth in the ISS program, then began a different program (the Orbital Space Plane) that also was cancelled. In September 2005, NASA announced that the new Crew Exploration Vehicle (CEV) it is building to implement the President's Vision for Space Exploration (the "Moon/Mars" program) will be designed to take crews to and from the ISS, and to serve as a lifeboat. NASA currently hopes to have it ready by 2012.

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 long duration Expedition crews are regularly visited by taxi crews, and by the space shuttle bringing up additional ISS segments or exchanging Expedition crews. When the shuttle is unavailable, Expedition crews are taken back and forth on the "taxi" flights.

Space Station Costs. From FY1994-FY2001, the cost estimate for building ISS grew from $17.4 billion to about $25 billion. The $17.4 billion estimate 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-FY2012 at $72.3 billion. In 1998, GAO estimated the life-cycle cost at $95.6 billion (GAO/NSIAD-98-147). More recent, comparable, life-cycle estimates are not available from NASA or GAO.

As costs continued to rise, Congress voted to legislate a $25 billion cap on development of the ISS program, plus $17.7 billion for associated shuttle launches, in the FY2000-2002 NASA authorization act (P.L. 106-391). In January 2001, however, NASA announced that the cost would be 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. The decision truncated construction of the space station at a stage the Administration called "core complete." In 2001, the space station program office at Johnson Space Center (JSC) estimated that it would cost $8.3 billion from FY2002-FY2006 to build the core complete configuration, described at that time 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 included the addition of European and Japanese laboratory modules (then anticipated in 2008).

The new policy was followed by President Bush's January 2004 "Vision for Space Exploration," which directs that U.S. research on ISS be restricted only to that which supports the Vision. A new research plan, incorporating the President's Vision, has not been released by NASA. However, the 2005 NASA authorization act (P.L. 109-155), directs that at least 15% of ISS research spending be non-Vision-related (Sec. 204).

At a January 2005 Heads of Agency meeting, the partners endorsed a final configuration of ISS, but NASA subsequently announced changes to it. The agency now plans to conduct only 16 (instead of 28) shuttle launches to the ISS, all before the end of FY2010 (September 30, 2010), and has dropped plans to launch the centrifuge and its accommodation module, and Russia's Science Power Platform. The agency plans to meet with the other ISS partners to discuss these changes.

The changes to the ISS are largely due to the new direction NASA is taking in response to the Vision for Space Exploration. Inter alia, the Vision calls for development of a Crew Exploration Vehicle (CEV) to take astronauts to and from the Moon. It also can take them to and from the ISS, and NASA Administrator Griffin stated at a September 19, 2005 press conference that the CEV would be used to take crews to and from the ISS, and to serve as a lifeboat for them. If the CEV is built as announced, it would fulfill the U.S. commitment to build a crew return capability, and allow the ISS crew size to increase to its originally planned complement of seven. The CEV is planned to be ready by 2012.[1]

---

[1] [http://www.nasa.gov/audience/formedia/archives/index.html]

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 [a]
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 [b]	2,285	2,085
2005	2,412	2,058
2006	1,995	1,972
2007	1,894	

These numbers reflect NASA's figures for "the space station program." Over the years, what is included in that definition has changed. In recent years, funding for ISS research has been located in a different account from ISS development funding. The figures here represent the ISS development and ISS research request and appropriations to the maximum extent possible.

a. NASA's FY1999 budget documents showed $2.501 billion in the expectation Congress would approve additional transfer requests, but it did not.

b. Reflects shift to full cost accounting.

The Space Shuttle

The Space Transportation System (STS) — the Space Shuttle — is a partially reusable launch vehicle and is the sole U.S. means for launching humans into orbit. It consists of an airplane-like Orbiter, with two Solid Rocket Boosters (SRBs) on each side, and a large, cylindrical External Tank (ET) that carries fuel for the Orbiter's main engines. The Orbiters and SRBs are reused; the ET is not. NASA has three remaining spaceflight-worthy Orbiters: *Discovery*, *Atlantis*, and *Endeavour*.

The *Challenger* and *Columbia* Tragedies. A total of 115 shuttle launches have taken place since April 1981. Two ended in tragedy, each killing seven astronauts. In 1986, the space shuttle *Challenger* exploded 73 seconds after launch because of the failure of a seal (an O-ring) between two segments of an SRB. In 2003, the space shuttle *Columbia* disintegrated as it returned to Earth after 16 days in orbit (see CRS Report RS21408, *NASA's Space Shuttle Program: The Columbia Tragedy, the Discovery Mission, and the Future of the Shuttle*, by Marcia S. Smith). A hole in *Columbia's* left wing, caused during launch by a piece of foam insulation that detached from the ET, allowed hot gases to enter the wing during reentry, deforming it and causing the shuttle to break up. The *Columbia* Accident Investigation Board (CAIB) found that the tragedy was caused by technical and organizational failures, and made 29 recommendations, 15 of which it said should be completed before the shuttle returned to flight.[2]

Sean O'Keefe, NASA's Administrator from December 2001-February 2005, said NASA would comply with the CAIB recommendations. He established an RTF ("Return to Flight") Task Group, chaired by two former astronauts, Tom Stafford and Dick Covey, to oversee NASA's implementation of the CAIB's 15 RTF recommendations. The Stafford/Covey Task Group [http://www.returntoflight.org] did not address management and culture changes, and was not tasked to determine whether the shuttle was ready to return to flight. Its assignment only was to evaluate NASA's compliance with the CAIB recommendations for RTF. The Task Group ultimately concluded that NASA met the intent of 12 of the 15 CAIB RTF recommendations, but not the other three: eliminating debris shedding from the External Tank, hardening the Orbiter so it can better survive debris impacts, and developing an on-orbit method of repairing the shuttle's thermal protection system. Michael Griffin, who became NASA Administrator in April 2005, said that NASA and contractor personnel are those responsible and accountable for determining if and when the shuttle is ready for RTF, and would not commit to meeting every CAIB recommendation.

Return to Flight (RTF). NASA launched the space shuttle *Discovery* on the first of two "Return to Flight" (RTF) missions — STS-114 — on July 26, 2005 and it successfully landed on August 9. On July 27, however, NASA announced that a piece of foam had detached from STS-114's ET during launch, similar to what

---

[2] National Aeronautics and Space Administration. *Columbia Accident Investigation Board Report*. August 2003. See CRS Report RS21606, *NASA's Space Shuttle Columbia: Synopsis of the Report of the Columbia Accident Investigation Board*, by Marcia S. Smith.

happened to *Columbia*. Cameras and other sensors on *Discovery* and on the International Space Station — to which *Discovery* was docked for much of its mission — imaged the Orbiter and determined that it was not damaged, but further shuttle launches were suspended. Meanwhile, the images revealed that two "gapfillers" — ceramic coated fabric placed between thermal protection tiles — were protruding on the belly of the Orbiter that could have affected aerodynamic heating during reentry. One of the *Discovery* astronauts removed them during a space walk. The second RTF mission — STS-121 — was scheduled for September 2005, but deferred.

STS-121 launched on July 4, 2006, and returned safely to Earth on July 17. The shuttle *Atlantis* launched September 9 on STS 115, during which construction of the International Space Station was resumed. *Atlantis* returned to earth September 21. *Discovery* is scheduled to be launched on STS 116 in early December.

The United Space Alliance (USA). In 1995, NASA decided to turn most shuttle operations over to a "single prime contractor" — the United Space Alliance (USA), a limited liability company owned 50-50 by Boeing and Lockheed Martin. USA was created to pull together the 86 separate contracts with 56 different companies under which the shuttle program was then operating. NASA officials assert that it has saved $1 billion a year compared to what the costs would have been without it. NASA manages separate contracts with Lockheed Martin for the External Tank, ATK Thiokol for the Solid Rocket Boosters, and Pratt & Whitney Rocketdyne (owned by United Technologies) for the Space Shuttle Main Engines.

The Shuttle's Future. NASA attempted unsuccessfully for many years to develop a "second generation" reusable launch vehicle (RLV) to replace the shuttle. In 2002 NASA indicated the shuttle would continue flying until at least 2015, and perhaps 2020 or beyond. The *Columbia* tragedy, and President Bush's 2004 Vision for Space Exploration — to return astronauts to the Moon by 2020 and someday send them to Mars — forced NASA to revise that plan.

The President's Vision calls for the shuttle program, which absorbs approximately 25% of NASA's annual budget, to be terminated in 2010. A primary motivation is to make that funding available to implement other aspects of the Vision, although there also is concern about shuttle safety. Congress has been debating the Vision, including its impact on the shuttle and on U.S. human access to space. Some Members want to terminate the shuttle earlier than 2010 because they feel it is too risky and/or that the funds should be spent on accelerating the Vision. Others want to retain the shuttle at least until a new spacecraft, the Crew Exploration Vehicle (CEV), is available to take astronauts to and from the ISS. The CEV is now planned for 2012 at the earliest, leaving a multi-year gap during which U.S. astronauts would have to rely on Russia for access to the ISS.

At the beginning of 2005, NASA officials indicated 28 shuttle flights were needed to complete ISS construction. In the fall of 2005, NASA announced a new plan showing 18 shuttle missions to the ISS, and possibly one more to service the Hubble Space Telescope (see CRS Report RS21767, *Hubble Space Telescope: Should NASA Proceed with a Servicing Mission?* by Daniel Morgan). As part of its FY2007 budget request, NASA reduced to 16 the number of shuttle flights it now

plans to the ISS (plus one possible flight to Hubble). The two that were cut were logistics flights taking cargo to the ISS. NASA is hoping that a commercial launch service provider will develop vehicles that can perform that task. The original versions of what became the 2005 NASA authorization act (P.L. 109-155) had conflicting language about the future of the shuttle. The original Senate bill (S. 1281) directed NASA not to terminate the shuttle until a replacement was available; the House version (H.R. 3070) directed NASA not to fly the shuttle after December 31, 2010. The final law states that it is U.S. policy to have human access to space on a continuous basis, and directs NASA to submit several related reports to Congress.

Shuttle Budget. NASA's FY2006 Initial Operating Plan shows that NASA plans to spend $4.8 billion on the shuttle in FY2006. NASA Administrator Griffin conceded in 2005 that NASA's FY2006 budget request (prepared prior to his arrival at NASA) contained estimated ("placeholder") figures for shuttle funding in FY2008-2010 that were significantly lower than what is actually needed, and the program was underfunded by $3-5 billion over those three years. The FY2007 budget request adds $2 billion to the shuttle program to help compensate for that shortfall. For FY2007, NASA is requesting $4.1 billion for the shuttle program. The projected figures for FY2008-2010 are $4.1 billion, $3.8 billion, and $3.7 billion respectively, with a FY2011 projected funding level of $147 million as the program is terminated.

On June 29, 2006, the House passed the FY2007 Science, Justice, Commerce and Related Agencies appropriations bill (H.R. 5672), which includes funding for NASA. The bill would fund the Exploration Capabilities account, which includes the shuttle and the ISS, at $6.194 billion in FY2007. Relative to the Administration's request, this is a reduction of $41 million, of which $33 million would be from the ISS program. The Senate Appropriations Committee reported its version of H.R. 5672 (S.Rept. 109-280) on July 13, 2006, recommending $6.235 billion for Exploration Capabilities. (For details on the NASA budget, see CRS Report RS22381, *National Aeronautics and Space Administration: Overview, FY2007 Budget in Brief, and Key Issues for Congress*, by Daniel Morgan and Carl E. Behrens.)

Issues for Congress

In passing the 2005 NASA authorization act (P.L. 109-105), Congress basically agreed with the President's plan for directing NASA's attention to a return to the Moon and manned missions to Mars. Included in the Moon-Mars "Vision" is the plan to end flights of the Space Shuttle in 2010, and restriction of U.S. experiments on the ISS mostly to those that forward the goal Moon-Mars goal. A number of critical questions remain, however.

- Adequacy of funding is the chief question raised about NASA's activities. In present the moon-Mars vision, the President did not request significantly increased money for NASA, despite chronic indications that the missions it was already charged with were underfunded. NASA has responded to the new mission by cutting

back funding for its other activities, primarily in scientific research and aeronautics.

- Although *Discovery's* "Return to Flight" mission of July 2006 was a success, the ability of the shuttle fleet to carry out enough flights to complete construction of the ISS by 2010 is still in question. With a history of more than a hundred successful missions, it might be assumed that another 15 or so would be considered more or less routine, but instead, each launch is still a major and risky event. The great complexity of the vehicle and the extreme environment in which it operates require constant attention to possible accidents and malfunctions, many of which must be addressed on an ad hoc basis.

- The future role of the ISS is also unclear. Assuming that enough shuttle flights are made to carry out "core completion" of the station by 2010, it is not clear what will be done with the ISS after that. In particular, there will be a gap of several years between retirement of the shuttle in 2010 and beginning of flight of the Crew Exploration Vehicle, to be designed for the return to the moon but able to serve as a vehicle to reach the ISS. The current schedule is to fly the CEV by 2012, but design of the vehicle is just beginning.

These and other issues are discussed in greater detail in CRS Report RL32988, *The National Aeronautics and Space Administration's FY2006 Budget Request: Description, Analysis, and Issues for Congress*, by Marcia S. Smith and Daniel Morgan. crsphpgw