



THE U.S. HUMAN SPACE FLIGHT PROGRAM AND THE SPACE SHUTTLE COLUMBIA ACCIDENT

Testimony before the
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Mr. Chairman, members of the subcommittee, thank you for inviting me here today to discuss the history of the human space flight program in the context of the space shuttle *Columbia* accident. You asked that I address the fundamental question of “How did we get here?” The answer has two components: Why does the United States have a human space flight program, and why did we decide to build the space shuttle? These are complex issues and my brief statement cannot do them justice. But I will try to provide an overview of some of the factors that shaped those decisions in the past, and summarize options as you reassess those decisions for the future.

Why Human Space Flight?

The dream of people journeying into space was the lore of science fiction for centuries. By the time Sputnik 1 ushered in the Space Age on October 4, 1957, a cadre of enthusiasts was ready to make such dreams a reality.

Congress passed the National Aeronautics and Space Act in July 1958, creating NASA and establishing as one objective “the preservation of the role of the United States as a leader in aeronautical and space science and technology and in the application thereof to the conduct of peaceful activities within and outside the atmosphere.” NASA opened its doors on October 1, 1958, and 6 months later the first group of astronauts—the Mercury 7—was selected.

Two years later, on April 12, 1961, the first human orbited the Earth. But it was not one of the Mercury 7. Instead, it was a Soviet cosmonaut, Yuri Gagarin.

Gagarin’s flight added new impetus to the U.S. program. America’s leadership in space science and technology, its international prestige, and, many believed, its national security, were at stake. Three weeks later, Alan Shepard became the first American in space, but it was a suborbital flight. The United States did not match Gagarin’s feat until 10 months later, when John Glenn became the first American in orbit.

The risks were high in those early flights. We had little experience with launching rockets into space, and with the spacecraft that protected the astronauts. Yet the nation was willing to accept those risks, and pay the cost, to ensure American preeminence. Indeed, only three weeks after Alan Shepard’s flight, President Kennedy called on the nation to commit to the goal of landing a man on the Moon by the end of the decade, and the nation said yes. Although the space program has changed in many ways over the past four decades, human space flight as an indicator of technological preeminence appears to remain a strong factor.

Human space flight is risky. It has claimed the lives of 17 American astronauts and four Russian cosmonauts in spaceflight-related accidents so far.¹ While this is a relatively small percentage of the more than 400 people who have made space journeys, their loss is felt deeply. Human space flight also is quite expensive. NASA will spend about \$6 billion on the space shuttle and space station programs in this fiscal year. Yet we persevere. President George H.W. Bush articulated what many consider a guiding impetus. In July 1989, on the 20th anniversary of the first Apollo lunar landing, he stood on the steps of the National Air and Space Museum and announced a commitment to returning humans to the Moon, and going on to Mars. He said:

Why the Moon? Why Mars?
Because it is humanity's destiny to strive, to seek, to find,
And because it is America's destiny to lead.

That is not to say that human space flight is without controversy. The debate over the need to send humans into space is as old as the space program itself. Over the past 42 years, little progress seems to have been made in bridging the divide between those who believe human space flight is essential, and those who believe it is a waste of money and an unnecessary risk to human life. The Senate Committee on Aeronautical and Space Sciences—the predecessor to this subcommittee—held hearings on that debate forty years ago, and little has changed. I know your other witnesses today will resume that dialogue, so I will not devote much of my statement to it. Briefly, critics of human space flight believe that robotic probes can gather the needed scientific data at much less cost, and that humans contribute little to space-based scientific research. They point out that no ground-breaking scientific discoveries have emerged from 42 years of human space flight that can be uniquely attributed to the presence of humans in space. Proponents insist that human ingenuity and adaptability are essential for some types of basic research in space, and can rescue an otherwise doomed mission by recognizing and correcting problems before they lead to failures. While proponents point to the value of “spin-off” technologies that were developed for human space flight but found broader application in medicine or other fields, critics argue that those technologies probably would have been developed in any case. Past economic studies that attempted to quantify the value of spin-offs were criticized because of their methodologies, and critics suggest that investing federal monies in non-space areas might have yielded equally valuable spin-offs or led directly to new scientific knowledge or technologies. The two sides of this debate have been, and remain, quite polarized. To date, the United States and other countries have decided in favor of human space flight, despite its risks and costs.

While a desire for preeminence has been one motivation in pursuing human spaceflight, it has not precluded cooperation. Even at the height of U.S.-Soviet space competition in the early days of the Space Race, the United States and Soviet Union also worked together—at the United Nations through the Committee on Peaceful Uses of Outer Space, and through bilateral cooperative agreements as early as 1962. In 1963, President Kennedy proposed that

¹ The 17 American astronaut spaceflight-related fatalities counted here include the three Apollo 204 astronauts who were killed in a pre-launch test in 1967. Some sources exclude these astronauts because they were not killed in an actual spaceflight. The table at the end of this statement provides more information on the space tragedies that ended in death: the 1967 Apollo fire (3 deaths), the 1967 Soyuz 1 mission (one), the 1971 Soyuz 11 mission (three), the 1986 space shuttle *Challenger* accident (seven), and the 2003 space shuttle *Columbia* accident (seven). The *Columbia* accident is also discussed in CRS Report RS21408 and CRS Issue Brief IB93062.

the two countries cooperate in sending astronauts to the Moon, but the Soviets did not accept the offer. Human space flight cooperation between the two countries, and with other countries, grew as the space programs matured.² The United States and Soviet Union agreed to a joint docking of a Russian Soyuz and an American Apollo in 1975 to demonstrate “detente in space.” The United States brought Canada and the European Space Agency (ESA) into the space shuttle program, with Canada building a remote manipulator system (“Canadarm”) and ESA building the Spacelab module for conducting scientific experiments in the shuttle’s cargo bay. In 1977, the Soviet Union began launching cosmonauts from allied countries to its space stations, and the United States included representatives of many other countries in space shuttle crews beginning in 1983. To date, astronauts and cosmonauts from 29 other countries³ have journeyed into space on American or Russian spacecraft. And today, of course, 15 nations—the United States, Russia, Canada, Japan, and 11 European countries—are partners in building the International Space Station.

The international landscape has influenced the course of human space flight over these decades. But fundamentally, the desire to pursue such activities seems based on a quest for national technological preeminence and a yearning to explore new frontiers.

Why the Shuttle?

The first decade of the U.S. human space flight program saw the execution of the Mercury, Gemini, and Apollo programs. As 1969 dawned and the first Apollo lunar landing neared, President Nixon took office and faced the question of what goals should guide the space program in the post-Apollo years. He established a “Space Task Group,” chaired by Vice President Agnew, to develop recommendations. The group’s report laid out a plan that called for developing a space station, a reusable space transportation system to service it, and sending humans to Mars. But after America won the Moon Race with the Apollo 11 landing in July 1969, it became apparent that support for expensive human space missions was waning. Attention turned to other national priorities, and NASA found that it had to pick just one of those new projects. It decided that the first step should be development of the reusable space transportation system—the space shuttle. One goal of the shuttle program was to significantly reduce the cost of launching people and cargo into space. President Nixon announced the shuttle program in 1972. It was quite controversial in Congress, but ultimately was approved.

The reusable space shuttle was intended to replace all other U.S. launch vehicles, so-called “expendable launch vehicles” (ELVs) that can only be used once. By transferring all space traffic to the shuttle, NASA projected that the shuttle’s development and operations costs would be amortized over a large number of annual launches— 48 flights per year—with resulting cost efficiencies.

² There has been extensive cooperation in other space activities as well since the beginning of the Space Age.

³ Afghanistan, Austria, Belgium, Bulgaria, Canada, Cuba, Czechoslovakia, France, Germany, Hungary, India, Israel, Italy, Japan, Kazakhstan, Mexico, Mongolia, Netherlands, Poland, Romania, Saudi Arabia, Slovakia, South Africa, Spain, Switzerland, Syria, Ukraine, United Kingdom, and Vietnam.

That premise has not held true, however. The costs were higher than expected, and the annual flight rate much lower. Since 1981 when the shuttle was first launched, the greatest number of launches in a single year has been nine. One factor in the lower launch rate was policy changes in the aftermath of the 1986 space shuttle *Challenger* accident. The Reagan White House reversed the decision to phase out ELVs and announced that, with few exceptions, the shuttle could be used only for missions requiring the shuttle's "unique capabilities" such as crew interaction. Commercial communications satellites, expected to comprise a large share of shuttle launches, no longer could be launched on the shuttle. While that provided a market for the resurrected ELVs, the effect on the shuttle program was many fewer launches and a higher cost-per-launch. Today, many point to the shuttle as an outstanding technical success, but an economic failure.

In the 22 years since the shuttle's first flight, NASA (sometimes working with DOD) has initiated several attempts to develop a successor to the shuttle—a "second generation reusable launch vehicle"—with the continued goal of reducing costs. Each attempt has failed in turn, in large part because anticipated technological advances did not materialize. Thus, the shuttle continues to be the sole U.S. vehicle for launching people into space, and the only launch vehicle capable of meeting the International Space Station's requirements for taking cargo up and back. Late last year, NASA again reformulated its plan to develop a successor to the shuttle, asserting that an economic case could not be made at this time for investing as much as \$30-35 billion in such a vehicle. Instead, NASA plans to continue operating the shuttle until at least 2015 (instead of 2012), and perhaps 2020 or longer.

That decision was made prior to the *Columbia* tragedy, but NASA officials have subsequently made clear that no change is expected. NASA plans to build an "Orbital Space Plane" that could supplement (but not replace) the shuttle early in the next decade, and there are discussions about potentially flying the shuttle with as few as two crew members, or perhaps autonomously (without a crew), in the long term future. For the present, however, NASA asserts that the shuttle is needed to support the International Space Station program, and to service the Hubble Space Telescope.

Options for the Future

In the wake of the *Columbia* tragedy, Congress is again assessing the costs and benefits of human space flight. Congress has faced these questions before—in the early days of the Space Age, after the 1967 Apollo fire that took the lives of three astronauts, after the United States won the "Moon Race", and after the 1986 space shuttle *Challenger* tragedy that claimed seven lives. Based on past experience, many expect that the decision will be made to continue the human space flight program essentially unchanged once the cause of the *Columbia* accident is determined and fixed. But there are a number of options to consider, each with its own set of advantages and disadvantages. The major options and some of the associated pros and cons are discussed next.

1. Terminate the U.S. human space flight program, including the space shuttle, U.S. participation in the International Space Station (ISS) program, and plans to develop an Orbital Space Plane.

Pros: The annual budget for the space shuttle is approximately \$4 billion, and for the space station is approximately \$2 billion. That amount of funding, plus whatever would be spent on the Orbital Space Plane (which is still in the formulation phase) could be saved, or

redirected to other space or non-space priorities such as robotic space flight, scientific research, homeland security, or the costs of the Iraqi war. Human lives would not be at risk. Human spaceflight might remain a long term vision.

Cons: To the extent that human space flight is still perceived as a measure of a nation's technological preeminence, that advantage would be lost.⁴ Although the United States is the leader of the International Space Station (ISS) program, ISS could continue without U.S. involvement, as long as the other partners had the requisite funds.⁵ Thus, the more than \$30 billion U.S. investment in the space station could be lost for American taxpayers, while the other partners could continue to use it for their own purposes. Without servicing missions by the space shuttle, the Hubble Space Telescope might not achieve its scientific potential, and non-shuttle options for disposing of it at the end of its life would have to be developed.⁶ There also could be consequences for the U.S. aerospace industry, particularly Boeing and Lockheed Martin.⁷

2. Terminate the shuttle and Orbital Space Plane programs, but continue participation in the ISS program, relying on Russian vehicles for taking U.S. astronauts to and from space when possible.

Pros: The annual budget for the space shuttle is approximately \$4 billion, so that amount of funding, plus whatever would be spent on OSP, could be saved or redirected to other space or non-space priorities (as above). The lives of fewer astronauts would be at risk. Compared to Option 1, this would leave open the possibility of U.S. use of the space station whenever NASA could obtain flight opportunities on Russia's Soyuz spacecraft.

Cons: Similar to Option 1, but if the United States wanted to continue using ISS, it would need to work with the other partners to solve the problem of how to deliver cargo to and return it from ISS.⁸ If only the Soyuz spacecraft is used to take crews to and from the space

⁴ Some would find this ironic at a time when China is about to become only the third country capable of launching people into space. It has launched four test spacecraft as part of that goal; the first launch carrying a Chinese astronaut, or "taikonaut," is expected late this year

⁵ The ISS program is an international partnership among the United States, 11 European countries, Japan, Canada, and Russia. The Russians have three decades of experience in operating space stations without a space shuttle. Most of the remaining segments of the space station are designed to be launched on the shuttle, so construction would remain stalled until and unless some other launch vehicle becomes available to launch the remaining segments, but operation of the existing space station could continue using Russian Soyuz and Progress spacecraft if funds are available.

⁶ At least one more servicing mission is planned in 2004 to enable the telescope to operate until 2010. At that time, NASA plans to use the shuttle to return the telescope to Earth because it does not want it to make an uncontrolled reentry into the Earth's atmosphere. Such a reentry could pose hazards from falling debris.

⁷ The two companies operate the space shuttle (under a joint venture called United Space Alliance). Boeing is also the prime contractor for the space station program.

⁸ Vehicles other than the shuttle are available, or are expected to become available in the next few years, to take cargo to the space station, but none can bring cargo back to Earth. Russia's Progress spacecraft is the only other cargo craft available today. Russia has indicated that it cannot afford to build more than about three per year, however, which is insufficient to resupply even a two-person
(continued...)

station, agreements would have to be reached with Russia on how often American astronauts would be included in the space station crews and how much it would cost.⁹ The issues related to the Hubble Space Telescope and the U.S. aerospace industry (discussed above) would remain.

3. Terminate the shuttle program, but continue participation in the ISS program and continue to develop the Orbital Space Plane or another replacement for the shuttle.

Pros: The annual budget for the space shuttle is approximately \$4 billion, so that amount of funding could be saved, or redirected to other space or non-space priorities (as above). Costs for developing and operating an Orbital Space Plane or a successor to the shuttle are not yet known, however, so there might not be any net savings over the long term. A new vehicle might be safer and more cost effective.

Cons: The disadvantages of this option would be similar to those for Option 2, except that at some point in the future, a U.S. human space flight vehicle would become operational, ameliorating questions about access to the space station by American crews.

4. Continue the shuttle program, but with fewer missions—perhaps limiting it to space station visits—and as few crew as possible.

Pros: Would limit the risk to shuttle crews. If the space station was equipped with a system to inspect the shuttle prior to undocking,¹⁰ problems could be identified and possibly repaired. Continues U.S. leadership in space and any resulting benefits therefrom.

Cons: There would be little, if any, financial savings from this option.¹¹ Astronaut lives would remain at risk. The question of what to do with the Hubble Space Telescope (discussed above) would remain if flights were limited only to space station visits.

⁸ (...continued)

crew (this problem is being addressed currently). Under the Iran Nonproliferation Act, NASA is prohibited from making payments to Russia in connection with the space station program unless the President certifies that Russia is not proliferating certain technologies to Iran. Without such a certification, NASA could not pay Russia for Progress flights. Europe and Japan are both developing spacecraft that will be able to take cargo to the space station, but they will not be available for several years, and cannot return cargo to Earth. U.S. expendable launch vehicles potentially could be used to take cargo to the space station, although a cargo spacecraft equipped with autonomous rendezvous and docking systems would have to be developed. These also probably would not be able to return cargo to Earth.

⁹ The Iran Nonproliferation Act (discussed in the previous footnote) would also prohibit U.S. payments to Russia for Soyuz flights unless the President certifies that Russia is complying with the Act.

¹⁰ This would be in addition to inspections that could be accomplished using Department of Defense ground- and space-based sensors.

¹¹ There are only two non-space station missions on the shuttle's schedule today, both to the Hubble Space Telescope. At NASA's current estimate of the marginal cost of a shuttle launch (\$115 million), that would save only \$230 million. The costs for fixing the problems that caused the *Columbia* accident are unknown, but seem likely to exceed that amount.

5. Resume shuttle flights as planned.

Pros: Allows construction and utilization of the space station to continue as planned. Allows the Hubble Space Telescope to be serviced and returned to Earth. Continues U.S. leadership in space and any resulting benefits therefrom.

Cons: There would be no financial savings, and costs would be incurred to fix the shuttle. The risk to human life would remain.

Options 4 and 5 could be coupled with directives to NASA to:

- equip the space station with a system that could inspect the shuttle while it is docked;
- upgrade the shuttle to make it safer, perhaps including additional crew escape systems or making the crew cabin survivable if the vehicle breaks apart;
- develop systems to enable the shuttles to fly autonomously (without a crew); and/or
- accelerate efforts to build a successor to the shuttle with the emphasis on improved safety, even if that meant not reducing costs as much as desired.

Summary

Mr. Chairman, as I said, this brief statement provides only a cursory review of these complex issues. As the world readies to celebrate the 42nd anniversary of Yuri Gagarin's historic flight 10 days from now, the future of the U.S. human space flight program is in question. Apart from the broad questions of whether the U.S. human space flight program should continue, a more specific focus may be the cost of returning the shuttle to flight status and how long it will take. Those answers will not be known until the cause of the *Columbia* accident is determined, and remedies identified. If the costs are high, difficult decisions may be needed on whether to use the funds for the shuttle, for other space initiatives, or for other national priorities such as paying for the Iraqi war and homeland security. While many expect that the United States will once again rally behind NASA, only time will tell if the past is prologue.

BRIEF HISTORY OF HUMAN SPACE FLIGHT: 1961-2003

United States	Soviet Union/Russia
<p>Mercury (1961-1963) Purpose: To demonstrate that humans can travel into space and return safely. Flights: Six flights (two suborbital, four orbital). Alan Shepard, first American in space (on suborbital flight), May 5, 1961. John Glenn, first American in orbit, Feb. 20, 1962.</p>	<p>Vostok (1961-1963) Purpose: To demonstrate that humans can travel into space and return safely. Flights: Six flights (all orbital). Yuri Gagarin, first man in space (made one orbit of the Earth), Apr. 12, 1961. Valentina Tereshkova, first woman in space, June 16, 1963.</p>
<p>Gemini (1965-1966) Purpose: To prepare for lunar missions by extending the duration of spaceflight (to 14 days), developing experience in rendezvous and docking, and demonstrating ability to work outside the spacecraft (extravehicular activity—EVA) Flights: 10 flights. Ed White conducted first U.S. EVA (June 1965).</p>	<p>Voskhod (1964-1965) Purpose: Modified Vostok spacecraft used to achieve two more space “firsts”: first multi-person crew, and first EVA. Flights: Two flights. Voskhod 1 carried three-person crew. On Voskhod 2, Alexei Leonov performed the first EVA (March 1965).</p>
<p>Apollo Lunar Program (1967-1972) Purpose: To land men on the Moon and return them safely to Earth. Flights: Eleven flights, nine to the Moon. Of the nine, two (Apollo 8 and 10) were test flights that did not attempt to land, one (Apollo 13) suffered an in-flight failure and the crew narrowly averted tragedy and were able to return to Earth, and six (Apollo 11, 12, 14, 15, 16, and 17) landed two-man teams on the lunar surface. Neil Armstrong and Buzz Aldrin were the first humans to set foot on the Moon on July 20, 1969, while Mike Collins orbited overhead.</p> <p>Space Tragedy The Apollo program saw the first spaceflight-related tragedy when the three-man crew (Gus Grissom, Ed White, and Roger Chaffee) of the first Apollo mission was killed on January 27, 1967, when fire erupted in the Apollo command module during a pre-launch test. The Apollo program resumed flights 21 months later.</p>	<p>Soyuz (1967-present) Purpose: To develop a spacecraft for taking crews back and forth to Earth orbit. Early flights extended the duration of human space flight (to 18 days) and practiced rendezvous and docking. Flights since Soyuz 10 (1971) have been largely devoted to taking crews back and forth to Soviet space stations (Salyut and Mir, see below), and to the International Space Station. Flights: The Soyuz is still in use today, although it has been modified several times. The original Soyuz was replaced by Soyuz T in 1980, by Soyuz TM in 1987, and by Soyuz TMA in 2002. There were 40 flights of Soyuz, 15 of Soyuz T, 34 of Soyuz TM, and one flight of Soyuz TMA to date. (A few of these missions did not carry crews.) Space Tragedy: The Soyuz program saw the first Soviet space tragedy when Vladimir Komarov was killed during the first Soyuz mission on April 24, 1967. The craft’s parachute lines tangled during descent and he was killed upon impact with the Earth. The Soyuz program resumed flights 18 months later.</p>

United States	Soviet Union/Russia
<p>Skylab (1973-1974) Purpose: First U.S. Space Station Flights: The Skylab space station was launched in May 1973. Three three-person crews were launched to Skylab using Apollo capsules from 1973 to 1974, extending the duration of human space flight to a new record of 84 days. A wide variety of scientific experiments were conducted. Skylab was not intended to be permanently occupied. It remained in orbit, unoccupied, until 1979 when it made an uncontrolled reentry into the Earth's atmosphere, raining debris on western Australia and the Indian Ocean.</p>	<p>Salyut 1 (1971) Purpose: First Space Station Flights: Salyut 1 was launched in April 1971. This was a "first generation" Soviet space station with only one docking port. Two crews were launched to the space station. The first docked, but was unable to open the hatch to the space station, and returned home. Space Tragedy: The second crew, Soyuz 11, docked and entered the space station, and remained for three weeks. When they returned to Earth on June 29, 1971, an improperly closed valve allowed the Soyuz's atmosphere to vent into space. The three cosmonauts (Georgiy Dobrovolskiy, Vladimir Volkov, and Viktor Patsayev) were not wearing spacesuits and asphyxiated. The Soviets had eliminated the requirement for spacesuits because they had confidence in their technology, and three space-suited cosmonauts could not fit in the Soyuz as it was designed at that time. The Soyuz returned to flight 27 months later. The Soviets have required spacesuits since that time, and launched only two-person crews for the next 10 years until the Soyuz T version was introduced which could accommodate three cosmonauts in spacesuits.</p>
	<p>Other "First Generation" Salyut Space Stations (1974-1977) <i>Unnamed launch (1972)</i> did not reach orbit. <i>Salyut 2 (1973)</i> broke apart in orbit. <i>Kosmos 557 (1973)</i> broke apart in orbit. <i>Salyut 3 (1974)</i> hosted one crew (another was unable to dock) and was designated in the West as a military space station dedicated to military tasks. <i>Salyut 4 (1974-1975)</i> hosted two crews, and was designated in the West as a civilian space station. A third crew was launched to the space station, but the launch vehicle malfunctioned and the crew landed in Siberia (the so-called "April 5th anomaly" or Soyuz 18A). <i>Salyut 5 (1976-1977)</i> hosted two crews and was designated in the West as a military space station. A third crew was unable to dock.</p>

United States	Soviet Union/Russia
<p>Apollo-Soyuz Test Project (1975) Purpose: Cooperation with the Soviet Union. Flight: A three-man Apollo crew docked with a two-man Soyuz crew for two days of joint experiments to demonstrate “detente in space.” This was the last flight in the Apollo series. No Americans journeyed into space for the next six years while waiting for the debut of the space shuttle.</p>	<p>Soyuz-Apollo Test Project (1975) Purpose: Cooperation with the United States Flight: See column at left.</p>
<p>Space Shuttle (1981-present) Purpose: Reusable launch vehicle for taking crews and cargo to and from Earth orbit. Flights: <i>Pre-Challenger</i>. Twenty four successful shuttle missions were launched from 1981-1986. The shuttles were used to take satellites into space; retrieve malfunctioning satellites (using “Canadarm,” a remote manipulator system built by Canada); and conduct scientific experiments (particularly using the Spacelab module built by the European Space Agency). Sally Ride became the first American woman in space in 1983, Guion Bluford became the first African American in space in 1983, and Kathy Sullivan became the first American woman to perform an EVA in 1984. Senator Jake Garn and then-Representative (now Senator) Bill Nelson made shuttle flights in 1985 and 1986 respectively. Space Tragedy: On January 28, 1986, the space shuttle <i>Challenger</i> exploded 73 seconds after launch when an “O-ring” in a Solid Rocket Booster failed. All seven astronauts aboard were killed: Francis (Dick) Scobee, Mike Smith, Judy Resnik, Ellison Onizuka, Ron McNair, Gregory Jarvis, and Christa McAuliffe (a schoolteacher). The space shuttle returned to flight 32 months later. <i>Post-Challenger</i>. From September 1988-January 2003, the shuttle made 87 successful flights. Nine of these docked with the Russian space station Mir. Since 1998, most shuttle flights have been devoted to construction of the International Space Station. Space Tragedy: On February 1, 2003, the space shuttle <i>Columbia</i> broke apart as it returned to Earth from a 16-day scientific mission in Earth orbit. All seven astronauts aboard were killed: Rick Husband, William McCool, Michael Anderson, David Brown, Kalpana Chawla, Laurel Clark, and Ilan Ramon, an Israeli. The cause of the accident is under investigation.</p>	<p>“Second Generation” Salyut Space Stations (1977-1986) Purpose: Expand space station operations. The second generation space stations had two docking ports, enabling resupply missions and “visiting” crews that would remain aboard the space station for about one week visiting the long duration space station crews, who remained for months. These space stations were occupied intermittently over their lifetimes. <i>Salyut 6</i> (1977-1982) hosted 16 crews (two others were unable to dock). The Soviets increased the duration of human space flight to 185 days. The visiting crews often brought cosmonauts from other countries. The first non-U.S., non-Soviet in space was Vladimir Remek of Czechoslovakia in 1978. <i>Salyut 7</i> (1982-1986) hosted 10 crews. A new duration record of 237 days was set. Among the visiting crews was the second woman to fly in space, Svetlana Savitskaya. She visited Salyut twice (in 1982 and 1984), and on the second mission, become the first woman to perform an EVA. One crew that was intended to be launched to Salyut 7 in 1983 suffered a near-tragedy when the launch vehicle caught fire on the launch pad. The emergency abort tower on top of the launch vehicle propelled the Soyuz capsule away from the launch pad to safety. Unlike all the previous Soviet space stations, which were intentionally deorbited into the Pacific Ocean, Salyut 7 made an uncontrolled reentry in 1991, raining debris on Argentina. There was insufficient fuel for a controlled reentry.</p>

United States	Soviet Union/Russia
	<p>“Third Generation” Mir Space Station (1986-2001) The Mir space station was a modular space station with six docking ports. The core of the space station was launched in 1986. Additional modules were added through 1996. Mir hosted a large number of crews, and inaugurated the era of “permanently occupied” space stations where rotating crews were aboard continuously. Mir was permanently occupied from 1989 to 1999. A new duration record of 438 days was set. In 1991, following the collapse of the Soviet Union, the United States and Soviet Union increased cooperative activity in human spaceflight, including Russian cosmonauts flying on the U.S. shuttle, and American astronauts making multi-month stays on Mir. Nine U.S. space shuttles docked with Mir from 1995-1998. In 1997, a fire erupted inside Mir when a “candle” used to generate oxygen malfunctioned. That same year, a Russian cargo spacecraft (Progress) collided with Mir during a failed docking attempt. These events called into question the wisdom of keeping crews on Mir, but both the Russians and the Americans continued to send crews to the space station. Mir was intentionally deorbited into the Pacific Ocean in 2001.</p>
<p>International Space Station (1998-present) Purpose: Space Station Flights: The United States initiated the space station program in 1984. In 1988, nine European countries (now eleven), Canada, and Japan formally became partners with the United States in building it. In 1993, the program was restructured due to cost growth, and Russia joined the program as a partner. Construction began in 1998 and is currently suspended pending the space shuttle’s return to flight. Successive three-person crews have permanently occupied ISS since November 2000. The three-person crews are alternately composed of two Russians and one American, or two Americans and one Russian. ISS is routinely visited by other astronauts on Russian Soyuz spacecraft or the space shuttle (prior to the <i>Columbia</i> accident) some of whom are from other countries.</p>	<p>International Space Station (1998-present) See column at left.</p>