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NASA's Space Shuttle Program: The *Columbia* Tragedy, the *Discovery* Mission, and the Future of the Shuttle

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Summary

On August 9, 2005, the space shuttle *Discovery* successfully completed the first of two "Return to Flight" (RTF) missions — STS-114. It was the first shuttle launch since the February 1, 2003, *Columbia* tragedy. NASA announced on July 27, 2005, the day after STS-114's launch, that a second RTF mission has been indefinitely postponed because of a problem that occurred during *Discovery*'s launch that is similar to what led to the loss of *Columbia*. Two shuttle-related facilities in Mississippi and Louisiana were damaged by Hurricane Katrina, which is further affecting the shuttle schedule. It currently is expected some time in 2006. This report discusses the *Columbia* tragedy, the *Discovery* mission, and issues for Congress regarding the future of the shuttle. For more information, see CRS Issue Brief IB93062, *Space Launce Vehicles: Government Activities, Commercial Competition, and Satellite Exports*, by Marcia Smith. This report is updated regularly.

The Loss of the Space Shuttle *Columbia*

The space shuttle *Columbia* was launched on its STS-107 mission on January 16, 2003. After completing a 16-day scientific research mission, *Columbia* started its descent to Earth on the morning of February 1, 2003. As it descended from orbit, approximately 16 minutes before its scheduled landing at Kennedy Space Center, FL, *Columbia* broke apart over northeastern Texas. All seven astronauts aboard were killed: Commander Rick Husband; Pilot William McCool; Mission Specialists Michael P. Anderson, David M. Brown, Kalpana Chawla, and Laurel Clark; and payload specialist Ilan Ramon, an Israeli. The last communication with *Columbia* was at about 09:00 EST. The shuttle was at an altitude of 207,135 feet, traveling at a speed of Mach 18.3 (about 13,000 miles per hour).

The Space Shuttle *Columbia* and the STS-107 Mission

The Space Transportation System (STS) — the space shuttle — consists of an airplane-like orbiter, two Solid Rocket Boosters (SRBs) on either side, and a large cylindrical External Tank that holds the fuel for the orbiter's main engines. The SRBs detach from the orbiter 2½ minutes after launch when their fuel is spent, fall into the ocean, and are recovered for refurbishment and reuse. The External Tank is not reused, but is jettisoned as the orbiter reaches Earth orbit, and disintegrates as it falls into the Indian Ocean. At the beginning of 2003, all planned shuttle launches, other than STS-107 and two missions to the Hubble Space Telescope, were scheduled to support assembly and operation of the International Space Station (see CRS Issue Brief IB93017).

Columbia was one of four spaceflight-worthy reusable space shuttle orbiters in NASA's fleet. The remaining orbiters are *Discovery*, *Atlantis*, and *Endeavour*. A fifth orbiter, *Challenger*, was lost in a 1986 accident. Another orbiter, *Enterprise*, was used for approach and landing tests in the 1970s and was not designed to travel in space. *Enterprise* now belongs to the Smithsonian's National Air and Space Museum.

Columbia was the first spaceflight-worthy orbiter built for NASA by Rockwell International (the space division of Rockwell, which built the orbiters, was later bought by Boeing). It was used for the very first shuttle flight on April 12, 1981. The STS-107 mission was *Columbia*'s 28th flight. Although *Columbia* was the oldest orbiter, *Discovery* has been used for more flights (30). NASA has conducted a total of 113 shuttle launches to date. Orbiters are periodically taken out of service for maintenance and overhaul. *Columbia* last underwent such an "orbiter major modification" (OMM) period in 1999-2001. STS-107 was *Columbia*'s second flight after the OMM. It was a scientific research mission that, unlike most current shuttle launches, was not related to the International Space Station (ISS) program (see CRS Issue Brief IB93017). The crew conducted a research program involving 59 separate investigations. Some of the research required analysis of specimens and data sets after the shuttle returned to Earth, and most were destroyed along with the crew and orbiter. Other data, however, were transmitted to ground-based researchers during the flight, and a few specimens were retrieved among the debris, so some of the research survived. Quantifying the amount is difficult.

Previous Spaceflight-Related Crew Fatalities

The United States has suffered two other spaceflight-related accidents that caused astronaut fatalities. On January 27, 1967, the crew of the first Apollo mission — Virgil "Gus" Grissom, Edward White, and Roger Chaffee — died when electrical arcing in spacecraft wiring caused a fire in their Apollo command module during a pre-launch test. Apollo flights resumed after 21 months. On January 28, 1986, the space shuttle *Challenger* (STS 51-L) exploded 73 seconds after launch, killing all seven astronauts aboard: Francis "Dick" Scobee, Michael Smith, Judith Resnik, Ellison Onizuka, Ronald McNair, Gregory Jarvis (a payload specialist from Hughes Aircraft), and schoolteacher Christa McAuliffe. A commission chaired by former Secretary of State William Rogers determined that cold weather at the launch site caused a rubber "O-ring" in one of the SRBs to fail, allowing gases to escape, resulting in a catastrophic explosion. The shuttle system was grounded for 32 months.

Four Soviet cosmonauts also died during spaceflights. Cosmonaut Vladimir Komarov died during the first Soyuz flight on April 24, 1967. The spacecraft's parachutes did not function properly and it struck the ground with great force, killing Colonel Komarov. Soviet human spaceflights were suspended for 18 months. Three cosmonauts died on Soyuz 11 on June 29, 1971 when an improperly sealed valve allowed the spacecraft's atmosphere to vent into space. The cosmonauts — Georgiy

Dobrovolskiy, Vladislav Volkov, and Viktor Patsayev — were not wearing spacesuits, and were asphyxiated. There were no Soviet human spaceflights for 27 months.

The *Columbia* Accident Investigation Board (CAIB)

Then-NASA Administrator O'Keefe established the *Columbia* Accident Investigation Board (CAIB) within hours of the tragedy, and transitioned responsibility for the investigation to it on February 6, 2003. Chaired by Adm. (Ret.) Harold Gehman, former NATO Supreme Allied Commander, Atlantic, CAIB had 12 other members (see [http://www.caib.us]). All were appointed by Mr. O'Keefe, although some were added to the initial roster upon the recommendation of Adm. Gehman. NASA revised the Board's charter three times to clarify its independence from NASA, primarily in response to congressional concerns. However, the CAIB was created by NASA, included NASA representatives, and the Board members were appointed by the NASA Administrator, so concerns about its independence continued. CAIB released the results of its investigation on August 26, 2003 in Vol. 1 of its report; Volumes II-VI were released in October 2003. All are available at CAIB's website. Board member Brig. Gen. Duane Deal wrote a 10-page supplement, which is published in Vol. 2, providing additional recommendations and viewpoints that he felt were important to convey.

The Causes of the Accident. The Board concluded that the tragedy was caused by both technical and organizational failures. The technical cause was damage to *Columbia*'s left wing by a 1.7 pound piece of insulating foam that separated from the External Tank's left "bipod ramp" and struck the orbiter's left wing 81.9 seconds after launch. The foam strike created a hole in a Reinforced Carbon-Carbon (RCC) panel on the leading edge of the wing, allowing superheated air (perhaps exceeding 5,000^{o}F) to enter the wing during reentry. The extreme heat caused the wing to fail structurally, creating aerodynamic forces that led to the disintegration of the orbiter. Organizationally, the Board pointed to detrimental cultural traits and organizational practices that developed over the institutional history of the program. Adm. Gehman cited a loss of "checks and balances" in the program's management that should have led to a recognition of the danger posed by "foam shedding" from the External Tank, which had occurred on previous shuttle missions. The Board also cited long term budget constraints, and schedule pressure associated with assembly of the International Space Station, as factors.

CAIB's Recommendations and the Stafford/Covey Task Group. The CAIB made 29 recommendations, of which 23 are technical and six are organizational. Of the 29 recommendations, the Board specified that 15 be completed before the shuttle returned to flight status (see CRS Report RS21606 for a synopsis).

NASA created a task group chaired by two former astronauts — Thomas Stafford and Richard Covey — to evaluate NASA's compliance with the 15 CAIB recommendations that were to be completed before Return to Flight (RTF). The Stafford/Covey Task Group ([http://returntoflight.org]) did not address organizational or cultural issues, and was not tasked to determine whether the shuttle was ready to fly. The Task Group held its final public meeting on June 27, 2005, concluding that NASA had met the intent of 12 of the 15 CAIB RTF recommendations, but not the other three — preventing debris shedding from the External Tank, hardening the orbiter against damage from debris, and developing inspection and repair techniques for the thermal protection system. Some Task Group members indicated, however, that NASA had made considerable improvements to shuttle safety, and considered the shuttle ready to fly.

Then-NASA Administrator O'Keefe said during 2003 and 2004 that not only would NASA comply with the CAIB recommendations, but would "raise the bar" to ensure the shuttle is as safe as possible. Dr. Michael Griffin became NASA Administrator in April 2005. At an April 18 press conference, he said he would listen carefully to advice from the Stafford/Covey group, but that NASA and contractor personnel were those responsible and accountable for determining if and when the shuttle is ready for RTF. He would not commit to meeting every CAIB recommendation. In testimony to the House Science Committee on June 28, 2005, he said that NASA had spent lot of money trying to meet all the recommendations, but did not have the knowledge to do so in every case, such as stopping all debris shedding from the External Tank.

The CAIB report also cited cultural issues (e.g., the safety culture) that could affect shuttle safety. Those issues were addressed by an internal NASA study led by then-NASA Goddard Space Flight Center Director Al Diaz. NASA also hired an outside consulting firm, BST, to assess NASA culture and make recommendations about what changes are needed. A February 5, 2005 BST report concluded that there is improvement, but a significant number of people at NASA's field centers do not yet perceive change. Dr. Griffin terminated the contract with BST soon after becoming Administrator, saying that NASA could deal with these issues internally.

Return to Flight: The STS-114 (*Discovery*) Mission

NASA launched the space shuttle on its first Return to Flight (RTF) mission, STS-114, on July 26, 2005, using the *Discovery* orbiter. The STS-114 crew was composed of six NASA astronauts and one from the Japan Aerospace Exploration Agency (JAXA): Commander Eileen Collins, Pilot James Kelly, and Mission Specialists Charles Camarda, Wendy Lawrence, Soichi Noguchi (JAXA), Steve Robinson, and Andy Thomas. STS-114 docked with the International Space Station (ISS) for most of its mission. STS-114 delivered supplies, repaired ISS components, and tested inspection and repair techniques for the orbiter. The STS-114 mission was extended one day so the shuttle crew could assist the ISS crew in stowing supplies. Inclement weather at Kennedy Space Center, FL delayed landing until August 9, and diverted it to Edwards Air Force Base, CA.

On June 27, NASA announced that further shuttle launches would be indefinitely postponed after discovering that a comparatively large piece of foam broke off from *Discovery*'s External Tank during launch, similar to what happened to *Columbia*. In this case, NASA determined that it did not hit the orbiter. Subsequently, several smaller pieces were found to have broken off and may have hit the orbiter's wing. Cameras and other sensors aboard *Discovery* and the ISS took detailed images to determine if there was any damage and none was discovered. However, the images revealed that two "gapfillers" — ceramic-coated fabric that fills gaps between the thermal protection tiles — on the bottom of the orbiter were protruding, which could affect aerodynamic heating during reentry. Astronaut Robinson removed them during a spacewalk.

The second RTF mission was scheduled for September 2005 with the mission of continuing testing post-*Columbia* fixes and resupplying the ISS. NASA continues to study why the foam loss on STS-114 occurred. That work was slowed by hurricane damage to the Michoud Assembly Facility, in New Orleans, LA, where the External Tanks are manufactured. It is operated for NASA by Lockheed Martin. The next shuttle launch currently is expected no earlier than May 2006.

Issues for Congress

Cost. In July 2004, NASA released a cost estimate for RTF covering the years FY2003-2009: $2.2 billion, double the previous estimate of $1.1 billion. For FY2005, NASA requested $4.3 billion for the shuttle program. In November 2004, NASA informed Congress it needed $762 million more than expected for FY2005. In the FY2005 Consolidated Appropriations Act (P.L. 108-447), Congress approved the $4.3 billion requested, subject to an across-the-board 0.80% rescission, and said that NASA could submit a request for supplemental appropriations, or reprogram funds from other NASA programs. According to a May 10, 2005 update to its FY2005 operating plan, NASA reprogrammed the following funds into RTF: $55 million from the Science Mission Directorate ($20 million from space science, $35 million from earth science); $375.8 million from the Exploration Systems Mission Directorate ($73 million from biological and physical research, $204 million from human and robotic technology, and $98 million from transportation systems); and $331.2 million from the Space Operations Mission Directorate ($160 million from the space station, $170 million from space shuttle upgrades, and $1.2 million from space flight support). Separately, Congress appropriated $126 million to NASA in an FY2005 emergency supplemental (P.L. 108-324) for damages at Kennedy Space Center, FL, from the 2004 Florida hurricanes. NASA officials say those funds are not available for RTF.

The CAIB noted that long term budget constraints were a factor in the *Columbia* tragedy. NASA requested and received $4.5 billion for the shuttle (subject to a 0.28% rescission) in the FY2006 appropriations bill that includes NASA (P.L. 109-108). The FY2006 request, developed by then-Administrator O'Keefe, included a projection that the shuttle budget would decline to $2.4 billion by FY2010. Many observers considered that unrealistic if NASA intends to use the shuttle to complete ISS construction. At a November 3, 2005 House Science Committee hearing, Dr. Griffin agreed that NASA will need $3 billion-$5 billion more than that projection for FY2008-FY2010. The source of those funds is unclear.

The Shuttle's Future. The foam-shedding event during *Discovery*'s launch and the resulting decision to suspend further shuttle launches adds to the complexity of decisions about the shuttle's future. Prior to *Discovery*'s launch, discussion was focused on President Bush's January 2004 directive that the shuttle be retired in 2010. That decision was made in the context of the President's announcement of a new "Vision for Space Exploration," wherein NASA is to focus its attention on returning astronauts to the Moon by 2020 and someday sending them to Mars (see CRS Report RS21720). Under the plan, the shuttle — in its current form — would be terminated in 2010, primarily so that its funding can be redirected towards achieving other aspects of the Vision. The 2010 date also coincides with the CAIB's recommendation that if the shuttle is to be flown longer, it should be recertified. Two key issues raised by the decision to end shuttle flights by 2010 are the extent to which the United States wants its own ability to launch astronauts into space, and the importance of completing ISS construction and meeting U.S. commitments to other ISS partners.

The shuttle is the only U.S. vehicle capable of taking astronauts to space today. As part of the Vision, NASA is building a new "Crew Exploration Vehicle" (CEV). The original schedule called for it to be available for launching crews to Earth orbit by 2014, meaning there would be a multi-year gap between the end of the shuttle program and the availability of CEV. During that time, NASA would be dependent on Russia for human access to space. Dr. Griffin wants to accelerate CEV availability to reduce the gap as much as possible in part because he believes the United States should not be dependent on any other nation for human access to space. NASA's current target is 2012. The Senate adopted an amendment to the FY2006 Department of Defense authorization bill (S. 1042) on November 15, 2005 expressing the sense of the Senate that it is in the national security interest of the United States to maintain preeminence in human spaceflight. Initial versions of the NASA authorization bill (H.R. 3070/S. 1281) contained conflicting language about the future of the shuttle. The Senate bill originally directed NASA not to terminate the shuttle until a replacement was available. The House version originally directed NASA not to fly the shuttle after December 31, 2010. Both were modified before the bills were passed by each chamber. Now, the Senate version directs the NASA Administrator to act to ensure that the United States has assured human access to space, and to make several related reports to Congress. The House-passed version is silent on this topic.

The shuttle's primary purpose today is assembly and servicing of the ISS. Dr. Griffin also promised to reassess whether or not to use the shuttle for one more servicing mission to the Hubble Space Telescope (see CRS Report RS21767). The need to complete ISS assembly and meet U.S. commitments to its ISS partners, and to service Hubble, will need to be weighed against the costs of fixing the foam-shedding problem and the risks of shuttle launches. ISS construction is about 50% completed, and some of the segments waiting to be launched are those built by the other partners. President Bush said the United States would meet its commitments to the ISS partners. NASA's current target is to launch the shuttle 18 times to support the ISS, with one potential additional launch to Hubble, by the end of 2010. Whether it can achieve that many launches remains to be seen. Another question is whether setting a firm deadline for ending shuttle flights places undue schedule pressure on shuttle program managers to complete as many launches as possible within whatever remaining time there is. CAIB cited schedule pressure as a factor in the *Columbia* accident.

The effect on ISS utilization by NASA and its partners is another issue. ISS was designed to be serviced by the shuttle, which can carry larger crews than the Russian Soyuz spacecraft, and larger and heavier cargo than the Russian Progress cargo spacecraft. In addition, the shuttle is the only cargo spacecraft that can return large amounts of material to Earth (Russia's Progress burns up as it reenters the atmosphere). Without the shuttle, the results of scientific experiments, equipment needing repair, and other items could only be returned if they fit within the small confines of the Soyuz capsule along with whatever crew members were returning to Earth (unless new cargo spacecraft are developed). How NASA can ensure that the shuttle system will remain safe as workers and vendors move on to other projects as the shuttle program comes to an end is also being discussed. NASA plans to develop two "shuttle-derived" launch vehicles (see CRS Issue Brief IB93062), which could mitigate some of the shuttle workforce displacements.