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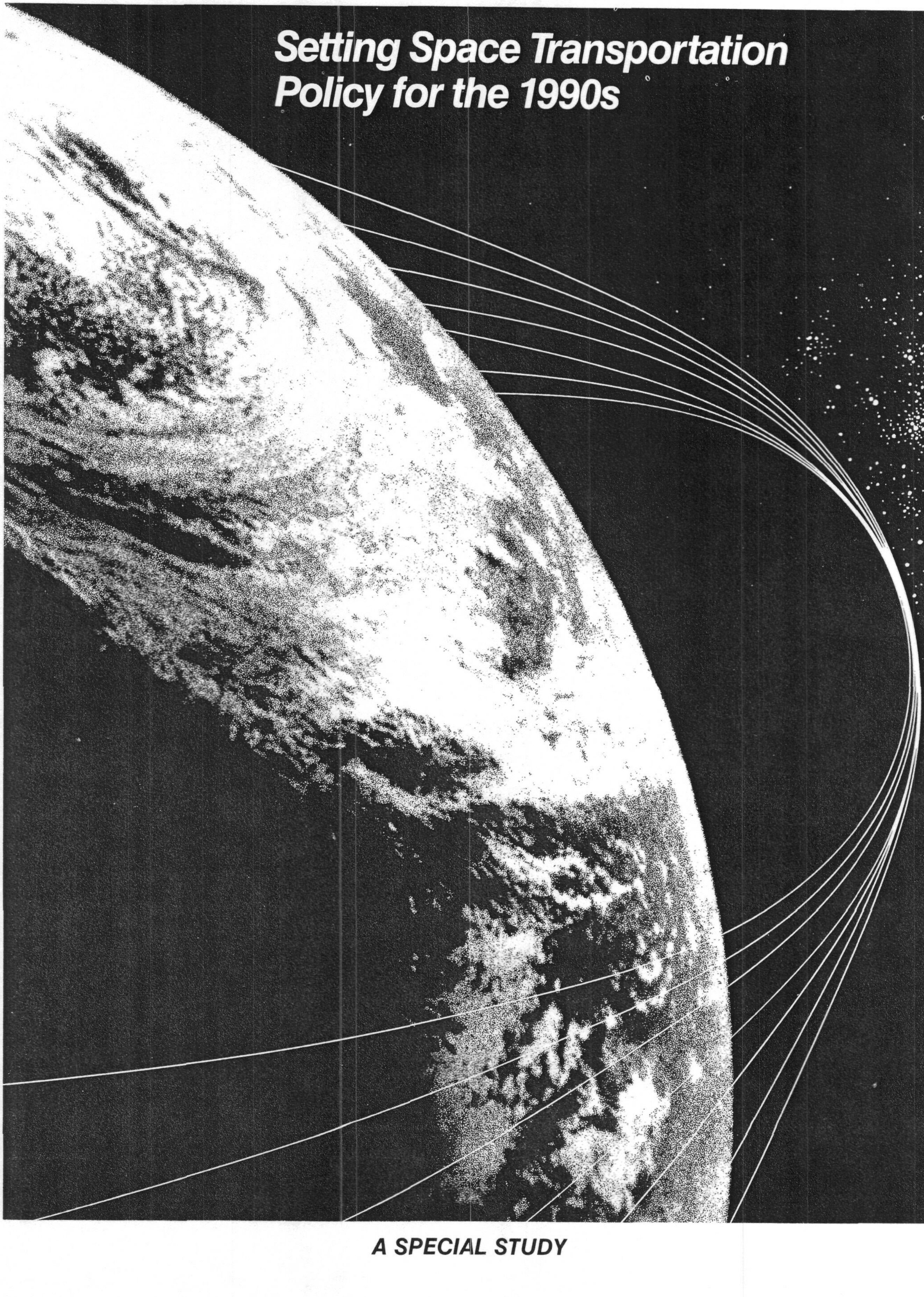
Setting Space Transportation Policy for the 1990s



A SPECIAL STUDY

CONGRESSIONAL BUDGET OFFICE
U.S. CONGRESS
WASHINGTON, D.C. 20515

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Setting Space Transportation Policy for the 1990's

October 1986

In this study, Table 11, on page 39, should appear as attached.

The text referring to Table 11, on pages 38 and 39, should appear as below:

> "If a new orbiter was flown four times each year and the marginal cost of a shuttle flight was $65 million, then the real discounted cost of building and operating the additional orbiter at full capacity is estimated to be **$4.3 billion** from 1987 through 2000. Expendable launch vehicles, each of which is capable of carrying only 40 percent of a shuttle flight and is launched at a cost of $60 million, can provide comparable capacity at a cost of **$5.0 billion** over the same period."

TABLE 11. THE DISCOUNTED COST OF SHUTTLE CAPACITY COMPARED WITH EQUIVALENT ELV PRODUCTION AT DIFFERENT ANNUAL FLIGHT RATES, 1987-2000 (In billions of 1986 dollars)

Annual Number of Equivalent Shuttle Flights	ELV	Shuttle
1	1.4	2.7
2	2.7	3.2
3	3.5	3.7
4	5.0	4.3

SOURCE: Congressional Budget Office.

NOTES: The estimates include: $2.2 billion cost for a replacement orbiter with funding authorized from 1987 through 1992; a marginal operating cost of $65 million per shuttle flight; a $60 million launched cost for a .4 equivalent shuttle flight ELV at the three and four equivalent shuttle flight operating rate; a $65 million launched cost for the same ELV at the two equivalent shuttle flights annual level; and $70 million launched cost for the same ELV at the one shuttle flight operating rate.

See footnote 1 in this chapter for a definition of discounting.

SETTING SPACE TRANSPORTATION

POLICY FOR THE 1990s

The Congress of the United States
Congressional Budget Office

PREFACE

The loss of the space shuttle Challenger has raised important issues in national space policy, including: should a replacement orbiter be purchased and, if so, how should it be financed; and what institutional arrangement should the United States adopt to participate in the international market for satellite launches? This special study, requested by the Senate Committee on Commerce, Science and Transportation, investigates these and other issues affecting the future U.S. role in space. In keeping with the Congressional mandate to provide objective nonpartisan analysis, the report makes no recommendations.

David H. Moore, of the Congressional Budget Office's (CBO) Natural Resources and Commerce Division, prepared the report, under the supervision of Everett M. Ehrlich. Mark R. Dayton, Paul DiNardo, and Lane Pierrot of CBO provided valuable comments and assistance. Many outsider reviewers, including individuals from the aerospace industry, made helpful comments and criticisms. Patricia H. Johnston edited the manuscript, and Kathryn Quattrone prepared the manuscript for publication.

Rudolph G. Penner
Director

October 1986

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SUMMARY

The Challenger accident has catalyzed reconsideration of national space policy. Initial discussion centered on whether to replace the Challenger with another orbiter or with expendable launch vehicles (ELVs). But the accident soon focused the policy debate on underlying questions concerning the capacity of the shuttle system, the nation's future demand for launch services, the roles of the public and private sectors in meeting them, and the U.S. share of the worldwide commercial launch market. In addressing these space transportation issues, the Congress will also determine how quickly and to what extent the nation will realize the major objectives of the civilian space program: scientific exploration of space, provision of public services with satellites, encouragement of economic growth through private-sector use of space technology, and enhancement of national prestige.

The Administration recently proposed to replace the Challenger with a new orbiter, which would be funded, in large part, by reprogramming the future NASA budget. The Administration also proposed gradually removing the shuttle system and NASA from the launch market for commercial communication satellites, with the proviso that the shuttle would fly a portion of the existing 44 launch commitments. The purpose of the shift in commercial launchings is to allow the shuttle to serve the backlog of government cargos created by the accident and, simultaneously, to encourage U.S. private firms to offer ELV services to the commercial market.

The Congress also has initiated new actions. The Senate appropriations bill for fiscal year 1987 includes full funding for a new orbiter in the Department of Defense (DoD) budget rather than in the NASA budget. A bill presented to the Space Subcommittee of the House Science and Technology Committee (H.R. 5429) proposed that NASA procure 15 Delta rockets over five years to supplement the federal launch capacity.

U.S. LAUNCH SUPPLY, DEMAND, AND COSTS

The Administration proposed and the Congress approved new capacity for space transportation in a 1986 supplemental appropriation. The procurement of Titan IV expendable launch vehicles was increased from 10 vehicles over five years to 23 over the same period. In addition, a new ELV program--the medium launch vehicle (MLV)--was approved and is scheduled to provide launches for four satellites annually beginning in 1989. As ELV production requires 24 to 36 months to bring new vehicles on line, and modification of the shuttle system will delay resumption of reasonable annual flight rates until 1989, the U.S. capacity to provide launch services is virtually nonexistant until that date.

Supply and Demand.

The Congressional Budget Office (CBO) estimates that in 1989 the U.S. launch systems--the three remaining orbiters, the Titan ELV production line and launch facilities, and the as yet undertermined MLV production line and launch facility--will provide a capacity to launch 21 to 24 shuttle flight equivalents annually.[1] This estimate serves as a starting point to evaluate whether additional new capacity--whether orbiter or ELV--is necessary to meet the nation's space transportation requirements.

Before the Challenger accident, the launch market traditionally served by U.S. capacity--national security, civilian government, and a major share of the free world's commercial demand--was projected in official estimates to require an annual average of 30 equivalent shuttle flights from 1986 through 2000 (without including those required for the deployment of a space-based defense system or extensive new space manufacturing). These projections envisaged rapid growth in the late 1980s, with a peak of 35 flights annually during the early 1990s when the U.S. space station was to be built. This level of activity would more than quadruple the annual average launch activity from 1970 through 1985. If realized, this high level of demand would justify added launch capacity, such as that provided by a fourth orbiter.

If the historical record is a guide, NASA, DoD, and NASA contractors have consistently overestimated launch demand. Moreover, the ramifications of the accident itself should lower launch requirements by raising the cost of space transportation and by making unanticipated demands on the NASA and DoD budgets. This analysis lowers the preaccident projections of

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1. A shuttle equivalent is defined as an orbiter capable of carrying 65,000 pounds (lbs.), launched with a 50,000 lbs. load from the Kennedy Space Center to a low earth orbit of 28.5 degrees, 160 nautical miles above the Earth. This represents a load factor of slightly above 75 percent.

demand for 1986 through 2000 according to two other possible courses for demand. From NASA's estimate of an average of 30 shuttle flight equivalents per year, a **constrained version** of the official case sets an upper bound of 16.5 flights annually and a **historical case** projects a lower bound of 10.5 flights a year. This lower rate is based on extrapolating through the end of the century the demand over the last 15 years.

The resulting range of annual average demand--10.5 to 16.5 flights--could be served by CBO's estimated 1989 U.S. launch capacity (21 to 24 shuttle equivalents) without acquiring new launch capacity. The level of capacity estimated for 1989 ranges from 130 percent to 145 percent of projected annual demand in the constrained case and from 200 percent to 230 percent of the historical demand projection. The backlog of payloads accumulated while the shuttle is grounded, however, and the requirements of the space station, as currently planned, can be used to support arguments for procuring new capacity with a replacement orbiter or additional ELVs from existing facilities.

Costs

Before the loss of Challenger, the major issues of U.S. space transportation policy had been settled. The shuttle system was to be the primary mode of space transportation for all U.S. government payloads, because it was less costly and more capable than the older, expendable rocket technology that preceded it.

This report concludes that an additional orbiter should receive no significant cost advantage relative to expendable launch vehicles in deploying satellites. With the postaccident reduction in shuttle system capacity, shuttle costs are likely to increase, eliminating what was once a clear-cut cost advantage for additional orbiter capacity compared with ELVs. For example, between 1987 and 2000, the real discounted cost (at a 2 percent rate) of a new orbiter flown an average of three times each year is estimated to be $3.7 billion, compared with the $3.5 billion cost of comparable ELV services. If the orbiter is used more often, its cost-effectiveness improves relative to ELVs. An orbiter used an average of four times a year is estimated to cost $4.3 billion, compared with $5.0 billion for an equal ELV capacity. The demand projections developed in this analysis, however, suggest that an additional orbiter would actually experience lower demand and lower annual average flight rates. An orbiter flown only twice a year is estimated to cost up to $500 million more than comparable ELV capacity. In the face of uncertain demand, ELVs could offer the advantage of a smaller initial funding commitment.

Both the options to replace the orbiter and to acquire additional ELVs offer certain noncost advantages. ELVs would not involve as great and direct a risk to human life as shuttle flights. An additional orbiter, as indicated, would be necessary to accomplish the construction phase of the space station as currently planned and would provide a degree of insurance in the event of unanticipated growth in demand or the loss of another orbiter. But most of the benefits of the shuttle's unique capabilities and, perhaps, a space station of different design could be realized by the existing three-orbiter fleet.

INSTITUTIONAL OPTIONS TO PROVIDE SPACE TRANSPORTATION FOR THE COMMERCIAL MARKET

Uncertainty concerning the capacity and capability of the shuttle system has prompted new interest in ELVs as an alternative to the shuttle in the commercial launch market. But it is not obvious who should build and operate these ELVs. Several institutional options are open to the United States in pursuing its goals for space transportation policy.

Preaccident policy for commercial space launches was strongly oriented towards shuttle technology, with NASA as the public-sector provider of U.S. launch capacity to the world market. Beginning in 1989, shuttle prices were to be established at a level approximating the long-run marginal cost of shuttle service. This price would have encouraged effective use of shuttle capacity and would have produced a surplus of current revenues over current costs, leading to a net contribution to the NASA budget. Since the federal government would incur the high fixed cost of operating the shuttle to meet federal needs whether the commercial market was served or not, pricing shuttle service to the commercial market at long-run marginal cost would allow the shuttle to capture at least 50 percent of the worldwide commercial market, without the need for government subsidies. In sum, in the preaccident environment, the United States was to become internationally competitive and economically efficient in providing space transportation, effectively using past federal investment in shuttle capacity while providing current budget support to NASA through sales to the commercial launch market.

The accident has negated this vision of the shuttle's future and its role in attaining U.S. space policy goals. The shuttle system's costs and capabilities now are uncertain; and its cargo, once flights resume in 1988, will be dominated by government payloads. Reflecting this change, the Administration has proposed commercializing U.S. ELVs by removing the federal government from the commercial market and by encouraging private enterprise to replace it. But questions can be raised about whether the ELV commercialization option would lead to an internationally competitive industry in the 1990s, and whether it would provide cost-effective use of federal space transportation capacity. The Congress may wish to consider two alternatives to ELV commercialization: allowing NASA to provide ELV services to the commercial market, and creating a mixed enterprise like Europe's Arianespace to bring an explicit public-sector/private-sector partnership into the commercial launch market. The ELV commercialization option and the two alternatives present both advantages and disadvantages when their implications are considered according to the following criteria:

- The international competitiveness and economic efficiency of the U.S. launch presence in the commercial market;

- The cost-effective use of federal space transportation capacity;

- The future role of NASA and its budget; and

- The administrative and legislative ease in implementing the chosen arrangement.

The **ELV commercialization option** would replace the government in the commercial market with U.S. private firms. These businesses would compete on the world market, initially with Arianespace, but later with other foreign entrants into the market. U.S. private firms would provide ELVs to their customers and launch them at rented government facilities. The NASA would continue to operate the shuttle and DoD would serve its own requirements with ELVs purchased from its budget. Either DoD or NASA, however, could purchase ELV services from the private sector. Direct federal acquisition of ELVs from potential private entrants is the most important federal influence on the international competitiveness of U.S. firms, since it would reduce the unit costs of ELVs through procurement of larger numbers.

The commitment of the DoD to purchase ELVs, the backlog of payloads created by the Challenger accident, and only limited foreign competition could characterize an environment through the early 1990s in which U.S. private firms could become internationally competitive and economically efficient. But after that time, the dissolution of the backlog and intensified (and perhaps subsidized) foreign competition could leave U.S. producers at a competitive disadvantage.

Maintaining international competitiveness through attempting to eliminate subsidies--for example, through the General Agreement on Trade and Tariff (GATT) framework--would be most consistent with the commercialization option. Alternatives, such as providing government subsidies for operating costs or technology development to specific U.S. private firms, would be possible, although less consistent with this option's emphasis on private investment and markets. Finally, the ELV commercialization option would provide a model for the future transfer of the shuttle technology to the private sector, but it would not facilitate an easy and integrated reintroduction of the shuttle to the commercial market in the early 1990s, if that were desired.

The **public sector option** of allowing NASA to provide ELV services to the commercial market would offer no immediate competitive advantage compared with the other alternatives. Government regulatory requirements and administrative overhead could actually make the price NASA could offer the commercial market higher than the price a commercial ELV vendor would charge for the same service.

The NASA option suggests different U.S. responses to the changing competitive circumstances of the 1990s. Subsidies for operating existing vehicles and developing new ones could be provided more easily, but the force of U.S. agruments for free and unsubsidized competition in the launch market would be diminished accordingly. The NASA option could promote effective use of the shuttle system by including commercial cargos on shuttle flights that would be flown in any case. Nevertheless, the NASA option would maintain NASA's role as an operator of space transportation, a role critics have argued distracts NASA from its primary research function.

The **mixed enterprise option** would create a public/private-sector partnership. Elements of NASA, U.S. aerospace firms, and even the general public (through a stock offering) would be melded into an entity that would operate the shuttle and U.S. ELV services. The enterprise would provide services to the commercial market and federal government, possibly even including all national security needs. The enterprise would require substantial financial and administrative efforts to begin operations, and might involve some additional short-term costs relative to the other options. As under the other alternatives, the mixed enterprise option would probably gain a substantial part of the market in the early 1990s.

Advocates of a mixed enterprise option argue that it would substantially enhance U.S. competitiveness in the 1990s. Like the NASA option, the mixed enterprise alternative would offer the prospect of an integrated ELV and shuttle capacity, but unlike the NASA option, the enterprise would not maintain NASA as a system operator. The integration of federal and commercial ELV demand would also permit the most competitive U.S. ELV presence in the world market, particularly if, as some advocates suggest, the more favorable market of the interim period would permit the development of a modernized U.S. ELV. Although such new investments would be possible under the other two options, they would be less likely to occur.

CHAPTER I

INTRODUCTION

Important matters of U.S. space policy must be decided in the near future and their ramifications will carry into the next century. In the wake of the Challenger accident, space transportation--and therefore space programs--will be less capable and more costly just as major new military and civilian space efforts (most notably, the space station) are being formulated and as the Congress seeks to meet the targets of the Balanced Budget Act. Thus, questions concerning national space transportation policy--what type, how much, and in what institutional framework--are being considered at a time of programmatic urgency and budget stringency.

MAJOR ISSUES

Since the Challenger accident, the Administration has developed three major initiatives in space transportation that could affect U.S. policy for the foreseeable future. First, expanded use of expendable launch vehicles (ELVs) by the Department of Defense (DoD) has already been approved by the Congress. Second, replacement of the Challenger is now being considered by the Congress as part of the 1987 budget process. Third, the Administration plans to move commercial satellite launches from the National Aeronautics and Space Administration (NASA) and the shuttle to rocket launches by private industry, unless the Congress directs otherwise.

Neither the Administration's objectives nor the means proposed to attain them are shared universally, nor have all the issues raised by the loss of the Challenger been fully addressed. In considering the Administration's space program in the fiscal years 1987 and 1988 budgets, the Congress will evaluate these proposals. The Challenger could be unreplaced, procured more quickly, purchased by the DoD as the Senate appropriations bill proposes, or even bought by the private sector and leased back to the government. Both the scientific and commercial communities could be provided with expendable launch vehicles through NASA, or through a U.S. mixed enterprise modeled on the Arianespace example. 1/

1. Arianespace is a quasipublic enterprise that is one-third owned by the French National Space Agency and two-thirds owned by European banks and aerospace firms. Its ongoing (continued)

This analysis addresses these issues of national space policy in the context of the debate over replacing the launch capacity lost in the Challenger accident. It examines the total demand for the U.S. space launch capability through the end of the century, the options available to meet that demand, and the budgetary implications of these options. As this study examines these alternative technological and institutional combinations, it also considers their implications for the larger issues confronting the future of the U.S. space program.

BACKGROUND

Before the Challenger accident, U.S. space officials thought that the late 1980s would see the realization of the shuttle's promise.[2] Planners at NASA and DoD foresaw few obstacles to filling the anticipated capacity of 24 flights a year. The shuttle system had been declared operational and was to enter its second year as the workhorse in deploying satellites. The market traditionally serviced by U.S. launch capability was projected to require the equivalent of 30 shuttle flights annually in the early 1990s, roughly four times the level of actual average launch activity experienced from 1970 to 1985. (Moreover, this estimate was based on scaled-down immediate demands of new, space-based commercial enterprises and excluded the deployment requirements for a new defense system.) While emerging international competition was expected to win a portion of the commercial market that had formerly been a U.S. monopoly, NASA had established a minimum shuttle price that positioned the system to win the dominant share of that market.

The proficient shuttle system was not to be limited to a bulk cargo carrier. Its unique capability, already demonstrated in satellite repair and retrieval, was to be put to use as more Spacelabs were launched and Strategic Defense Initiative (SDI) experiments were conducted. These activities would provide the vital experience in on-orbit construction needed to fulfill the key shuttle role in building NASA's "next logical step," the space station.

1. (continued) research and development program is conducted by the European Space Agency, a consortium of Belgium, Denmark, France, Germany, Ireland, Italy, Netherlands, Spain, Sweden, Switzerland, and the United Kingdom..

2. See Congressional Budget Office, *Pricing Options for the Space Shuttle* (March 1985) for a more detailed history of the space shuttle program.

Space officials also anticipated the realization of cost-effective shuttle operations that would redound favorably on the capability of the entire space program. From a budgetary standpoint, commercial activities would produce revenues in excess of current costs, as would servicing DoD launch requirements. These revenues not only would enable NASA to offset some of the high fixed costs of operating the shuttle system, but also--with modest real growth (one percent annually) in its budget--would allow it to conduct a vigorous space science program and to begin the international space station. NASA also had started to develop a framework for operating the space station, extending NASA's responsibilities to the operation of space infrastructure as well as its primary research and development mission.

The Challenger accident has forced these plans to be held in abeyance. Subsequent developments may all but completely undermine them. Even NASA no longer sees a four-orbiter shuttle system--much less one of three--as capable of reaching a level of 24 flights annually. The DoD is firmly committed to a mixed fleet of the shuttle and rockets and, by 1990, will have available an annual complement of four Titan IVs and at least four medium-lift launch vehicles, the equivalent of almost six shuttle flights. The Administration's announced goal of removing commercial communication satellite traffic from the shuttle will eliminate this source of revenues in the future, and budgetary transfers from DoD are likely to be less than anticipated in the early 1990s, as a portion of the national security workload is carried by DoD expendable launch vehicles (ELVs). The physical capability of even a four-orbiter fleet to build and support the space station has not been proven in actual experience. Finally, the future NASA budget outlook is yet to incorporate reduced DoD transfers, lower commercial revenues, uncertain future real growth, and new costs to improve shuttle safety and replace the Challenger.

Against this backdrop, the arguments for and against the various options facing the Congress assume new complexity. The question of replacing the Challenger can be examined against the demand for space launches in general and demand for the shuttle's unique capability in particular, and how that capability relates to specific programs. The Administration's proposal to replace Challenger does not specify the source of its funding, but is clear that the orbiter will not be built with all new funds. This raises the question of what previously planned activities will suffer cuts and how these cuts will effect the overall national space agenda. The current Senate alternative proposes DoD funding, but leaves open the question of which planned DoD activities will have to be cut back to provide for the orbiter.

Proposals to commercialize ELV launches have been resurrected by the Challenger accident. Yet, commercialization may be a short-sighted option since foreign public and mixed enterprises are likely to crowd the launch market of the early and middle 1990s. Other alternatives have been raised, including a return to ELV services provided by NASA or the establishment of a U.S. mixed enterprise similar to Arianespace. The current situation marks a turning point in U.S. space transportation policy. Therefore, the Congress may wish to consider these alternatives as they could affect not only the remainder of the 1980s but the competitive position of the United States in commercial space activities throughout the rest of the century.

CHAPTER II

FEDERAL AND COMMERCIAL DEMAND FOR SPACE TRANSPORTATION

The federal government has been its own best customer for launch services over the past 15 years and is likely to remain so over the next 15 years. Anticipating these requirements, thus, is a major factor in determining the proper investment in federal space transportation. At the same time, a consistent objective of U.S. space policy has been to foster and serve the commercial demand for launch services that currently is dominated by communication satellites. Gaining a share of this market for the United States remains a policy objective in spite of evolving competition in the international launch market. For this reason, the total anticipated demand for launch services must be considered in the decision to invest in space transportation.

The demand for space launches is defined as payloads that are ready to be integrated with launch vehicles and that have enough financing, public or private, to cover launch costs. Launch demand is measured in units of shuttle flight equivalents (see box). Total demand is usually presented as the sum of demands from three different categories of users: U.S. defense and national security, U.S. civilian government (including NASA), and foreign and commercial. The primary **defense and national security demand** arises from the launch of satellites that provide communications, photo reconnaissance, early warning, and weather forecasting. In the immediate future, navigational aids will be added to this list. **Civilian government demand** consists of deployable scientific payloads for such purposes as planetary exploration; satellites providing public services, such as the Tracking and Data Relay Satellite (TDRS); and a new set of round-trip scientific experiments, some with commercial potential, made possible by the shuttle. The space station (currently planned for the 1990s) would initiate significant new demand for space transportation during its construction period and an ongoing requirement to serve space station personnel and projects. **Commercial demand** includes both private payloads and those of foreign governments that lack appropriate launch services. It is currently dominated by deployable communications satellites, but could expand in the future to include early space manufacturing ventures.

MEASURING LAUNCH ACTIVITY

The "shuttle flight equivalent" is used as a unit of measure throughout this report and is defined in standard terms and conditions established by NASA convention over the years. While the unit is precise enough to provide a reasonably accurate representation of the level of launch activity, it is defined with reference to a specific set of parameters that not all shuttle launches, past or projected, conform to. A shuttle equivalent is defined as an orbiter capable of carrying 65,000 pounds (lbs.), launched with a 50,000 lbs. load from the Kennedy Space Center to a low earth orbit of 28.5 degrees, 160 nautical miles above the Earth. This represents a load factor of slightly above 75 percent, acknowledging that:

- Not all shuttle flights can be reasonably expected to be loaded fully at all times;
- Not all orbiters are capable of carrying the 65,000 lbs.; for example, the older, heavier Columbia cannot carry as heavy a load as the newer Atlantis and Discovery; and
- The 65,000 lbs. capability requires that the space shuttle main engines must run at 109 percent of rated capacity and other key systems--for example, the orbital maneuvering system--must operate at safety margins too thin to be acceptable in a presumably more conservative postaccident environment.

Thus, the shuttle equivalent used by NASA and in this report can be seen either as a fully capable shuttle carrying 75 percent of a load on average, or as a fully loaded but less capable shuttle.

Both the historical estimates and demand projections of annual launch activity developed in this chapter and the capacity projections presented in Chapter III require that the capability of U.S. expendable launch vehicles be converted into equivalent space shuttle loads. Conversion introduces additional imprecision into the estimation procedure in that the capabilities of specific ELVs have grown through time--for example, the Delta of 1970 is not precisely the same as the Delta of 1980. These discrepancies have been corrected to the extent possible. The specific equivalencies used in converting the historical activity of ELVs into equivalent shuttle flights were: Saturn I = .6; Titan III = .5 to .7; Titan Agena = .33; Atlas Agena = .33; Atlas E/F = .25; Delta = .15 to .21; Atlas Centaur = .33; and Scout = .125. Past shuttle flights themselves were adjusted downward to account for their carrying less than a full shuttle equivalent according to estimates of actual loads provided by NASA and data presented in *Space Shuttle Payload Flight Assignments*, NASA Space Transportation System (November 1985).

THE OFFICIAL CASE

The NASA and DoD have projected the level of launch demand that will need future U.S. launch capability. In addition, NASA contracts with Battelle's Columbus Laboratories to perform an annual survey of commercial launch demand.[1] Although developed before the Challenger accident, these projections provide an official view of U.S. space transportation demand between now and the end of the century; for example, they are the basis for estimating the backlog of payloads awaiting launch when shuttle service is reinstituted. Before the Challenger accident, federal officials anticipated impressive growth both in traditional satellite deployment and in new kinds of activity, such as space construction, servicing orbiting spacecraft, and round-trip scientific experimentation. According to this official view, the group of users traditionally served by the United States would rapidly expand its requirements from about 7.5 shuttle flight equivalents annually in the first half of the 1980s to almost 30 equivalents annually throughout the 1990s.

Official Case Projections

A set of projections constituting one version of the official case is presented in Table 1. Rapid growth in launch demand was anticipated in the late 1980s as the demand traditionally met by U.S. providers climbed from an actual level of 12 equivalent flights (including ELVs) in 1985 to a projected level of more than 30 flights in 1989. The latter level was projected to last throughout the 1990s, with a peak of 35 reached in 1993, the assumed starting year of space station construction.[2] Under the official case, the shuttle flights lost from 1986 through 1988 would create a backlog of about 60 equivalent flights to be added to new demand beginning in 1989. Even these high demand levels could be viewed as a conservative version of the official case, in that two potential sources of launch demand growth--deployment of a space system to defend against nuclear attack (as a result of the Strategic Defense Initiative, or SDI), and extensive manufacturing in space--are not included in this case.

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1. Battelle's Columbus Laboratories, "Outside Users Payload Model" (July 1985).

2. In the past, demand projections were synonymous with demand for U.S. capacity. The commercial component, some 25 percent to 30 percent of the total load projected, however, will now be partially served by foreign launch providers, such as Arianespace.

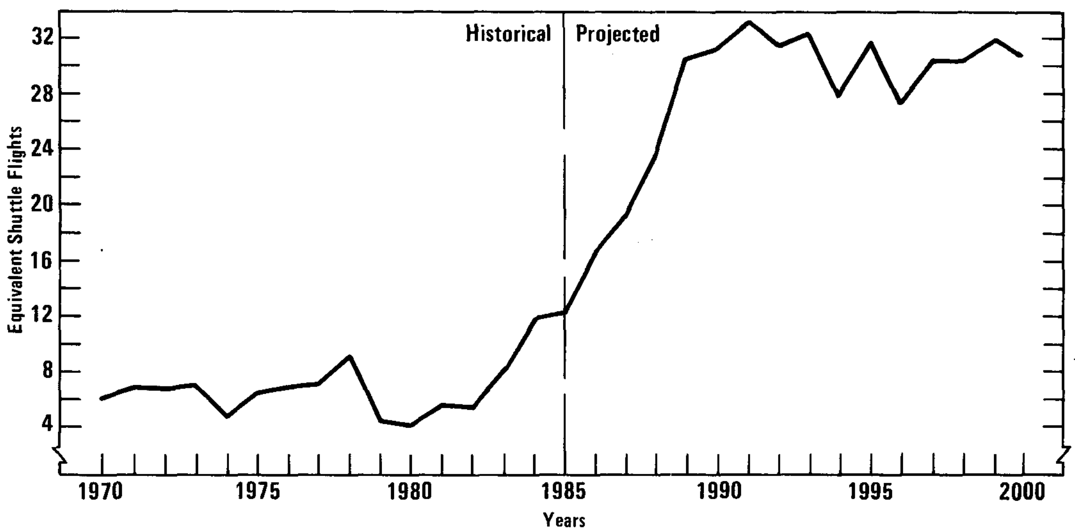
TABLE 1. OFFICIAL CASE DEMAND PROJECTIONS, BY MAJOR COMPONENTS, 1986 THROUGH 2000
(In equivalent shuttle flights)

Year	Department of Defense	NASA and Other Federal Agencies	Commercial	Total
1986	3.0	7.2	6.7	16.9
1987	5.7	8.7	5.1	19.5
1988	12.0	6.9	4.8	23.7
1989	15.2	8.7	6.9	30.8
1990	13.8	12.2	5.4	31.4
1991	16.9	9.7	6.8	33.4
1992	14.4	11.0	6.2	31.6
1993	15.1	10.0	7.4	32.5
1994	12.4	9.0	6.7	28.1
1995	12.4	13.0	6.3	31.7
1996	10.4	11.0	5.9	27.3
1997	12.1	11.0	7.4	30.5
1998	12.1	11.0	7.3	30.4
1999	12.1	11.0	8.9	32.0
2000	12.1	11.0	7.7	30.8

SOURCES: The official case projection is drawn from several primary sources. Federal government projections for 1986 through 1992 reflect the preaccident shuttle manifest as presented by NASA at a briefing to National Research Council, May 16, 1986, and publicly announced DoD plans to begin operations of the Titan IV and Titan II ELVs in the late 1980s. DoD requirements for 1993 through 1995 reflect the DoD mission model of January 28, 1986 less three flights in 1993 and six flights each in 1994 and 1995 for Strategic Defense Initiative deployment. Requirements for 1995 through 2000 are projected at the annual average level of the preceding five years. NASA and other federal government requirements for 1993 through 1995 are estimates of space station construction, logistics, and payload support as presented in a statement by John D. Hodge, Space Station Administrator, NASA, before the Subcommittee on Space Science and Applications of the House Committee on Science and Technology, 99:2, April 10, 1986. The estimates for 1996 through 2000 are the average annual requirements of the preceding five years. Commercial demand for 1986 through 1994 is based on the 1985 Battelle low model estimate of commercial demand. Battelle's Columbus Laboratories, "Outside Users Payload Model" (July 1985). Demand thereafter through 2000 reflects the Battelle model plus one additional shuttle equivalent in 1995 and 1996 for commercial operations taking advantage of the space station, two additional flights for the same purpose in 1997 and 1998, and three of this type of flight for 1999 and 2000.

According to official case projections, all types of shuttle users would increase their launch demands above current levels. In the late 1980s, DoD requirements are projected to increase threefold above the five to six shuttle equivalents they required in the early 1980s. This increase would stem from deployment of two new systems (Global Positioning System--to support precision navigation--and Milstar--an advanced communication system); limited SDI tests and experiments; and upgrading of existing satellite systems. In order to build and support the space station, NASA requirements would grow dramatically during the first half of the 1990s to an average of more than 10 flights a year. Thereafter and through the end of the century, NASA activity would continue at a high level (11 flights annually) to support the space station, the activities of other on-orbit spacecraft, and general civilian government requirements. The emergence of Arianespace as a competitor, on the other hand, was expected to diminish the U.S. share of the annual average of 7 equivalent flights required by the commercial market. Nevertheless, the shuttle's unique capabilities and low prices were expected to capture 75 percent of that market. Figure 1 presents this projected official case and compares it with actual launch demands during the 1970 through 1985 period.

Figure I.
Historical and Projected Official Case Launch Activity



SOURCE: Congressional Budget Office estimates, based on data from NASA and Department of Defense.

NOTE: The launch activity represented here is for the market traditionally served by U.S. launch capacity. Until 1983, that market was monopolized by the United States. Begining in 1983, foreign commercial launches are included as follows: 0.5 equivalent shuttle flights for 1983 and 1 each for 1984 and 1985.

Critiquing the Official Case

The official case is based on NASA and DoD projections of their own requirements and projected commercial demand as estimated by contractor studies sponsored by NASA. In the past, these projections of launch demand have been greatly overstated. Moreover, the Challenger accident has reinforced the conditions that tend to force actual launch demand below official projections.

Previous projections of launch demand have overestimated actual demand in both the immediate future (one to three years beyond the date when the forecast was made) and the longer term (beyond three years). The history of the NASA forecast of launch activity for 1985 is illustrative. Like the official case projected above, this forecast was used in policy planning and represented a synthesis of NASA's internal needs, DoD's assessment of its own needs, and contractor projections of commercial demand. In 1979, 44 shuttle flight equivalents were projected for 1985, but this estimate dropped to only 39 flights in the 1980 projection for 1985 and 22 flights in the 1983 projection.

Some of this decline represented a fall in anticipated shuttle capacity. But if problems of shuttle capacity created the 22 flight difference for 1985 between the projections of 1979 and those of 1983, then 1983 was sufficiently early for users--public and private alike--to procure ELV launches to assure access to space. The clear implication is that part of the 44 flights projected in 1979 resulted from overestimation of demand. The history of forecasts for 1985 ends with an early 1985 forecast of 14 shuttle flight equivalents, close to the level of slightly over 12 (including ELVs) actually undertaken. [3]

In the current situation, overestimated demand for 1986 through 1992 could lead to an unrealistically high estimate of the backlog waiting to be flown when both the shuttle and expendable launch vehicles are again in service. If the backlog is defined as the flights that would have been flown from 1986 through 1988, the official case backlog would be 60 flight equivalents. As seen in Figure 2, the 1979 forecast for 1986 through 1988 projected 49 flights in 1986, 52 in 1987, and 58 in 1988. Like the forecast for 1985, these estimates have fallen over time. Between 19 and 25 shuttle equivalents are projected in more recent versions of the official case.

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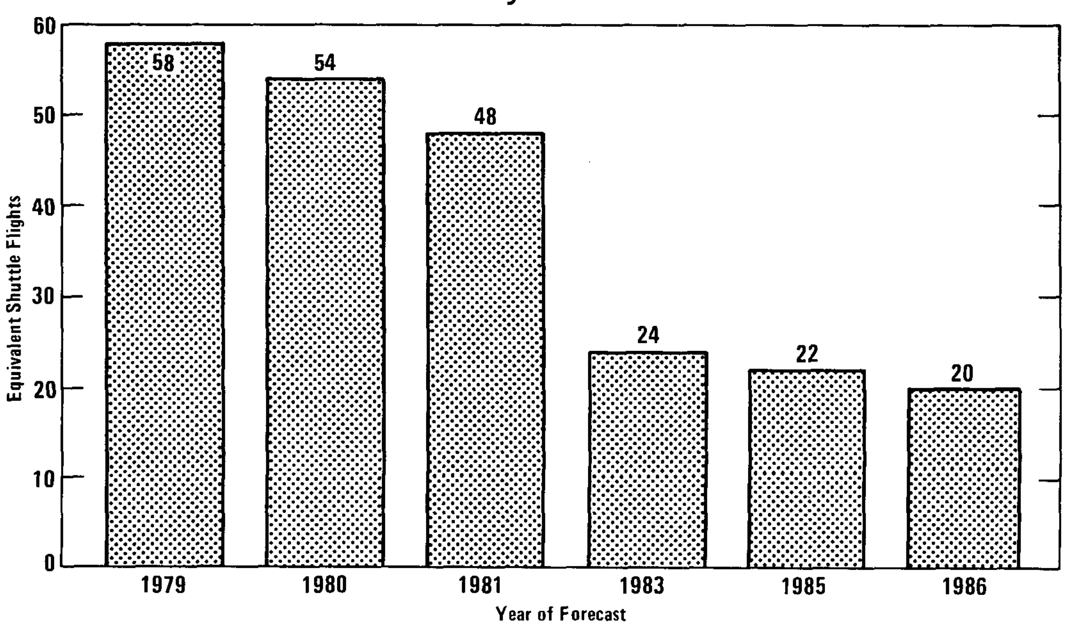
3. General Dynamics, Space Systems Division, "Launch Vehicle Availability Assessment" (prepared for annual NASA forecast data, March 1986).

There are several reasons for the consistent overestimation of launch demand. First, in responding to projection surveys, potential launch service users systematically underestimate the technical, market, and budgetary constraints that tend to force actual space transportation demand below planned demand. Second, military launch requirements are overestimated because DoD assumes that satellite life spans will be far shorter than actual experience indicates. Third, NASA's projections of its own needs, particularly when the shuttle system is concerned, are often overstated because it is assumed that planned capacity (usually overstated itself) will be filled by budget-supported demand when, in fact, the Congress regularly has approved lower appropriations than reflected in NASA's advanced planning.

Budgetary considerations are likely to have a greater effect on the official case projection in the future then they have in the past because of the Challenger accident. All other budgetary issues aside, the accident will require unanticipated NASA spending to reconstitute the system. If, as the Administration proposes, a replacement orbiter would be only partially financed by new funding, decreases would be likely in the funds available to plan and prepare for future launches. Accordingly, NASA's demand will be less than predicted in the official case.

Figure 2.
NASA Forecasts of Launch Activity in 1988



SOURCE: Congressional Budget Office, based on NASA data.

The cost of launching also is likely to increase as more conservative methods are introduced into shuttle operations. This point is pertinent to fulfilling DoD requirements which will cost more than anticipated in the official projection, whether they are carried on the shuttle or ELVs. Higher launch costs will tend to decrease the attractiveness of marginal activities and accordingly lower DoD demand.

The current official case is likely to go the way of its predecessors--that is, over time it will come to represent an overly optimistic vision of what actually will occur. Consequently, an alternative reference point is needed to examine future launch needs. Historical launch activity and its determinants are a place to begin.

LAUNCH ACTIVITY: 1970-1985

From 1970 through 1985, the launch market traditionally served by the United States averaged 7.5 equivalent shuttle flights each year, excluding the Apollo launches of the early 1970s. Table 2 presents the Congressional Budget Office's (CBO) estimate of this activity for 1970 through 1985. This launch demand was entirely served by U.S. launchers until 1983. From 1983 through 1985, these estimates include the foreign activities that contributed between 0.5 and 1 shuttle flight equivalent during each year. Table 2 shows an upward trend in annual average total launch activity. Actual launch activity in any given year need not equal the demand for launch services in that year--for example, problems with launch vehicles have periodically delayed the launch of payloads that were ready to fly. Throughout the 1970s and until the shuttle-induced delays in the early 1980s, however, the supply of ELVs was sufficiently flexible to permit actual launch activity to reflect total demand. In other words, the annual production levels of ELVs could be matched to total demand.

Federal requirements have consistently dominated the demand for U.S. launch services. Over 80 percent of launches from 1957 through 1982 were used by the public sector. From 1970 through 1985, national security alone accounted for an average of 45 percent of the payloads flown on U.S. systems. During the same period, other federal requirements--NASA and the National Oceanic and Atmospheric Administration (NOAA)--accounted for another 25 percent of the spacecraft launched by the United States, with foreign and commercial demands making up the remaining 30 percent. The

TABLE 2. U.S. SPACE LAUNCHES, 1970 THROUGH 1985
(In equivalent shuttle flights)

Years	Flights
1970	6.1
1971	7.0
1972	6.9
1973	7.1
1974	5.0
1975	6.6
1976	7.2
1977	7.3
1978	9.3
1979	4.5
1980	4.2
1981	5.7
1982	5.5
1983	8.4
1984	12.2
1985	12.4

SOURCES: Congressional Budget Office estimates. Expendable launch vehicle activity is taken from TRW Electronics and Defense Sector, *TRW Space Log 1982-1983* (TRW: Redondo Beach, Calif., 1984), pp. 40-44; and Congressional Research Service, *Space Activities of the United States, Soviet Union and Other Launching Countries/Organizations: 1957-1984*, Report No. 84-85 (1985). Shuttle flights themselves were adjusted downward according to estimates provided by NASA.

national security share has been stable over the past 15 years. 4/ The NASA share fell during the 1970s when the agency and its budget were preoccupied with the shuttle. The foreign and commercial portion has increased during the 1980s as telecommunications deregulation in the United States has permitted new entries into the long-distance telephone market and low shuttle launch prices have encouraged acceleration of satellite launch schedules.

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4. Primary data for distribution of activity by type drawn from *TRW Space Log 1982-1983* (TRW Redondo Beach, Calif., 1984); Congressional Research Service, *Space Activities of the United States, Soviet Union and Other Launching Countries/Organizations: 1957-1984*, Report No. 84-85 (1985); and *Aeronautics and Space Report of the President*, (various issues).

Within the bounds of existing launch technology, public policy, both at home and abroad, has been the most significant determinant of total launch demand. Federal demand has been fueled by programs that require the use of space and their supporting budgets. Military and national security programs need satellite systems for communications, photo intelligence, early warning, weather prediction, and navigation. The demand from foreign governments--primarily to launch communications satellites--is also motivated by public spending and constitutes half of the commercial market. During the 1970s, public policy heavily influenced the demand of private communications firms for launch services because of the Federal Communication Commission's (FCC) authority to allocate the orbital positions occupied and the radio frequencies used by private communications satellites.

Spacecraft technology ranks second in significance as a determinant of the demand for launch services. But improvements in satellite capability do not have an unambiguously positive or negative influence on the demand for launch services. On one hand, the demand for launch services is increased by improvements in satellite reliability and capability that permit wider use of space in meeting new private and public demands, or by lower costs of providing established services. On the other hand, increases in satellite reliability, capability, and lifespan diminish the demand for launch services as new satellites are not required to replace old ones, or as a single spacecraft is used to preform the work previously undertaken by several. Larger satellites are more capable, but also more costly. Increases in spacecraft cost, with all other factors held constant, will tend to decrease the requirements for launch services, particularly those that would originate with the budget-constrained public sector.

Private market demand has been a less significant determinant of the demand for launch services than public policy and technology during the last 15 years. When the FCC opened domestic telecommunications to private competition, a surge of private demand for launch services occurred, but this demand, while increasing throughout 1985, remains small relative to that of the public sector. The advent of competition to launch these spacecraft during the 1980s introduced the phrase "commercial launch market" into the space transportation vocabulary. The commercial launch market evokes visions of private satellite companies purchasing launch services from private launch companies. To date, not a single communications satellite launch is true to this vision, however, unless the quasipublic Arianespace is considered a private firm. If the launch reservation by Federal Express on a Martin Marietta Titan vehicle leads to an actual launch, a new era in space will be initiated.

This analysis does not formalize the relationship between historical experience and identifiable determinants of launch demand. These elements are brought to bear in a less formal way, however, to create a more realistic view of demand than the official case. The resulting range of demand provides a basis to assess the adequacy of U.S. space transportation capacity and the need for new investment.

THE DEMAND FOR SPACE TRANSPORTATION: ALTERNATIVES TO THE OFFICIAL CASE

The range of demand estimates offered in this analysis are bounded by a **constrained case** (a downscaled version of the official case) and a **historical case** (a linear projection of the previous 16 years of experience from 1970 through 1985). The constrained case foresees total demand increasing to 21 flight equivalents in 1991 and maintaining a level slightly below 20 flights per year during the 1990s. The historical case projects a smaller increase over the next 16 years, from the level of about 10 flight equivalents annually in the early 1990s to almost 12 flights per year by the end of the century. Table 3 provides the projected annual launch demands for the constrained and historical cases.

The Constrained Case

The constrained case can be thought of as a downscaling of the official case in order to correct for the budgetary and technical optimism that exaggerates federal requirements and to recognize the role foreign providers will play in meeting demand in the commercial market. The average annual launch demand for 1986 through 2000 would be 16.5 flight equivalents compared with 28.5 flights in the official case. The difference between the official and the constrained cases approximates the difference between projected and actual launch activities during the 1980s. While constrained relative to the official view, these projections still represent a historically high level of demand--more than twice the average level of the preceding 16 years.

Table 4 presents the major demand components included in the constrained case--DoD, NASA and other government agencies, and commercial. The DoD and national security demand is reduced to 70 percent of the official case projection. The projected eight to eleven flight equivalents through the 1990s is still significantly above the three to five flights undertaken over the last 15 years and consistent with the historical share of U.S.

TABLE 3. DEMAND PROJECTIONS FOR TWO ALTERNATIVE CASES, 1986 THROUGH 2000
(In equivalent shuttle flights)

Year	Constrained Case	Historical Case
1986	7.1	9.0
1987	10.5	9.2
1988	14.9	9.4
1989	17.3	9.6
1990	18.9	9.8
1991	21.3	10.0
1992	19.8	10.2
1993	18.9	10.4
1994	16.0	10.6
1995	18.3	10.9
1996	15.9	11.1
1997	17.4	11.3
1998	17.6	11.5
1999	16.3	11.7
2000	16.7	11.9

SOURCE: Congressional Budget Office.

activity accounted for by DoD. Demand by NASA and other government agencies is reduced by 50 percent to five to six flights a year--a level slightly above that undertaken in the preceding 16 years. This reduction from the official case anticipates budgetary and technical problems in launching the space science, planned for the late 1980s, and a slower, smaller, and more incremental approach to the space station than currently planned. Finally, the commercial portion of the constrained case projection would be 50 percent of the preliminary Battelle model projection of 1986. 5/ The resulting level of three to five flights a year is consistent with emerging foreign competition for the previous U.S. launch monopoly and the setback dealt to space manufacturing by the Challenger accident. Even these levels of commercial demand, it should be noted, represent an optimistic assessment of both the entire commercial market and the U.S. share

5. Battelle Columbus Laboratories, "Outside Users Payload Model" (Draft, August 1986).

of that market. The constrained case backlog resulting from the Challenger accident is 32.5 equivalent shuttle flights, the sum of flights projected for 1986 through 1988.

The Historical Case

The historical case is a simple extrapolation of the actual trend of the past 16 years, modified to reflect the atypically high launch activity of the Apollo program in the early 1970s. The average annual demand is projected to be 10.5 shuttle equivalents. By its very nature and perhaps to its ultimate benefit, the projection does not account for plans to expand space activities. Instead it simply carries forward a real set of past activities that took place in the presence of the cost overruns, policy changes, budget shortfalls, and technical problems that mark enterprises as complex as those undertaken in space. The backlog under this projection is 28 flights.

TABLE 4. CONSTRAINED CASE DEMAND PROJECTIONS, BY MAJOR COMPONENTS, 1986 THROUGH 2000 (In equivalent shuttle flights)

Year	Department of Defense	NASA and Other Federal Agencies	Commercial	Total
1986	2.1	3.6	1.4	7.1
1987	4.0	4.4	2.2	10.6
1988	8.4	3.5	3.0	14.9
1989	10.6	4.4	2.3	17.3
1990	9.7	6.1	3.1	18.9
1991	11.8	4.9	4.6	21.3
1992	10.1	5.5	4.2	19.8
1993	10.6	5.0	3.3	18.9
1994	8.7	4.5	2.8	16.0
1995	8.7	6.5	3.1	18.3
1996	7.3	5.5	3.1	15.9
1997	8.5	5.5	3.4	17.4
1998	8.5	5.5	3.6	17.6
1999	8.5	5.5	2.3	16.3
2000	8.5	5.5	2.7	16.7

SOURCE: Congressional Budget Office.

DEMAND PROJECTIONS AND SPACE TRANSPORTATION INVESTMENT

Demand projections provide a crude yardstick that can be used to measure the adequacy of launch capacity. While the federal government can easily adjust the annual level of space transportation supplied within a given scale of operation, the scale of operation itself (orbiters in the fleet and operating plants to produce expendable launch vehicles) requires more time and expenditures to change. As such, the current period is critical in that major decisions must be made about the ability of the United States to supply space transportation over a long period, perhaps into the next century.

While members of the space community are aware of the persistent overestimation of total launch demand, they are unanimous in their view that the question is not *if* there will be a large increase in the demand for space transportation, but *when* that increase will occur. Nevertheless, the past 15 years of U.S. space launch activity have been characterized by steady but slow growth rather than rapid acceleration. The shuttle system was to have spurred acceleration by lowering the cost of transportation, by providing a unique capability, and, more recently, by generating net revenues for NASA to permit the agency to do more for a given level of appropriations. But in the wake of the Challenger accident and revelations about the operation of the shuttle system, only the unique capability of the shuttle remains as a stimulus to growth. The current situation is far too uncertain to claim revolutionary cost advantages or net revenue gains for NASA as engines of growth for launch service demand. Therefore, it appears unlikely that the official case projections can serve as an adequate guide to future demand. Either the constrained or historical case could, perhaps, better inform federal investment decisions.

CHAPTER III

SPACE TRANSPORTATION SUPPLY

During the late 1970s and early 1980s, U.S. space transportation policy envisioned a shuttle-dominated system to serve both federal requirements and much of the worldwide commercial market. Some observers contemplated enough emerging commercial demand to stimulate the production of private launch supplies in the form of additional shuttles or expendable rockets. In this view, private launch supplies would provide the nation with standby capacity for space launches, much in the same way the U.S. merchant marine would augment the Navy's sea-lift capability in a national emergency. Foreign competition by expendable launch vehicles (ELVs) was for the most part discounted, primarily because the shuttle was viewed as far and away the lowest-cost option.

As the shuttle-dominated system was to maintain the preeminent role of the United States in the international commercial market, it was also to assert NASA's dominance as the provider of federal space transportation, replacing the preshuttle arrangement by which NASA and DoD maintained separate ELV capacities and swapped vehicles as launch needs required. Revenue flows to NASA from the commercial market and intragovernmental transfers from DoD were to have been combined with real increases in the NASA budget to help support the $8 billion NASA contribution to the international space station. The DoD was to lose its independent launch capacity as its Titan ELV program was phased out; but DoD was to gain the benefit of lower-cost shuttle transportation.

As doubts emerged about the shuttle program, U.S. expendable launch vehicles again became a viable option for commercial space transportation. In 1983, the President explicitly recognized the relationship between the effectively subsidized price NASA offered to its private and foreign customers, on the one hand, and the prospects of "commercializing" the ELV industry on the other. 1/ To provide a more competitive environment, the

1. Shuttle pricing policy has never been formulated to subsidize commercial customers explicitly in that price levels have always been set to cover, at a minimum, the estimated additive cost of flights undertaken to service commercial clients. Actual costs, however, have consistently exceeded estimated costs, effectively subsidizing commercial customers.

President proposed that NASA charge a full-cost price to commercial users of the shuttle. This stimulated a debate over whether or not full cost should include past investments in the shuttle system itself or only the cost of operating it.

By 1985, perhaps in response to the perception that commercial firms would not enter a market that was growing more slowly than anticipated and was subject to competition from foreign governments, the U.S. government had begun to modify its plans for a shuttle-only system. The Air Force started the Complementary Expendable Launch Vehicle (CELV) program (recently renamed Titan IV) to provide 10 large missiles, each capable of launching the equivalent of one shuttle load into orbit.

CURRENT WORLD CAPACITY

At the time of the accident, the United States was phasing down its ELV capacity. The combination of four orbiters and the production line for the Titan rockets was supposed to provide sufficient launch capacity--more than 30 shuttle equivalents a year--to allow the Atlas and Delta rocket lines to be shut down. The accident has not affected Europe's continued contributions to world launch supplies with the Ariane vehicle, or the planned entry by Japan, China, and the Soviet Union into the market.

U.S. Capacity

In May 1986, responding to the Challenger accident, the Congress appropriated supplemental funds for fiscal year 1986 to increase Titan IV procurement by 13 vehicles to a total of 23, permitting an annual launch rate of four to six beginning in 1989. To increase U.S. launch capacity further, procurement of a medium launch vehicle (MLV) was also approved, with a target of four launches, or roughly 1.5 shuttle equivalent per year, by 1989. These actions have not only increased the volume of U.S. launch capacity but also will ensure that the United States has three independent space launch systems--two ELV systems and the shuttle fleet.

The nation's space launch capacity is the number of orbiters in the shuttle fleet and the production facilities for expendable launch vehicles. The capacity to provide space transportation services may exceed current production, scheduled shuttle flights, and ordered ELV services. The CBO estimates that, under current policy, U.S. launch capacity in 1989 will be 21 to 24 shuttle flight equivalents, divided almost equally between the shuttle fleet and ELVs with production facilities in operation. Table 5 provides a breakdown of U.S. capacity in 1989 and illustrates the potential volume that could be added by procuring a new orbiter or by making a long-term procurement commitment for a third ELV option.

This analysis is conservative in its estimation of the U.S. capacity to supply space launches. NASA's preaccident projection of six flights annually for each orbiter is lowered to three to four flights per orbiter. Currently, all three U.S. ELV production lines--Delta, Atlas, and Titan--are open for new orders. The capacity estimates in Table 5, however, include only current plant capacity for which federal procurement commitments have been made--the Titan line and an as yet unspecified MLV producer.

International Launch Capacity

The quantity of space transportation supplied worldwide does not depend solely on its market value. Indeed, the capacity to provide launch services

TABLE 5. U.S. SPACE LAUNCH CAPACITY IN 1989 AND EXPANSION OPTIONS (In equivalent shuttle flights)

Launch Systems	Equivalent Shuttle Flights per Year
1989 Capacity	
Orbiters	9-12
Expendable Launch Vehicles	
Titan Family	9
Medium Launch Vehicle	3
Subtotal, ELVs	12
Total	21-24
Expansion Options	
New Orbiter	3-4
Additional ELVs	3-5

SOURCE: Congressional Budget Office.

may exceed the demand for such services for long periods of time (and may actually grow in periods of excess supply) as new public launch vehicles enter the market in pursuit of various noneconomic objectives. The requirements and plans of governments in the space transportation area, therefore, are the starting point for analyzing international supply conditions.

During the 1970s, the U.S. government supplied the entire noncommunist world with launch services. While individual payloads may have been delayed by launch vehicle problems, the supply of space transportation within the prevailing structure of technology and cost was more than sufficient to meet physical launch demand. Paying customers needed only to order their vehicle and wait for it to be produced. Institutional constraints on supply, among them the U.S. hesitancy in 1971 to launch a European communications satellite, Symphonie, prompted the European Space Agency to develop the Ariane rocket and permanently add to world launch capacity. 2/ Like the United States and the Soviet Union, China has developed a launch capability as a byproduct of its military rocket program. The Japanese plan to increase their capability, but are unlikely to fly non-Japanese payloads before 1992.

Table 6 presents the CBO estimate of foreign capacity that will be available to the commercial market in the early 1990s. The commercial demand projection of four to, at best, nine flight equivalents per year in the 1990s is roughly equal to this potential supply, without any use of U.S. capacity. Although the Challenger accident has created a demand backlog that will need to be launched in the early 1990s, worldwide launch capacity should exceed commercial demand once this backlog is relieved. U.S. launchers seeking a share of this market are likely to encounter extremely rigorous price competition, a factor to be considered in choosing a U.S. supply policy.

THE SHUTTLE AND ELVS: SUPPLY ALTERNATIVES

Over the next 15 years, shuttle-like vehicles and improved expendable launch vehicles will constitute the available supply options. Both the shuttle system and the U.S. ELV capacity are assessed below to establish how each could best meet the major goals of U.S. space policy: first, to supply cost-

2. This hesitancy was based on U.S. adherance to the 1971 International Telecommunications Satellite Organization Agreement, which committed the U.S. to the Intelsat System, to which the Symphonie satellite was a competitive threat. See Office of Technology Assessment, *Civil Space Policy and Applications* (1982), p. 363.

TABLE 6. FOREIGN ELV CAPACITY IN THE EARLY 1990s

Foreign Supplier (Vehicle)	Equivalent Shuttle Flights
Europe (Ariane)	4-5
Japan (H-Series)	1-2
China (Long March)	1-2
Soviet Union (Proton)	0-1
Total	6-10

SOURCE: Congressional Budget Office.

NOTE: The Soviet Union could supply more capacity. A conservative estimate of foreign capacity, however, must recognize the political constraints limiting use of Soviet vehicles.

effective launch services to meet federal requirements, and second, to gain a share of the commercial market for public or private U.S. launch services which would require matching new capacity to market demands.

The Shuttle

Shuttle Costs. In 1985, CBO analyzed the projected costs of the shuttle system for 1989 through 1991.[3] The Challenger accident forces a reexamination of this data, but not the underlying cost concepts relevant to the shuttle system. These are described in the accompanying box. Three considerations stand out in the postaccident period. First, the shuttle remains a high fixed-cost system--the average cost of each flight declines as more

3. See Congressional Budget Office, *Pricing Options for the Space Shuttle* (March 1985).

flights are launched. Second, the additional cost borne by the government to procure and operate a replacement orbiter is the relevant cost standard to use in comparing shuttle costs with ELVs in serving the commercial market. Third, the fixed and variable operating costs of the system will increase as a result of the accident.

The NASA estimates that a replacement orbiter built over four years would require $2.2 billion in new expenditures. A decision to build an orbiter must be made soon or the possibility will be precluded, as Rockwell International and the subcontracting base may shut down all shuttle production facilities. This study assumes that the funds to build an orbiter for

CATEGORIES OF COST

Cost analysis concerns three different types of cost--total, average, and marginal. The **total cost** of a service or a product is the sum of all the funds necessary to buy materials, equipment, and facilities and to pay workers and owners their wages and profits. **Average cost** is simply total cost divided by the number of units of service or product provided--for the shuttle, flights are usually thought of as the unit of output. **Marginal cost** is the cost of providing or producing an additional unit of service or product. Generally, providing one more unit changes some costs but not others. For example, an additional shuttle flight would increase fuel costs, but, unless the physical capacity of the system had been reached, it would not require construction of new buildings or orbiters. Only under special circumstances will marginal cost equal average cost. For the shuttle, as with other high fixed-cost industries, marginal costs are less than average costs for all relevant levels of service.

Cost becomes more complicated when time is introduced. Two distinctions are important: **fixed** versus **variable costs** and **short-run** versus **long-run** costs. Over many years, all the shuttle system costs may be seen as variable. Given enough time, new facilities could be built at Kennedy Space Center or Vandenberg, the fleet of orbiters could be doubled in size, or the entire program could be eliminated. The period of time in which all costs are variable is called the long-run. For the shuttle, such a period could be 20 or 30 years. The shorter the time under consideration, however, the more costs become fixed. For example, since a new orbiter requires four to seven years to construct, the cost of this resource is fixed for time periods of four years or more.

Once a period of analysis is specified, fixed and variable costs can be identified, and the total, average, and marginal costs can be estimated. Total costs are separated into total fixed costs and total variable costs. Marginal costs are then the change in total variable cost attributable to a one unit increase in the level of service.

flights in 1991 would be authorized over a six-year period, beginning in 1987. Thereafter, the replacement orbiter would cost an annual sum equal to the marginal cost of the additional flights flown by that orbiter each year. The CBO's analysis of shuttle costs estimated that the marginal cost of a 1989 shuttle flight would be $48 million, a "base case" estimate drawn from a broad range from a low of $32 million to a high of $81 million (all in 1986 dollars). A 1986 study by Resources for the Future estimated a marginal cost range from $33 million to $70 million (both in 1985 dollars). [4]

The Challenger accident will increase the marginal cost of shuttle operations, but by how much is uncertain. Before the accident, the bulk of shuttle costs that varied directly with the flight rate were attributable to the solid rocket booster, the external tank, Kennedy Space Center (KSC) launch operations, and Johnson Space Center (JSC) flight operations. The future cost of the solid rocket booster is unknown, but lower volume purchases and probable redesign undoubtedly will lead to higher costs, both fixed and marginal. If a competitive second manufacturer was introduced to supply solid rocket boosters, it is not clear whether competitive pressures to cut costs would triumph over lower volume purchases and the high up-front cost of qualifying a second source. The net result could be additional costs. Lower volume purchases could also raise the cost of external tanks. The JSC flight operations should not be significantly affected by postaccident changes, but both the fixed and variable costs of KSC launch operations are likely to increase. Finally, all CBO cost estimates will increase relative to NASA projections as the benefits of learning by doing are reflected in those projections.

The range of marginal cost estimates in the CBO March 1985 study of shuttle costs was broad enough to include higher postaccident marginal costs. For example, the base case estimate recognized that the flight rate underlying the NASA cost estimates would probably not be achieved and cost savings based on learning effects accordingly would be lower. In addition, allowance was made for simple cost escalation. [5] Until such time as an independent audit of the cost of postaccident shuttle operations is under-

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4. Michael Toman and Mollie Macauley, *Commercial Policies and International Competition: The Example of Space Transportation Policy* (Washington, D.C.: Resources for the Future, 1986), p. 15.

5. A separate Air Force study of shuttle costs, using a historical cost growth factor, estimated that operating costs would be over 40 percent higher than NASA projections, as cited in E. Blond and W. Knittle, *Space Launch Vehicle Costs* (prepared by the Aerospace Corporation for Department of Transportation, Office of Commercial Space, 1984), p. 25.

taken, a precise estimate cannot be made. However, the upper end of the marginal cost range developed by CBO in 1985 (from the base case of $48 million to the high level of $81 million) provides a reasonable estimate at this time.

Shuttle Flight Rate. Since the late 1970s, NASA has continuously lowered its projections of the annual flight capacity of the shuttle system. Before the loss of Challenger, many analysts outside NASA questioned the ability of the four-orbiter fleet to achieve the long-predicted flight rate of 24 per year by 1989.[6] This pessimism was justified by the preaccident record. As the Rodgers Commission stated, "The capabilities of the system were strained by the modest nine-mission rate of 1985, and the evidence suggests that NASA would not have been able to accomplish the 15 flights scheduled for 1986."[7] This analysis adopts a conservative range of future shuttle flight rates, estimating 9 to 12 flights annually by the three orbiters remaining in the fleet and three to four additional flights if a Challenger replacement is procured.

Expendable Launch Vehicles

U.S. expendable launch vehicles have developed in "families," generally consisting of an older basic vehicle suitable for smaller payloads and newer larger vehicles developed in response to increasingly heavy payloads. For example, the General Dynamic's Atlas vehicle has been produced in four different versions--E, F, H, and G/Centaur--with the early members of the family capable of lifting 3,000 pounds to low earth orbit and later versions capable of lifting 13,500 pounds to the same orbit. Two new designs under consideration, the Atlas Centaur Super G and the Atlas K, would continue to increase the lift capability of the Atlas.[8] Increases in ELV weight capability generally are achieved by lengthening the fuel tanks of liquid fuel main engines or by adding on solid rocket boosters. The two other families of U.S. ELVs with active or near-active production lines are McDonnell

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6. For example, see National Academy of Sciences, National Research Council, Committee on NASA, Scientific and Technological Program Review, "Assessment of Constraints on Space Shuttle Launch Rates" (1983).

7. *Report of the Presidential Commission on the Space Shuttle Challenger Accident* (July 1986), vol. 1, p. 164.

8. General Dynamics, Space Systems Division, *Launch Vehicle Availability Assessment* (March 1986).

Douglas' Delta and Martin Marietta's Titan. 9/ A Hughes Aircraft/Boeing Company response to an Air Force request for proposal would add an additional option, the Jarvis, an all liquid fuel vehicle which uses elements of the Saturn ELV and shuttle propulsion systems.

Table 7 illustrates the growth in lift capability in the three major families of U.S. expendable launch vehicles and the proposed Jarvis vehicle. The launch capabilities shown in Table 7 are based on specific launch configurations of a booster or first stage rocket--Titan, Atlas, or Delta--and an upperstage rocket--Centaur, IUS (inertial upper stage), and PAM (payload assistance module). Upperstages are used by both the shuttle and ELVs to place satellites into higher orbits. This report is concerned with the booster industry where ELVs and the shuttle are interchangeable for most satellite deployments, rather than the upperstage industry because neither national capacity nor industrial organization in the upperstage rockets industry are a major current policy concern.

Currently, the Titan IV is the only new vehicle being produced, but both General Dynamics and McDonnell Douglas have stated that they can deliver their respective new vehicles within 24 months of an order and can reach significant production rates in three to four years. 10/ The Hughes/Boeing proposal stated that delivery of the Jarvis could take place in 38 to 42 months if the Air Force accepted its bid.

Production of ELVs and Launch Services

Supplying launch services consists of several important stages: production of key components, production of launch vehicles, integration of payloads and upperstages with launch vehicles, and the actual launch itself. The three current major U.S. suppliers of ELVs provide all these services. Ancillary services include financing and insurance. 11/ Engines are the most sig-

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9. McDonnell Douglas manufactures the Delta rocket but has negotiated the commercial marketing and service rights to a newly started company, Transpace Carriers, Inc.

10. Keith Mordoff, "ELV Makers Gear for Production Restart," *Commercial Space* (Spring 1986), p. 46.

11. Problems of insurance are not covered in this analysis. Even before the Challenger accident, increasing losses and rising insurance rates had raised questions about whether federal action to assure coverage was appropriate. One alternative to direct federal intervention would be to change the distribution of risk between satellite owners and insurers. For example, owners could purchase coverage for less than the full value of their satellites. Sharing risk by creating a pool contributed to by satellite owners, manufacturers, and launch providers is also an option. New entrants in the commercial launch market, particularly the Chinese, have included very low insurance rates in their launch package in order to increase the attractiveness of their launch services.

TABLE 7. THE EVOLVING LIFT CAPABILITY OF U.S. ELVS

Vehicle	Weight to Low Earth Orbit (In pounds)	Weight to Geosynchronous Transfer Orbit (In pounds)
	Atlas Family (General Dynamics)	
Atlas E	3,000	a/
Atlas H	4,400	a/
Atlas G/Stretched b/	8,000	3,000
Atlas G/Centaur	13,500	5,200
Atlas Super G/Centaur b/	14,500	6,000
	Titan Family (Martin Marietta)	
Titan II	4,200	a/
Titan 34/D IUS	32,000	10,000
Titan 34D/Centaur D-1	32,000	16,000
Titan IV/Centaur b/	40,000	20,000
	Delta Family (MacDonald Douglas)	
Delta M-6	2,000	1,000
Delta 3920	5,500	2,800
Delta 4920 b/	c/	3,900
Delta 5920 b/	c/	4,400
	Jarvis Family (Hughes Aircraft/Boeing Co.)	
Jarvis b/	85,000	12,500-20,000 d/

SOURCES: For Atlas: General Dynamics Space Systems Division, "Launch Vehicle Availability Assessment" (March 1986); for Titan: Martin Marietta, "Commercial Titan" (undated); for Delta: Delta, "Transpace Carriers" (undated); for Jarvis: Hughes/Boeing Co., "Jarvis Launch Vehicle" (August 19, 1986).

a. The rockets are not used in this orbit.
b. Proposed for development.
c. Not available.
d. Weight depends on upperstages.

nificant component supplied by subcontractors to prime ELV producers, with Aerojet and United Technology supplying the Titan family; Rockwell International's Rocketdyne Division, the Atlas family; and Rocketdyne, Morton Thiokol, TRW, and Aerojet, the Delta. The Jarvis proposal would require Rocketdyne to restart production of the F-1 and J-2 engines developed for the Saturn program.

U.S. producers could meet easily the production levels of ELVs discussed in this analysis. During the 1960s, U.S. producers supplied relatively large volumes of ELVs for space launches and Intercontinental Ballistic Missles (ICBMs). For example, space launches alone averaged over 50 vehicles per year between 1962 and 1969. 12/ General Dynamics built over 100 ICBMs a year in each of two years. 13/ Martin Marietta produced Titan II at a rate of 20 per year in building up the U.S. ICBM force, and now indicates that its current production facility could turn out 14 vehicles annually by mixing refurbishment of Titan IIs with new production of Titan 34Ds and Titan IVs. 14/ Table 8 provides company estimates of interim and sustainable production rates, using the current production base; these represent a baseline for estimates of capacity. 15/ U.S. prime producers of launch vehicles have indicated that the lead times involved in the overall production process are sufficient to permit the engine producers to increase their output sufficiently to meet demand.

Currently, the federal government owns and operates the facilities capable of launching ELVs: Kennedy Space Center (including the Eastern Test Range at Cape Canaveral) and Vandenberg Air Force Base (VAFB). These facilities are adequate to support the ELV launch rates in the U.S. launch capacity estimates presented in Table 5. Modest investment in additional facilities, however, might be required to increase U.S. ELV launch rates. The NASA, the Air Force, and their respective contractors could provide enough launch personnel and support to meet the levels of supply permitted by vehicle production and launch facilities. The Space Launch Commercialization Act of 1984 (P.L. 98-575) directed the Department of

12. TRW, *Space Log 1982-1983* (1984), pp. 40-42.

13. General Dynamics, "Launch Vehicle Assessment" (March 1986).

14. Martin Marietta, "Commercial Titan" (undated).

15. Vehicle production can be expanded rapidly at a relatively low cost. For example, General Dynamics estimates that retooling and removing "choke points" would permit Atlas production capacity to increase from 5 to 25 vehicles by 1990. General Dynamics, "Launch Vehicle Assessment."

TABLE 8. ILLUSTRATIVE U.S. ELV INTERIM AND SUSTAINED PRODUCTION RATES
(In number of vehicles delivered for launch)

ELV	1988	1989	1990	1991
Atlas Family	3	5	5	5
Titan Family	4	14	14	14
Delta Family	0	6	10	10

SOURCES: For Atlas Family: General Dynamics, Space Systems Division, "Launch Vehicle Availability Assessment" (March 1986); for Titan Family: Martin Marietta, "Commercial Titan" (undated); and for Delta Family: "Air Force Seeks Shuttle Alternative," *Metalworking News* (July 28, 1986), p. 1.

Transportation's Office of Commercial Space Transportation to establish a regulatory framework to permit ELV producers to launch nongovernment payloads from government facilities for a fee. No obstacle to such launches is apparent to date.

Cost and Competition. Competitive supply of launch services, particularly to the commercial market, depends on three elements:

- Obtaining scale economies through adequate production rates,
- Compatibility with satellite designs, and
- Ability to provide flexible, multiple payload launches.

To a lesser extent the location of launch facilities is relevant in that the rotational speed of the earth and inclination to orbit allows a particular rocket configuration to lift more weight into orbit from an equatorial site than from a nonequatorial site. 16/

The cost of expendable launch vehicles is significantly influenced by both the absolute size of an order and the annual production rate. U.S. producers evaluate ELV production ventures on a project basis and, accordingly, amortize total project costs over an entire order. This value is then reflected as an element of unit cost. This approach to cost and pricing

16. For example, Arianespace's equatorial site at Kourou, French Guiana, provides a 10 percent lift advantage for some launches relative to the Kennedy Space Center.

demonstrates an aversion to risk compared with the view taken in other manufacturing industries in which investments are made on the basis of forecasted demand rather than orders in hand. Setting aside the absolute size of a particular procurement order, the unit cost of launch services to the government declines as the annual production rate increases. 17/ For the Delta family of rockets, each of the eight units produced would cost about 69 percent of the cost of the second unit. For Atlas rockets, this ratio would be 65 percent, and for the Titan family, 59 percent. This fall in unit costs results from spreading fixed direct production costs, overhead, and subcontractor's fixed costs and overhead over a larger production base. 18/

The cost of launch services includes both hardware and operational components. At an annual rate of four launches per year, hardware costs--the booster, upper stage and payload--represented an average of 66 percent of the unit cost for the major U.S. ELVs families. Operations, launch, and range accounted for an average of 21 percent of launch cost, with "other government costs" representing an average of 13 percent. Lower booster costs represented the largest part of decreasing unit costs as production increased. Launch support costs also fell significantly as the volume of launches increased. 19/

The published version of the Aerospace Corporation report did not disclose estimates of commercial bids developed in the study. The breakdown of cost for each class of launch service provided to the government includes the category "other government costs," however. Aerospace contractors traditionally argue that doing business with the government imposes costs above those of the commercial market. Thus, an estimate of commercial price can be obtained by subtracting other government costs from the total unit cost. 20/ These estimates for each of the vehicles covered in the Aerospace report are presented in Table 9 for production levels of four and eight vehicles.

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17. Blond and Knittle, *Space Launch Vehicle Costs*.

18. Data were unavailable to carry forward the unit cost function to higher levels of output. It should be recognized, however, that increased output eventually may require new capital investments that slow or negate the fall in unit cost. In any event, the portion of the market for launch services U.S. expendables are likely to be called upon to serve should not push output far beyond the current production base.

19. Blond and Knittle, *Space Launch Vehicle Costs*.

20. Jacques S. Gansler, *The Defense Industry*, (Cambridge, Mass., Massachusetts Institute of Technology 1980), Chapter 3.

A launch vehicle will be more competitive to the extent that it is compatible with a wider range of satellite designs. Recent failures in launch systems have led satellite producers toward designs that can be flown on both the shuttle and the Ariane rocket family. For U.S. providers considering entry into the commercial market, compatibility with the Ariane is imperative. To this end, the Martin Marietta Company has recently sought to purchase payload support equipment rights permitting payloads designed to fly Ariane to fly Titan.

In order to be competitive, larger launch vehicles must carry two payloads per flight. The lift capability within a given family may vary considerably, and individual members of different families may overlap certain payload weight classes. In general, however, the Delta is the smallest ELV; the Atlas, the mid-sized ELV; and the Titan, the largest. The payloads to be carried may be broken down into the same classes: under 3,000 pounds--Delta class; 5,000 pounds--Atlas class; and over 6,000 pounds--Titan class. The probable distribution of future payloads is skewed towards the small and medium groups, suggesting that dual launches will be a consistent element of competitive strategy. A launch system will be more attractive to the

TABLE 9. ESTIMATED U.S. ELV UNIT COSTS FOR THE COMMERCIAL MARKET (In millions of 1984 dollars)

Vehicle and Configuration	4 Units per Year	8 Units per Year
Delta 3920/PAM	39	36
Atlas K/SGS IIA	44	37
Atlas G/Centaur D-1A	54	48
Titan 34D/Support Module	78	59
Titan 34D/IUS	121	100

SOURCE: Congressional Budget Office etimates, based on Aerospace Corporation estimates of cost to the government taken from E. Blond and W. Knittle, *Space Launch Vehicle Costs* (prepared by the Aerospace Corporation for Department of Transportation, Office of Commercial Space, 1984), p. 25.

extent that the launch dates of some payloads are flexible so that other users with tight launch time frames can be accommodated sooner. Even smaller, single payload systems may require such flexibility, in that launch delays for a particular payload or commercial targets of opportunity can require changing the manifest to win a particular bid.

U.S. competitiveness in the commercial launch market will require government procurement of ELVs regardless of whether the public sector or the private sector or some hybrid of the two ultimately delivers the services. Only the federal government can offer the volume of business sufficient to permit production rates high enough to allow cost competitiveness with foreign ELVs. Similarly, only governmental launch requirements are so large that schedule delays can be absorbed to permit the flexible launch times and the sale of services by the pound necessary for competitive supply.

PROJECTED DEMAND, CAPACITY, AND THE OBJECTIVES OF U.S. SUPPLY POLICY

The projections of demand provided in the preceding chapter can be compared with the capacity provided for by current policy and expansion prospects developed in this chapter. This assessment of the adequacy of the capacity provided by current policy depends on the view taken of future demand. The official case suggests barely adequate capacity, since even the addition of a new orbiter would only raise U.S. capacity during the 1990s to a range of 24 to 28 annual flights, less than the projected average annual demand of about 30 flights per year. Under this case, federal procurement of ELVs would undoubtedly increase, causing new capacity to be brought online. An increase in the size of the orbiter fleet to five might also be in order, as the backlog of shuttle flight equivalents stacked up from 1986 through 1988, is estimated at 60.

A very different view of the need for new capacity emerges if the more realistic range of demand is used as a starting point. As Table 10 shows, only in the official case would the average annual level of demand expected between now and the end of the century exceed the capacity provided by the three-orbiter fleet and the ELV production facilities that DoD procurement will keep active through the early 1990s. In the constrained case, annual capacity provided by current policy would cover 130 percent to 145 percent of average annual demand. Adding the capacity provided by an additional orbiter would increase this range to 145 percent to 170 percent. If demand were to follow the historical case path, the capacity provided by current policy could carry 200 percent to 230 percent of annual demand, and addition of a new orbiter would increase the range to 230 percent to 270 percent of the projected annual launch requirements, dramatically above projected demand.

The backlog of demand, which actually would grow in the official case, is also more manageable under the more likely alternative views. The 30 some flight equivalents of backlog in the constrained case projection would represent three to six years worth of the excess of capacity over the annual requirements of that case with no additional capacity expansion. If demand was expanded by the three to four flight equivalents per year provided by a new orbiter, the backlog could fall to only two to three years worth of the excess of capacity over demand. Because the historical case projects a backlog of only five fewer flights than the constrained case, the relation between current capacity, the addition of a new orbiter, and the backlog would be basically the same. The urgency of the backlog could be overstated in all cases in that civilian scientific experiments, while desirable, may impose little cost to society if delayed and commercial demand might seek launch services.

TABLE 10. ALTERNATIVE DEMAND PROJECTIONS COMPARED WITH ESTIMATES OF CURRENT POLICY AND EXPANDED CAPACITY

	(In equivalent shuttle flights)				
	Projected Annual Average Demand	Estimated Current Policy Capacity	Estimated Expanded Capacity (Replacement orbiter)	Projected Demand as a Percentage of Current Policy Capacity	Projected Demand as a Percentage of Expanded Capacity
Official Case	28.5	21-24	24-28	74-84	84-98
Constrained Case	16.5	21-24	24-28	127-145	145-170
Historical Case	10.5	21-24	24-28	200-229	229-266

SOURCE: Congressional Budget Office.

Under the official case projection, new and backlogged demand would permit the shuttle capacity to be used fully and the federal volume of ELV procurements to be sufficiently large to allow a competitive U.S. offering of expendable launch vehicles to the commercial market. Under either of the more likely cases, however, a potential conflict emerges between cost-effective use of the shuttle and federal procurements of ELVs at rates sufficiently high to permit competitive commercial offerings. Extensive use of ELVs would cause the shuttle fleet to be underused, while full use of the fleet would lower ELV procurements, increasing the per unit cost of ELVs to the government and diminishing their attractiveness to the world market. In this context, the Administration's proposal to withdraw the shuttle from the commercial market could ensure the underuse of an expanded--or perhaps even the current--shuttle fleet, thereby increasing the cost differential to the government between using ELVs for its own needs and investing in an additional orbiter. These comparative costs are estimated in the next chapter.

CHAPTER IV

OPTIONS

In the aftermath of the Challenger accident, policymakers focused on whether Challenger should be replaced. Indeed, this question is still unresolved. But the evolution of the national debate about space transportation policy has created a new context in which to consider this issue: whether to develop a private-sector industry to serve the commercial launch market and reserve the shuttle for government use.

The Administration has proposed replacement of the Challenger, but would restrict its use to government purposes. While the shuttle will provide service for those commercial payloads only it can carry--the European Space Agency Spacelab, for example--the U.S. presence in the commercial satellite market is to be maintained by private firms providing expendable launch vehicle (ELV) services. This ELV commercialization option could help the United States maintain its 50 percent share of the commercial market through the early 1990s.

Large Department of Defense (DoD) ELV procurements, limited foreign competition, and a backlog of commercial payloads all point towards this result. Beyond the early 1990s, however, the backlog of commercial satellites will be reduced, and new foreign capacity will enter the market. The result could be a loss of U.S. competitiveness. This possibility encourages the consideration of alternative institutional arrangements to ELV commercialization, specifically, a return to the preshuttle system of NASA as a provider of ELV launch services or the creation of a mixed public/private enterprise, a U.S. Space Transportation Company.

THE REPLACEMENT ORBITER DECISION

The case for buying a fourth orbiter is strongest when considered in the context of the space station program as currently planned and weakest when presented as a cost-effective launch vehicle to deploy satellites during the 1990s. Constructing the space station would require 19 shuttle flights spread over two years, roughly equal to the capacity of a three-orbiter fleet. As a bulk carrier, however, the shuttle has lost much of its attractiveness compared with expendable launch vehicles as the shuttle system has consistently fallen short of its projected flight rate, has been more costly to operate than estimated, and may, in the future, be restricted to lower payload weights.

Cost Comparison

The annual average new demand requiring U.S. launch capacity over the next 15 years probably will range from 10.5 to 16.5 equivalent shuttle flights rather than the almost 30 flights projected before the Challenger accident. With capacity estimated to be 21 to 24 equivalent shuttle flights annually by 1989, new annual demand and the backlog of cargos created by the grounding of the shuttle could be served more economically by increased production at operating ELV facilities rather than by the large investment entailed in procurement of a replacement orbiter.

The preaccident cost advantage of additional orbiter capacity relative to increased ELV production has been negated by increases in the marginal cost of providing an additional shuttle flight, lower annual flight rates which restrict the system's capacity, and diminished orbiter carrying capacity. In Chapter III, it was shown that shuttle marginal costs were likely to increase from about $48 million to a range of $65 million to $80 million and that a new orbiter could only contribute three or four flights a year rather than the six flights implied by the preaccident goal of 24 flights per year. It is most likely that changes resulting from the Rogers Commission report will add weight to the shuttle's configuration and restrict the thrust provided by the main engines, lowering the payload weight an individual orbiter can carry.

The CBO has compared the net present value of the stream of costs that would be generated from 1987 through 2000 by a notional fourth orbiter and comparable ELV carrying capacity, as shown in Table 11. The essential cost advantage of either system depends on the number of equivalent flights launched each year. If for the reason of inadequate demand, rather than flight rate restrictions, the orbiter flies less than four times a year, its comparative cost position is eroded. If a new orbiter was flown four times each year and the marginal cost of a shuttle flight was $65 million, then the real discounted cost of building and operating the additional orbiter at full capacity is estimated to be $5.0 billion from 1987 through 2000. 1/ Expend-

1. Discounting is a way to convert a future expenditure or stream of expenditures (in this case those over the 1987-2000 period) to their value today (present value), reflecting the notion that a dollar held in the future is worth less than a dollar held today. The discount rate used in this paper is 2 percent.

able launch vehicles, each of which is capable of carrying only 40 percent of a shuttle flight and is launched at a cost of $60 million, can provide comparable capacity at a cost of $4.3 billion over the same period. If the replacement orbiter could add only three flights a year or was flown only three times a year because of insufficient demand, the cost advantage would shift to ELVs by $200 million. The Chapter III comparison of capacity and demand suggest underutilization is likely. The most dramatic illustration of the ELV cost advantage relative to an underused shuttle is the $1.3 billion difference between a new orbiter used only once a year at a cost of $2.7 billion and a comparable ELV capacity priced at $1.4 billion. Increasing the real discount rate to 4 percent would favor the ELV option; conversely, lowering the discount rate to zero would favor the orbiter option.

Noncost Elements

The cost comparison of the shuttle and ELVs as carriers of deployable satellites obviously fails to credit the shuttle for its unique capabilities as an on-

TABLE 11. THE DISCOUNTED COST OF SHUTTLE CAPACITY COMPARED WITH EQUIVALENT ELV PRODUCTION AT DIFFERENT ANNUAL FLIGHT RATES, 1987-2000
(In billions of 1986 dollars)

Annual Number of Equivalent Shuttle Flights	ELV	Shuttle
1	1.4	2.7
2	2.7	3.2
3	3.5	3.7
4	4.3	5.0

SOURCE: Congressional Budget Office.

NOTES: The estimates include: $2.2 billion cost for a replacement orbiter with funding authorized from 1987 through 1992; a marginal operating cost of $65 million per shuttle flight; a $60 million launched cost for a .4 equivalent shuttle flight ELV at the three and four equivalent shuttle flight operating rate; a $65 million launched cost for the same ELV at the two equivalent shuttle flights annual level; and $70 million launched cost for the same ELV at the one shuttle flight operating rate.

See footnote 1 in this chapter for a definition of discounting.

orbit laboratory or "factory" and as a platform for satellite servicing and in-space construction activities. On the other hand, a fourth orbiter is not necessary to reap most of the benefits from these activities in that three orbiters remain intact and will fly again beginning in 1988.[2/] In their favor, ELVs provide a degree of scheduling and inventory flexibility not present in the shuttle system and do not involve as direct a risk of human life.

The case for procuring an additional orbiter is more strongly made in considering the requirements of the space station program as planned by NASA. Under the assumptions used in this analysis, the two years of station construction would require almost the full capacity of a three-orbiter shuttle system for that period. Because some of the shuttle system will have to be used for other activities, the specifics of the current space station plan are unlikely to be accomplished without a fourth orbiter. Once the station is in operation, it would continue to provide a rationale for an additional orbiter, although the justification would be less powerful. The NASA has indicated that it is considering the use of ELVs to provide the station with logistical support. By the late 1990s, the European Space Agency (ESA) plans to develop its own manned vehicle, the Hermes, which could also provide logistical support to the station.

The case for a fourth orbiter is reenforced by the long-term outlook for the development of a new manned space vehicle. The shuttle system is likely to be the sole U.S. manned access to space for the next 20 years. While the fleet will be improved periodically, the basic vehicles will stay in service. The means to produce orbiters is limited to the next several years, since it is very unlikely that production lines will be reopened once they have been completely shut down. Given the unclear demand picture in the late 1990s and thereafter, additional orbiter capacity is arguably a reasonable insurance policy against an unforeseen increase in the demand for unique shuttle services or the loss of another orbiter.

On the other hand, the national space agenda continues to grow in scope and cost. With current budget constraints, the choice of a fourth orbiter implies forgoing or delaying other transportation options. The budget now contains funding for two major new programs for space transporta-

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2. The announced intentions of the European space consortium, Japan, and the Soviet Union to fly shuttle-like craft reflect the claimed benefits of shuttle capabilities. Foreign perception of these benefits, however, does not add any particular force to the case for four orbiters as opposed to three.

tion: the orbital maneuvering vehicle (a spacecraft carried into orbit by the shuttle and designed to move across low earth orbits or to park in orbit with the space station) and the transatmospheric vehicle (a fully reusable space plane). Among other candidates for future space vehicles, the most likely is a vehicle that can lift heavy cargoes to meet future SDI requirements.

FINANCING A FOURTH ORBITER

Several plans have been suggested to procure a new orbiter. The Administration has proposed that a replacement orbiter be built over five years (for delivery in 1991) and funded over six, primarily by reprogramming NASA's projected preaccident budget. If the Congress decides to procure a new orbiter, it could modify the Administration's plan in two ways: the timing of the spending and the source of the funding--whether from new funds and/or those already projected for other programs. The Senate has included full budget authority for a replacement orbiter in the 1987 Defense Appropriations bill, but has withheld obligation of these funds until August 1987. Because this bill must remain within 1987 budget targets, the replacement orbiter would have to be funded with reprogrammed rather than new defense funds. The bill requires that construction be completed by 1991, but does not specify a schedule for obligational spendout.

Before the Administration announced its plan, NASA had proposed a crash effort to procure and produce a new orbiter for delivery as early as 1990, with the Administration's six-year funding schedule compressed into four years. Other proposals would finance a new orbiter with private capital and then lease it back to the government. While such programs would be consistent with a number of production schedules, they essentially are stretch-out schemes that, like the Administration's proposal, would allow the cost of the new capacity to be spread over more rather than fewer budget years. The lease-back scheme would add an additional set of costs stemming from the higher, competitive rate of return required by private investors.

If a replacement orbiter is built, it would probably be cost-effective to do so as quickly as possible. For example, under the assumptions developed in this analysis, the annual additional operating cost of an orbiter providing three flights a year is $195 million, while a comparable ELV capacity could cost from $450 million to $515 million. An additional cost of a stretched-out construction period is the increase in the unit cost of the orbiter attributable to additional years of exposure to inflation and to less than optimal scheduling. The NASA estimated these additional costs at about $200 million before the Administration announced its plan for a new orbiter funded over six years.

In March 1986, CBO prepared a preliminary analysis of the budgetary effects of the Challenger accident.[3] Using NASA data and estimates, the report concluded that replacing the capacity lost in the Challenger accident would require new budget authority or cuts in other NASA activities, since savings from not operating the shuttle system would be consumed by the cost of improving the existing system and new requirements to maintain research and development activities. Although specific cost and saving estimates have changed since that report, it remains clear that a new orbiter will require either new NASA budget authority or deferral of planned activities. To date, only the space station has been explictly identified as an activity that will **not** be cut. Until such time as explicit cuts are identified, the effects of funding a new orbiter out of the preaccident NASA budget cannot be determined.

INSTITUTIONAL OPTIONS

As multiple uncertainties surround the shuttle system's immediate future--how many orbiters, what carrying capacity, what flight rate--a consensus has emerged that the United States should provide ELV services to the commercial market. The Administration has proposed an ELV commercialization option, and moved to implement that option by phasing the shuttle system out of the commercial market. In considering how to achieve space policy goals, the Congress could choose to encourage ELV commercialization or either of two alternatives--providing ELV services through NASA or creating a mixed enterprise to provide space transportation. Each of these three options is described in the following sections.

Commercialization of Launch Services

This option emphasizes incentives to draw U.S. ELV producers into active participation in the commercial launch market. The NASA would be re-

3. Congressional Budget Office, Staff Working Paper, *Budget Effects of the Challenger Accident* (March 1986).

moved from the commercial market as a primary carrier, either directly by executive order or less directly by raising shuttle prices to very high levels. Under this option, the shuttle system could be used only by those commercial payloads that could only be carried by the shuttle. 4/ The NASA would continue to provide shuttle services for its own needs and for DoD. The DoD would also procure and operate the Titan and the medium launch vehicle (MLV) for national security missions. As in the public launch service option, NASA could procure launch vehicles through DoD to meet its own needs. Both DoD and NASA could also procure ELV services from private providers, if the need arose. In fact, a bill introduced before the Subcommittee on Space of the House Committee on Science and Technology, the Assured Access to Space Act (H.R. 5469), calls for NASA to procure ELVs to meet government demand and to provide additional incentives to commercialization.

Current producers of ELVs and new entrants to the market would be encouraged to compete directly with foreign launch providers, such as Arianespace. A primary incentive would be the removal of the federal government from the commercial market. A second incentive would be federal procurement of ELVs, such as the Titan, MLV, and Delta. A complementary third step to encourage the commercial U.S. ELVs industry would be to slip launch dates for noncritical government payloads in order to provide space for commercial loads with critical time frames.

The federal role in space transportation would change dramatically under this option. In the immediate future, federal procurement of ELVs would improve the competitiveness of U.S. producers in the commercial market by lowering the unit costs of ELVs through larger production runs. Thereafter, the federal government would assume the roles of a facilities operator for launch sites, a regulator of the launch service industry, a purchaser of services, and a guarantor of fair trade practices in the international arena.

In this option, the shuttle system would continue to be operated by NASA for the immediate future. The precedent established for commercialization, however, could eventually lead to the transfer of the existing fleet to commercial operators or to the financing of additional shuttle capacity by the private market.

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4. There are gradations of shuttle and ELV dual compatibility. In the longer term, only payloads requiring a roundtrip and/or human support are not dual compatible. In the immediate future, however, a small group of deployable satellites has been designed to fly the shuttle only and would require modification to be flown by an ELV.

The Public Sector as Launch Provider

This option represents a return to the system of the past. The NASA would provide launch services for all civilian users, both public and private, by using the shuttle and procuring expendable launch vehicles--perhaps the Delta-class rocket, for example. The NASA and DoD would divide space transportation capacity to avoid redundant operating and procurement systems. The NASA would provide launch services for its own and other civilian agency requirements and sell services to the commercial market. The DoD would provide services for its national defense needs by procuring and operating the Titan and medium launch vehicles. If, in servicing its own needs and those of other civil users, NASA required a Titan or MLV, it would be procured through the Air Force. Conversely, DoD needs for the shuttle or smaller expendable vehicles would be met by NASA.

Under this option, the cost of space transportation would be carried in the federal budget, with fees from the commercial community counted as offsetting receipts and intragovernmental financial transfers made to cover the cost of service provided by one part of the federal government to another. The NASA would provide ELV services to the private sector. The NASA's use of ELVs would not preclude the shuttle from flying commercial payloads in the future, but it would remove this immediate pressure on the shuttle's capacity. Launch prices to the private sector could be established at the level of the marginal cost of ELV services as this cost measure would lead users to value space transportation services at the cost of replacing them, the correct economic standard for pricing such services. [5]

This option would require an examination of the Commercial Space Launch Act (Public Law 98-575). The private sector would continue to be involved in space transportation by selling rockets and launch services to NASA and DoD, but incentives to sell private launch services outside the NASA framework would essentially disappear.

A National Space Transportation Company

A third option would create a mixed public/private U.S. space transportation company similar to the European consortium, Arianespace. A proposal of this type could be structured in a number of different ways, but it would require a continued federal role in the near term, and the application of

5. See Congressional Budget Office, *Pricing Options for the Space Shuttle* (March 1985).

private management and market discipline to increase the operating efficiency of U.S. launch services. This goal would be sought in a mixed ownership structure with NASA as the government representative, aerospace contractors as a second party, and the public, through a stock offering, as a third party. The company would assume control of the shuttle fleet and procure ELVs to provide launch services to DoD, NASA and other federal agencies, and the commercial market. Establishing such an entity would involve the transfer of federal assets and personnel to the company, thus entailing major legislative changes.

The physical process of providing launch services would remain much as it is under current policy. Existing contractors would manufacture hardware and provide services. Contractor and NASA personnel would conduct launch operations at existing facilities, but under a new management organization. The role of NASA would be dramatically changed as it would no longer provide launch services even for its own payloads. While the DoD could maintain a separate ELV capacity, this option would work best if all U.S. government launch services were procured from the company which, in turn, would obtain hardware and other services from the aerospace members of its ownership.

These procurements and use of the orbiter fleet would be undertaken to provide the most cost-effective mix of services to meet federal requirements and market demand. The shuttle would continue to carry commercial payloads when it was cost-effective to do so. Production of ELVs would be consolidated into a single production system, and eventually a single, more competitive ELV should emerge. Advocates argue that only by lowering cost in this way can the objective of the U.S. competitiveness be achieved. In this arrangement, as in the others, the cost of space transportation would largely be borne by the federal government, but as the purchaser of launch services rather than through hardware procurement.

INSTITUTIONAL OPTIONS COMPARED AND EVALUATED

The first goal of any institutional mechanism that seeks to serve the U.S. and international commercial launch market is to provide adequate launch capacity. Each of the options considered above can accomplish this objective by the late 1980s. The options show various strengths and weaknesses when measured against certain other criteria, as follows:

- o The international competitiveness and economic efficiency of the U.S. industry;

- The cost-effective use of the federal space transportation investment;
- The impact on the NASA and its budget; and
- The legislative and administrative ease of the alternative arrangements.

Competitiveness, Efficiency, and Subsidy

The end of the U.S. monopoly on space transportation in the noncommunist world has made international competitiveness (defined as a substantial share of the commercial launch market) an important space policy goal. The shuttle pricing debate of 1985 ended with the establishment of a commercial market price roughly equal to the long-run marginal cost of a shuttle flight. This price would have allowed NASA to win no less than 50 percent of the market, without damage to larger goals of U.S. economic policy, such as free trade and efficient resource allocation. Specifically, no explicit subsidies were to be tendered to the shuttle system and thus, the goals of competitiveness and efficiency could be pursued simultaneously.

Removing the shuttle from the commercial market in favor of U.S. ELV entrants, public or private, would change the prospect of meeting these goals simultaneously, regardless of the choice of institutional arrangement. By removing the shuttle system from the commercial market, the United States will forgo any cost advantage provided by the shuttle technology and its unique circumstance as a "declining cost" enterprise, while facing increased competition from foreign enterprises. 6/ Although the immediate backlog of commercial payloads could leave U.S. market share unaffected by the loss of this "least-cost" technology option, by the early 1990s excess launch supply is likely to exist. Under conditions of excess supply, realizing the goal of a substantial share of the world market might require subsidies, regardless of the institutional arrangement.

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6. The present value comparison of cost between an additional orbiter and federal ELV capacity granting no advantage to a replacement orbiter is consistent with the cost comparison between shuttle services offered to the commercial market and ELV services that grants the shuttle an advantage. In evaluating the stream of costs to the government of an orbiter, the full investment value of the replacement orbiter was included, whereas the cost calculation for the efficient commercial price level included only part of the orbiter investment and spread that cost over a longer life.

The ELV commercialization option could foster a competitive and economically efficient U.S. presence in the commercial market into the early 1990s. The backlog of demand would provide willing customers. Federal procurements would drive down the unit cost of ELVs. Arianespace would capture as much of the market as its capacity permits, but it would have every incentive to maximize revenues through increasing prices rather than increasing its share, given substantial excess demand.

But, beyond the early 1990s, market conditions are likely to change and the commercialization option might leave the United States in an uncompetitive position. The demand for launch services would revert to its lower level as the backlog is flown off. At the same time, new foreign capacity would enter the market, in some instances with the support of direct government operating subsidies. In this environment, the ELV commercialization option might require U.S. government actions beyond federal ELV procurement by the government to maintain the U.S. share.

Countervailing subsidies to lower the operating cost of U.S. private firms is one response. But such subsidies would be inconsistent with a commercialization option emphasizing the use of markets and the value of private enterprise. Moreover, since the level of subsidies would be tailored to individual firms under the commercialization option, they might be considered inequitable within the overall economic system. The commercialization option would be more consistent with eliminating subsidies through trade negotiations and international agreements, such as the General Agreement on Trade and Tariffs (GATT). It might be difficult to reach such agreements, however, or to enforce them once reached, jeopardizing the goal of maintaining the U.S. market share.

Development of newer, lower-cost U.S. ELV technology is another response to a more competitive environment in the launch market of the 1990s. But the commercialization option would be unlikely to induce private firms to invest the substantial sums of money necessary to develop new vehicles. While these firms would be quite willing to accept government funds to develop a rocket system uniquely designed for the commercial market, the advantage to the federal government would be lost relative to the other options in which public investment would directly benefit the public sector as well as private producers.

The commercialization option offers both advantages and disadvantages in the 1990s if the U.S. response to increased competition is to reintroduce the shuttle system into the commercial market. On the one hand, ELV commercialization would provide a precedent for commercialization of the shuttle. On the other hand, the alternative of providing an integrated shuttle and ELV space transportation capacity under a unified management would be precluded.

The NASA option would produce results similar to those of the commercialization option in the immediate future. Eager customers would be as willing to buy NASA launch services as those of private firms over the next few years, and the level of foreign competition would not change, regardless of whether the public or private sector provided service. The cost of services provided by NASA would likely be higher than equivalent commercial services because government involvement would impose regulatory and administrative costs above those that would occur under a private enterprise.

The NASA option might offer the advantage of long experience in the launch business and, consequently, greater reliability than potential private entrants. But this point should not be overemphasized since the contractors providing extensive support to NASA in its launch activities are the potential commercial ELV entrants and would provide service in one form or another under all the options. Moreover, much of the NASA in-house ELV experience was lost during the 1980s when NASA activities were focused on the shuttle.

A NASA public sector option might enjoy an advantage relative to the commercialization option in maintaining the U.S. market share as competitive conditions change. As NASA would control a mixed commercial fleet, the shuttle could be reintroduced into the commercial market more easily. The threat of easy shuttle reentry might discourage some foreign competitors from offering subsidies, or a least decrease their size. Public funding for new vehicle development could be appropriated in the traditional way through the NASA budget (although other concerns, such as the space station, might be more pressing). The NASA option would also provide a ready conduit to channel U.S. subsidies should they be deemed necessary to countervail support by foreign governments. The use of international trade negotiations to eliminate subsidies would probably be less effective under the NASA option for these very reasons.

The U.S. Space Transportation Company option offers no short-term advantages relative to the alternatives. It could be less efficient and more costly than either the ELV commercialization or NASA options over the next several years, because of the added expense of transferring assets and establishing a complicated new structure. Like the alternatives, however, the mixed enterprise would establish itself in the relatively easier market conditions of the late 1980s and early 1990s.

Into the 1990s, the mixed enterprise would share with the NASA option the advantages of direct government participation in responding to subsidized foreign competition, and would share with the commercialization option the subjection of its operating cost to the discipline of the market. The case for a mixed enterprise option could be made most strongly, however, for its potential to modernize the supply of U.S. space transportation by the early 1990s, and to allow high production volume to force down unit costs.

Advocates of a mixed enterprise have been explicit in including development and extensive federal use of a more cost-effective U.S. ELV as part of their proposals. Countering foreign competition is the objective. The relatively easy market of the next several years would provide a breathing space for a new enterprise, during which both public and private funds could be channelled into a new vehicle that would allow the United States to meet its market share goals in the 1990s, without providing operating subsidies. Such an effort could be undertaken under either of the other options. The motivation to do so is lacking, however, in the NASA option, as NASA is committed to the shuttle in the long run. The merits of public investment in new technology are less clear under a strict regime of ELV commercialization, because a single firm might benefit disproportionately.

Cost-Effective Use of Federal Transportation Capacity

The choice of an institutional option to provide a U.S. ELV capacity to the commercial market is related to the cost-effective use of federal space transportation capacity. If commercial payloads were not flown on shuttle flights dedicated to their use, but rather were placed on flights that would have been flown in any case, the cost of federal space transportation would decrease by opening the shuttle to commercial payloads. Even if the shuttle was temporarily removed from the commercial market, the benefits of such an integrated approach would more likely be realized in a framework in which the shuttle and civilian ELV capacity was controlled by a single organization as in either the **public sector or mixed enterprise options.**

If federal capacity exceeded launch demand and U.S. ELV producers required continuing federal procurements of vehicles to maintain cost competitiveness in the international market, the goals of gaining a share of the commercial market and effectively using the shuttle system might be in conflict. Extensive use of ELVs to meet federal needs could result in underutilization of the shuttle. Full use of the shuttle could result in insufficient federal ELV procurements to permit international competitiveness by the private sector. The **public sector and mixed enterprise approaches** are more likely to reach both goals simultaneously than is the **commercialization option.** Regardless of the institutional arrangement, procurement of a replacement orbiter would increase the possibility of overinvestment by the federal government, while stronger demand for launch services would decrease this prospect.

The NASA Budget and NASA's Role

Under the preaccident institutional arrangement, NASA functioned as a provider and operator of infrastructure, in addition to its primary mission of research and development. This role has immediate consequences for the NASA budget over the next five years as well as more long-term implications for the space station program.

The **commercialization and mixed enterprise options** would directly affect the NASA budget over the next five years by lowering the inflow of funds from the commercial market, estimated to total $1.04 billion for 1986 through 1990. 7/ The move away from the shuttle-only system to a mixed fleet for all U.S. users would further intensify the budget issue by calling into question an additional $3.3 billion that is scheduled to be transferred from the DoD to NASA during the same period. Table 12 presents the annual estimates of these user fees from the commercial market and intragovernmental transfers from DoD.

The net of commercial revenues over the cost of services provided will not be as great as NASA projected in any case, since the marginal cost of shuttle services is expected to increase, as shown in Chapter III. Pursuit of the *commercialization option*, however, would create a need to reexamine the NASA budget plan and to increase expenditures or cut back activities.

More significant from a budgetary point of view is the potentially greater use of ELVs by DoD and related cutbacks in anticipated funding transfers to NASA. This prospect is aggravated to the extent that national policy implicitly requires public use of ELVs to permit private competitiveness on the international market. Because either of the options directly involving the public sector would secure easier integration of ELV and shuttle capacity, they would lessen these disadvantages. None of the options,

7. Because the reimbursements discussed here are based on preaccident shuttle schedules, and shuttle flights are now being held in abeyance until 1988, NASA obviously will not receive all these funds until the shuttle resumes launches, regardless of the option considered.

however, would facilitate the accommodation of lower DoD reimbursements in the NASA budget.

Beyond budgetary questions, the institutional arrangement chosen to provide U.S. ELV services to the commercial market will affect NASA's role in the long run. Before the Challenger accident, NASA was to be the pre-eminent provider of space transportation to all U.S. users. But even granting technical feasibility, this position was sometimes viewed as incompatible with NASA's basic research and development mission. From this perspective, the *commercialization and mixed enterprise options* would be superior to NASA's continued participation in the market.

Those who support removing NASA from the space transportation business see NASA as burdened by operational responsibilities, including marketing, that it is ill-suited to carry out. These responsibilities, it is contended, have required a disproportionate share of the agency's time and budget and would continue to do so into the indefinite future as NASA takes on operating a space station and, perhaps, a lunar base. Spinning off space transportation, if only the civilian ELV operation, would allow NASA to concentrate on research-related tasks. The *mixed enterprise option* would move the

TABLE 12. ESTIMATED SHUTTLE REIMBURSEMENTS UNDER SHUTTLE-ONLY SYSTEM
(By fiscal year, in millions of dollars)

Revenue Source	1986	1987	1988	1989	1990
DoD	223	531	787	775	983
Foreign/ Commercial	97	173	252	348	169
Total	320	704	1,039	1,123	1,152

SOURCE: Congressional Budget Office, based on NASA budget for fiscal year 1987.

NOTE: These estimated reimbursements are based on shuttle flights scheduled before the Challenger accident. With the flights held in abeyance until 1988, NASA will not receive these revenues until the shuttle starts to fly again, regardless of the option considered.

shuttle system and ELVs outside NASA as currently structured and, at the same time, establish a model for space station operation after NASA has built the initial configuration. The *commercialization option* would be more incremental in that only ELVs would be commercialized; however, it would establish a path that the shuttle system could follow in the future.

Administrative and Legislative Ease

The **commercialization option** would have a clear and immediate advantage in meeting these criteria. The essential machinery to implement a commercialization policy already exists. The formal issues of use of government-developed technology and rental of government facilities are now being addressed by the Department of Transportation. The more substantive issues of removing NASA from the launch business and federal procurement of ELVs are also moving forward, although a clearer definition of how soon NASA will leave the launch business would help new U.S. private entrants in signing critical early launch agreements.

The machinery to **restore NASA's role** in providing ELVs to the launch market is also in place. Legal questions and the need for new legislation could well arise if NASA began to market ELV services, however. At a minimum, ELV commercialization would have to be dropped explicitly as a goal of national space policy if NASA were to stay in the commercial market.

The **mixed enterprise option** would present substantial legislative and administrative obstacles. The form of the enterprise would require precise and complex new legislation. Complications abound: how would national security requirements be integrated? Would special antitrust relief be necessary? What level and type of federal support should be provided? Should providers of U.S. communication satellites be included or not? On the other hand, moving towards such an enterprise now could diminish longer-term administrative problems, including that of the eventual ownership and operation of the shuttle system.