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NASA'S SPACE STATION PROGRAM: EVOLUTION OF ITS RATIONALE AND EXPECTED USES

Testimony before the
Subcommittee on Science and Space
Committee on Commerce, Science, and Transportation
United States Senate

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Madam Chairwoman, members of the subcommittee, thank you for inviting me to testify here today about the space station program. You asked that I focus my remarks on how the rationale behind the program has changed over the years, particularly in terms of its expected benefits — essentially, what was promised, and whether those promises are likely to be met under the current plan.

The space station program has been an international endeavor since its inception. Today, Russia, Canada, Japan, and 10 European countries[1] are partners with the United States in building the International Space Station (ISS). My testimony will not address how the non-U.S. partners have won support from their governments, or what benefits they expect, however. The focus here is on how NASA and the White House have explained the rationale for and expected benefits from the program to the U.S. Congress. My testimony would not be complete, though, without noting that the other partners are vital to NASA's use of the space station. NASA is dependent on Russia for crew and cargo transportation to and from ISS while the space shuttle is grounded. Under President Bush's Vision for Space Exploration, NASA will continue to be dependent on Russia to enable NASA astronauts to remain aboard the space station for long duration missions, and to have them there at all once the space shuttle is terminated in 2010. In addition, some of the research facilities that will be available to U.S. researchers are in Europe's Columbus module and Japan's Kibo module. Also, Japan is building a centrifuge and its accommodation module for NASA in exchange for NASA launching Japanese hardware. However, NASA reportedly is reconsidering whether it needs the centrifuge.

RATIONALE FOR AND EXPECTED USES OF THE SPACE STATION

Four Presidents have shaped the space station program — Ronald Reagan, George H.W. Bush, Bill Clinton, and George W. Bush — so I have separated this historical discussion into the time periods of those administrations. This is not meant to suggest that they were the only forces affecting the program. Congress has played a strong role in the space station's evolution through funding decisions and oversight. The two space shuttle tragedies — *Challenger* in 1986 and *Columbia* in 2003 — also impacted the program. Perhaps the biggest influence has been the incessant cost growth and schedule delays that have characterized the program since its earliest days. Assembly was originally planned for completion by 1994; now it is 2010. NASA estimated the space station would cost $8 billion

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[1] Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, and Switzerland. The United Kingdom signed the Intergovernmental Agreement that governs the program, but is not financially participating in it, so the number of participating European countries is sometimes listed as 11.

(FY1984 dollars) when it first came to Congress to obtain approval for the program. Congress now has appropriated approximately $35 billion (FY1985-2005, in current dollars), and NASA estimates it will cost another $10 billion through the end of construction in FY2010. (Estimates do not include shuttle launch costs.)

The cost growth and schedule delays over the past 21 years have subjected the space station to repeated downsizings and consequent reductions in its capabilities.

It is not possible in this short statement to review comprehensively the record of statements made to Congress by the White House and NASA about the rationale for building a space station and what could be expected from it. The examples herein are illustrative. For your convenience, I have summarized the various changes to the space station's configuration in a table appended to this statement.

Reagan Administration

The space station program, today known as the International Space Station (ISS), was formally initiated by President Ronald Reagan in his January 25, 1984 State of the Union Address. President Reagan directed NASA to build a permanently occupied space station "within a decade" and to invite other countries to join in the project. He explained his reasons for wanting to build such an orbiting facility in this way:

> America has always been greatest when we dared to be great. We can reach for greatness again. We can follow our dreams to distant stars, living and working in space for peaceful, economic, and scientific gain. Tonight, I am directing NASA to develop a permanently manned space station and to do it within a decade.
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> A space station will permit quantum leaps in our research in science, communications, in metals, and in lifesaving medicines which could be manufactured only in space. We want our friends to help us meet these challenges and share in their benefits. NASA will invite other countries to participate so we can strengthen peace, build prosperity, and expand freedom for all who share our goals.[2]

NASA officials at this time articulated the need for a new space station[3] by using the motto that it was "the next logical step" in the space program. Indeed, in 1969, Vice

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[2] Ronald W. Reagan. State of the Union Address. January 25, 1984. Text available on the University of California Santa Barbara (UCSB) American Presidency Project website at:[http://www.presidency.ucsb.edu/ws/index.php?pid=40205].

[3] The space station approved in 1984, and currently under construction, is NASA's second space station. The first NASA space station was Skylab, launched in 1973. Skylab was not intended to be permanently occupied. Visited by three 3-person crews in 1973-1974, it made an uncontrolled reentry through Earth's atmosphere in 1979, spreading debris on Australia and the Indian Ocean. The space station approved in 1984 was intended to go beyond Skylab, to a permanently occupied facility with sequential crews onboard year-round. Meanwhile, the Soviet Union had launched the world's first space station in 1971 (Salyut 1). By 1984 when President Reagan announced the plan to build NASA's space station, the Soviets were operating their sixth successful space station (Salyut 7). In 1986, they launched the first element of the modular Mir space station. Several other modules were added to the Mir complex over many years, and Mir was permanently occupied from 1989-1999 (including multi-month visits by seven NASA astronauts, and nine dockings between Mir and NASA's space shuttle). Mir made a controlled deorbit into the Pacific Ocean in 2001.

President Agnew had chaired a Space Task Group to recommend goals for the post-Apollo space program. Briefly, the plan was to build a space station, a reusable space transportation system to service it, and to send people to Mars. Budget constraints led President Nixon to approve only one element of that plan in 1972 — development of a reusable space transportation system, which became known as the space shuttle. NASA declared the space shuttle "operational" in 1982, and then was ready to proceed with the next step, building a space station.

Two months after the State of the Union Address, then-NASA Administrator James Beggs testified to the House Appropriations Committee that the cost estimate for the space station was $8 billion (FY1984 dollars), and identified the eight functions that the space station would serve:

- a laboratory in space, for the conduct of science and the development of new technologies;
- a permanent observatory, to look down upon the Earth and out at the universe;
- a transportation node where payloads and vehicles are stationed, processed and propelled to their destinations;
- a servicing facility, where these payloads and vehicles are maintained, and if necessary, repaired;
- as assembly facility where, due to ample time on orbit and the presence of appropriate equipment, large structures are put together and checked out;
- a manufacturing facility where human intelligence and the servicing capability of the Station combine to enhance commercial opportunities in space;
- a storage depot where payloads and parts are kept on orbit for subsequent deployments; and
- a staging base for more ambitious future missions.[4]

This original concept envisioned three separate space station facilities: an occupied base for eight crew members in a 28.5° orbit, an automated co-orbiting platform nearby, and an automated "polar platform" in orbit around Earth's poles (an orbit typically used for earth observations). By the fall of 1985, NASA had settled on a "dual-keel" design for the facility, with four laboratory and habitation modules. Over the next several months, NASA approved other details, including a few changes from that baseline design. Among the changes was reducing the number of U.S. modules from four to two (but the new U.S. modules would be larger so the total habitable volume was relatively unchanged), with plans for two more modules to be provided by Europe and Japan. NASA also agreed to add a U.S. Flight Telerobotic Servicer at congressional urging, to supplement Canada's planned Mobile Servicing System.

In 1985, as you may recall Senator Nelson, NASA's Associate Administrator for Space Station, Phil Culbertson, told you at a hearing you convened on the space station and space science, that a "fundamental concept upon which the space station has been and will continue to be defined is that it will be designed, operated, and evolved in response to user

[4] U.S. Congress. House. Committee on Appropriations, Subcommittee on HUD-Independent Agencies. Department of Housing and Urban Development — Independent Agencies Appropriations for 1985, Part 6, National Aeronautics and Space Administration. March 27, 1984. Washington, U.S. Govt. Print. Off., p. 8

requirements."[5] Mr. Culbertson explained that NASA had worked closely with prospective users for the previous three years, and established a Task Force on Scientific Uses of the Space Station, to advise NASA on what the scientific community wanted and needed. He listed the following as examples of the planned scientific uses: earth observations; astronomical observations; basic biological and physiological research, including the effect of long duration exposure to microgravity conditions; research on the processing and behavior of materials in microgravity, including crystals and pharmaceuticals (with research to be conducted on the occupied base, and full scale commercial production either on the occupied base or on spacecraft serviced from the occupied base); and applications and technology research such as advanced communications, energy conversion, propulsion, controls, and human factors.

Funding challenges, and the January 1986 Space Shuttle *Challenger* tragedy, soon impacted the space station design. In late 1986, the dual-keel design was reaffirmed, but emphasis was placed on building a single-keel first because of the reduction in the number of shuttle flights, and the reduced amount of cargo that would be allowed aboard the shuttle, in the wake of the *Challenger* tragedy. An emphasis on early accommodation of experiments, fewer spacewalks, an extended "safe haven" concept with the possibility for "lifeboats" for emergency return to Earth (not made a requirement at this time reportedly for cost reasons), and increased use of automation and robotics, were made part of the program.

In 1987, in response to continued cost growth, the program was split into two phases. Phase I, to be completed by 1996, would include a single keel of the occupied base (including the four modules), and the polar platform. The second keel, the co-orbiting platform, and solar dynamic power were deferred to Phase 2, on which further decisions were anticipated in 1991.

In 1988, Canada, Europe, and Japan formally joined the program after three years of negotiations. Canada agreed to build a Mobile Servicing System (Canadarm2), while Europe and Japan each agreed to build laboratory modules (Columbus and Kibo, respectively). The partners named the space station *Freedom*. In return for providing services such as electrical power and crew and cargo transport, NASA obtained utilization rights to half of the research facilities in the European and Japanese modules.

George H.W. Bush Administration

On July 20, 1989, six months after taking office, the senior President Bush made a major space policy address on the 20th anniversary of the Apollo 11 landing on the Moon. He called on the United States to return humans to the Moon and someday go to Mars. Space Station *Freedom* featured prominently in the President's vision for the future of the space program. This excerpt may be helpful in comparing the role envisioned for the space station as part of a program of human space exploration at that time, versus today. The senior President Bush said:

> In 1961 it took a crisis — the space race — to speed things up. Today we don't have a crisis; we have an opportunity. To seize this opportunity, I'm not proposing a 10-year

[5] U.S. Congress. House. Committee on Science and Technology. Space Science and the Space Station. September 24, 1985. Washington, U.S. Govt. Print. Off., 1985, p. 6.

> plan like Apollo; I'm proposing a long-range, continuing commitment. First, for the coming decade, for the 1990's: Space Station Freedom, our critical next step in all our space endeavors. And next, for the new century: Back to the Moon; back to the future. And this time, back to stay. And then a journey into tomorrow, a journey to another planet: a manned mission to Mars.
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> Each mission should and will lay the groundwork for the next. ...
>
> And to those who may shirk from the challenges ahead, or who doubt our chances of success, let me say this: To this day, the only footprints on the Moon are American footprints. The only flag on the Moon is an American flag. And the know-how that accomplished these feats is American know-how. What Americans dream, Americans can do. And 10 years from now, on the 30th anniversary of this extraordinary and astonishing flight, the way to honor the Apollo astronauts is not by calling them back to Washington for another round of tributes. It is to have Space Station Freedom up there, operational, and underway, a new bridge between the worlds and an investment in the growth, prosperity, and technological superiority of our nation. And the space station will also serve as a stepping stone to the most important planet in the solar system: planet Earth. ...
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> The space station is a first and necessary step for sustained manned exploration.... But it's only a first step. And today I'm asking ... Vice President, Dan Quayle, to lead the National Space Council in determining specifically what's needed for the next round of exploration. ... The Space Council will report back to me as soon as possible with concrete recommendations to chart a new and continuing course to the Moon and Mars and beyond.
>
> ... 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.[6]

Despite this glowing endorsement of Space Station *Freedom*, on a practical level, the program continued to experience cost and schedule problems, resulting in more changes that further reduced its capabilities. In 1989, the same year as the President's speech, NASA indefinitely postponed Phase 2, and the polar platform was transferred out of the space station program and into NASA's Office of Space Science and Applications.

By this time, five years after the program began, of the eight functions identified by Administrator Beggs in his 1984 testimony, only one remained: a single-keel occupied base to serve as a laboratory. Construction of that base was, in turn, divided into two phases: an "initial phase" with reduced capabilities (crew size was reduced from eight to four, electrical power reduced from 75 kw to 37.5 kw, and an open-loop instead of a closed-loop life support system would be used); and an "assembly complete" phase when full capabilities would be restored. NASA asserted that the capabilities envisioned in the 1987 Phase 2 program (dual-keel etc.) could still "evolve" sometime in the future to support expeditions to the Moon and Mars.

In 1990-1991, the space station was further downsized because of continued cost problems, weight growth, and growing estimates of the number of spacewalks needed for its

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[6] George H. W. Bush. Remarks on the 20th Anniversary of the Apollo 11 Moon Landing. Text available from the Bush Library website at:
[http://bushlibrary.tamu.edu/research/papers/1989/89072000.html].

construction. The U.S. modules were reduced in size from 44 feet to 27 feet in length; the total length of the facility was reduced from 493 feet to 353 feet; the Flight Telerobotic Servicer was canceled; crew size was formally reduced to four; and electrical power was formally reduced from 75 kw to 56 kw. A "lifeboat" was added to the station's design, but was not included in the cost estimate. The "assembly complete" designation was abandoned in favor of a concept that the station would continually evolve in an undefined and unbudgeted "follow-on phase."

The 1990-1991 downsizing raised concern in the scientific community. Among other things, the redesign excluded plans for a centrifuge. The Space Studies Board (SSB) of the National Research Council issued a report saying that the limited microgravity research that could be conducted on the redesigned station did not merit the investment required. The SSB said that while it strongly endorsed the need for a space station to study the physiological consequences of long-term space flight, the redesigned station did not have the necessary facilities to do so. It cited the following as "absolutely fundamental to the acquisition of the data necessary to determine the feasibility of long-term human space exploration" —

- a dedicated life sciences laboratory with adequate scientific crew to conduct research;
- a variable speed centrifuge of sufficient radius to accommodate small primates;
- sufficient numbers of experimental subjects (humans, plants and animals) to address the stated scientific goals; and
- sufficient laboratory resources, i.e. power, equipment, space, and atmosphere, to support the above research requirements.[7]

In testimony to this subcommittee on April 16, 1991, SSB Chairman Louis Lanzerotti noted that "For over twenty years, virtually every internal and external life sciences advisory group to NASA has emphasized the absolutely critical need for a centrifuge in space. A variable force centrifuge (VFC) is the single most important facility for space biology and medicine research."[8]

The White House Office of Science and Technology Policy issued its own report, which essentially agreed with the Academy's findings, and similarly emphasized the need for a centrifuge.[9] In response, NASA restored a 2.5 meter centrifuge to the design.

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[7] U.S. National Academy of Sciences. National Research Council. Space Studies Board. Space Studies Board Position on Proposed Redesign of Space Station Freedom. Letter report to NASA Administrator Richard Truly, March 14, 1991. pp 1-3.

[8] U.S. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. NASA's Plan to Restructure the Space Station Freedom. Hearing. April 16, 1991. S. Hrg. 102-268. Washington, U.S. Govt. Print. Off., 1997, pp. 52-53.

[9] White House. Letter from Dr. D. Allan Bromley, Assistant to the President for Science and Technology, to the Honorable Dan Quayle, Vice President of the United States. March 11, 1991. Dr. Bromley's report called not only for a centrifuge able to accommodate animals, but a larger one for human subjects.

Clinton Administration

As President Clinton took office in 1993, NASA announced $1 billion in cost growth in the Space Station *Freedom* program. In response, the President directed NASA to redesign the space station again to reduce costs. Many in the space community consider this to be the most crucial year in the space station's history, as the continued cost growth, schedule delays, and redesigns took their toll on congressional support for the program.

Ultimately, a scaled-down version of the *Freedom* design was selected. President Clinton issued a statement announcing the decision on June 17, 1993 that included the following rationale for proceeding with the program:

> At a time when our long-term economic strength depends on our technological leadership and our ability to reduce the deficit, we must invest in technology but invest wisely, making the best possible use of every dollar. That's why I asked for a review of NASA's space station program. ... I instructed NASA to redesign the space station program in a way that would preserve its critical science and space research and ensure international cooperation, but significantly reduce costs and improve management.
>
> NASA has met that challenge ...
>
> I am calling for the U.S. to work with our international partners to develop a reduced-cost, scaled-down version of the original Space Station Freedom. At the same time, I will also seek to enhance and expand the opportunities for international participation in the space station project so that the space station can serve as a model of nations coming together in peaceful cooperation....
>
> To make maximum use of our investments and meet the scientific goals we have set, the specific design we will pursue will be a simplified version of Space Station Freedom...
>
> There is no doubt that we are facing difficult budget decisions. However, we cannot retreat from our obligation to invest in our future. Budget cuts alone will not restore our vitality. I believe strongly that NASA and the space station program represent important investments in that future and that these investments will yield benefits in medical research, aerospace, and other critical technology areas. As well, the space station is a model of peaceful international cooperation, offering a vision of the new world in which confrontation has been replaced with cooperation.[10]

A week later, on June 23, 1993, the House voted to continue the space station program by a one-vote margin as it considered a NASA authorization bill. A week after that, on June 28, it voted to support the program by a somewhat wider (24 vote) margin when considering NASA's appropriations bill for that year. Two months later, on September 21, 1993, the Senate voted to continue the program 59-40.

By the time of the Senate vote, the space station had changed again, however. On September 2, Vice President Gore announced that Russia had agreed to join the space station partnership as part of broader cooperation in human space flight and other science and technology areas. Some of the expected benefits of bringing Russia into the space station

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[10] William J. Clinton. Public Papers of the President. June 17, 1993. Available from the Government Printing Office at: [http://www.gpoaccess.gov/pubpapers/index.html].

program were in the foreign policy arena and, while important, are not the focus of your hearing this morning, so I will not discuss them here. In terms of the capabilities of the new space station design, NASA said that, in comparison with the design announced in June 1993, the space station would be ready one year sooner, cost $2 billion less,[11] have 25% more usable volume and 42.5 kilowatts more electrical power, and accommodate six[12] instead of four crew members.

Mr. Daniel Goldin, the Administrator of NASA from 1992-2001, often stated that this redesigned space station — now referred to simply as the International Space Station (the name *Freedom* was dropped in 1993) — would have "world-class" research capabilities. In 1997, he articulated the expected scientific payoff in response to questions posed at a hearing before this subcommittee:

> ... We happen to be building a station in Earth orbit that has unique characteristics where we could do research in biomedicine, biotechnology, advanced materials, combustion research, advanced communications and advanced engineering and Earth science that we could do on no other platform.
>
> We already have results back from our very early missions on the Mir space station... [W]e have been getting absolute breakthroughs in the kind of science we have in the areas of cancer research, pharmaceutical research.
>
> We have even built a half-centimeter piece of human cartilage in the bioreactor .... We have done incredible research in combustion.
>
> The key to it is time on orbit and the absence of gravity. The International Space Station is going to provide that capacity.
>
> Furthermore, we're going to have exploration of space. ... In the process of understanding how people can adapt to space, we study healthy physiology in an abnormal environment and compare it to abnormal physiology or sick people in a normal environment here. This is yielding great results, and, in fact, it is so exciting that the American Medical Association has signed a cooperative agreement with NASA to take advantage of the International Space Station to help upgrade medical techniques right here on Earth.
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> ....This is a place where we use the absence of gravity to understand the laws of physics and chemistry and biology much better and rewrite textbooks.[13]

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[11] Initially, NASA and the White House said that Russia's participation would save 2 years and $4 billion, but later lowered it to 1 year and $2 billion. The estimated savings were based on the fact that NASA was spending about $2 billion per year on the program, so accelerating the schedule by one year would save that amount. For more information, see CRS Issue Brief IB93017.

[12] Although NASA said six at the time, the revised intergovernmental agreements that formally brought Russia into the program in 1998 call for a permanent space station crew of seven.

[13] U.S. Senate. Committee on Commerce, Science, and Transportation. Subcommittee on Science, Technology, and Space. International Space Station. Hearing. September 18, 1997. S. Hrg. 105-792. Washington, U.S. Govt. Print. Off., 1997, pp. 12-13.

After further discussion, he cautioned that "...I cannot tell you that I could give any American a cure for cancer...." or make other promises because NASA engages in long term, high risk research for which the payoff could be 10-20 years in the future.[14]

The basic design of the space station remained unchanged throughout the Clinton Administration. But cost growth and schedule delays remained a constant companion. In 1997, NASA began to shift funds from space station research into space station construction.

In 1998, the first two elements of the space station were launched. A 19-month hiatus followed, waiting for Russia to launch its "Service Module" that provides crew quarters. With the successful launch of the Service Module in 2000, successive space station crews took up residency, initiating permanent occupancy of ISS.

George W. Bush Administration

As President George W. Bush took office in 2001, NASA again announced significant cost growth, not unlike the situation when President Clinton took office in 1993. With space station construction already under way, redesign options were limited. The Bush Administration decided to truncate ISS construction at a phase called "core complete," which included the launch of certain U.S. components, and the hardware under construction by other ISS partners. The White House said that if NASA could demonstrate better program management, it would consider adding "enhancements" to the station later.

Three major U.S. elements were cancelled then or the next year: a Crew Return Vehicle for returning astronauts to Earth in an emergency; a Propulsion Module; and a Habitation Module. The Administration also cut the budget for space station research by $1 billion, and directed NASA to reprioritize its research program accordingly. NASA created a Research Maximization and Prioritization (ReMaP) Task Force to do so. Its report was completed in 2002.

Mr. Goldin, who remained Administrator for most of the first year of the Bush Administration, told the House Science Committee that the downscaled space station still would support the "high priority goals of: 1) permanent human presence in space, 2) accommodation of all international partner elements; and 3) world-class research in space."[15] One major concern was the decision to terminate the Crew Return Vehicle (CRV), which was needed if the crew size was going to increase from three to six or seven. The size of the crew was considered vital to the amount of scientific research that could be conducted there, since NASA estimated that it took "2 ½" astronauts to operate and maintain the facility, leaving only half of one person's time for research when the crew size was limited to three. Mr. Goldin said that "human-tended science would be greatly degraded" with a three-person crew, but he expressed hope that a solution would be found so that the larger crew size could be restored.[16]

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[14] Ibid, p. 15.

[15] U.S. Congress. House. Committee on Science. Space Station Cost Overruns. Hearing, April 25, 2001. Washington, U.S. Govt. Print. Off., p. 74.

[16] U.S. Congress. House. Committee on Science. Subcommittee on Space and Aeronautics. NASA (continued...)

Mr. Sean O'Keefe became NASA Administrator in December 2001, with a mandate, inter alia, to "fix" the space station program. Eleven months later, he won White House support to submit a FY2003 budget amendment that called for adding $706 million to the ISS program for 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.[17] In December 2002, he and the heads of the other partners' agencies agreed on a process for selecting a final ISS configuration by December 2003, including how to increase the crew size.

The crew size limitation is based on the number of astronauts who can be returned to Earth in an emergency by a single Russian Soyuz spacecraft. In this context, it is referred to as a "lifeboat" or "crew return" capability. Russia is committed to having one Soyuz docked with ISS at all times throughout its lifetime to serve as a lifeboat for three people. The U.S. Crew Return Vehicle (CRV) was to serve the same function for another four. The Bush Administration had terminated the CRV, however. Without it, the only option for augmenting lifeboat services is for Russia to provide additional Soyuz spacecraft. Each Soyuz can only remain in orbit for 6 months. Today, Russia launches two Soyuzes per year. To enable crew size to increase to six, it would have to launch four per year. Russian space officials said that they could not afford to build and launch the additional Soyuzes, and needed to be compensated. NASA, however, is not permitted to pay Russia for ISS-related activities unless the President certifies that Russia is not proliferating certain technologies to Iran under the Iran Nonproliferation Act.[18] The other partners did not offer to pay for the additional Soyuzes, leaving the situation in a stalemate, where it remains today.

Debate over the long term plans for the ISS was soon complicated by the February 1, 2003 space shuttle *Columbia* tragedy. The *Columbia* tragedy has affected the space station program in many ways. One outcome is that it led to a review of the reasons that the United States engages in human space flight at all. That review resulted in an announcement by President Bush of a new Vision for Space Exploration on January 14, 2004. The President said:

> Today I announce a new plan to explore space and extend a human presence across our solar system. We will begin the effort quickly, using existing programs and personnel. We'll make steady progress — one mission, one voyage, one landing at a time.
>
> Our first goal is to complete the International Space Station by 2010. We will finish what we have started, we will meet our obligations to our 15 international partners on this project. We will focus our future research aboard the station on the long-term effects of space travel on human biology. The environment of space is hostile to human beings. Radiation and weightlessness pose dangers to human health, and we have much to learn about their long-term effects before human crews can venture through the vast voids of

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[16] (...continued)
Posture. Hearing, May 2, 2001. Washington, U.S. Govt. Print. Off., p. 31.

[17] The ISS increases were proposed to begin in FY2004. By the time Congress deliberated the FY2004 budget, ISS construction was suspended because of the *Columbi*a tragedy, and Congress cut $200 million from the ISS budget. The budget amendment also initiated an Orbital Space Plane program that would have been able to take crews to and from ISS, but it was terminated a year later.

[18] The relationship between the ISS and the Iran Nonproliferation Act is discussed in CRS Report RS22072.

> space for months at a time. Research on board the station and here on Earth will help us better understand and overcome the obstacles that limit exploration. Through these efforts we will develop the skills and techniques necessary to sustain further space exploration.
>
> To meet this goal, we will return the Space Shuttle to flight as soon as possible, consistent with safety concerns and the recommendations of the Columbia Accident Investigation Board. The Shuttle's chief purpose over the next several years will be to help finish assembly of the International Space Station. In 2010, the Space Shuttle — after nearly 30 years of duty — will be retired from service.[19]

A NASA budget chart released the same day as the President's speech showed NASA completing its use of the space station by FY2017. Funds now devoted to the space shuttle and space station programs could thereby be redirected to fulfilling the "Moon/Mars" goals enunciated in the Vision. So although the *Columbia* tragedy was a catalyst for a new Vision for the human space flight program, if that Vision is implemented, it also would spell the end of the space shuttle and ISS programs (from a U.S. perspective that is; the other partners might continue to use ISS after NASA completes its utilization).

If the Vision is adopted, the full extent of its impact on U.S. use of ISS is not yet clear. What is known is that the scope of research would be narrowed to only that which supports the Vision; there would be fewer years during which NASA will conduct research[20]; and the shuttle would not be available to support scientific operations by taking experiments and equipment up to the ISS ("upmass") or back to Earth ("downmass") once construction is completed. NASA's ReMaP Task Force cited lack of upmass capacity as one of the limiting factors on conducting high priority research.

What is not known is details of the new research program and therefore what benefits can be expected from it, what the ISS crew size will be, whether the centrifuge will be completed, and what capabilities may be available from other partners or the U.S. commercial sector to take cargo to and from ISS instead of the shuttle.

Conclusion

The space station was originally presented to Congress as a facility that would have eight functions. Within five years, that had been reduced to one — a laboratory for world-class research. That research program has been affected by reductions in funding (in the late 1990s by shifting funds from research into construction, and in 2001 as part of the cost-cutting in response to cost growth in the overall program), and now by the direction of President Bush, narrowing the scope to only research that supports the Vision.

The extent to which space station research will "rewrite textbooks" as forecast by Mr. Goldin in 1997 remains to be seen.

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[19] President Announces New Vision for Space Exploration Program. Available at: [http://www.whitehouse.gov/news/releases/2004/01/20040114-3.html].

[20] Space Station Freedom was designed with a 30 year lifetime. When the program was redesigned in 1993, NASA shortened the operational lifetime of the new station to 10 years (the modules are designed for 15 years — 5 years during assembly, and 10 years of operation). Under the Vision, NASA officials say the agency will complete its use of the ISS by 2016, six years after construction is completed.

Major Program Changes to the U.S. Portion of the International Space Station*

CALENDAR YEAR	NATURE OF CHANGE	REASON
REAGAN ADMINISTRATION		
Fall 1985-May 1986	Original space station concept envisioned three elements: an occupied base for 8 crew members in a 28.5° orbit, an automated co-orbiting platform nearby, and an automated "polar platform" in orbit around Earth's poles. The original reference design for the occupied base was called the "Power Tower," but a "dual-keel" approach was chosen instead as the baseline design in the fall of 1985; the details were approved by NASA in May 1986. Changes included: arrangement of truss structure and modules modified to place modules at center of gravity; solar dynamic power added to photovoltaic arrays; number of U.S. laboratory and habitation modules reduced from 4 to 2, with plans for 2 more provided by Europe and Japan (the new U.S. modules would be larger than the original design, however, so total habitable volume relatively unchanged); U.S. Flight Telerobotic Servicer added at congressional urging to supplement Canada's planned Mobile Servicing System.	Cost and user requirements. NASA stated that the dual-keel design would provide a better microgravity environment for scientists, more usable area for attached payloads, and better pointing accuracy. Cost estimate maintained at $8 billion ($FY1984).
Late 1986	Dual-keel design reaffirmed, but emphasis on building single-keel first in recognition of reduced availability of shuttle flights and reduced amount of cargo that would be allowed aboard the shuttle in the wake of the Challenger tragedy. Emphasis on early accommodation of experiments; fewer spacewalks; extended "safe haven" concept with the possibility for "lifeboats" for emergency return to Earth (not made a requirement at this time reportedly for cost reasons); increased use of automation and robotics; "lead center" management approach replaced with dedicated program office for the space station in Reston, VA.	January 1986 space shuttle Challenger tragedy and concern by astronauts at Johnson Space Center about the number of hours of spacewalks, or "EVAs"; quality and quantity of living space; standard of safety for "safe havens" (to which astronauts would retreat in emergencies such as depressurization or dangerous sunspot activity); lack of "lifeboats" for emergency return to Earth when the space shuttle was not docked with the station. Cost estimate unchanged.

CALENDAR YEAR	NATURE OF CHANGE	REASON
1987	Program split into "phase 1" and "phase 2," with single keel of occupied base built in phase 1 and second keel delayed until phase 2; polar platform part of phase 1; co-orbiting platform and solar dynamic power pushed into phase 2.	Rising program costs and expected budget constraints. Cost estimate had risen to $14.5 billion ($FY1984) for research and development. New design estimated to cost $12.2 billion ($FY1984) for Phase 1 and $3.8 billion ($FY1984) for Phase 2, saving money in the near term, but costing more in the long term.
GEORGE H. W. BUSH ADMINISTRATION		
1989	Phase 2 indefinitely postponed; polar platform transferred from space station program to NASA's Office of Space Science and Applications (was for earth observation studies). Only remaining element is single-keel occupied base, divided into an initial phase with reduced capabilities (e.g. crew reduced from 8 to 4; electrical power reduced from 75 kw to 37.5 kw; use of open-loop instead of closed-loop life support system) and an assembly complete phase when "full capabilities" would be restored. NASA asserted that the capabilities envisioned in the 1987 Phase 2 program (dual-keel etc.) could still "evolve" sometime in the future to support expeditions to the Moon and Mars.	Cost growth and expected budget constraints. NASA termed this a "rephasing." Cost for Phase I estimated at $19 billion real year dollars,* or $13 billion FY1984 dollars, for R&D; NASA estimated total program costs through assembly complete at $30 billion real year dollars.
1990-1991	U.S. modules reduced in size (from 44 feet to 27 feet); "pre-integrated truss" chosen in effort to reduce EVA requirements; total length reduced (from 493 feet to 353 feet); Flight Telerobotic Servicer canceled; crew size formally reduced to 4; electrical power reduced (from 75 kw to 56 kw); "lifeboat" added to the station's design but not included in the cost estimate; "assembly complete" designation abandoned with concept that station would continually evolve in an undefined and unbudgeted "follow-on phase."	Beginning in 1990, concerns developed over rising program costs, weight, and too many EVAs for maintenance. In Dec. 1990, NASA estimated program costs through assembly complete at $38.3 billion real year dollars. Congress directed NASA to restructure the station. New plan released in March 1991. NASA stated it would cost $30 billion real year dollars through 1999, though this was no longer the time when assembly would be completed (see column to the left). GAO estimated total program costs through 30 years of operation at $118 billion.

CALENDAR YEAR	NATURE OF CHANGE	REASON
CLINTON ADMINISTRATION		
1993	Space Station Freedom program terminated. New design developed (initially called Alpha), which NASA said would use 75% of Freedom's hardware and systems. Russia added as another international partner in a second phase of the 1993 activity. Program renamed International Space Station Alpha, and, later, simply International Space Station (ISS). Two U.S., 1 European, 1 Japanese, and 5 Russian modules (3 for science) accommodate crew of 6; Canada to build Mobile Servicing System; station located in 51.6^{o} orbit (to allow access from Russia); operating period shortened from 30 to 10 years and annual operating costs reduced; "assembly complete" designation reinstated (but no "follow-on phase" or "evolution" or capabilities envisioned by the 1987 Phase 2 plan); space station management changed to "host center" (later "lead center") at Johnson Space Center, TX; Reston, VA office closed.	Cost growth and foreign policy considerations. There were two phases of space station program changes in 1993. The first (February-September) was prompted by $1.08 billion cost overrun (which NASA termed "cost growth") and resulted in a new design, tentatively called Alpha, involving the original space station partners (U.S., Canada, Europe and Japan). This design was released on Sept. 7, but 5 days earlier, the White House announced plans to merge the space station program with Russia's primarily for foreign policy reasons. In November, a new "Russian Alpha" design was announced including Russia as a partner. NASA said with Russian involvement, "Russian Alpha" would be ready 1 year sooner, cost $2 billion less (a figure GAO disputes), and have more scientific utility than the Sept. 7 Alpha version. NASA's current estimate of program costs for FY1994-2002 (assembly complete) is $17.4 billion real year dollars, not including launches or civil service salaries (adding those costs would raise it to $47.9 billion, using average shuttle costs). Monies spent prior to FY1993 ($11.4 billion) and operational costs for 10 years ($13 billion) are not included. [All funding figures from NASA.]

CALENDAR YEAR	NATURE OF CHANGE	REASON
GEORGE W. BUSH ADMINISTRATION		
2001-2002	ISS construction to be terminated after completion of "U.S. Core" and attachment of European and Japanese modules. Propulsion Module canceled. Habitation Module and Crew Return Vehicle indefinitely deferred pending demonstration of improved program management (later canceled). Could mean that crew size would be limited to 3 instead of 6 or 7 because only one Russian Soyuz (which can accommodate 3) would be available as a lifeboat. Smaller crew size would limit amount of science that could be conducted. Funding for research program cut $1 billion cut. At December 2002 "Heads of Agency" meeting, partners agree that crew size should be restored to six, but no details on how to accomplish it.	Cost growth of $4 billion over estimate made in its FY2001 budget submission. ISS had been estimated to cost $17.4 billion (real year dollars) when it began in 1993 (FY1994). NASA's estimate rose to $21.3 billion and then $22.7 billion in 1998, to $23.4-26 billion in 1999, and to $24.1-26.4 billion in 2000. NASA's March 2001 plan to discontinue construction after the "U.S. Core" is completed and attachment of the European and Japanese module results in a cost estimate of $22-23 billion and a "completion" date of November 2003-October 2004. Hardware being built for NASA by Europe and Japan (Node 3 and Centrifuge Accommodation Module, respectively) as part of barter agreements could be launched if NASA has sufficient funding for integration costs.
2004	Construction of ISS to be completed by 2010, and shuttle program thereupon to be terminated, so shuttle will not be available during the ISS operational phase to rotate crews, bring supplies or new equipment and experiments, return results of experiments, or return equipment needing repair. U.S. ISS research program to be reformulated to support only the Vision. If crew size is to increase, will be via additional Soyuz spacecraft, but no details on how to accomplish that (NASA prohibited from making payments to Russia for ISS because of the Iran Nonproliferation Act). New Crew Exploration Vehicle (CEV) to be built to take crews to the Moon; Earth-orbit capability by 2014. Between 2010 (when shuttle is terminated) and 2014, U.S. will rely on Russia for crew transport to ISS. NASA to rely on other partners, and U.S. commercial sector, to take cargo to and from ISS after shuttle retirement. No commitment to use CEV to service ISS, although it is an option. According to NASA budget chart, U.S. use of ISS to end by FY2017.	President Bush's announcement of the Vision for Space Exploration, which directs NASA to focus its activities on returning humans to the Moon by 2020 and someday sending them to Mars and "worlds beyond."

Notes:

Prepared by CRS, based on information from NASA, historical CRS publications, congressional hearings, and articles in the trade press.

* According to NASA's budget books (e.g., page SI-6 of the FY2001 budget book), estimates in "real year dollars," reflect current and prior year spending unadjusted for inflation, plus future year spending that includes a factor accounting for expected inflation.