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Space policy and the size of the space shuttle fleet

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Abstract

During the space shuttle era, policy makers have repeatedly wrestled with the issue of fleet size. The number of shuttles had both practical and symbolic significance, reflecting the robustness of the space transportation system and US preeminence in space. In debating how many shuttles were needed, NASA and other government entities weighed various arguments to determine the optimum number of vehicles for human spaceflight. Deliberations and decisions about shuttle fleet size reflected changing policy priorities and attitudes about the role of the shuttle. That history frames issues that may arise again in planning for new space transportation vehicles beyond the shuttle.
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The US space program suffered a tragic accident on 1 February 2003 with the loss of *Columbia* and the STS-107 crew. Virtually without warning at the end of a successful mission, the orbiter disintegrated during reentry, resulting in the deaths of seven astronauts and the destruction of one fourth of the space shuttle fleet. The most urgent responses to the accident were to investigate, understand, and remedy its causes, and to return the shuttle to flight. But the accident also triggered a broad reassessment of space transportation requirements and prompted President George W. Bush to announce within a year that the shuttle will be retired by 2010. In this new effort to define the optimum types of spacecraft for the post-shuttle future, the space community once again confronts the question that has punctuated the shuttle era: how many vehicles are needed for human spaceflight?

In the thirty-plus years since the 1972 decision to develop the shuttle as the primary vehicle for carrying out US activity in space, the issue of fleet size has arisen repeatedly, in normal times and in crisis. Fleet size received sustained attention at two key junctures in the shuttle program, from 1976 to 1982 as the first orbiters were being built, and from 1986 to 1991 in the aftermath of the *Challenger* accident. While it has been NASA's responsibility to articulate a fleet size rationale, decisions about the number of shuttles to build have been made in the White House, where programs and politics intersect in an environment of competing interests. NASA has argued for more shuttles, critics have argued for fewer, and three presidents have decided, for various reasons, that a four-vehicle fleet would adequately meet the nation's needs.

Examination of these deliberations reveals that the shuttle fleet has been shaped by a changing balance of operational requirements, budgetary pressures, and political agendas. Decisions about space shuttle fleet size reflect, to a great extent, other policy priorities. They also reflect a gradual shift in attitude about the role of the shuttle in serving the nation's space transportation needs. With the shuttle fleet now reduced to three vehicles and widespread reassessment of its utility in progress, a review of past decisions gives some historical perspective to the question, "How many shuttles do we need?"

Decisions made decades ago influence the bind NASA is in today. Using the shuttle as both the primary launch vehicle for cargo delivery and the sole vehicle for human spaceflight, the USA has banked on the expectation that the shuttle will operate reliably and frequently. With assembly and full staffing of the International Space Station dependent on regular shuttle service, NASA had already realigned operations of the four-orbiter fleet to meet the demands of the space station program. Other types of missions disappeared from the manifest as the four shuttles were dedicated to supporting the space station. With the fleet reduced to three orbiters and a lengthy hiatus in shuttle launches since the *Columbia* accident, the space transportation system is temporarily

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paralyzed and may be sorely taxed to do the remaining work. The minimum viable fleet of three orbiters—the situation now—was always thought to be a worst case scenario.

Although a significant body of literature exists on the decision to build *the* space shuttle, there is little attention to the recurrent consideration of *how many* shuttles to build [1]. Fleet size was a crucial issue that drove funding requirements, production schedules, and US launch and space operations capabilities, as well as perceptions of US preeminence in space. Examining how the shuttle fleet size was debated, established, and justified illuminates space policy priorities during the space shuttle era. It also may offer useful insights for answering the "How many do we need?" question for the shuttle's replacement, whatever that may be.

1. The idea of a shuttle fleet

The idea of a fleet of space shuttles served the goal of an economical transportation system for "routine access to space". It marked a profound shift away from the approach to human spaceflight that prevailed in the 1960s—reliance on standardized but single-use launch vehicles and crew vehicles for missions in Earth orbit and to the Moon. The new objective was to support human activity in near-Earth orbit, not at a far destination, on missions that would be more practical than exploratory. A reusable vehicle and its crews would be versatile enough to accomplish various kinds of missions, as different as satellite deployment, in-orbit servicing, and laboratory research. For space to become a workplace for useful purposes and benefits on Earth, a fleet of reusable spaceplanes would be needed to provide frequent, reliable, routine transportation, and to do it more economically than expendable vehicles.

The space shuttle concept emerged as one of several options for the post-Apollo space program, but it was not the self-evident next step. As planning began well before Americans first walked on the Moon in 1969, advocates achieved no clear consensus on what the next step should be. NASA was eager to embark on another highly ambitious human spaceflight project—an orbital space station or a human mission to Mars—to preserve momentum and expand the capabilities developed during the race to the Moon. However, the sense of urgency that had sustained political and financial support for human spaceflight in the early 1960s had evaporated by the end of the decade. NASA soon realized that, with a shrinking agency budget and lukewarm political interest bringing the Apollo lunar program to an early end, a very expensive new endeavor would not win approval. Of the new programs under consideration, only a reusable space transportation system—the space shuttle—was deemed practical enough, and possibly cheap enough, to gain support and funding.[1]

The story of the tortuous process of reaching a space shuttle design that would achieve reusability at low enough cost to win approval has been well told elsewhere.[2] Perhaps the greatest consequence of this effort during 1970–1971 was that, under intense pressure from the federal budget office and Congress, NASA was forced to justify the new space transportation system as cost-effective. The shuttle's economic viability, rather than its capabilities and uses, became the primary measure of its worth. This legacy has been an important factor in decisions about the size of the shuttle fleet.

President Richard Nixon's announcement on 5 January 1972 of the decision to proceed with development of the shuttle sounded the themes that would serve as policy guidelines for human spaceflight during the 1970s. The rationale for the new space transportation system was to make space "easily accessible for human endeavor" by making spaceflight more economical and routine. A reusable shuttle would become the "workhorse" of the space program, serving as both a commuter vehicle for people going to work in space and a delivery or servicing vehicle for satellites and other payloads. It would sharply reduce costs and take "the astronomical costs out of astronautics". Although not a formal space policy directive, this announcement effectively gave the US space program a new purpose: "to achieve a real working presence in space" for practical uses and benefits on Earth [3].

The rhetoric of the announcement resonated with the heady optimism of advocacy. Promoting it as a revolution in space transportation, the President claimed that the space shuttle would replace almost all launch vehicles, serve a variety of missions, and deliver the benefits of space into the daily lives of all people. Proponents of the shuttle envisioned airline-like operations between Earth and orbit. In that spirit, NASA set about developing the space shuttle fleet.

2. Plans for a five-shuttle fleet

To bolster the case for the economic viability of the shuttle and win approval to embark on the new program, NASA had commissioned analyses from the research firm Mathematica, Inc. Its tasks were to assess the economics of a reusable shuttle compared to expendable launch vehicles, and then to assess the most cost-effective type of shuttle vehicle to serve all foreseeable space missions. One of the most critical, yet most

[1] For an overview of this period of planning, see Logsdon. The evolution of US space policy and plans (Chapter 3), in [2]. Also Heppenheimer, Ref. [1, Chapter 2, NASA's uncertain future].

[2] Primarily Logsdon, Launius, and Heppenheimer, Ref. [1].

problematic, factors in this analysis was an estimate of user demand for the shuttle, expressed as the number and types of payloads that might fly on the shuttle during its first decade in operation. Mathematica's reports issued in 1971 and 1972 emphasized the importance of projected user demand for space transportation; mission traffic would be fundamental to the economic viability of the shuttle.[3]

To estimate user demand for the shuttle, Mathematica's economists collected and assimilated data on possible future space activity from NASA, the Department of Defense (DoD), and other sources. The analysis rested heavily on a composite mission traffic summary or "mission model" developed by The Aerospace Corporation for NASA in 1971. This model projected almost 900 potential flights from 1979 to 1990. According to Mathematica's analysis of mission traffic ranging from 300 to 900 flights, the anticipated demand would yield high enough annual flight rates to justify the investment in a shuttle system.[4] With hindsight, skeptics might justifiably question these figures, but at the time there was no strong independent analysis pointing to different conclusions.

Such projections were necessarily speculative, and Mathematica admitted the uncertainties of predicting mission traffic years ahead for a vehicle not yet in existence. The study called the demand for space transportation "the principal open problem," but expressed optimism that the demand would grow markedly as the space shuttle came into service.[5] These projections, however hypothetical, enabled NASA to assert that sufficient user demand existed for an economical shuttle operation.

The estimate of user demand also served as a basis for calculating how many shuttles would be needed. Concurrent with development of the mission model, NASA also began working on fleet size analysis. This planning effort likewise depended on largely hypothetical assumptions about how many payloads in what combinations the shuttle could carry, how long mission duration and turnaround times would be, what the flight rate would be, how long orbiters might be out of service for maintenance, how many missions might fail, and a host of other operational considerations. Even though the shuttle had not yet been designed, the size of the shuttle fleet needed to support the estimated traffic was being defined.

The space shuttle development contract awarded to Rockwell in mid-1972 called for five orbiter vehicles. The contract and orbiter deliveries were set up in phases.[6] Two shuttle orbiters would be built during the development phase; one would be used for tests on the ground and in the atmosphere before being refurbished for spaceflight, and the other would be used for several orbital flight tests before being refurbished for full operational use. Three additional orbiters would be delivered during the production phase for use when the shuttle was declared operational. The two refurbished original orbiters plus the three new ones would make up the operational fleet of five shuttles.

The traffic model included in the contract anticipated a flight rate increasing from 6 missions in the first year (with one orbiter) to 40 in the fifth year and then sustaining (with five orbiters) at 60 flights per year through the 10th year, for a total of 445 missions. For 60 flights a year each of the five orbiters would fly once a month, on average, with no vehicle lost to prolonged maintenance or an accident. Optimistic or unrealistic as that flight rate seems today, it was the basis for the rationale for a fleet of five shuttles.

NASA and the Department of Defense collaborated in the development of the shuttle, jointly defining its capabilities and planning for its use. For an overview of civil-military cooperation in space shuttle development, see Ref. [5]. One result of that collaboration was an agreement to operate the shuttle from two launch sites to meet different mission requirements. In a fleet of five orbiters, three would be stationed in Florida and two would operate from a western launch site at Vandenberg Air Force Base in California. Most commercial and scientific missions would be launched into low-inclination orbits from the east coast. The western site would be used primarily for Defense Department national security missions, especially launches of reconnaissance satellites into polar orbit. It was desirable to have two orbiters at each site for assured launch capability, with the fifth available for use on scheduled missions or as a backup vehicle in case one of the others was out of service. With an operational fleet capacity of 60 flights per year, about 40 would be launched from Florida and 20 from California.

This rationale for a five-orbiter fleet was sustained by a succession of mission models during the development

[3] Mathematica documents, all in the Historical Reference Collection at NASA Headquarters, Washington, DC. Economic analysis of new space transportation systems, executive summary, 31 May 1971. Factors for a decision on a new reusable space transportation system, 28 October 1971 (also in Ref. [2, vol. I, p. 549–55]). Economic analysis of the space shuttle system, executive summary, 31 January 1972 (also in [4]).

[4] Chapter 4, Space missions and payloads 1979–1990, in Mathematica. Economic analysis of the space shuttle system, executive summary, 31 January 1972, in Historical Reference Collection, NASA Headquarters.

[5] Mathematica. Factors for a decision on a new reusable space transportation system, 28 October 1971, in Historical Reference Collection, NASA Headquarters (also in Ref. [2, vol. I, p. 553]).

[6] NASA Contract NAS9-14000 to Rockwell International Corporation. System integration and orbiter vehicle development, space shuttle program, Exhibit A, Space shuttle program statement of work, 1 December 1972, A2-2, in Historical Reference Collection, NASA Headquarters.

phase of the shuttle program, when only the first two of the five planned orbiters had been funded.[7] As the development phase neared its peak with delivery of the first orbiter in 1976 and assembly of the second orbiter in progress, NASA budgeted for the third vehicle and gained approval to start the production phase. However, the fourth and fifth orbiters had not yet been approved.

To this point, fleet size was essentially a calculation matching flight rate to predicted user demand. Early in 1976, fleet size became a tangible procurement issue, as NASA and DoD decided to press for approval and funding for the two additional orbiters.[8] NASA Deputy Administrator George Low directed Associate Administrator for Space Flight John Yardley to verify the need for five orbiters and prepare the arguments that would yield a favorable decision.[9] Yardley led a NASA-DoD effort to craft a joint position paper for use by the NASA Administrator and Secretary of Defense to convince the President to commit to the full fleet.

NASA and DoD had agreed on the need for five orbiters since conducting a joint fleet size analysis in 1973 and revalidating it in 1974 and 1975.[10] The baseline mission model, subject to occasional revision, then stood at 572 flights, with a target rate of 60 flights a year still pacing the number of orbiters. Now the case had to be made to the White House. Meeting notes and memos between Low and Yardley in the spring of 1976 give some insight into the thought process of preparing this document. Low harshly criticized an early draft, stating "If this is the best we can do, we might as well give up now".[11] He instructed that the argument be clear, concise, logical, and factual, without "arm-waving," and he recommended that the fleet size analyses be appended so their validity could be examined. A later draft was revised to describe the need for six orbiters (five plus a spare for attrition).[12] Drafts of the paper also addressed the question of whether to fund the fourth and fifth orbiters through NASA or DoD.

By the end of May 1976 the joint NASA-DoD issue paper on fleet size and orbiter procurement was ready. This document reaffirmed the need for five orbiters as the *minimum* viable fleet capable of meeting both defense and civil needs and recommended that NASA receive the necessary additional funding to proceed with production. It also stated that a sixth orbiter would be desirable to support the 60-flights-per-year rate and ensure adequate space transportation in case of attrition of one orbiter, and it suggested consideration of a sixth shuttle in the near future. The pillar of the fleet size rationale was the requirement for assured launch capability and scheduling priority for national security missions. This issue paper accompanied a letter for NASA Administrator James Fletcher and Secretary of Defense Donald Rumsfeld to take to President Gerald Ford for a decision. The letter presented a recommendation to proceed with a five-orbiter fleet by authorizing procurement of the fourth and fifth shuttles in the next budget cycle[13].

Both the mission model and the fleet size rationale were based on the premise that the shuttle, as a matter of policy, would become the sole launch vehicle for all foreseeable space transportation needs. According to the various fleet size analyses, the economic benefit of the shuttle would be realized only with a high flight rate achieved by phasing out expendable launch vehicles. NASA and DoD agreed that a fleet of fewer than five orbiters would not adequately support the anticipated traffic and mission requirements. A limited shuttle fleet would mean the continued use of expendables for assured DoD launch capability, unacceptably compromising the economic viability of the shuttle. The recommendation to commit to a five-orbiter fleet was an effort to obtain the presidential decision that would assure as policy the shuttle's role as the nation's principal, if not sole, launch vehicle.

3. Fleet size rationale challenged and defended

Because the shuttle program was funded incrementally, the transition from development to production presented an opportunity for Congress and the administration to reassess the fleet size rationale before making the significant financial commitment to build more orbiters. As NASA and DoD refined their argument, both the Government Accounting Office (GAO) and the

[7] A list of STS traffic models for 1971 (581 flights), 1973 (725 flights), 1974 (572 flights), and 1976 (560 flights) appears in a briefing, Shuttle fleet size considerations and procurement options presentation to the administrator, 27 July 1977, in Historical Reference Collection, NASA Headquarters.

[8] Joint NASA/DOD position statement on space shuttle orbiter procurement, 23 January 1976, in Historical Reference Collection, NASA Headquarters (also in Ref. [5, vol. II, p. 389–90]).

[9] Memorandum to Associate Administrator for Space Flight from Assistant Executive Officer. NASA/DOD orbiter procurement, 26 January 1976, in Historical Reference Collection, NASA Headquarters.

[10] In these planning exercises, the baseline mission model was adjusted from 725 flights (1973) to 572 flights (1974), with flight rates increasing to 60 flights a year as the fleet reached full strength.

[11] Memorandum to Associate Administrator for Space Flight from Deputy Administrator. Comments on April 7 issues paper on orbiter procurement, 19 April 1976, in Historical Reference Collection, NASA Headquarters.

[12] Meeting record. Orbiter procurement, 11 May 1976, in Historical Reference Collection, NASA Headquarters.

[13] Space shuttle issue paper: fleet sizing/orbiter procurement funding, and Memorandum for Secretary of Defense and NASA Administrator, Space shuttle orbiter procurement funding, 28 May 1976, both in Historical Reference Collection, NASA Headquarters.

Office of Management and Budget (OMB) challenged the presumed five-orbiter fleet in preparation for the orbiter procurement decision. Not surprisingly, these guardians of government spending were far less sanguine than NASA about the need for more shuttles.

In the 1976–1978 period GAO sent to Congress three critiques of the shuttle program plan and urged a delay in committing to a five-orbiter fleet [6]. GAO analysts viewed the mission models with skepticism because they were based on uncertain predictions about user demand instead of firm requirements. They were not convinced that flight rate and cost–benefit assumptions were valid enough to proceed with building more than the first three orbiters, and they also doubted that the western launch site was necessary. The GAO reports charged that the mission models, fleet size rationale, cost and schedule projections, and buttressing assumptions were inherently optimistic. With no assurance that demand for flights would increase enough to warrant a larger fleet, and no experience yet to assure reduced operating costs, GAO recommended waiting until use of the space transportation system built greater confidence in the assumptions underlying the fleet size rationale before building more shuttles.

This "fly-before-buy" position was at odds with the five-vehicle production plan favored by NASA and supported by DoD. The agencies' responses to GAO's critique were included in the reports. NASA Administrator James Fletcher countered that deferring production or delaying a fully operational fleet would drive up costs and reduce the economic benefit sought in the shuttle, an injustice to taxpayers. The agency's prior experience offered a reassuring set of precedents, as other spacecraft production efforts had successfully proceeded before newly minted vehicles were thoroughly proven. He also argued that the mission model reflected reasonable forecasts derived from planning studies both within and outside the agency by users willing to take advantage of the shuttle's capabilities. Fletcher closed his rebuttal letter to GAO by reaffirming that "the national interest will be best served by committing now to the procurement of a five-orbiter fleet," a judgment that GAO did not find persuasive.[14]

In mid-1976, as they were finishing work on the joint five-orbiter fleet position paper, the Office of Management and Budget asked NASA and DoD to complete a fleet size study as a basis for its consideration of the orbiter procurement decision [7]. The scope of the study included launch/landing site considerations, mission model and payload data, and detailed fleet size and cost-effectiveness analyses. At OMB's direction, the study evaluated alternative fleets of three, four or five orbiters at two launch sites against the latest civil and defense mission models. It also evaluated a three-orbiter fleet operating only from Florida and various mixes of shuttles and expendable launch vehicles.

The report, "Joint NASA/USAF Study on Space Shuttle Orbiter Procurement and Related Issues", concluded that five orbiters was "the minimum acceptable fleet size to meet planned national requirements and to provide the nation with a level of space capability with which it can maintain its world leadership" [7, p. 183]. It also concluded that a five-orbiter fleet operating from two sites would be more economical than any alternative mix of expendables and fewer shuttles, and that significant cost penalties were associated with delaying or foregoing the fourth and fifth orbiters.

Presenting the study results to OMB and recommending that two additional orbiters be funded, NASA Administrator James Fletcher argued that "in order to achieve the full economic and operational benefits of the Space Shuttle, there must be enough orbiters to provide for the full space transportation requirements of the nation".[15] While emphasizing that a five-orbiter fleet was the right size and the most cost-effective means to meet these requirements, Fletcher also voiced space policy themes likely to win favor in the White House. He linked the future space capability of the nation to the fleet size decision, noting that too few orbiters would adversely impact US leadership in space technology. A fleet of five shuttles would encourage an early transition from expendable vehicles and development of new uses for the vehicle that would increase the benefits of exploiting space. It would also enhance the nation's strength and prestige.

Fletcher thus began to elevate the shuttle fleet size issue from the prosaic level of procurement to the more engaging realm of space policy by adding several attractive political considerations to the fleet size rationale. This strategy bolstered what became a long but ultimately futile effort to gain approval for a fifth orbiter. In the coming years NASA would rely less on the tenuous mission model and more on policy values to make the case for a five-orbiter fleet.

4. A fleet of four shuttles

Although OMB had solicited the joint NASA-USAF study as input for the fall 1976 budget deliberations, the orbiter procurement decision was not made until a year later. By then, Jimmy Carter had become president, NASA had a new administrator (Robert Frosch), and both had a chance to shape the future of the shuttle

[14] Letter from NASA Administrator James Fletcher to Comptroller General Elmer Staats, 6 April 1977, in GAO Report Space transportation system: past, present, future. Ref. [6, p. 65–6].

[15] Letter from NASA Administrator James C. Fletcher to OMB Director James T. Lynn, 22 October 1976, in Ref. [4, vol. IV, p. 286–8].

program. In a budget-conscious administration attempting to curb federal spending, there was strong pressure to scale back, or even cancel, the commitment to the space shuttle [8]. However, successful atmospheric test flights by the first shuttle had just increased the visibility and momentum of the program. This demonstrable progress in the development phase meant the time was near to proceed into the production phase of the program, and it was time to decide how many more orbiters to build.

OMB requested an update to the previous study for the fall 1977 budget deliberations, and the NASA-USAF reexamination of fleet size variations again reaffirmed a fleet of five orbiters operating from two sites as the best plan.[16] However, OMB recommended that President Carter consider a three orbiter/one site option and a four orbiter/two site option [9]. To a last-minute memo from Secretary of Defense Harold Brown noting that the smaller fleet options would jeopardize DoD participation in the shuttle program, Carter jotted in reply, "I agree on two sites—have doubts between 4 & 5. Check with OMB".[17] OMB was not yet ready to endorse five orbiters, for reasons of cost and uncertain demand. It would cost less then to build a fleet adequate to meet early mission requirements; more orbiters could be funded later if the longer-range forecast materialized.

The principal argument against a fleet of three orbiters operating from one site was the DoD requirement for assured launch capability. The Defense Department wanted the California site for national security missions, and it wanted two shuttles stationed there to guarantee its ability to launch those missions. The classified roster presumably included reconnaissance satellites to monitor arms control agreements and other high-priority payloads that could not be compromised by launch vehicle readiness. Although DoD had helped craft the rationale for a five-orbiter fleet, when faced with the threat of only three shuttles Secretary Brown reportedly made a convincing argument for four orbiters as the minimum for meeting these national security requirements [10]. If DoD's needs could be satisfied with four shuttles, President Carter and OMB had good reason to defer any commitment to a fifth orbiter.

When it became evident that the decision would be to approve only four orbiters, NASA Administrator Frosch appealed to Carter and OMB to preserve the option for a fifth vehicle, but the attempted persuasion failed.[18] The administration had determined that a total fleet of four operational orbiters would meet foreseeable civilian and military flight requirements. Any additional orbiters might be considered in the future if flight rates or loss of a vehicle warranted a larger fleet. Operations from both launch sites were approved to encourage use of the shuttle and phasing out of expendable launch vehicles.

President Carter's decision had two effects: it authorized the shuttle program to proceed into production, and it established the rationale for a smaller fleet. The indefinite deferral of a fifth orbiter frustrated NASA's desire to gain a commitment to the full fleet and foreshadowed the difficulty ahead. The arguments based on mission model projections and flight rates had not been convincing enough to win a first round decision for a five-orbiter fleet. What reasoning might prove more effective?

The Carter administration's December 1977 orbiter procurement decision resulted from the routine budgetary process rather than a formative policy process. Nothing about it gave a clear vision of what the shuttle meant in the grander scheme of national life or the shuttle as a priority on the nation's agenda. The shuttle's utility for national security purposes—reconnaissance and arms control verification—probably was the salvation for a viable fleet, but that was a last-hour emphasis rather than a starting premise. Commenting on the status of the space program in the 1970s, one historian noted that "budget begat space policy instead of space policy begetting budget" [11]. That aphorism could aptly apply to the decision to constrain the shuttle fleet.

Several months earlier President Carter had directed the policy review committee of the National Security Council to develop a coherent US space policy.[19] That effort was under way as the shuttle fleet size was being considered, but no statement of national goals in space yet existed as context for the shuttle fleet size decision. The National Space Policy appeared in May 1978, a largely classified directive that primarily addressed national security activities in space. It offered only the broadest guidance for civil space programs—to increase scientific knowledge, develop and operate useful space technology, maintain US leadership, and further US domestic and foreign policy objectives. The unclassified clauses did not mention the space shuttle at all.[20]

A more detailed civil space policy was issued in October 1978, a year too late to have influenced the shuttle fleet size decision but still pertinent to planning

[16] Joint NASA/USAF study on space shuttle orbiter procurement and related issues, 1977 update summary briefing, in Congress, House. Space shuttle appropriations for fiscal year 1979: hearings before Subcommittees of the Committee on Appropriations, 95th Congress 2nd Session, 1978.

[17] Memorandum from the Secretary of Defense for the President. Budget decision on space shuttle, 11 November 1977, Jimmy Carter Library.

[18] Letter from James T. McIntyre Jr. (OMB) to Robert A. Frosch (NASA), 23 December 1977, in Ref. [4, vol. IV, p. 288–9].

[19] Presidential Review Memorandum/NSC 23: A coherent US space policy, 28 March 1977, in Historical Reference Collection at NASA Headquarters.

[20] Presidential Directive/NSC-37: National space policy, 11 May 1978, in Ref. [2, vol. I, 574–5].

for use of the shuttle. The policy's emphasis on practical applications, scientific research, fiscal constraints, reduced costs, and international cooperation held implications for the shuttle era. The strategy to utilize the shuttle was hardly visionary; it indicated that the space transportation system would be improved incrementally as necessary. Even more conservatively, the policy stated that "It is neither feasible nor necessary at this time to commit the US to a high-challenge, highly visible space engineering initiative comparable to Apollo", thus ruling out a space station.[21] Under the Carter policy guidelines, the civil space program would be a restrained, practical, and frugal enterprise.

The four-orbiter fleet decision matched that cautious, pragmatic approach to space policy. President Carter continued to defer action on a fifth orbiter, leaving the shuttle on the table of budget deliberations rather than bringing it into a policy arena that defined clear goals in space. The size of the shuttle fleet initially was shaped more by the question "how many can we afford?" than "why do we need them?" As the shuttle was not yet operational and space policy remained dormant, there was no compelling reason to consider expanding the shuttle fleet during the rest of Carter's term in office.

5. A fifth shuttle reconsidered

The late-1977 decision to proceed with four orbiters did not kill interest in a fifth shuttle. For several years, the uncertain prospect of a fifth orbiter lingered in the background of the shuttle program. Congress continued to raise it in NASA's annual budget hearings and program reviews, and eventually President Ronald Reagan gave it consideration as well.

Although the indefinite deferral of a fifth orbiter was a disappointing setback for the agency, NASA had a more urgent priority than fleet size demanding its attention: preparing for the first shuttle mission. From 1978 to 1981, the shuttle program fell 2 years behind schedule through a combination of technical and financial problems. After those problems were resolved and the shuttle successfully launched, expansion of the fleet could be reconsidered.

Within months of the first shuttle mission in 1981, the Reagan administration issued a policy directive declaring the space transportation system to be the primary space launch system for US government missions and ordering transition to the shuttle "as expeditiously as practical" [12]. This strong expression of confidence in the new vehicle signaled to the civil, military and commercial communities to begin using the shuttle. With a stated commitment to service all authorized space users and a discounted pricing plan for reimbursable flights, NASA expected to build customer demand for the operational fleet of shuttles.

Upon completion of four successful orbital flight test missions in 1981 and 1982, Reagan declared the shuttle operational and issued a national space policy to guide the conduct of the US space program [13]. The policy opened with a statement of the central importance of the space shuttle in both national security and civil space programs, and it included a substantial set of guidelines for use of the space transportation system. At about the same time NASA released a report on national space transportation system policy issues [14]. It took another look at fleet size options and concluded that a fifth orbiter, and possibly a sixth, could be needed by 1986 to 1990.

As the space policy appeared, the shuttle program approached a critical milestone. Two orbiters were in service, another was almost ready for delivery, and the fourth was in production. A decision point loomed: whether to build more orbiters or close the production line. NASA had another chance to make its fleet size case in 1982 as Congress and the White House both reviewed the need for a fifth orbiter, and as President Reagan reached a decision in early 1983.

The Congressional hearing and report addressed several concerns: whether an increase in the size of the shuttle fleet was required, when a decision should be made to avoid a costly gap in production, and whether private sector acquisition of an orbiter should be considered [15]. NASA testimony indicated that the planned shuttle fleet would be capable of supporting 24–30 missions per year by 1988 with four fully available orbiters. Since 1976, NASA had reduced the mission model to more realistic levels, from 572 flights to 560–487 and then to 300 missions [16]. However, projected traffic was mentioned only in passing as a reason for additional orbiters, and there was no indication that an increase in demand warranted another orbiter. NASA's previous arguments for the fleet size rationale—meeting demand and cost-effectiveness—were muted.

Instead, the testimony focused on new arguments. NASA emphasized the operational impact of attrition (losing an orbiter in an accident or taking one out of service for extended repair) as a reason to augment the fleet. Another consideration was the cost-economy of purchasing another orbiter (or at least spare components) before production facilities closed upon completion of the four-orbiter fleet; a block-buy of fifth, sixth and perhaps seventh orbiters would be even more economical. DoD testimony in the same record indicated that a four-orbiter fleet was sufficient for its needs, but it supported a fifth orbiter as insurance against attrition.

[21] Presidential Directive/NSC-42: civil and further national space policy, 10 October 1978, in Ref. [2, vol. I, p. 575–8].

Several months after the Congressional hearing on the need for a fifth orbiter, the Reagan administration addressed the issue. Within the National Security Council, the Senior Interagency Group for Space, called SIG (Space), served as the deliberative body for space policy. In late 1982 this panel prepared a recommendation for the President's decision on production of a fifth orbiter.

While most SIG (Space) papers remain inaccessible for review in classified National Security Council materials, a published issue paper from this task summarized some of the deliberations on a fleet size rationale. The SIG rejected user demand as the main argument for another orbiter, stating that such projections were not a reliable enough basis for a decision. Instead, they recast the issue as a decision whether to continue or curtail production capability while there was not yet a clear need for another orbiter. Reluctant to constrain the nation prematurely to a four-orbiter fleet that might prove inadequate for future demand or to build another shuttle that might not be needed, the group sought a compromise option. Their recommendation was an interim measure to maintain production of selected structural spares that could be used to repair shuttles currently in the fleet or to assemble another orbiter if future demand actually materialized [17].

This SIG document placed the fleet size issue within the context of national space policy. Acknowledging US policy commitments to maintain world leadership in space transportation and to provide shuttle launch service to commercial and foreign users, it concluded that the nation's best interest would be served by preserving orbiter production capability until demand was better known. Although the paper showed costs for the three options under consideration, the pro and con analysis was more substantive than fiscal. The SIG strove to make a prudent decision for the present, yet retain enough future flexibility to carry out the shuttle's role in space policy.

President Reagan accepted this recommendation and decided not to approve production of a fifth orbiter. The decision to maintain only limited production of structural and component spares was issued in February 1983 as a National Security Decision Directive [18]. In the directive Reagan allowed for possible future approval of a fifth orbiter and stated his intent that the full potential of the shuttle be achieved. Ironically this was the first of several decisions that gradually shifted space policy away from full reliance on the shuttle.

Even as Reagan blessed the space shuttle as the nation's primary vehicle for spaceflight, his administration was moving towards a commercial space initiative that would erode this role. Proponents in government and industry sought to stimulate more private enterprise in the aerospace market, especially the development of a commercial launch services industry. By 1983 they had challenged NASA's virtual monopoly on launch services and opened the door to private sector development and operation of expendable launch vehicles [19]. The Commercial Space Launch Act followed in 1984, easing the way for launch vehicle entrepreneurs to compete with NASA for customers. This shift in policy did not bode well for a shuttle fleet whose growth was predicated on increased user demand.

Another impediment to the expansion of the shuttle fleet began to loom in the military sector. The Department of Defense had valid concerns that reliance on a sole launch vehicle would compromise its mission if the shuttle were not readily available in a time of crisis or conflict. By early 1985, DoD had secured a presidential national security directive for the Air Force to buy ten expendable Titan launch vehicles to improve its assured launch capability [20]. Although these rockets were construed to be "complementary" to the shuttle and DoD committed to use the shuttle as its primary launch vehicle, the directive took the first step toward a mixed fleet. The document also directed NASA and DoD to begin studies for the next generation space transportation system. With DoD continuing to use other launch vehicles and momentum starting for a post-shuttle system, NASA's prospects for a larger fleet of shuttles began to dim.

6. Fleet size after the *Challenger* accident

Fleet size analyses typically included orbiter attrition—loss of a vehicle—as a factor in assessing capability to support mission traffic. One of the arguments for a fifth orbiter had been that it was a hedge against attrition; if the fleet lost one vehicle to accident or prolonged repairs, the remaining four orbiters could still support the highest priority shuttle missions. A five-orbiter fleet would marginally "tolerate" attrition of one vehicle, whereas a smaller fleet reduced by attrition would not be able to sustain an acceptable flight rate to meet anticipated requirements.

Attrition was a hypothetical factor in fleet size calculations until the space shuttle *Challenger* was destroyed in a launch accident in January 1986, suddenly reducing the shuttle fleet to three orbiters. In addition to mourning the death of the crew and determining the cause of the accident, policy makers faced the challenge of restoring lost launch capability. Once again, fleet size became an issue as tragedy prompted a reconsideration of the shuttle rationale.

Within days of the accident, NASA, Congress and the White House began to consider the need for a replacement orbiter. Over the next several months the Senior Interagency Group for Space (SIG-Space) led the review for the administration. News reports indicated that there was vigorous debate on such issues as

budgeting for the cost of building another shuttle and redefining the role of the shuttle for example [21].

Several unclassified papers exchanged among key members of the National Security Council and OMB reveal some of the issues in play in the SIG. There was considerable resistance to a replacement shuttle on the grounds that it would be a costly "overcapacity" because there was not enough user demand on the horizon to justify it.[22] NASA countered that assembly and operation of Space Station *Freedom*, an initiative Reagan had approved in 1984, would constitute much of the demand. Writing to the OMB Director, NASA Administrator James Fletcher polished the argument with a political gloss: "A decision to procure a replacement orbiter at this critical time would provide a signal of strong Presidential leadership through a highly visible commitment to continued US preeminence in space".[23]

OMB, however, was not persuaded and raised three questions: (1) do we need additional capacity? (2) If so, what kind would be the most cost-effective? (3) How do we pay for it? The budget director favored maintaining a three-orbiter fleet, putting some payloads on expendable launch vehicles, scaling back on less critical shuttle missions, and delaying the space station. Finding no clear need for an immediate increase, OMB recommended that the President not commit to more launch capacity or, if he did, to choose expendable launch vehicles over another shuttle.[24]

One argument for replacing *Challenger* had some practical credence: a fourth orbiter would serve as "insurance" against loss or incapacitation of another orbiter, which would reduce a three-shuttle fleet to an unacceptable level. NASA, OMB, and DoD agreed on this value but it was not judged a strong enough reason to justify the expense.

During the same period of the SIG review in spring to summer 1986 representatives of NASA, DoD and several companies appeared in Congress to discuss how to replace the lost space launch capacity. The theme of these hearings was "assured access to space". Most speakers agreed that some mix of shuttles and other launch vehicles would be necessary to assure the nation's space transportation requirements. Some saw an opportunity for private enterprise to purchase a replacement orbiter. Even NASA and DoD admitted the vulnerability of reliance on one launch vehicle for all missions. It was clear from the hearings that NASA could no longer presume that the shuttle would serve as the nation's primary launch vehicle. The Secretary of the Air Force spoke quite frankly about a "balanced approach" for DoD missions; he meant shifting as many DoD payloads as possible from the shuttle onto expendable launch vehicles [22].

Given the government's efforts to stimulate commercial launch vehicles and DoD's evident eagerness to continue using expendable launch vehicles, there was no compelling case to build another orbiter to meet demand. As a practical matter, it was more important to get the three remaining shuttles off the ground again to relieve the mission backlog. Debate continued within the administration for 6 months before President Reagan announced his decision in August [23].

Reagan's decision was actually a double-edged sword. The USA would build a shuttle to replace *Challenger*. However, the shuttle would no longer be used to launch commercial satellites; private enterprise would assume that role. Why build up the fleet while at the same time banishing most commercial payloads from the shuttle? Why not carry on with a three-orbiter fleet instead of adding a new fourth vehicle? The announcement made no reference to the issues SIG had debated—actual need for an extra shuttle or insurance against loss of another shuttle. The President's language suggested that policy values rather than operational requirements guided his decision to replace *Challenger* and restore fleet size to four orbiters.

Reagan cast the decision as an action to ensure America's leadership in space, the core value at the heart of national space policy. Restoration of the four-orbiter fleet would preserve NASA's essential capabilities and also enable the nation to move ahead with the space station and other new projects. Freed from launching private satellites, the shuttle would carry out pioneering activity on the space frontier, a fundamentally different role than providing routine, utilitarian access to space. Allusions to pioneering, leading the way and breaking new ground strongly hinted that the decision to replace *Challenger* responded less to a practical need for another shuttle and more to a symbolic need to demonstrate a renewed commitment to the space program. It would restore public confidence in the nation's resolve to continue space exploration and reassure foreign users of their access to spaceflight. Rebuilding the fleet and rededicating the nation to America's leadership in space would be the greatest tribute to the lost crew.

This decision, formalized in December 1986 as the new United States Space Launch Strategy, marked a

[22] For example, letter from Secretary of Commerce Malcolm Baldridge to Chief of Staff Donald Regan, 4 June 1986, in White House Office of Records Management (WHORM) Files, Ronald Reagan Library. Also OMB briefing charts "Major Issues that Need to be Resolved", undated, and making the same points, Memorandum for the President from OMB Director James Miller, "Possible Fourth Orbiter for NASA", 25 July 1986, both in WHORM Files, Ronald Reagan Library.

[23] Letter and position paper from NASA Administrator James Fletcher to OMB Director James Miller, "Space Transportation System Reconstitution," 23 June 1986, in WHORM Files, Ronald Reagan Library.

[24] OMB briefing charts "Major Issues that Need to be Resolved" and memorandum "Possible Fourth Orbiter for NASA," 25 July 1986, See footnote 22.

major change in space policy [24]. The Strategy called for a mixed fleet of shuttles and expendable launch vehicles to serve the nation's needs, reversing the original plan to use the shuttle as the nation's sole launch vehicle. This space policy directive empowered both the Defense Department and the commercial community to use expendables, a movement already under way but now given full throttle.[25] NASA had resisted earlier efforts to reduce dependence on the shuttle, but the *Challenger* accident weakened its position. The new post-*Challenger* launch strategy denied NASA the large customer base for a five-orbiter fleet and restricted the shuttle to pioneering kinds of missions. It virtually assured that there would be no future need to expand the shuttle fleet.

7. Fleet size in the 1990s

When in the early 1980s Reagan's advisors had encouraged him to hold the fleet to four shuttles, the decision to continue producing spare parts proved beneficial; spare fuselage segments, wings, and tail were ready to be assembled into a replacement orbiter after the *Challenger* accident. Shuttle flights resumed in 1988, and within two years most of the backlog of delayed missions was cleared. The new shuttle *Endeavour* entered service in 1991, and the four-orbiter fleet settled into a pace averaging seven missions a year.

By this time, however, interest was shifting away from expansion of the shuttle fleet and toward the development of new launch technologies for improved access to space. With military and commercial traffic riding into space on other launch vehicles and with the space station mired in political problems and still years away from assembly, NASA had more shuttle capability than it could use. After almost a decade of shuttle flight experience, planners knew the vehicle's limitations and began to look ahead to something new.

One of the early calls for a new approach to space transportation appeared in the report of the National Commission on Space, an advisory group appointed by President Reagan and chartered by Congress to set goals for the nation's future in space. *Pioneering the Space Frontier*, issued in 1986, mapped out a "highway to space" for low-cost access to the solar system. While crediting the space shuttle as "a technological triumph and a magnificent achievement", the commission stated that "cheaper, more reliable means for transporting both people and cargo to and from orbit must be achieved". It warned that failure to develop new technologies would mean losing preeminence in space and advised that because the prospects were not good for lowering current transportation costs, the shuttle should be replaced by a new vehicle [25].

In 1990, as urged by the White House, NASA Administrator Richard Truly convened an Advisory Committee on the Future of the US Space Program chaired by Norman Augustine to review the programs and issues before the agency and make recommendations toward its goals. NASA and the committee would present their findings to Vice President Dan Quayle, chairman of the National Space Council in the George H.W. Bush administration, to energize support for the space program. The committee interviewed hundreds of people, including Truly, himself a former shuttle astronaut, who made a pitch for one or more additional orbiters. However, the shuttle did not fare well with this group, who recommended against procurement of another shuttle to make a five-orbiter fleet. It viewed development of a heavy-lift launch vehicle and a new space transportation system as higher priorities [26].

These advisory reports signaled a diminishing commitment to the shuttle in the space community. That shift had already begun in official circles. The mixed fleet concept codified by the Reagan administration's Space Launch Strategy in 1986 was the first brake on an expansive future for the shuttle. Reagan's 1988 space policy further reduced the shuttle's prospects; it directed that the fleet maintain the nation's capabilities, with improvements or enhancements as needed, but that NASA should begin developing new technologies for human spaceflight [27]. The Bush administration's National Space Launch Strategy issued in 1991 pushed the brake harder [28]. It froze the shuttle fleet at four, stating as policy that further production of shuttle orbiters was not planned. Instead NASA and DoD were directed to jointly develop a new space launch system—a family of vehicles—to meet civil and national security needs.

This document began to shift the focus of the nation's space policy toward a successor to the shuttle. It outlined a conservative use of the existing shuttle fleet only for important missions requiring a human presence or unique shuttle capabilities. It limited prospects to maintaining and improving the shuttle to extend its life, and it anticipated using spare parts if another orbiter should ever be needed. Clinton administration space policy assumed a limited life for the shuttle, directing NASA to maintain it until a replacement became available [29]. This strategy has prevailed to the present. During the 1990s NASA began to upgrade the aging orbiters, taking one at a time out of service for almost a year. These temporary reductions of the operational fleet occurred without adversely affecting the nation's launch capability. As production of spares declined, regular vehicle maintenance gradually consumed the

[25] For an overview of the Defense Department's retreat from dependence on the shuttle, see Day. Ref. [9]. For an overview of the development of a commercial launch industry, see Logsdon and Reed Ref. [19].

inventory of replacement parts. By the end of the decade, capability to sustain the shuttle fleet was beginning to wear thin.

The Bush administration also continued to urge expanding private sector activity in space by issuing back-to-back commercial space policy directives in 1990 and 1991 [30]. During the Clinton presidency, and under NASA Administrator Daniel Goldin in the 1990s, the impetus toward commercialization penetrated NASA itself in the movement to privatize the space shuttle. Much of the shuttle processing on the ground—servicing, launch preparation, payload integration—was handed over to a contractor. The eventual goal was for a commercial entity to operate the shuttle fleet entirely, freeing (or forcing) NASA to go back to research and development.

During the 1990s NASA commissioned conceptual studies and funded initial work on a variety of "next-generation" shuttle or successor vehicles, such as the X-33 single-stage-to-orbit vehicle. Some of these projects were plagued by organizational and funding problems, as well as the absence of a defining mission. None led to a firm commitment to develop a new vehicle. Nor did NASA and DoD jointly develop a new launch system as called for in 1991. As NASA's attention and resources increasingly turned to the International Space Station, there was no real progress toward a space transportation system for the new century. Caught in stasis, NASA looked at ways to keep the existing shuttles operable for another 10–20 years.

In the aftermath of the *Columbia* accident there is no cry for a replacement shuttle or restoration of a four-orbiter fleet. The old argument to satisfy demand is dead. Since 2000 the main use of the shuttle has been to commute to and from the International Space Station on assembly, resupply and crew exchange missions. Supporting the station requires only occasional shuttle traffic, a flight every few months. With few other missions in the queue, there is no compelling argument for an extra shuttle. Nor is the old argument for assured access to space convincing, as the fleet of shuttles is grounded again by tragedy. As the vehicles age, more problems are prompting mission delays or preventive groundings, with the consequence that shuttle launches are not assured.

Rather, the call now is for a new vehicle—or two, one for people and a heavy-lifter for cargo. The aim is lower cost and less complexity in another attempt to reach the elusive goal of routine, economical access to space. The current focus is on a yet-to-be defined orbital space plane as the possible successor to the shuttle. However, without a well-defined mission based on clear goals, without a space policy to guide the effort, NASA, Congress and presidents in the post-shuttle era may again face fleet size issues in deciding how many vehicles are needed to serve the nation's future needs in space.

8. Perspectives on space policy and the shuttle fleet

Except for the *Challenger* and *Columbia* losses, the size of the shuttle fleet has been static since the initial decision to operate four orbiters. Despite arguments to increase to five or reduce to three, four was the magic number that answered two questions: how many shuttles do we need, and how many shuttles can we afford? In contrast, the rationale for fleet size—*why* we need this many shuttles—has been dynamic, evolving as NASA and OMB crafted their arguments, and reflecting the space policy of successive presidents.

Although the original fleet size rationale rested on quantitative measures—number of future shuttle missions, annual flight rates, cost figures—they were never a convincing basis for decisions about how many orbiters to build. Early projections were necessarily speculative, based on assumptions and possibilities that had less foundation in experience than in optimism and salesmanship. While NASA's mission models were treated with skepticism by some decision makers, no one else had a more valid set of numbers to inspire confidence as a foundation for decisions. Reduced mission models after the shuttle came into service were hardly more reliable. In a battle of numbers, without credible validated projections, the need for orbiters was trumped by budgetary constraints. NASA never won a fleet size decision based on its math.

Since the economic arguments for the fleet size rested on precarious mission models, NASA's prolonged insistence on five orbiters is puzzling. NASA continued to use an indefensible strategy well into the 1980s, when it finally collapsed under the reality of actual operational experience and a shrinking mission model. Perhaps the agency was motivated by the memory of the 1970–1971 struggle to win approval for the space shuttle. Having been forced then to justify the shuttle on economic grounds, NASA continued to use the cost-effectiveness strategy in efforts to "sell" the five-orbiter fleet and was frustrated to find that it did not work. The insistence on five orbiters also may have been an effort to ensure the full fleet "up front" to avoid the tedious, and politically riskier, process of incremental build-up; the more times NASA had to seek another orbiter, the more chances there were for delay or defeat. As the effort to win a fifth orbiter failed repeatedly, the agency's arguments for preserving a four-orbiter fleet became more persuasively political.

The goal of assured launch capability played a dual role in the fleet size rationale. It was a convincing basis for establishing a four-orbiter initial fleet, but it later became the argument for reducing reliance on the shuttle. When the shuttle was intended to be the primary (or sole) launch vehicle for all foreseeable missions, insufficient launch capacity was a danger to be avoided. Without enough orbiters, critical national security

missions could not be guaranteed a timely launch. DoD's needs were crucial to the rationale for a four-orbiter fleet. However, as the Air Force clung to expendable launch vehicles, and as the Vandenberg launch site was delayed and eventually cancelled, launch certainty lost importance as a factor in decisions about the number of shuttles. Instead, policy shifted from reliance on a single launch system (shuttle) to a mixed fleet of vehicles (shuttle plus expendables) for assured access to space.

Projections of user demand and assured launch capability were the two pragmatic tenets of the shuttle fleet size rationale. The first failed to gain a fifth orbiter and nearly failed to gain a fourth, until that was saved by the military's need for assured access to space. The political tenets of leadership and prestige were secondary until the *Challenger* accident prompted a reconsideration of the fleet size rationale. In that instance, President Reagan eloquently expressed a rationale for the shuttle fleet that transcended the practical and numerical. Upon abandoning the old economic arguments and embracing the more persuasive political ones, NASA won back the lost orbiter.

Historians argue that recent presidents have paid only marginal attention to space policy and that it is a myth that presidential leadership is the key to a vigorous space program [31]. The course of the shuttle fleet size issue over the past three decades shows that even with a limited ideological commitment to human spaceflight, presidents wield considerable influence in shaping it, if only through making routine budgetary decisions or mediating contrary advice on policy pronouncements. At critical junctures, both Presidents Carter and Reagan chose to authorize a larger shuttle fleet than most of their advisors thought necessary. In so doing, they shaped the space transportation system in service to other interests.

Perhaps more than the presidents before and after him, Reagan perceived the shuttle as a symbol of American leadership. In making the 1986 replacement orbiter decision, he calculated the value of the shuttle as an instrument of national and international policy. Even as he restricted the shuttle from further commercial activity, he anointed it with the rhetoric of the American frontier and gave it mythic importance. Restoring the fleet size to four was a sign of strength and pioneering spirit and optimism, for "We must always set our sights on tomorrow" [32].

The shuttle fleet is now reduced to three orbiters, and it will not increase again. It will probably operate at a reduced level as well, to conserve the life cycle of the remaining vehicles until a new space transportation system of some type comes into service to take their place. As the new crew vehicle concept emerges, the issue of fleet size will likely arise if a reusable spacecraft is desired. NASA and OMB will again muster their arguments about how many vehicles are needed and affordable. If they remember the shuttle experience, this time they may base the economic arguments on credible data rather than hope or skepticism. Perhaps the future president who makes the next fleet size decision will articulate a space policy that grounds the decision in clear goals.

On the other hand, it is quite possible that the post-shuttle future will develop around vehicles reminiscent of the pre-shuttle past. Varieties of expendable crew vehicles under consideration may supplant the reusable shuttle as the next space transporter. In that case, fleet size will be moot in a spaceflight enterprise based on supply-and-demand production, with as many vehicles as there are approved missions.

As the planning process continues, the quest is much the same as it was at the dawn of the shuttle era: to develop a reliable new vehicle (or set of vehicles) for economical space transportation and US leadership in space.

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