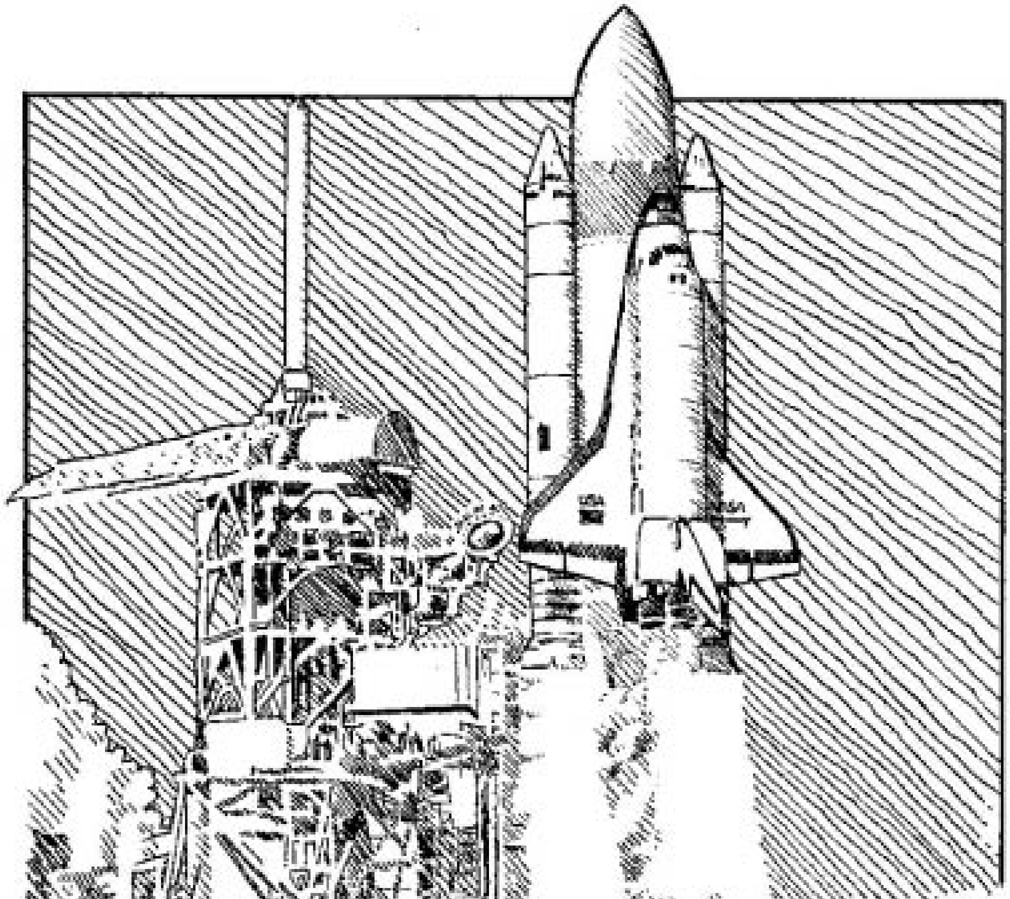

CHAPTER 14: Aspects of Shuttle Development

Although the Shuttle flights, beginning with the four orbital test flights in 1981 and 1982, took Americans back into space after an absence of 6 years, the ground rules or “Earth rules” for spaceflight had changed. The Shuttle had a different commitment and different purposes than previous programs. The Shuttle was exclusively an Earth-to-orbit transportation system. Defense and earth sciences loomed proportionately larger in its development and operation. Costs remained critical. Benefits were of the essence. “Payloads” became a Shuttle euphemism for payoff. Popular enthusiasm for space waned. National prestige was no longer so threatened as it had been before Apollo. Americans in the Shuttle era no longer mobilized for space as though preparing for a hopefully short and determinate war. They began to learn to accept space, with its technology, its benefits and its costs, as a part of everyday life.

The enthusiasm, the commitment, and the funding for space ventures declined perceptibly after Apollo. Apollo had the national spotlight. It was a prestigious program, was popular, and seemed to have unlimited backing. Money was always available for necessary work. The Shuttle was conceived under that same aura, but developed and flown under different circumstances. When the Shuttle began, it was to be one element of a grand design which included a space station, unmanned planetary missions, and a manned flight to Mars. The Johnson Space Center was to become a multiprogram center.[1] But the Shuttle ended up being the only program.

The designation of JSC as lead center, effectively transferred Level II or technical control of Shuttle development from Headquarters to JSC. During Apollo, although Headquarters nominally exercised technical control, technical management was actually dispersed among the spaceflight centers which operated under very strong leadership. Thus, the designation of one center as lead center put technical control where NASA had in-depth technical support. Headquarters exercised less technical management on the Shuttle than it had on Apollo, in part because of its relatively smaller technical staff.[2] The lead center management style made most efficient use of NASA’s personnel and resources.

Owen Morris, previously identified as a cofounder of Eagle Engineering after he retired from NASA as head of the Systems Engineering and Integration Division in the Shuttle Program Office, had primary responsibility for integrating the orbiter in the overall Shuttle system. He believed that under lead center management the work and coordination among the centers went quite well. The Shuttle represented a challenge to systems engineering. It was a much more complex machine. There had been a progressive increase in the complexity in the interfaces involved in each program from Mercury through the Shuttle. The Apollo manned capsule interface with the propulsion system was accomplished with 96 bolts and 93 wires. The Shuttle was an integrated vehicle and much more complex. There were 3200 separate wires leading from the propulsion system of the Shuttle. The forthcoming space station has yet a “much, much more complex interface.”[3]

Despite budget and personnel cuts, the Shuttle was a relatively well designed and managed program. The budget cuts were most damaging in that NASA could never plan for lean years and good years. Cuts were always followed with promises of better funding ahead; thus NASA always tried to rebuild and gear up for another productive surge, only to have the funds cut at the last minute—often by OMB rather than by Congress. OMB, which functioned under the authority of the Executive Office, tended to be less supportive of NASA programs than did Congress. But the real problem with lean years was that invariably research funding suffered first, and as development and construction began, budget constraints often translated into reducing spare parts or redundant systems. Rodney G. Rose, who headed a special flight operations planning group for Apollo, believed that budget constraints meant that the Shuttle became operational with far fewer spares than the Air Force, for example, considered adequate.[4]

Moreover, inasmuch as the program office made research allocations, research funding tended to be directed to specific purposes and lacked the broad base and diversity needed. In addition, when basic research and developmental work was delayed or slipped to meet a launch deadline, it meant that down the line some of the essential "dirty-handed" engineering would not be available when needed.[5] The costs of Shuttle development were exacerbated by the delays. The technical losses (largely in the area of basic research and development) were long-term rather than immediate.

One unique element in Shuttle development had to do with mission operations planning, which had evolved to a considerably higher level of sophistication compared to that of the Apollo and earlier programs. Mercury had begun with a fairly simplistic aircraft flight operations approach. The process matured during Gemini operations when a systems handbook and direct interface between flight control teams and the crew provided real-time ground-to-space interaction. Gemini EVA heightened the relationship between the astronaut, the task, and the working environment. During Apollo, the operations team "worked in an integrated fashion on all issues involving flight systems, flight design, science, and manned operations."[6]

Shuttle flights, however, had greater and more diversified capabilities and more participants in terms of federal agencies, institutions, and even foreign nations. Skylab flight operations were much more of a learning experience for Shuttle flight operations than had been Apollo. During Skylab, systems engineering and integration processes began to be applied to flight operations in a formal context. Skylab, as the Shuttle would have, had a complex flight program involving the designer and builder of the craft, the science experiment user, the crew, and mission control. Critical engineering support for Skylab flights was derived through the creation of a joint JSC/Marshall Space Flight Center review team which screened the systems engineering and integration processes as they related to the flight plan. In other words, it tested prior to flight the compatibility of the men and the machine and anticipated the ability of both to accomplish the mission. This was done through formal systems operations compatibility and assessment reviews.[7]

Whereas one might remember that the Mercury capsule was built almost oblivious to the fact that it would carry a person (almost by accident did an astronaut discover that the original design had no visor plate), Shuttle design and construction involved close support from the mission operations team. The Shuttle was built with the understanding that good flight operations required something of a symbiotic relationship between the human occupants and the machine—and that this relationship must extend to its ground support systems. For flight operations, systems engineering and integration is a process by which "the technical, operational, economic and political aspects of programs are integrated to support the program objectives and requirements consistent with sound engineering, design and operations management principles."[8]

Shuttle flight, STS-5 *(Columbia)* crewmember Joseph P. Allen observed, is technologically complex, cooperatively challenging, and personally exhilarating. Each launch is unique and one of the "richest events" of a lifetime. It was a sentiment generally shared by NASA personnel at each of the centers, and especially by the mission control personnel linked to the Shuttle through the invisible threads of radio, electronics, and human spirit.[9] It was at the Mission Control Center during Shuttle flight that the rich mixture of crew, machinery, engineering, scientific and support structures melded.

Fewer operators worked the Mission Control Center at JSC than in the days of the Apollo lunar missions, but Shuttle flight operations required a networking of the support team composed of the flight control room, the multipurpose support rooms with the payload operations control centers located at JSC or elsewhere. A payload operations control center at Goddard Space Flight Center, for example, monitored all free-flying (satellite) systems delivered, retrieved or serviced by the Shuttle, including the two communications satellites delivered into orbit by *Columbia* on the STS-5 mission. Both satellites were built by Hughes Aircraft Company under contract—one for a private company, Satellite Business Systems, and the other for Telesat of Canada. Hughes engineers, as well as technicians representing the contractors, monitored the satellite launches from remote payload operating control centers. In the event the Shuttle was delivering satellites for interplanetary exploration, as would be true in later flights, a payload operating control center at the Jet Propulsion Laboratory in Pasadena, California, managed the payload.[10]

Beneath the primary flight control rooms at JSC (on the second floor of the Mission Control Center or for DoD missions on the third floor), the network interface processor provided an intermittent flow of real-time information coming from the Shuttle and other operating centers and fed it to flight control. Also on the first level, the data computation complex compared tracking and telemetry data with Shuttle flight progress.[11] Although the facade and apparatus of the Mission Control Center had changed little since the days of the Apollo lunar flights, flight control systems were enhanced substantially due to the advances in electronics and computer technology—advances which were in part derived from previous NASA spaceflight experiences.

Shuttle flight control became much more streamlined than during Apollo flights, and depended on advanced information systems and computer programs (although the external hardware in the Mission Control Center was much the same). The Shuttle required all new computer software—adjusted and reconfigured for each Shuttle mission. Development and ownership of software was a big challenge in the design of Shuttle operations. Improved information systems, derived from more sophisticated computer hardware and sophisticated programming, at least in part, facilitated the reduction in the numbers of flight control personnel. Better systems engineering and integration also helped. Mission Control teams for

This photograph of the Upper Atmosphere Research Satellite in the payload bay of the Earth-orbiting Shuttle Discovery *shows the large size and versatility of the new space vehicle designed for near-Earth operations.*

the Shuttle were pared to one-half the size of Apollo teams with 80 people on each flight control team and 3 teams for each mission. The 22 controllers stationed in the flight control room of the Mission Control Center managed a host of technical advisors in multipurpose support rooms in the Control Center and had access to support groups stationed throughout the United States—and indeed in other countries. As mentioned earlier, Wayne Hale, a Shuttle flight director, likened the operation of the Shuttle to the operation of a battleship, except that instead of thousands of crewpersons aboard the ship, there were only six or seven on the orbiter and the other thousands were stationed on Earth.[12]

Mission planning for early Shuttle missions began 3 or 4 years before each mission. Approximately one-third of the Shuttle flights developed problems during flight which required adjustments in the mission flight plan. Shuttle flying time usually consumed only about 10 percent of the total hours that went into each mission with most of the hours and work related to flight planning, simulation, training, and preflight preparation. Payload planning and payload mission planning often consumed as much time and energy as did Shuttle flight preparations. Whereas during Mercury, Gemini and Apollo years the flight was itself the essence of the mission, for the Shuttle (as had been true of the Skylab missions), the payload was the most important element of the mission.

Payload decisions had to do with commercial competition, foreign governments, competition for payloads between NASA centers, as well as broader scientific and earth-resource interests. NASA began to tackle the problem very early in the Shuttle's development by creating one of those interim, ad hoc, shadow organizations that appeared, made a critical decision or contribution, and then disappeared. Such was the Ad Hoc Shuttle Payload Activities Team organized in January 1974 under the tutelage of Charles Donlan, who returned to NASA for one of the frequent periods of activity following his retirement some years earlier. The Payload Team met at each of the NASA centers during January 1974 to discuss the establishment of management policies affecting Shuttle payloads.[13]

The issues raised at those meetings, more than the resolution of the problems, denoted the complexity and sensitive aspects of payload decisions. A JSC contingent attending Payload Team meetings held in Houston on January 10 and 17, for example, believed that because Shuttle involved both manned and unmanned operations (the unmanned being the payloads), the traditional manned versus unmanned program definitions within the NASA management system should be abandoned. Lewis Research Center personnel called for a radical change in thinking because payload operation had to be separated from operation of the transportation system. Kennedy Space Center observers stressed that a single center needed to be responsible for the sustained engineering of the Space Shuttle to accommodate each payload. Vehicle preparation for certain payloads could take years. Some individuals thought that there might be greater efficiency and payoff in missions if planning were subordinated to letting the crew and specialists go up and "klunk around" in space.[14]

JSC managers noted that an Agency guideline specifying that mission decisions should consider "minimum practical total cost to attain mission and program objectives" was a "state of mind" rather than real criteria. The Agency needed a double standard for the Shuttle: transportation systems would have to meet high standards and rigid criteria, while payloads would have to meet varying but generally lower standards. And JSC people wanted to squelch a recurring suggestion that Mission Control for the Shuttle be placed somewhere other than at JSC. "There is no viable alternative to doing this job at JSC," they said, "and entertaining alternatives is divisive and inhibits developing harmony within NASA.[15]

The issues discussed ranged from the very broad to the very finite. Mission planning would have to be separated from flight planning. Low-cost payloads could not come in the form of de-emphasizing sophistication in scientific instruments. Langley proposed to assign the Marshall Space Flight Center responsibility for maintenance and operation of the experiment modules and pallets, and it wanted to manage its own payload operations, but do so through the Mission Control Center at JSC. Ames Research Center experiences argued against giving the Shuttle or transportation operator any responsibility for payload decisions. Jet Propulsion Laboratory personnel advised that mission specialists (as part of the flight crew) should operate the payloads and come from the payload organization. They also thought that Shuttle crew operations and payload maintenance could properly be combined under the authority of the Kennedy Space Center. And Ames advised Headquarters to stick to policy decisions regarding payloads and avoid operational decisions.[16] It thus became clear long before the Shuttle began to fly that it was mechanically much more complex than previous spacecraft, and socially (or procedurally and politically) much more complicated and integrated.

The following year, 1975, JSC established a Shuttle Payload Integration and Development Program Office under Glynn S. Lunney. Lunney, it might be recalled, left Lewis Research Center in 1958 to join the Space Task Group and served as Chief of the Flight Director's Office during the Apollo flights. The Payload Integration Office (redesignated the STS Operations Program Office in 1980) had responsibility for planning and integrating JSC-sponsored payloads to include engineering and operations interface and integration responsibilities.[17]

Lunney believed that the Shuttle was a dramatically different program than Apollo, and that it particularly drew upon one of the greater strengths of JSC—the interaction between the design engineers and the flight crews. It involved a complete change of "mind-set" by JSC, from the tradition of pouring every energy into every single flight to the idea that the flight itself was peripheral to the payload. NASA and JSC ceased being inventors and became producers. Production, for example, required the development of standard connectors in the cargo bay for payloads, and assimilating the customer's emphasis on containing costs—that is doing that which was necessary, but no more. Shuttle missions related to payloads and to external relations with people around the Nation and in other countries (which is one reason, Lunney added, that the Apollo-Soyuz planning group which he headed became the payload integration team for the Shuttle).[18]

Shuttle development thus involved social as well as technical engineering. As the machinery was perfected, techniques of using the machine were honed by constant exercises involving the crew and ground control teams on the shuttle mission simulator (SMS). The SMS provided integrated training for flight crews, the Mission Control Center and mission operators, payload support groups, and tracking and telemetry systems. Built under a contract awarded in 1976 to Singer Company's Link Division, the SMS provided real-time simulation capability for all phases of Shuttle orbital flight. Its three basic stations, including a fixed-base crew station, a network simulation system, and a motion-base crew station, became operational in 1978. The machinery (and the station operating crews) could simulate every phase of the flight including motion and directional simulation, vehicle dynamics, orbital environment, visual scenes and aural cues. The SMS neatly blended the complex human and mechanical elements of Shuttle spaceflight.[19]

Owen Morris' conviction that the Shuttle was a well conceived, well engineered, and well built vehicle was certainly supported by the 24 Shuttle flights made between April 1981 and January 1986. During the first 5 years of Shuttle operations, NASA almost doubled the cumulative hours compiled by astronauts during the 10 years of Mercury, Gemini and Apollo flights. The critical moment in Shuttle development came, according to Morris, when for the first time NASA put the engine, the fuel tanks and the orbiter together on the test stand at the Mississippi Test Facility near Biloxi about March 1977. The Space Shuttle main engines experienced serious problems during tests until late 1980. Those engines (with three mounted on each Shuttle) were the most powerful hydrogen-oxygen engines yet built, and the technical problems proved to be considerably greater than anticipated in the design stage. Components, such as valves, seals, and pumps, had to be redesigned to withstand the pressures. One high-pressure fuel pump on an engine was so powerful it could empty an "Olympic-sized swimming pool in just 25 seconds."[20] Thus the engine itself represented a major technological advance, rather than a simple adaptation of existing knowledge.

One of the most frustrating Shuttle problems involved not just the development, but the adhesion of silicate fiber tiles to heat-bearing surfaces on the Shuttle. NASA engineers, working with Lockheed, McDonnell Douglas, Battelle/Columbus and university scientists and engineers, developed and tested a tile that could withstand the 2700 degree F (1428 degrees C) reentry. The featherweight tile "could throw off heat so quickly that a white-hot tile directly out of an oven, with a temperature of 2300 degrees F (1260 degrees C) could be held in a bare hand without burning or causing other injury." Although JSC engineers protest that the "bare hand" rhetoric overstated the case, the tiles could handle temperatures no previous man-made substance could withstand. But initially the tiles were very susceptible to meteorite and impact damage. Most tiles failed stress tests until they were thickened and redesigned with a ludox (silicon-boron) base. Next, each of the 31,000 tiles, with no two alike, had to be glued to the Shuttle surfaces—a job requiring an estimated 670,000 hours or 335 person-years of labor![21]

Despite the intensive tests of tiles and engines, the Shuttle's space-worthiness would be proved only by piloted flights. Unlike the earlier Gemini or Apollo spacecraft, there would be no automated tests of the Shuttle. The Shuttle was designed for manned flight. Thus, when John W. Young and Robert L. Crippen made the first orbital test flight of the new Space Shuttle (STS-1) *Columbia* on April 12, 1981, they were truly "man-rating" America's first aerospace vehicle. Crippen, a native of Beaumont, Texas, and a graduate of the University of Texas, came to the astronaut corps by way of the Air Force Manned Orbiting Laboratory Program. Among other things, he had immersed himself in Shuttle computer software problems. It was his first flight. Young, a Georgia Tech aeronautical engineer who was born in California, was a veteran astronaut who made his first flight as pilot of Gemini 3 and was command module pilot for Apollo 10 and commander of the Apollo 16 flight.[22] They were the real guinea pigs.

The flight was, by traditional aeronautical standards, an unusual one. About one million people were on hand to watch the launch from the Kennedy Space Center—millions more watched on worldwide real-time television. Nine minutes after launch the astronauts were in orbit. Once in orbit about the Earth they flew their craft tail-forward and upside down (to get a better view of Earth and its horizon). During their 2-day, 6-hour and 21-minute flight, they changed their orbit apogee (high point) by some 172 statute miles and checked out the computers, jet thrusters, cargo bay doors, and control systems. The flight marked, according to the official NASA Mission Report, "a new era in space promising countless benefits for people everywhere."[23] It was "top billing" in theatrical or PR (public relations) terms, but *Columbia*'s almost flawless voyage held enormous promise and infused great optimism in a NASA and JSC cadre that had lived on the edge during the past decade.

The Shuttle *Columbia* returned "hardly worse for wear" after its searing atmospheric reentry through temperatures that reached 3000 degrees F (1650 C). The two solid rocket boosters were recovered in the Atlantic off Daytona Beach and could be refurbished at a fraction of the cost of building new expendable rocket engines. And the Shuttle, but for the damage to 12 tiles on the tail section, returned intact and fully reusable. For a time the old surge of Apollo lunar mission pride and national resolve returned after a long American absence from space. President Ronald Reagan told Congress that the return to space "did more than prove our technological abilities. It raised our expectations once more. It started us dreaming again."[24]

A few months later *Columbia* was ready to fly again. Joe H. Engle and Richard H. Truly, who had flown the *Enterprise* in landings after drops from a Boeing 747 in 1977, manned *Columbia*'s second flight into space on November 12. Engle was unique. He entered the astronaut program already an astronaut, having completed 16 flights in the X-15 experimental aircraft during one of which he reached an altitude of 280,600 feet. Neither he nor Truly previously had flown an orbital mission. The STS-2 mission not only further flight-tested the readiness of the Shuttle, but also carried a test package of scientific experiments prepared by the Office of Space and Terrestrial Applications and a robotic arm for managing the Shuttle cargo built by the Canadian Government as its participation in Shuttle flights and technology. The pallet or container housing the five experiments carried by STS-2 was designed and developed by the Spacelab Program Office at Marshall Space Flight Center

The new Shuttle, designed as a reusable spacecraft, made its maiden voyage on April 12, 1981. After an absence of 6 years, America had returned to space. Eugene Kranz, Chris Kraft, and Max Faget monitor the return to space.

and built by the British Aerospace Corporation for Zentral Gesellschaft VFW-Fokker mbH on behalf of the European Space Agency.[25] The second flight helped identify the scientific and Earth resources orientation of Shuttle missions, and denoted the broadening of American space programs to include European and Canadian participation.

The experimental package included a Shuttle Imaging Radar-A designed to send and receive microwave radiation to create maplike images of the Earth. Satellites carrying such equipment previously recorded ancient Mayan canals, ice flow and ocean wave patterns, and, it was surmised, could aid in the study of Earth's geological formations leading to the discovery of oil and mineral deposits. A Shuttle multispectral infrared radiometer supplemented the radar surveillance by detecting the best spectral bands to be used in remote sensing. A feature identification and location experiment activated the infrared and radar experiments when atmospheric conditions were best suited for observation. Another package, called the Measurement of Air Pollution from Satellites, checked particularly for the distribution of carbon monoxide in the middle and upper troposphere (7.5 to 11 miles above Earth's surface). An ocean color experiment identified chlorophyll and other pigments in the oceans, thus providing locations for schools of fish and pollution.[26]

During the interim between the flight of STS-1 and STS-2, the House Subcommittee on Space Science and Applications held public hearings on "Future Space Programs" based on what the members considered "a look at the space program from the point of view of society." The intimation was that in previous hearings the focus had been on what society could do for the space program. The subcommittee hearings considered how space might relate to the "Nation's wealth, broadly defined," and what programs might be considered "fruitful investments." No NASA personnel were interviewed, although several of the guests had previous NASA associations. The comments from business and academia (e.g., Dr. Melvin Kranzberg, Professor of History of Technology at Georgia Institute of Technology; David Hannah, President of Space Services, Inc.; Dr. Donlin M. Long, Johns Hopkins Hospital; General Thomas Stafford (retired), former Head of USAF Space Programs) ranged widely but focused on the general theme of costs versus possible benefits. The committee finally called for broad debate on the civil space program and the definition of national goals.[27]

The cost-benefit theme had indeed preoccupied NASA through much of the Shuttle development phase. A critical element in those deliberations had to do with the establishment by NASA of a Shuttle cargo or payload policy. The kind of cargo or payload the Shuttle was to carry would be very critical in the cost-benefit evaluation. Payload decisions also had to do with commercial competition, foreign governments, and competition for payloads between NASA centers, as well as broader scientific and Earth-resource interests. NASA, as previously mentioned, began to tackle the problem very early in the Shuttle's development by creating one of those interim, ad hoc, shadow organizations that appeared, made a critical decision or contribution, and then disappeared.[28]

Headquarters ultimately approved Shuttle payloads. Each center, or other government agency such as DoD, and sometimes foreign governments and institutions might sponsor payload proposals. NASA solicited proposals from universities and the general public. The final payload decision ultimately rested on the technical feasibility and outfitting costs as judged by JSC's Payload Integration Office. Outfitting and redesign of the Shuttle to accommodate the varying payloads affected payload scheduling.[29]

The Payload Integration Office (redesignated the STS Operations Program Office in 1980) had responsibility for planning and integrating JSC-sponsored payloads to include engineering and operations interface and integration responsibilities. In January 1982, following the successful flights of STS-1 and STS-2, JSC Center Director Chris Kraft announced the merger of the STS Operations Office with the Space Shuttle Program Office. It meant that with payload management and integration problems resolved, after two more orbital test flights the Shuttle was ready to become fully operational.[30]

On schedule, with its turnaround time cut from 102 to 69 days, the Shuttle *Columbia* blasted off for its third successive flight on March 22, 1982. Commander Jack R. Lousma, a veteran of 59 days aboard Skylab, was a colonel in the Marine Corps who joined NASA in 1966 with the fifth group of astronauts. His pilot, C. Gordon Fullerton, had not flown in space but had manned three of the *Enterprise* glide flights during its initial tests in 1977. They now pushed the orbiter a bit closer to its flight limits. The scientific experiments approved by NASA's Office of Space Science investigated space plasma physics, solar physics, astronomy, life sciences, and space technology. The orbiter also carried Todd Nelson's "Insects in Flight Motion Study" experiment. Nelson, an 18-year-old high school student won a NASA and National Science Teachers Association competition for the opportunity. It denoted yet another broadening of Shuttle applications into the everyday world. Engineers performed additional tests on the Shuttle's control systems and its aerodynamic performance during launch and reentry, and accomplished a cold start of the orbital maneuvering engines. As mentioned previously, STS-3 was the first and only shuttle to land at the Northrup Strip at White Sands, New Mexico.[31]

Finally, the fourth flight of *Columbia* (STS-4), the first DoD secret mission, ended auspiciously on July 4, 1982, when flight commander Thomas K. (Ken) Mattingly and pilot Henry W. Hartsfield, Jr., returned from a 7-day orbital flight to the concrete runway (another first) at Edwards Air Force Base, California. It was the end of the beginning for the Shuttle program. "Its on-time launch, near-flawless completion of all assigned tasks, and perfect landing ushered in a new era in the Nation's exploration of space—a fully operational, reusable spacecraft now set to begin its job in earnest."[32]

The payload carried the Shuttle's first commercial package, an electrophoresis experiment (involving the separation of biological materials in fluids) developed by McDonnell Douglas Astronautics Company with the Ortho Pharmaceutical Division of Johnson and Johnson. Two high school students, Amy Kusske of California and Karla Hauersperger of North Carolina, submitted separate medical experiments testing chromium levels and cholesterol levels in the astronauts from urine and blood samples. Nine experiments by Utah State University students were funded under NASA's low-cost Getaway Special, a small, self-contained payload experimental program. The crew also tested the Shuttle skin and tiles for prolonged exposure to extreme heat and cold by changing the position of the spacecraft relative to the sun.[33] Spaceflight, many thought, had now become routine.

The business of space had changed markedly in that brief decade between the inception of the Shuttle program and the completion of four Shuttle orbital test flights.

The Shuttle was a much more complex mechanism. Its management systems had become much more integrated and involved political and economic decisions as well as technical decisions. Space appeared to be an evolving sector of the national economy and an increasingly significant element in the local and regional economy of Texas and the Southwest. Now that the engineering and developmental phase had ended, it was time to put the Shuttle to work.