



NASA'S SPACE STATION PROGRAM:
EVOLUTION AND CURRENT STATUS

TESTIMONY BEFORE THE
HOUSE SCIENCE COMMITTEE

APRIL 4, 2001

Marcia S. Smith
Specialist in Aerospace and Telecommunications Policy
Congressional Research Service

Mr. Chairman, Members of the committee, thank you for inviting me to testify today about the International Space Station program. You asked that I address two specific questions: what are the highlights of and major milestones for the space station program, and the history of its cost growth and schedule delays. Essentially you have asked— where is the program today and how did it get there?

EVOLUTION OF THE SPACE STATION PROGRAM: JANUARY 1984-JANUARY 2001

The space station program began 17 years ago. The program has had its share of ups and downs during that time. The story is quite complex. I have organized the program's history into several "eras," tied to four key years: 1984 when it began; 1991 when the House held its first floor vote on whether to terminate it; 1993 when it survived in the House by a one-vote margin, and, later, Russia joined the program; and 1998 when construction began. Two tables are appended to this statement that provide more detail on changes to the design, schedule, and cost estimates for the program.

1984-1990 The Program Begins, the Challenger Tragedy, International Partners Join, Repeated Cost Growth and Redesigns

In his January 25, 1984, State of the Union address, President Reagan directed NASA to build a space station within a decade and to invite other countries to join the United States in the endeavor.

Thus began NASA's ongoing space station program.¹ NASA had wanted permission to build a space station that could be permanently occupied by rotating crews since the late 1960s. Budget constraints, however, forced the agency to choose between a space station and a reusable space transportation system—the space shuttle. NASA decided to build the shuttle first. Soon after the first shuttle launch in 1981, NASA intensified efforts to win approval for a permanently occupied space station. President Reagan's 1984 speech was the culmination.

NASA estimated it would cost \$8 billion to build the space station, which at that time was envisioned as three separate orbital facilities: an occupied base for the crew and two automated platforms for scientific experiments and Earth observations. The cost estimate grew rapidly. Throughout the rest of the 1980s, NASA and Congress struggled to contain program costs. Redesign followed redesign. The automated platforms were deleted from the plan, and the occupied base was scaled back. Cost growth drove the redesigns, but the 1986 space shuttle *Challenger* tragedy also caused NASA to reassess the design. Among the changes was a decision to build a "lifeboat" capability to ensure the astronauts could return to Earth in an emergency.

During this period, the program was confined to the design phase. Little progress was made in actually building a space station. There was progress in other areas, though, particularly in bringing Europe, Canada, and Japan into a partnership with NASA to build the space station as an international undertaking. Formal agreement was reached in 1988. The partners decided to name the space station *Freedom*.

¹ NASA had an earlier space station, Skylab, from 1973-1974. Skylab was not designed to be permanently occupied. Three 3-man crews visited that station, one remaining for 84 days, a record at that time. Skylab made an uncontrolled reentry in 1979, raining debris on the Indian Ocean and Australia.

In July 1989, six months after taking office, President George H. Bush gave a speech commemorating the 20th anniversary of the Apollo 11 landing on the Moon. In that address, he committed the United States to returning humans to the Moon and going on to Mars, and endorsed the space station as the cornerstone of that effort. The *Freedom* program, however, was still experiencing cost growth and other problems, such as increased weight and growing requirements for spacewalks for in-orbit assembly. In 1990, Congress directed NASA to redesign it again. By December 1990, the cost estimate had grown to \$38.3 billion, though it was difficult to compare with the original \$8 billion estimate since they were expressed in different year dollars, and the larger figure included shuttle launches and other costs.

1991-1992 Growing Concern in Congress, Renewed U.S.-Russian Space Cooperation

NASA released its redesign of *Freedom* in March 1991, with a new cost estimate of \$30 billion (including launches). Congressional concern remained. Later that year, for the first time, a House floor vote was held specifically on the fate of the program after the House Appropriations Committee recommended its cancellation. That recommendation had come from the chairman of the VA-HUD-IA subcommittee (which funds NASA), Representative Traxler. On the floor, an amendment was offered by Representatives Chapman and Lowery to continue the program. The amendment was adopted 240-173, and the program survived. That was the first of 22 specific votes so far in Congress (14 in the House, 8 in the Senate) in NASA funding bills on whether to terminate the program. Each time, Congress has voted to continue it.

In 1992, following the collapse of the Soviet Union, President George H. Bush rejuvenated U.S.-Russian space cooperation. Among other initiatives, the two countries agreed to launch a Russian cosmonaut on the U.S. shuttle and an American astronaut to Russia's space station *Mir*, with a docking between the U.S. shuttle and *Mir*.

1993-1997 \$1 billion in Cost Growth, *Freedom* Replaced with International Space Station (ISS) Program, One-Vote Margin in House, Russia Joins as a Partner

In January 1993, as President Clinton took office, NASA announced more cost growth in the *Freedom* program. President Clinton directed NASA to redesign the station again to reduce costs. By the summer, a new design was beginning to emerge, but was not finalized when the House was ready to vote on NASA's FY1994 funding bills. What was known was that the *Freedom* program had been terminated, and would be replaced by a less expensive design. By then, NASA had spent \$11.2 billion on *Freedom*. Little hardware had been built, and none had been launched. The White House expressed support for the newly emerging design, but limited its funding commitment to \$2.1 billion a year for the next five years. Many in Congress were concerned about the program's direction. In June 1993, the House voted to continue the program by a one vote margin (215-216), defeating an amendment by Representative Roemer to the FY1994 NASA authorization bill to end the program. A week later, Representative Roemer tried again on the FY1994 VA-HUD-IA appropriations bill; that amendment failed by a wider margin (196-220).

The new design was released on September 7, but it had been preempted 5 days earlier by a dramatic announcement from the Clinton White House—Russia would join the space station program as a partner. Russia's participation had been contemplated during the redesign process, but as a supplier, not a partner. The Clinton Administration increased the number of joint flights that had been announced by President Bush, and vastly expanded the nature of the cooperation by essentially merging the U.S. and Russian space station programs. Russia agreed to build several modules including two that form the basis of the station (NASA agreed to pay for one of them), and

to launch two Soyuz spacecraft a year to serve as “lifeboats” and several Progress spacecraft per year to “reboost” the station periodically to keep it in the correct orbit. These Russian-built elements are critical to the design of the space station, and require a continuing commitment by Russia. The Clinton Administration’s motivation in bringing Russia into the space station program appears to have been rooted in foreign policy issues, among them the desire to convince Russia to abide by the Missile Technology Control Regime (MTCR) to stop ballistic missile proliferation. Russia’s decision to abide by the MTCR was announced at the same time as the space station cooperation.²

NASA said that the agreement was beneficial to the space station program, too, and would save \$2 billion and 1 year of schedule compared with the design it had just developed. The new “International Space Station” (ISS) program, including Russia, was estimated to cost \$17.4 billion.

Some argued that President Clinton’s decision to bring in Russia saved the program because its new foreign policy dimension attracted votes in Congress. Others contended that Russia might doom the program because of uncertainty as to whether it would be able to fulfill its sizeable commitments to the program. Shortly after the announcement that Russia would join the program, the Senate voted on the FY1994 VA-HUD-IA appropriations bill. A Bumpers amendment to terminate the program was defeated by 19 votes, the closest margin of any of the eight Senate votes on space station from 1991-1998.

From the beginning, challenges arose with Russia’s participation. Many promises were made by high ranking Russian government officials that sufficient funding would be provided to fulfill Russian commitments to ISS. Most were not kept. NASA initiated contingency plans to cope with the possibility that Russia might not build or launch elements that were in the critical path, including the Zvezda Service Module which provides crew quarters and guidance, navigation and control (GN&C) functions. Russia’s ability to provide sufficient Soyuz “lifeboat” spacecraft and Progress “reboost” spacecraft also was questioned. Funding for Russia’s space program was under severe stress, and construction of Zvezda, for which Russia was expected to pay, was significantly delayed.

After three years of insisting that it could build ISS for \$17.4 billion, in September 1997, NASA finally conceded it could not. Cost overruns on Boeing’s contract and the need for an additional \$430 million for NASA in FY1998 were announced. NASA began transferring funds from other NASA programs into space station construction.

On the positive side, however, construction of ISS hardware was finally underway and NASA was engaged in the shuttle-*Mir* program with Russia. U.S. shuttle dockings with *Mir* became routine, and American astronauts joined Russian cosmonauts aboard *Mir* for long duration (several month) missions. NASA gained significant operational experience that included learning to cope with emergency situations such as a fire, and a collision between *Mir* and a cargo spacecraft.

1998-January 2001 Chabrow Committee Reviews Program, In-Orbit Assembly Begins, More Cost Growth, Congress Legislates a Cap

Following the cost growth announced in late 1997, NASA convened an independent “cost assessment and validation team” headed by Jay Chabrow. The Chabrow committee concluded that the station could cost up to \$24.7 billion and take 10-38 months longer to build than NASA

² More information on the reasons for bringing Russia into the space station program are discussed in CRS Issue Brief 93017.

estimates. NASA did not accept those findings in their entirety, but agreed that it would take longer to build and cost \$1.4 billion more, bringing NASA's estimate at that time to \$22.7 billion.

Amidst these announcements of increased costs and delayed schedules, in-orbit assembly of the space station finally began. Almost 15 years after President Reagan's speech initiating the space station program, in November and December 1998 the first two segments were launched. First was the Zarya (Dawn) module, built and launched by Russia, but paid for by NASA. Second was the Unity module, which was built, launched, and paid for by NASA.

The launches of Zarya and Unity were good news, but they were followed by a 19 month hiatus because of Russian delays in building the Zvezda module, for which Russia itself was expected to pay. Without it, crews could not remain on the space station without the shuttle being present. In July 2000, Zvezda was successfully launched and the gates were opened for ISS assembly. The U.S. laboratory module, Destiny, has now been added, along with solar arrays to provide electricity to the station, and Control Moment Gyros (CMGs) to keep the station oriented properly.

The first crew, Expedition 1, took up residence in November 2000. The Mission Commander was American Bill Shepherd. He was joined by two Russians: Soyuz Commander Yuri Gidzenko and Flight Engineer Sergei Krikalev. Crews rotating on 4-6 month shifts are expected to continue through the lifetime of the station, conducting research in a variety of scientific disciplines.

Continuing attempts in the House to terminate the space station failed during this time period, with increasingly wider margins. The most recent House vote, in June 2000, defeated a Roemer amendment to the FY2001 VA-HUD-IA appropriations bill by a vote of 98-325. There have been no Senate floor votes on terminating the station since the retirement of Senator Bumpers, who had spearheaded such attempts, in 1998.

However, Congress did enact a cost cap on the station, including in the conference version of the FY2000-2002 NASA authorization act (P.L. 106-391) a Senate-passed provision limiting development costs to \$25 billion and associated shuttle launch costs to \$17.7 billion. According to the Act, the cap does not apply to operations, research, or crew return activities subsequent to substantial completion of the ISS (defined as when development costs comprise 5% or less of the total ISS costs for the fiscal year). Contingency funds of \$5 billion for development and \$3.5 billion for launch were also provided, although those funds may only be used for the following contingencies: lack of performance or termination of participation of any of the international partners; loss or failure of a U.S.-provided element during launch or on-orbit; on-orbit assembly problems; new technologies or training to improve safety on ISS; or the need to launch a shuttle to ensure the safety of the crew or maintain the integrity of the station.

ISS PROGRAM STATUS TODAY

Assembly of the space station is continuing. The first crew exchange took place in March 2001, and one Russian (Commander Yuri Usachev) and two Americans (Flight Engineers James Voss and Susan Helms) now are aboard. The first research "rack" has been delivered. According to NASA, Russia appears to have sufficient funding to provide Soyuz and Progress spacecraft for this year and 2002, but Russian funding constraints and the overall relationship between Russia and the United States continue to add an element of uncertainty to the program's future.

Of more immediate note, President George W. Bush's "budget blueprint" revealed \$4 billion in cost growth for FY2002-2006, which would exceed the legislated cap. NASA insists that the figure is still being "scrubbed" and the final amount may be \$2-3 billion instead. Even the lower

figure represents a significant level of growth that many find all the more surprising because it is occurring so late in the program. Much of the U.S. hardware has been built and in-orbit assembly is underway. Many had assumed that, barring a catastrophe, the program was past its major cost hurdles. Instead, NASA now says that a “bow wave” of requirements had built up over the years that now are coming due.

Congress is now facing a proposal from NASA to take actions to reduce costs and stay within the legislated cost cap. I know these will be addressed by Mr. Goldin, so I will only briefly summarize them here. NASA is still assessing the extent of the cost growth and options for addressing it, so this represents a work in progress. Mr. Goldin may have more details in his testimony today. What is being considered includes:

- Terminating ISS construction after completion of the “U.S. Core” and launch of the European and Japanese laboratory modules. Several segments of the station scheduled for launch after the U.S. Core is completed (defined by NASA as the launch of Node 2) are being built for NASA by Europe and Japan as part of barter agreements. Node 3 and a Cupola are being built by Europe, and a centrifuge and its associated Centrifuge Accommodation Module by Japan, in exchange for NASA launching the European and Japanese laboratory modules. The fate of these elements is unclear, since if they are canceled, NASA would have to renegotiate the barter agreements. Also, the costs to integrate them onto the space station may be sufficiently small that they can be accommodated within NASA’s proposed revised budget. Many in the scientific community consider the centrifuge to be one of the premier pieces of scientific equipment planned for the space station.
- Indefinitely postponing the U.S. Habitation Module (the “Hab”) and the Crew Return Vehicle (CRV) and canceling the Propulsion Module. Without the Hab and CRV, crew size could be limited to three instead of six or seven, with consequent impacts on the amount of scientific research that can be conducted. NASA estimates that it takes “2 ½” people to operate the station, so only half of one person’s time would be available for research. The Propulsion Module was initiated by NASA to reduce dependence on Russia for reboost. NASA has canceled it already. The European Space Agency (ESA) is planning to build an Automated Transfer Vehicle which could fulfill this function and is expected to be available in 2004. NASA apparently plans to rely on Europe as a backup to Russia for this purpose.
- Reducing the ISS scientific research budget by 40%.

It must be noted that the \$4 billion cost growth estimate is accompanied by a list of “threats” that might materialize, possibly resulting in additional cost growth in the future.

SYNOPSIS OF COST GROWTH AND SCHEDULE DELAYS

The two tables appended to this statement provide details on cost growth and schedule delays in the space station program over the past 17 years.

Briefly, when NASA began the space station program in 1984, space station assembly was expected to be completed by 1994. By the time NASA terminated that design in 1993, that date had stretched to 2000. In 1993 when NASA announced initiation of the current ISS design, assembly was to be completed in 2002. That date has slipped to 2006. If compared to the original

expectations in 1984, the current completion date is a 12 year delay. Compared to what was initially promised for this design in 1993, it is a 4 year delay.

As Appendix 1 explains, comparing the costs for the space station is extremely difficult since over the years what is included in those estimates has changed significantly. The \$8 billion estimate provided in 1984 was expressed in FY1984 dollars (as if all the funds were paid out that year). The estimate for the current design has grown from \$17.4 billion in 1993 to \$28-30 billion today. Both of those figures are expressed as “real year dollars,” which according to NASA reflect current and prior year spending unadjusted for inflation, plus future year spending that includes a factor accounting for expected inflation. The estimates for the original design in 1984, and for the current ISS design, are similar in that neither includes costs for launching the station into orbit, civil service salaries, or operational costs. They are dissimilar in that they reflect significantly different designs, with the current ISS design providing many fewer capabilities than the 1984 design.

Focusing on cost growth for the current ISS design, the \$17.4 billion estimate in 1993 has grown to \$28-30 billion today, an increase of 61-72%. The growth occurred in stages. NASA maintained the \$17.4 billion estimate until March 1998 when the agency announced that its new estimate was \$21.3 billion. That cost growth led NASA to initiate the review by the Chabrow committee. Although NASA did not accept all of the Chabrow committee’s findings, the agency raised its own estimate to \$22.7 billion later in 1998. That figure grew to \$23.4-26 billion in 1999, and to \$24.1-26.4 billion at this time last year. The \$28-30 billion figure today reflects the recently announced \$4 billion in cost growth. NASA spent \$15.8 billion on ISS from FY1994-2000; \$2.1 billion was appropriated for FY2001.

CONCLUSION

Mr. Chairman, you asked where the space station program is today. The brief answer is that assembly is underway and crews have begun working aboard the station, but the program finds itself in a familiar situation—experiencing significant cost growth. Congress once again is faced with difficult choices about how to proceed with the program.

Congress has steadfastly supported the program— though sometimes with very close vote margins—through these many years. The questions Congress will need to address this year are whether to insist that NASA stay within the cap imposed last year or to relax that cap or permit the cost increase to be covered by the contingency funds. If the decision is made to retain the cap, questions are likely to arise about how to cope with the risk of continuing dependence on Russia and the impact of potentially reducing the amount of research that can be conducted there. If the cap is relaxed, the issue would remain of where additional funding might be found. Congress may also decide to direct NASA to build some, but not all, of the capabilities currently under review. For example, the decision could be made to build the Crew Return Vehicle, but not the Habitation Module.

The choices are difficult, and there are no guarantees that, whatever decision is reached this year, Congress will not be presented with announcements of further cost growth in the future. That is one aspect of the space station program that has remained constant throughout the past 17 years.

Appendix 1: Space Station Cost Estimates: 1984-2001

Table 1 shows cost estimates used by NASA since 1984 (FY1985) to represent the cost of the U.S. portion of the space station program. These numbers are not directly comparable with each other, however. Hence, caution must be used in comparing these estimates.

For example, the \$8 billion estimate from 1984 was only for research and development, and was expressed in FY1984 dollars. In the FY1988 NASA authorization bill, however, Congress directed NASA to include other costs in the estimate, including, for example, marginal shuttle launch costs during assembly, tracking and data services, the since-canceled Flight Telerobotic Servicer, and ground test facilities. Subsequent estimates for the *Freedom* program therefore included those additional items. Also, NASA began expressing the estimates in “real year dollars,” which in NASA parlance means that funding shown for previous years is not adjusted for inflation, while estimates of future year funding are adjusted for inflation. For the on-going International Space Station program, NASA returned to the practice of not including launch costs, for example, but includes the costs of science experiments, which were not included in cost estimates for *Freedom*.

Another complication when comparing the original \$8 billion cost with today’s estimates is that the original design was not only for an occupied base where astronauts would live and work, but two automated platforms as well (one in an orbit near the space station for scientific research and one in an orbit around Earth’s poles for earth observations). Other content changes also were made. Thus the \$8 billion was an estimate for a much more capable set of space facilities than only the occupied base being built today.

The estimates from FY1985-2000 are either through “assembly complete” or “permanent human occupancy,” and do not include operational costs past those dates. “Assembly complete” is the date when the space station would be completely assembled. “Permanent human capability” (PHC) was a benchmark NASA used for budgeting and scheduling purposes beginning with the March 1991 redesign through the end of the *Freedom* program in 1993. PHC denoted when a crew could remain aboard the station year-round without the space shuttle attached. NASA explained that it was using PHC instead of assembly complete to illustrate that the space station would continually evolve in an undefined and unbudgeted follow-on phase, and hence would not be “complete” at a particular point in time. With the advent of the International Space Station program, NASA returned to the practice of using an “assembly complete” date. However, in FY2000, NASA added another benchmark, “Development Complete,” to denote when a 6- or 7-person research capability would begin. (Although NASA said ISS would accommodate 6 people, for several years it has suggested that 7 could be accommodated if an appropriately designed Crew Return Vehicle was available.) For FY2000 and FY2001, NASA listed both dates with accompanying schedule and cost estimates. Only the estimates for assembly complete are shown in Table 2.

In March 2001, following additional cost growth in the program, NASA has proposed terminating construction of ISS after completion of the “U.S. Core,” defined as the launch of “Node 2,” followed by the attachment of the European and Japanese lab modules. NASA has released a new schedule and cost estimate using that as the benchmark, as shown in the final entry to this table. Since NASA’s decision has not been approved by Congress, it is shown as “under discussion.”

Table 1: NASA's Cost Estimates For The U.S. Portion of the Space Station: 1984-2001

Year	Estimate*
1984	\$8 billion (FY1984 dollars, R&D only, no shuttle launches).
April 1987	\$16 billion, following restructuring in which program was split into two "phases": \$12.2 billion for Phase I; \$3.8 billion for Phase II (FY1984 dollars, R&D only, no shuttle launches).
April 1989	\$30 billion for Phase I (real year dollars (RYD),* through assembly complete, including shuttle launches during assembly and other costs—such as the Flight Telerobotic Servicer and ground facilities). Phase II "indefinitely postponed," so not included in this or subsequent cost estimates.
Early 1990	\$37 billion (RYD, through assembly complete, including shuttle launches during assembly and other costs).
December 1990	\$38.3 billion (RYD, through assembly complete, including shuttle launches during assembly and other costs).
March 1991	\$30 billion (RYD, through permanent human capability, including shuttle launches during assembly and other costs).
Nov. 1993	\$17.4 billion, following termination of <i>Freedom</i> and initiation of International Space Station (RYD, development costs through assembly complete, no shuttle launches, includes costs for science experiments).
March 1998	\$21.3 billion (RYD, development costs through assembly complete, no shuttle launches, includes costs for science experiments).
April 1998	<i>Not a NASA estimate, but independent "Cost Assessment and Validation Team" headed by Jay Chabrow concludes cost could be \$24.7 billion through assembly complete.</i>
June 1998	\$22.7 billion (RYD, development costs through assembly complete, no shuttle launches, includes costs for science experiments). NASA did not accept the Chabrow figure, but agreed the program would cost \$1.4 billion more.
February 1999	\$23.4-26 billion (RYD, development costs through assembly complete, no shuttle launches, includes costs for science experiments).
February 2000	\$24.1-\$26.4 billion (RYD, development costs through assembly complete, no shuttle launches, includes costs for science experiments).
March 2001 (Under Discussion)	\$22-23 billion, assuming termination of construction after completion of "U.S. Core" and attachment of European and Japanese lab modules (RYD, development costs through completion of the "U.S. Core"; no shuttle launches; includes costs for science experiments, reduced 40% from previous estimates).

Prepared by CRS, using cost data from NASA.

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

Appendix 2: Major Program Changes to the U.S. Portion of the International Space Station

The space station program began in 1984, with a "Power Tower" configuration subsequently chosen as the reference design. In late 1985-1986, this was replaced by a "dual-keel" design; the details of this design were released in 1986 so this is listed as a 1985-1986 program change. Table 1 summarizes that change, and five subsequent major changes (another one later in 1986, 1987, 1989, 1990-1991, and 1993). All of these are often referred to as "redesigns," though NASA refers to most of them as "restructurings" or "rephasings" instead. Here they are referred to them as "program changes."

Some analysts count 1990 and 1991 as separate program changes. They are counted here as one, since although the problems surfaced in 1990 and NASA began addressing them, the new plan responding to all the problem areas was released in March 1991 (in response to congressional direction that NASA restructure the program). Also, the 1993 program change is counted as one, not two, even though there were two phases of the process: one which resulted in the September 7, 1993 "Alpha" design, and the other which led to the current International Space Station (ISS) program. Hence, Table 1 identifies six major program changes from 1984-1993, although other analysts may cite a higher number.

The table includes NASA's recent proposal to curtail space station construction once the "U.S. core" is completed because of \$4 billion in cost growth in the ISS budget. Since Congress has not yet approved NASA's decision, this potential program change is identified as "under discussion." If NASA proceeds in this direction, three U.S. elements will not be built until and unless additional funding is available—the Habitation Module, Crew Return Vehicle (CRV), and Propulsion Module. Decisions have yet to be made regarding hardware, such as Node 3 and the Centrifuge Accommodation Module and its associated equipment, being built by other countries for NASA on a barter basis. NASA has not decided whether these elements will continue to be part of the ISS program, depending on whether the integration costs NASA would incur can be accommodated within the new budget guidance. Thus, the impact of the recently proposed changes cannot yet be fully discerned. However, concern has been expressed that if the CRV is not built, the probable reduction in crew size from six or seven to three will limit how much scientific research can be conducted.

Table 2: Major Program Changes to the U.S. Portion of the International Space Station*

CALENDAR YEAR	NATURE OF CHANGE	REASON
Fall 1985-May 1986	The original space station concept envisaged 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 space station program office 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.
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.

CALENDAR YEAR	NATURE OF CHANGE	REASON
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 to 4 from 8; electrical power reduced to 37.5 kw from 75 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, insufficient electrical power, 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
1993	<p>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° 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.</p>	<p>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.]</p>
2001 (Under Discussion)	<p>International Space Station (ISS) construction to be terminated after completion of "U.S. Core" and attachment of European and Japanese modules. NASA will not build Habitation Module, Crew Return Vehicle, or Propulsion Module until and unless additional funds are made available. Then they would be "enhancements." Details still under discussion, but could mean that crew size would be limited to 3 instead of 6 or 7 because only one Russian Soyuz would be available as a lifeboat instead of the larger CRV. Smaller crew size would limit amount of science that can be conducted. Science program currently being restructured.</p>	<p>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.</p>

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.