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Chapter 2

The Strange Career of the Spaceplane: NASA and the Quest for Routine Human Space Operations*

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Abstract

For nearly forty years before the beginning of human spaceflight, leading experimenters and advocates for the human exploration and development of space in the United States envisioned a future in which humans flew into orbit aboard reusable, efficient, winged vehicles and then came back to Earth and landed on runways. Their model for that effort was the emerging airline industry. This belief dominated thinking before the space age, but in the rush to place humans into space during the Cold War of the latter 1950s the United States abandoned these dominant ideas about reusable spaceplanes in favor of the expediency of ballistic capsules, a technology already well underway to ensure reentry of nuclear missile warheads. During the 1960s Projects Mercury, Gemini, and Apollo employed these ballistic concepts, but the dream of a spaceplane did not

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abate. No sooner had victory in the space race been achieved through the Moon landing in 1969, than leaders in the National Aeronautics and Space Administration (NASA) returned to the spaceplane concept. NASA built the Space Shuttle to replace the capsules, an important step toward a spaceplane but not truly the vehicle envisioned earlier. Numerous efforts to build a successor spaceplane have foundered since the 1980s because of technology, budget, and other obstacles; still the goal remains. Only in the twenty-first century has NASA shifted its focus away from the spaceplane concept to return to a ballistic flight approach. The quest for an orbital spaceplane represents a unique story of the social construction of technology; one in which spaceflight professionals pursued a technological path dictated not so much by hard-headed engineering considerations but because of other priorities.

Introduction

For nearly forty years before the beginning of human spaceflight, leading experimenters and advocates for the human exploration and development of space in the United States envisioned a future in which humans flew into orbit aboard reusable, efficient, winged vehicles and then came back to Earth and landed on runways. Their model for that effort was the emerging airline industry. This belief dominated thinking before the space age, but in the rush to place humans into space during the Cold War of the latter 1950s the United States abandoned these dominant ideas about reusable spaceplanes in favor of the expediency of ballistic capsules, a technology already well underway to ensure reentry of nuclear missile warheads. During the 1960s Projects Mercury, Gemini, and Apollo employed these ballistic concepts even as the dream of a spaceplane continued unabated and studies continued.[1]

No sooner had victory in the space race been achieved through the Moon landing in 1969, than leaders in the National Aeronautics and Space Administration (NASA) returned to the spaceplane concept. NASA built the Space Shuttle to replace those earlier human spaceflight capsules, an important step toward a spaceplane but not truly the vehicle previously envisioned. A succession of projects designed to replace the Space Shuttle with a true spaceplane dominated much of the research and development in human spaceflight vehicles undertaken by NASA throughout the 1980s and 1990s. Only in the twenty-first century has NASA briefly shifted its focus away from the spaceplane concept to return to a ballistic flight approach. The quest for an orbital spaceplane represents a unique story of the social construction of technology; one in which spaceflight professionals pursued a technological path dictated not so much by hard-headed engineering considerations but because of other priorities.[2]

At some level this represents what historians refer to as the "social construction of technology." In recent years this concept has illuminated understanding and helped to explain seemingly difficult issues in the development of spaceflight. The social construction of technology offers tantalizing prospects for the study of the orbital spaceplane. It suggests that the nature of technological choices is sometimes made not for clear-cut technological reasons but for broader non-technical reasons. What perhaps should be suggested is that a complex web or system of ties between various people, institutions, and interests bring forward any space system, and each fundamentally affects the direction taken. The process whereby those decisions are made and implemented offer an object lesson for current engineers and policy makers involved in making difficult decisions.[3]

Social constructionism is present throughout the story of this quest for a winged, reusable human orbital capability. In three major ways the spaceplane ideal has dominated the thinking of spaceflight advocates until the present. First, it represented a strategic approach to flying into, through, and back from space in the era before the advent of the space age. Second, it remained a dream of spaceflight engineers and advocates even as the expediency of ballistic capsules became the norm during the space race and led to a return to the effort at the conclusion of the Moon landing program. Third, it governed the direction of replacement efforts for the Space Shuttle throughout the 1980s and 1990s, and not until the 2005 decision by NASA to move human spaceflight from the shuttle to the Constellation program was this changed by then NASA administrator Michael D. Griffin. Griffin, in arguing for an abandonment of winged reusable space vehicles, famously called the Space Shuttle a "mistake" that NASA had persisted in pursuing for more than 30 years despite its many flaws.[4] Notwithstanding, the spaceplane concept has proven critical in the overarching trajectory of human spaceflight throughout the twentieth century and into the twenty-first century.

Central to this concept is that the design of space vehicles is not dictated by one best way to do something, but that there are a range of options and a trading space for decisions in which pros and cons are always present. As often as not, critical decisions rest not specifically on technical consideration but on other, more aesthetic, rationales. The lack of a one-best-way to accomplish human spaceflight is an important insight arising from a consideration of the social construction of technology.

In terms of spaceplanes, an infatuation among those pursuing those efforts has been present from the first serious consideration of human journeys beyond

Earth. The linkage of visions of human flight in space to visions of human flight in the air beginning in the 1920s and 1930s suggested the necessity of winged vehicles that bore a strikingly close visual relationship to the emerging technological sophistication of aircraft. This became a powerful icon of spaceflight, despite the fact than in two of the three different regimes in which the vehicle must perform the features of a spaceplane are unnecessary or even a detriment. During orbital operations the spaceplane design is superfluous to the vehicle's performance and during launch a spaceplane's wings are an unnecessary drag on the vehicle. Only during reentry and landing are the unique features of the spaceplane significant components of the vehicle's performance. In such a situation, social construction represents a useful way of analyzing the decision-making process that led to a winged, reusable vehicle as the chosen path for American human spaceflight.[5]

Spaceplanes of the Imagination

Concepts for winged reusable spaceplanes go back at least to the 1920s with the science fiction of Buck Rogers and his Patrol Ship. That ship was able to take off horizontally like an airplane and accelerate to a high enough speed to go beyond the pull a planet's gravity into orbit. Buck Rogers first appeared in the August 1928 issue of *Amazing Stories* but became a long-running syndicated comic strip that premiered in newspapers on 7 January 1929, and was an immediate success. In addition, the Buck Rogers radio program commenced in 1932 and aired four times each week through World War II. This sparked a series of films, beginning with a ten-minute short that premiered at the 1933 World's Fair in Chicago and a 12-part serial released by Universal Pictures in 1939 starring Buster Crabbe.[6]

In every case, Buck Roger's winged reusable patrol ship served as the means of travel for the hero and his sidekicks. Although never a true "character" in these Buck Rogers stories in the same way that the starship "Enterprise" was in *Star Trek*, fans accepted at face value that the patrol ship should be winged vehicle that could undertake airplane-like operations. This popular culture icon paralleled the advancement of space technology in the twentieth century and introduced Americans to outer space as a familiar environment for swashbuckling adventure. The ideas expressed in the series both informed popular conceptions of what a human space vehicle might look like even as advances in technology informed the artwork used in science fiction. As former NASA Deputy Administrator Fred Gregory recalled in 2001 about the Space Shuttle program, "we had such great ideas about where we were going to go and what we were going to do; I was caught up in it. But, of course, I grew up with Buck Rogers."[7]

At the same time that Buck Rogers's spaceplane excited American ideas about space travel in science fiction, the stories became more fanciful and in the process turned off those with a penchant for reality. "That Buck Rogers thing" served as a dismissive for ideas that sounded outrageous. For example, in 1938 Jerome Hunsaker, of the Aeronautics Engineering Department at Massachusetts Institute of Technology (MIT), told Theodore von Kármán that Caltech could take the "Buck Rogers job" while MIT would work on serious problems in flight. Von Kármán reported in his book, *The Wind and Beyond*, that because of fanciful popular conceptions "the word 'rocket' was in such bad repute that for practical reasons we decided to drop it from our early reports and even our vocabulary."[8]

Even so, serious scientific studies of the feasibility of spaceplanes were also underway and soon recaptured the imagination of engineers and enthusiasts alike. The theoretical rocketplane studies of the 1930s by Austrian aerospace designer Eugen Sänger, for instance, were influential in laying the foundations for the modern concept of a spaceplane. Sänger's basic concept—the "Silbervogel" (Silverbird)—was a cross between a powered booster rocket and an aerodynamic glider. Inspired by Hermann Oberth's 1923 book, *By Rocket into Planetary Space*, Sänger changed his studies at the Viennese Polytechnic Institute from civil engineering to aeronautics. Beginning in 1929 Sänger conceptualized a reusable, rocket-powered spaceplane with straight-wings. Sänger privately published *Techniques of Rocket Flight* in late 1933 that contained a detailed description of the spaceplane. In collaboration with mathematician Dr. Irene Bredt, whom he later married, Sänger continued to refine this design for the next 30 years.[9] Propelled by a liquid rocket engine, by 1938 the Sänger/Bredt collaboration had yielded a design that would boost to lift-off velocity via a rocket-propelled sled, eventually reaching Mach 24.[10]

Americans were keenly interested in Sänger's ideas and a lecture on it by William Bollay at Caltech in 1936 seemingly kick-started rocket research efforts at the university. Because of a newspaper report on Bollay's lecture, several spaceflight enthusiasts gathered at Caltech around another graduate student, Frank Malina, to form the research team that eventually established the Jet Propulsion Laboratory in World War II.[11] After World War II, Sänger went to Paris to pursue his ideas on spaceplanes. He and Irene Bredt also worked with the U.S. Navy's Bureau of Aeronautics (BuAer), and succeeded in changing the perspective of many about the possibility of spaceplanes. They argued that a rocket-powered hypersonic aircraft could be built with only minor advances in technology. At the same time, many of his technical studies were translated and thoroughly studied by American aerospace engineers in the latter 1940s.

Working for JUNKERS in the Federal Republic of Germany in the early 1960s, Sänger wrote an influential report in August 1961 that laid out his spaceplane ideas in detail. Adding to this report until his death in 1964, Sänger concluded:

> It is my firm opinion, that for civil use of the aerospace transporter the catapult start by means of steam rockets and the main propulsion by liquid-hydrogen liquid-oxygen high pressure rocket engines, is the best initial approach. Later on the main stage may be powered by thermal nuclear fission rockets engines. The total launching weight should initially be chosen between 100 and 1,000 tons, and the use of single stage may be justified if catapults are applied for launching.[12]

This proposal, more clearly than others, advocated for a single-stage-to-orbit spaceplane that was catapulted through the atmosphere toward orbital velocity. Sänger's most important contribution, given that none of his designs for a spaceplane were ever built, was to focus attention on the potential of winged hypersonic flight, ultimately yielding such vehicles as the X-15 and the Space Shuttle. His ideas remained in vogue for nearly 20 years, anticipating the Space Shuttle by some 30 years, even though they were essentially "paper airplanes" never getting beyond the level of engineering studies.[13]

By the early 1950s winged-reusable spaceplane concepts had matured sufficiently that Darrell C. Romick's Goodyear Aircraft Corporation design for the three-stage "METEOR" (Manned Earth-Satellite Terminal Evolving from Earth-To-Orbit Ferry Rockets) met with approval by the American Rocket Society when unveiled in 1954. This spaceplane was to stand 142 feet tall and carry 35 tons while weighing roughly 18 million pounds and producing 32 to 38 million pounds of thrust at lift-off. Each stage of the vehicle was to have been piloted and had a delta wing design with retractable landing gear. In this way each individual stage could be flown as a glider to its landing site on Earth. The METEOR's purpose was to bring cargo and people back and forth between Earth and a space station.

Romick got into spaceplane design when he began working on Goodyear's experimental MX-778, a 100-mile range missile, and he realized that such ideas as those pursued by Sänger had potential. "The one thing that was missing in these studies," he later recalled, was a "practical launch vehicle that you could run like an airliner—the transport of cargo on a regular basis."[14] His answer was a reusable booster and, scrapping the catapult idea, in its most elaborate form involved a three-stage launch vehicle with oversized delta fins. The multiple stages allied the METEOR concept with ballistic missile ideas being pursued elsewhere. Its major difference was the spaceplane's reusability as each stage boasted a crew to fly that segment back to a landing on a runway.

Romick envisioned this spaceplane as supportive of an expansive human spaceflight effort that required a giant "space wheel" station. Romick speculated that America could build an entire space "city" of in Earth orbit, supporting them with a fleet of METEOR spaceplanes. Romick's concept was so spectacular it was featured in several magazines and newspapers, including a cover story in *Mechanix Illustrated* in 1956. Romick aggressively hawked his METEOR concept, even appearing on television and radio. METEOR was never built, but Romick was convinced for the rest of his life that it was simply "too ambitious" for its time but still represented a reasonable approach to reaching into space.[15]

Throughout the 1950s, until the actual beginning of the space age in 1957, the spaceplane concept remained the dominant approach offered by those who imagined an expansive human future in space. And it seemed for these advocates, more credible than ever before. The popular weekly news magazine *Collier's* featured a reusable spaceplane on the cover of its first special issue devoted to the prospects of human spaceflight on 22 March 1952, thereby promoting the idea to a broad audience.[16] The charismatic German émigré Wernher von Braun, technical director of the V-2 ballistic missile effort in World War II, led the *Collier's* issue with an impressionistic article describing human possibilities in space made possible by the development of a winged reusable spacecraft for travel to and from Earth orbit and ultimately reaching Mars, again with spaceplanes that could land on Mars. As von Braun wrote, "Imagine the size of this huge three-stage rocket ship: it stands 265 feet tall, approximately the height of a 24-story building. Its base measures 64 feet in diameter. And the overall weight of this monster rocket ship is 14,000,000 pounds, or 7,000 lbs—about the same weight of a light cruiser."[17]

Following close on the heels of the *Collier's* series, Walt Disney Productions contacted Wernher von Braun seeking assistance in the production of spaceflight shows for Disney's weekly television series. Two of these, "Man in Space" and "Man and the Moon," premiered on Disney's weekly television show in 1955 with an estimated audience of 42 million. They depicted a spaceplane supporting a wheel-like space station as a launching point for a mission to the Moon. Von Braun appeared on camera to explain his concepts for human spaceflight, while Disney's characteristic animation illustrated the basic principles and ideas with wit and humor.[18] Media observers noted the favorable response to the Disney shows from the public, and concluded that "the thinking of the best scientific minds working on space projects today" went into them, "making the picture[s] more fact than fantasy."[19]

A Dose of Reality

While the public discussion of technologies for human spaceflight in the United States emphasized spaceplanes, the Cold War pressures of the latter 1950s impinged on those ideas. The Department of Defense and NASA pursued a similar approach after its creation in 1958, abandoned spaceplanes in favor of ballistic capsules that could be placed atop launchers being developed to deliver nuclear warheads to the Soviet Union. The decision to pursue a capsule instead of the spaceplane ideal came only after aerodynamicists realized that the need to orbit a human vehicle before the Soviet Union outweighed the creation of the more elegant solution. As early as 1954 engineers at the National Advisory Committee for Aeronautics (NACA) began to wonder if, in the interest of expediency, the spaceplane would have to be tabled in favor of the capsule to assure the ability to achieve human orbital flight within the next decade.[20]

While research remained a critical component for the spaceplane concept, the NACA engineer John V. Becker recalled in 1968: "the exciting potentialities of these rocket-boosted aircraft could not be realized without major advances in technology in all areas of aircraft design. In particular, the unprecedented problems of aerodynamic heating and high-temperature structures appeared to be so formidable that they were viewed as "barriers" to hypersonic flight.[21]

Even into 1957 research into human spaceflight continued to examine winged vehicles. In particular, the NACA cooperated with the Air Force on the Manned Glide Rocket Research System, and the Ames laboratory looked into a flattop, round-bottom skip-glider. Nevertheless, after Sputnik was launched on 4 October 1957, it became obvious that a ballistic capsule was the best and quickest way to get Americans into orbit; the available launch vehicles simply could not support the increased weight of a winged vehicle.[22]

Notwithstanding, a minority within the NACA, mainly at Langley, continued to argue that lifting-reentry vehicles would be far superior to a non-lifting capsule. In fact, at the NACA Conference on High-Speed Aerodynamics in March 1958, John Becker presented a concept for a piloted 3,060-pound winged orbital satellite. According to Becker, this concept created more industry reaction—almost all of it favorable—than any other paper he had written, including the initial X-15 study. What ruled out acceptance of his proposal was that the 1,000 pounds of extra weight (compared to the capsule design presented by Max Faget) was beyond the capability of the Atlas launch vehicle. If the Titan had been further along, the concept would have worked, and Becker believes that the first U.S. human spacecraft might well have been a landable winged vehicle.[23]

At the same time that the NACA was pursuing its studies for a human spaceflight program, the United States Air Force proposed the development of a piloted orbital spacecraft under the title of "Man-in-Space Soonest" (MISS).[24] Initially discussed before the launch of Sputnik 1 in October 1957, afterward the Air Force invited Dr. Edward Teller and several other leading members of the scientific/technological elite to study the issue of human spaceflight and make recommendations for the future. Teller's group concluded that the Air Force could place a human in orbit within two years—the critical factor in a decision to abandon spaceplanes—and urged that the department pursue this effort. Teller understood, however, that there was essentially no military reason for undertaking this mission and chose not to tie his recommendation to any specific rationale, falling back on a basic belief that the first nation to do so would accrue national prestige and advance in a general manner science and technology.[25] Soon after the new year, Lieutenant General Donald L. Putt, the USAF Deputy Chief of Staff for Development, informed NACA Director Hugh L. Dryden of the intention of the Air Force to pursue aggressively "a research vehicle program having as its objective the earliest possible manned orbital flight which will contribute substantially and essentially to follow-on scientific and military space systems." Putt asked Dryden to collaborate in this effort, but with the NACA as a decidedly junior partner.[26] Dryden agreed; by the end of the summer he would find the newly created NASA leading the human spaceflight effort for the United States, with the Air Force being the junior player.[27]

Notwithstanding the lack of clear-cut military purpose, the Air Force pressed for MISS throughout the first part of 1958, clearly expecting to become the lead agency in any space program of the United States· To help make that a reality, it requested $133 million for the MISS program and secured approval for the effort from the Joint Chiefs of Staff.[28] Throughout this period, a series of disagreements between Air Force and NACA officials rankled both sides. The difficulties reverberated all the way to the White House, prompting a review of the roles of the two organizations.[29] The normally staid and proper director of the NACA, Hugh L. Dryden, complained in July 1958 to the President's Science Advisor, James R. Killian, of the lack of clarity on the role of the Air Force versus the NACA. He asserted that "The current objective for a manned satellite program is the determination of man's basic capability in a space environment as a prelude to the human exploration of space and to possible military applications of manned satellites. Although it is clear that both the National Aeronautics and Space Administration and the Department of Defense should cooperate in the conduct of the program, I feel that the responsibility for and the direction of the program should rest with NASA." He urged that the president state a clear division between the two organizations on the human spaceflight mission.[30]

As historians David N. Spires and Rick W. Sturdevant have pointed out, the MISS program became derailed within the Department of Defense at essentially the same time because of funding concerns and a lack of clear military mission:

> Throughout the spring and summer of 1958 the Air Force's Air Research and Development Command had mounted an aggressive campaign to have ARPA convince administration officials to approve its Man-in-Space-Soonest development plan. But ARPA [Advanced Research Projects Agency] balked at the high cost, technical challenges, and uncertainties surrounding the future direction of the civilian space agency.[31]

Dwight D. Eisenhower signed the National Aeronautics and Space Act of 1958 into law at the end of July, and the next month assigned the USAF's human space flight mission to NASA. Thereafter, the MISS program was folded into what became Project Mercury pursuing a ballistic capsule rather than a spaceplane.[32] The remainder of the 1960s followed the accelerated timetable of the Apollo project, tied as they were to Cold War public policy concerns, driving NASA to exploit ballistic missile technology despite desires to return to the spaceplane ideal. In the end, expediency froze out more elegant solutions to the prospect of flying humans to and from space. But even as Apollo was being pursued, NASA still undertook research on the technology, and even before the Moon landing objective was achieved, NASA leaders moved back toward building a capsule follow-on that was a winged, reusable spaceplane. As soon as Apollo was completed, NASA chose to retire that ballistic technology, despite its genuine serviceability, in favor of a return to that earlier winged, reusable vehicle. The Space Shuttle was the result.[33]

This begs the question, had there not been the crisis of the Cold War and the Apollo commitment that flowed from it, might NASA have pursued reusable spaceplane concepts as the launcher of choice from the beginning. This counterfactual question, of course, can never be known with certainty, but with all of the *sturn und drang* associated with spaceplanes even while the capsule era of the 1960s reigned, it seems logical that it would have done so.

Spaceplanes: More than Side-Trips in the 1960s

Aggressive spaceplane research continued throughout the Mercury-Gemini-Apollo programs, and yielded tangible results between 1959 and 1968 with the most celebrated experimental vehicle ever flown, the X-15. It has been lauded loud and long for two specific reasons: its outstanding technology and its exceptionally brave and proficient pilots. Both still stand as the primary legacy of the X–15, bespeaking an historical blind spot regarding the program.[34] Not only is this perspective incomplete, it suggests that the X–15 project proceeded smoothly from success to success, in the process calling into question more recent, troubled high-technology programs and their managers. This is unfortunate because the X-15 also had serious technical problems—and the budgets for it ran amok—but in the aftermath of a long and generally successful program these troubles rarely get discussed.[35]

The program began in earnest in 1954 with the issuance of preliminary specifications for the first hypersonic research aircraft. The NACA made these unusually concise, only four pages in length, with six additional pages of supporting data. The NACA viewed the program as both a flagship effort and an urgent one. John Becker recalled: "As the need for the exploratory data is acute because of the rapid advance of the performance of service aircraft, the minimum practical and reliable airplane is required in order that the development and construction time be kept to a minimum."[36] The X-15 that emerged from this effort had a long fuselage with short stubby wings and an unusual tail configuration. A Reaction Motors, Inc., XLR-99 rocket engine generating 57,000 pounds (253,549 newtons) of thrust powered the aircraft. Because the X-15 could operate in space as well as in the atmosphere, conventional mechanisms for controlling the aircraft were not sufficient, and the aircraft was equipped with small rocket engines in its nose for steering. This was the first vehicle to use such a steering method, although it was also in development for the Mercury spacecraft at the same time.

The X-15's designers anticipated that their biggest problem would be the intense heat that the aircraft would encounter due to the friction of air over its skin. The upper fuselage would reach temperatures over 460 degrees Fahrenheit (F). But other parts of the aircraft would reach temperatures of a whopping 1,230 degrees F and the nose would reach a temperatures of 1,240 degrees F. Designers chose to use a high-temperature alloy known as Inconel X, which unlike most materials, remained strong at high temperatures. It was a difficult material to work with. The wings of the X-15 were constructed of Inconel X skins over titanium frames and were bolted to the fuselage instead of being mounted to a main spar as was customary.

The X-15 first flew on 8 June 1959, on a glide flight. It was dropped from under the wing of a specially modified B-52 "mothership." The first powered flight took place on 17 September. Once the X-15 fell clear of the B-52, pilot Scott Crossfield ignited the rocket engine and flew to a relatively pokey Mach 0.79. But the X-15 was soon traveling many times the speed of sound. The X-15 continued flying until 24 October 1968. In all it made 199 flights divided among three aircraft, established many records, and yielded over 765 research reports. It was, according to one engineer, a spaceplane program that "returned benchmark hypersonic data for aircraft performance, stability and control, materials, shock interaction, hypersonic turbulent boundary layer, skin friction, reaction control jets, aerodynamic heating, and heat transfer."[37] At a fundamental level, spaceplane research is as much a political as a technological endeavor. Everyone should realize that critical reality.

In addition, during the same period the U.S. Air Force pursued the X-20 Dyna-Soar, a military spaceplane to be launched atop a newly developed launcher. It is, without question, one of the most memorable vehicles never flown. Dyna-Soar was officially designated System 620A on 9 November 1959, and a Boeing-Vought contractor team began work on the spaceplane. With ten Dyna-Soar gliders contracted for, the procurement schedule called for two vehicles to be delivered during 1965, four in 1966, and two during 1967. An additional two spaceplanes were to be used for static tests beginning in 1965.At the same time, the Glenn L. Martin Company was selected to develop a human-rated version of the Titan launch vehicle. After several reviews and much political infighting, on 27 April 1960, the Air Force awarded a contract to Boeing as the overall integration contractor and ordered ten. The procurement schedule called for two vehicles to be delivered during 1965, four in 1966, and two during 1967. The other two airframes were to be used for static tests beginning in 1965.[38]

The Air Force believed that the X-20 would provide long range bombardment and reconnaissance capability by flying at the edge of space and skipping off the Earth's atmosphere to reach targets anywhere in the world. Officially begun on 15 October 1957, the Air Force intended to use the Titan IIIC to launch its spaceplane.[39] From the beginning several problems were apparent. First, the difficulty of defining the military mission separate from that of NASA proved a challenge. At some level there were many possibilities and it was difficult to separate them from those of NASA. Second, the technical capabilities of Dyna-Soar made determining on a specific mission out of the many envisioned very difficult.

Despite the funding issues, political infighting, and confusion over mission, on 11 September 1961, the Air Force rolled out a full-scale mock-up.[40] It was an impressive sight. Unlike NASA's capsules, Dyna-Soar was designed to land on a concrete runway 8,000 feet long and 150 feet wide using a three-point landing skid arrangement based partially on the X-15.[41] It had a cross-range from orbit of 2,000 miles, making its entry interface (400,000 feet) approximately 3,000 miles wide and 8,000 miles long.[42]

Although successes were present, problems remained. This led to an end of Dyna-Soar that was every bit as convoluted as its beginning. On 10 December 1963, after expending $410 million ($3.7 billion in 2010 inflation adjusted dollars) on its development with another $373 million needed to attain an orbital test flight, Secretary of Defense Robert S. McNamara cancelled Dyna-Soar over the objections of many of his senior advisors. In so doing he explained that Dyna-Soar was not designed to perform space logistics operations, place substantial payloads into space, nor fulfill extended orbital missions. Somehow, McNamara completely ignored what the program had intended to accomplish and criticized it for not being things it had never aspired to. This ended the first serious attempt to build a spaceplane in the 1960s.[43] Even if Dyna-Soar had never flown an operational mission, it would have provided valuable information on entry flight control and heating, something that was seriously lacking during the development of the Space Shuttle ten years later.[44]

Pursuing the Space Shuttle

The dream of the orbital spaceplane did not die with Dyna-Soar. As the United States completed its major capsule programs in the 1960s—Mercury, Gemini, and Apollo—most involved in space advocacy still envisioned a future in which humans would venture into space aboard winged, reusable vehicles. Advocates asserted that the most expeditious, inexpensive, and reliable method for humans to reach Earth orbit was using a reusable spaceplane. This became the raison d'être for NASA as the Apollo program ended.[45]

With the shuttle program NASA intended to lower the cost of spaceflight so that it could conduct an aggressive space exploration effort. To do so, NASA officials declared, "efficient transportation to and from the earth is required." This could be best provided, they said, with "low-cost access by reusable chemical and nuclear rocket transportation systems."[46] Some NASA officials even compared the older method of using expendable launch vehicles to operating a railroad and throwing away the locomotive after every trip. The shuttle, they claimed, would provide the United States with low-cost, routine access to space. Because the Nixon administration refused to take a stand on a post-Apollo program for NASA until near the end of his first term in 1972, the agency moved forward on its own with planning for what became the Space Shuttle. It promised less expensive and more flexible space access.[47] The task proved more challenging than they believed, although the vehicle itself was technologically stunning and its operations universally impressive.

The economics of spaceflight were critical to developing the Space Shuttle. George M. Low, NASA's deputy administrator at the time, said in a memorandum to other NASA leadership on 27 January 1970: "I think there is really only one objective for the Space Shuttle program, and that is 'to provide a low-cost, economical space transportation system.' To meet this objective, one has to concentrate both on low development costs and on low operational costs."[48] From the outset, therefore, the economics of the shuttle outweighed any other aspects of the program. This was a striking difference from the Apollo program.

- Over a career of more than thirty years of orbital operations the Space Shuttle program has flown 135 missions and has left an important legacy.
- It is an important symbol of the United States' capability, universally recognized as such by both the American people and the larger international community.
- It is a magnificent piece of technology. Any assessment of the program that fails to recognize this unique accomplishment is incomplete and inaccurate.
- It has proven itself the most flexible space vehicle ever flown with the ability to carry a diversity of payloads, to accomplish a myriad of tasks on orbit, and to deploy and retrieve satellites are attributes that need to be considered in any effort to develop a follow-on system.
- It has served as a marvelous platform for scientific inquiry.
- It has clearly wrought a divided legacy for NASA. As a symbol of American technological excellence, and as a reliable, mature, flexible system on which stunning scientific experiments may be conducted it receives high marks. But, the program failed to achieve its core objectives, lowering the cost of reaching Earth orbit. In fact, President Nixon stated in 1972 that the shuttle's "resulting economies may bring operating costs down as low as one-tenth of those present launch vehicles."[49] It has cost between $400 million and $1 billion for every flight of the program.

Accordingly, even as the shuttle program proceeded, NASA pursued efforts to replace it. The inability of the Space Shuttle to meet the nation's space launch needs was emphasized in 1990 in a report by a presidentially appointed Advisory Committee on the Future of U.S. Space Programs, headed by aerospace corporation Martin-Marietta chief executive officer Norman R. Augustine. The report stated that 'the most significant deficiency in the nation's future civil space program is an insufficiency of reliable, flexible, and efficient space launch capability."[50]

Persistent Concepts

The result of these efforts relentlessly pursuing a spaceplane has resulted in a succession of aborted shuttle replacement programs. These have proven unsuccessful in every instance. Overall, they have resulted in the creation of large ambitious programs that are over-hyped, and then they fail as a result of unrealistic management, especially with regard to technical risk. These typically have blurred the line, which should be bright, between revolutionary, high-risk, high-payoff R&D efforts and low-risk, marginal payoff evolutionary efforts to improve operational systems. Two examples demonstrate the continued quest for a spaceplane despite both its technical difficulties and its high cost.

National Aero-Space Plane

In the early 1980s a full-fledged spaceplane again reemerged as the raison d'être of human space launch. Fueled by the realization that the Space Shuttle could never live up to its early expectations, aerospace leaders pressed to move on development of a hypersonic spaceplane. With the beginning of the administration of Ronald Reagan, and its associated military buildup, Tony DuPont, head of DuPont Aerospace, offered an unsolicited proposal to the Defense Advanced Research Projects Agency (DARPA) to design a hypersonic vehicle powered by a hybrid integrated engine of scramjets and rockets. DARPA program manager Bob Williams liked the idea, and funded it as a "black" program code-named "Copper Canyon" between 1983 and 1985.

The Reagan administration later unveiled it as the National Aero-Space Plane (NASP), designated the X-30. Reagan called it "a new Orient Express that could, by the end of the next decade, take off from Dulles Airport and accelerate up to twenty-five times the speed of sound, attaining low earth orbit or flying to Tokyo within two hours."[51] With this announcement of NASP, the hypersonic aerospace plane had returned.[52]

The NASP program initially proposed to build two research craft, at least one of which should achieve orbit by flying in a single stage through the atmosphere at speeds up to Mach 25. The X-30 would use a multicycle engine that shifted from jet to ramjet and to scramjet speeds as the vehicle ascended burning liquid hydrogen fuel with oxygen scooped and frozen from the atmosphere.[53] It never achieved anything approaching flight status.

NASP finally fell victim to budget cuts, in part as a result of the end of the Cold War. But it also ended because of its technological overstretch. For instance, NASA futurist and longstanding advocate of SSTO Ivan Bekey called NASP "the biggest swindle ever to be foisted on the country" because it "was full of dubious aerodynamic claims and engine performance claims and thermal claims."[54]

Although the program never came near to building or flying hardware, NASP advocates claim that it contributed significantly to the advance of materials capable of repeatedly withstanding high temperatures (on the vehicle's nose and body) or capable of tolerating repeated exposure to extremely low temperatures (the cryogenic fuel tanks). By the time of its cancellation in 1992, the government had admitted to making a $1.7 billion investment in the National Aerospace Plane, but parts of the R&D was highly secret and the official costs were probably somewhat higher.[55]

X-33/VentureStar™ and X-34

With the loss of NASP, NASA undertook two additional Space Shuttle replacement efforts. One, the X-34, also known as the Reusable Small Booster Program, was to demonstrate certain technologies and operations useful to smaller reusable vehicles launched from an aircraft. Among those were autonomous ascent, reentry, and landing, composite structures, reusable liquid oxygen tanks, rapid vehicle turnaround, and thermal protection materials.[56]

The other, the X-33, known also as the Advanced Technology Demonstrator Program, was far more challenging technologically. Among the operations and technologies it would demonstrate were reusable composite cryogenic tanks, graphite composite primary structures, metallic thermal protection materials, reusable propulsion systems, autonomous flight control, and certain operating systems, such as electronics for monitoring vehicle hardware.[57]

NASA began the hypersonic X-33 program in 1995, and the agency's leadership expressed high hopes that this small suborbital vehicle would demonstrate the technologies required for an operational SSTO launcher. The X-33 project, undertaken in partnership with Lockheed Martin, had an ambitious timetable to fly by 2001.[58]

Both the X-33 and the X-34 programs mired down in seemingly inscrutable technological problems and bureaucratic challenges, NASA lost faith in them and terminated both efforts in 2001. Thereafter, NASA officials expressed a deeper understanding that the technical hurdles proved more daunting than anticipated, as was the case thirty years ago with the Space Shuttle and more recently with the NASP. Any such vehicle, and both X-33 and X-34 perpetuated this pattern, would require breakthroughs in a number of technologies, particularly in propulsion and materials.[59]

Both NASP and the later X-33/X-34 programs proved enormous detours for those seeking to move forward with a replacement for the Space Shuttle, but few questioned the commitment to the spaceplane concept. Expending billions of dollars and dozens of years in pursuit of reusable spaceplane technology, the emphasis on this approach ensured the tardiness of development because of the strikingly difficult technological challenges. Some engineers referred to NASP as being built from "unobtainium" and thought the United States should instead pursue more conventional space access technologies. Whether appropriate or not for space access in the long run, the quest for a spaceplane has been a detriment to the cause thus far. Indeed, engineers have faced four major challenges vexing efforts to develop this technology:

1. Aerodynamics.
2. Guidance and Control.
3. Materials.
4. Propulsion.

In the first realm of aerodynamics, through a succession of projects and studies many of the roadblocks to effective shapes for a hypersonic vehicle have emerged. Many of the aerodynamic questions are now satisfactorily understood. The same is true for the second challenge of guidance and control. Materials research remains an important aspect yet to be resolved as researchers continue to research heat resistant materials and composites that can reduce weight. But the biggest issue remains propulsion. There is, as yet, no fully functional scramjet engine, at least not in the public arena. These are all problems for future researchers to solve before realizing the dream of a true spaceplane.[60]

At some level the pursuit of the spaceplane by the United States might be compared to the pie in the sky ideas pursued by some nations in the World War II period to create a death ray. Often identified with Nikola Tesla, the concept of a death ray is generally portrayed as some form of directed energy weapon that projects energy at a person or object in order to destroy them. While it represented one part of the Reagan administration's Strategic Defense Initiative in the 1980s, the quest for it energized some nations before and during World War II to pursue in a serious manner a weapon that was at that time essentially a device confined to science fiction. Nikola Tesla—a Balkan-American physicist, mathematician, inventor, and electrical engineer—advocated pursuing what he called the "Teleforce," a macroscopic particle beam projector, first publicly mentioned in the *New York Sun* on 10 July 1934. This system, Tesla asserted, used a specialized particle-beam projector to annihilate enemy forces as much as 200 miles away. The Japanese, apparently, pursued this possibility aggressively before and during World War II, with the intention of coming up with a decisive weapon. The Nohorito Laboratory, according to the Army Air Forces Scientific Advisory Group that investigated Axis research and development at the end of the war, conducted this research for a death ray. Although the Japanese work was rudimentary, the AAF Scientific Advisory Group expressed the belief that this death ray weapon had some promise and should be continued by the U.S. military. As it was, however, death ray research sent some of the best technical minds in Japan down a blind alley. Had they pursued nuclear weapons instead, they might have developed a decisive weapon. As it was, they achieved little.[61]

Persisting in Belief in the Twenty-First Century

The spaceplane ideal remained the norm into the twenty-first century. Only after the loss of the *Columbia* Space Shuttle in 2003 did this begin to change, albeit slowly and certainly incompletely. In the fall of 2005 the NASA administrator of some six months, but a longtime member of the space community, called the Space Shuttle a "mistake." Mike Griffin commented that NASA had pursued the wrong path with the shuttle when conceived in the 1960s and developed in the 1970s, and persisted with it long after its flaws had been discovered. He believed that this poor decision now had to be corrected, admittedly more than thirty years after the fact. "It is now commonly accepted that was not the right path," Griffin told *USA Today* in an interview that appeared as a page one story on 28 September 2005. "We are now trying to change the path while doing as little damage as we can."[62] Griffin's assertion that the Space Shuttle had been the "wrong path," a mistake persisted in for more than a generation set off a firestorm of debate within the spaceflight community to the extent that NASA issued a point paper explaining what Griffin had meant.[63] It also triggered not a little soul searching about the importance of the spaceplane in both the history of space exploration and in the larger context of world history and culture.[64]

After giving up trying to build another spaceplane, on 14 January 2004, President George W. Bush pressed the reset button by mandating that NASA focus on a new Moon/Mars exploration agenda using a capsule called the Crew Exploration Vehicle (CEV) that overturned any other initiative.[65] That program remained in place only until 2009, when President Barack Obama overturned it in favor of a commercial effort to replace the Space Shuttle. Although that might also be a capsule, by the end of 2010 NASA's Commercial Crew Development (CCDev) program was supporting yet another design for a winged spaceplane "very reminiscent of the Shuttle's design intended to ferry crews to and from the ISS." Orbital Sciences Corp., the company working on this latest quest for a spaceplane, asserted that

> a reusable space plane design as the cheaper and safer way to move crews to and from the ISS; its "blended lifting body" allows it to move from its

> orbital trajectory as it re-enters and place it's [*sic*] point of landing where the pilot wishes. Capsules, of course, come screaming through the atmosphere more or less at their orbital trajectory and rely on parachutes to soften the "splash down" and a recovery crew to locate and pick up the crew.

As the report appropriately concluded: "Both capsules and space planes have their advantages, and neither has a spotless safety record. But it will be interesting to see which mode NASA eventually selects for the next generation of ISS missions."[66]

There seems to be every reason to believe that NASA will continue the spaceplane concept in the future. Eighty-plus years of orientation to that approach will be difficult to overturn. This is especially the case when the elegance of a spaceplane is so present in society as a whole. Everyone sees it and only reluctantly wants to return to the capsule concept used in the 1960s with Mercury, Gemini, and Apollo. In the middle of that era an engineer working on NASA's lifting body research and development program drew a cartoon showing in one panel a Gemini spacecraft bobbing in the ocean as its crew awaited rescue at sea and in another panel a spaceplane landing on a runway. The caption read: "Don't be rescued from outer space, fly back in style." It captured the key difference between space capsule splashdowns at sea and spaceplane landings on a runway. It captured the goal of a spaceplane, a goal that was incompletely realized with the Space Shuttle but still something that has remained an objective of human spaceflight. Both approaches to spaceflight works; one is viewed as more desirable than the others and the engineers involved in the effort to build human spaceflight capabilities persist in its pursuit to the present.

Endnotes

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