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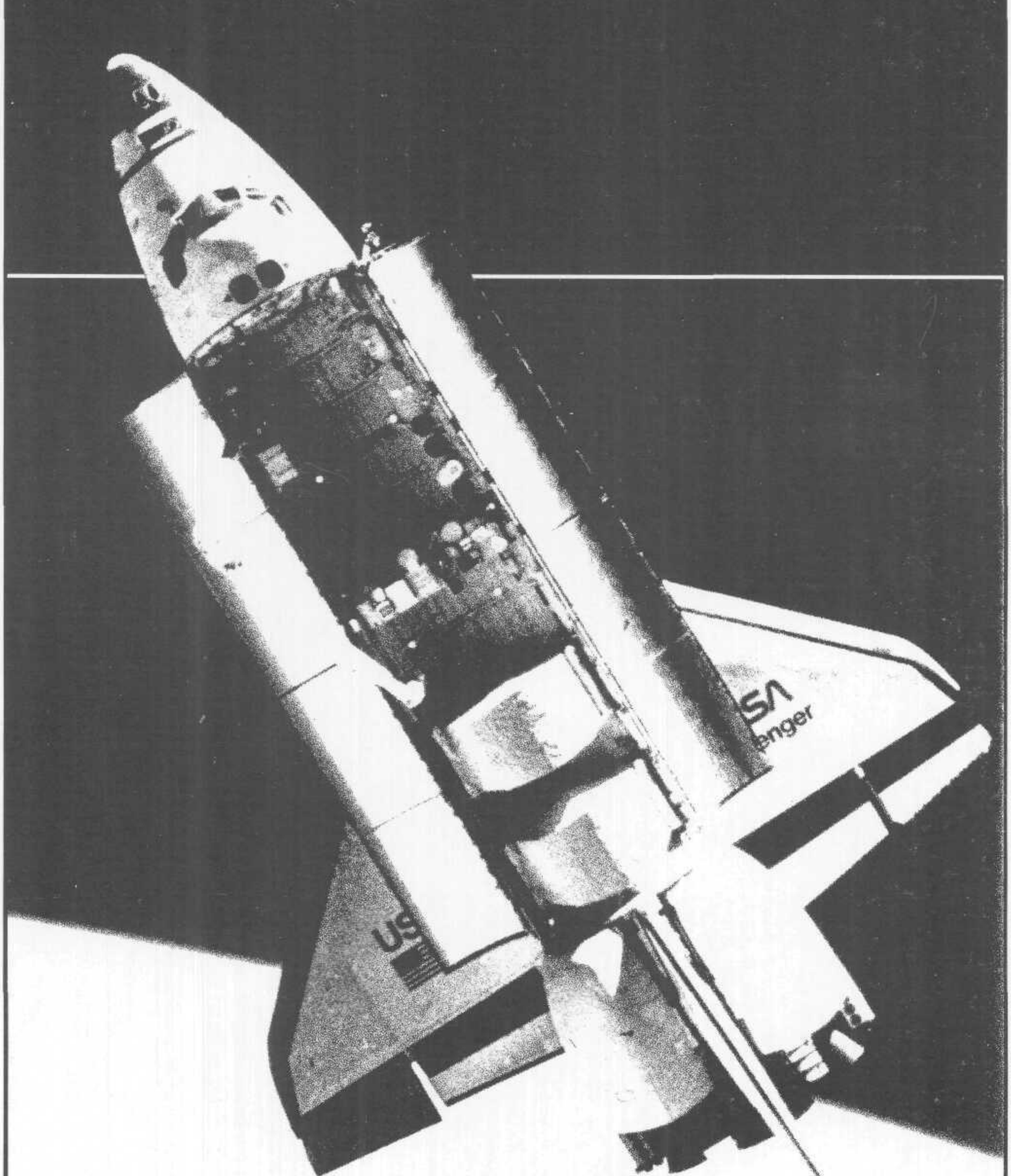
Pricing Options for the Space Shuttle



SPECIAL STUDY

CONGRESSIONAL BUDGET OFFICE
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Pricing Options for the Space Shuttle

March 1985

In this study, Table 5, on page 20, should appear as attached.

TABLE 5. PROJECTED TOTAL OPERATIONAL COST, FISCAL YEARS 1985-1990 (In millions of 1982 dollars)

	1985	1986	1987	1988	1989	1990
Solid Rocket Boosters	445.5	364.8	449.4	450.8	453.6	429.6
External Tanks	284.9	355.2	411.6	411.7	396.0	372.0
Launch Operations	298.1	376.0	287.7	324.3	338.4	352.8
Propellants	24.2	32.0	33.6	27.6	26.4	26.4
Flight Operations	301.4	334.4	350.7	340.4	331.2	333.6
Orbiter Hardware	135.3	153.6	163.8	170.2	163.2	158.4
Crew Equipment	29.7	35.2	35.7	36.8	36.0	36.0
Main Engine	30.8	35.2	33.6	36.8	45.6	79.2
Administration Contract	7.7	8.4	8.8	9.0	9.0	9.0
Research and Program Management	207.9	190.4	178.5	179.4	177.6	172.8
Network Support	16.5	24.0	31.5	34.5	36.0	36.0
Total	1,782.0	1,909.0	1,984.9	2,021.5	2,013.0	2,005.7

SOURCE: NASA for 1982 dollar per flight data. Total cost data derived by CBO by multiplying the NASA per flight estimates by total number of flights per year, including those launched from Vandenberg Air Force Base. NASA does not bear all of these costs of operating the shuttle. Specifically, launch operations and propellants are not covered by NASA for three flights in 1986, three flights in 1987, one flight in 1988, and four flights each in 1989 and 1990. The other components of cost are covered by NASA for all flights.

PRICING OPTIONS FOR THE SPACE SHUTTLE

The Congress of the United States
Congressional Budget Office

NOTES

Unless otherwise stated, all dollar amounts in this report are expressed in 1982 dollars.

All years in this report are fiscal years unless otherwise noted.

PREFACE

The development of space by the U.S. government and commercial enterprises is now underway. This spring, the Administration will announce a proposed pricing policy for the National Aeronautic and Space Administration's (NASA) space shuttle. Beyond its implications for the budget, this proposed pricing policy will be a major influence on what gets done in space, how it is done, and the fate of competing means of space transportation.

This study, undertaken at the request of the Senate Budget Committee, analyzes the costs of the shuttle system, develops a set of pricing options, and explores the implications of these options for space policy objectives. In keeping with CBO's mandate to provide objective analysis, this paper offers no recommendations.

The report was prepared by David H. Moore of CBO's Natural Resources and Commerce Division under the direction of David L. Bodde, Everett M. Ehrlich, and Richard R. Mudge. Paul Dinardo of CBO's Budget Analysis Division prepared the Appendix. Within CBO, Jeffery Nitta, Ralph Smith, and Molly Quasebarth offerred valuable comments. Barbara Stone and Mike Mann of NASA provided valuable assistance in understanding past pricing policies and the projected costs for the shuttle system. Useful information and critical comments were provided by many individuals, including Barton Borrasca, Karlyn Daube, Harry S. Dawson, Isaac T. Gillam IV, David Grimes, Douglas Heydon, Chester M. Lee, Deborah Lipman, Molly K. Macauley, Tom Maultsby, Paul R. Portney, Thomas F. Rogers, Phillip K. Salin, Antonio Savoca, Emery Simon, and Donald Trilling. Patricia H. Johnston edited the manuscript. Gwen Coleman prepared the report for publication in cooperation with Debbie Dove and Kath Quattrone.

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CONTENTS

SUMMARY

The space shuttle is the nation's most important means of placing satellites into orbit for scientific, commercial, and military purposes. The price that the National Aeronautics and Space Administration (NASA) charges foreign and commercial customers to use the shuttle's launch services has important implications for the development of space in general and for the future of the U.S. space program in particular. This study analyzes alternative shuttle prices, their relation to shuttle costs, and how alternative prices could affect the goals of the national space effort.

No single price for shuttle services can meet all the nation's space objectives. Some objectives--such as the efficient short-term use of the shuttle's capacity and the encouragement of commercial activities in space --are best met by a relatively low price, while others--such as full cost recovery and development of a private, domestic launch industry--require a high price. The new price proposed by NASA, and now under review by the Administration, represents an attempt to tradeoff competing policy objectives.

BACKGROUND

The President soon will submit to the Congress a new space shuttle pricing policy for launch services provided to non-U.S. government parties in the fiscal years 1989 through 1991. These users are foreign governments and mature commercial enterprises requiring launch services for payloads such as communication satellites and remote-sensing satellites. 1/

The current price charged these users, $38 million per launch plus additional fees, was set by NASA in 1977 to recover all operating and production costs, including orbiters and related equipment. 2/ By the early

1. In contrast, so-called "infant industries" (such as materials processing and pharmaceutical manufacture) receive free or very low-cost transportation from NASA until they approach financial self-sufficiency.

2. All dollar amounts are expressed in 1982 dollars unless otherwise noted.

1980s, the shuttle program was behind its technical schedule, and the market for launch services proved substantially smaller than expected. NASA, accordingly, had to increase the price it charged users other than the federal government. In 1982 a second pricing policy was set for launches in fiscal years 1986 through 1988. This price was significantly higher ($71 million per flight) but was intended to recover only part of the shuttle's operational costs. Because of continuing cost escalation and a lower than expected flight rate, this limited cost recovery objective will not be met. The new NASA price for the 1989-1991 period--$87 million per flight--calls for the recovery of average operating costs only. It remains substantially less than the price that would have been required to implement the original pricing policy of full-cost recovery.

In determining a price for space shuttle services, two sets of factors should be considered. The first is cost, which determines how closely the shuttle price is linked to the resources consumed by the use of the shuttle. The second is space policy objectives, because the shuttle price, in effect, sets priorities among conflicting space goals.

SHUTTLE COSTS

The cost of the shuttle will be determined by a number of factors, some of which are predictable and some of which are controversial. The need to establish a set of cost bases for pricing policy requires that choices be made concerning the questionable factors. The significant role of these factors in determining shuttle costs suggests that a range of cost estimates is also appropriate. The base-case cost estimates for pricing policy are:

- **Short-run marginal cost**--the operational cost of an additional shuttle flight ($42 million per flight);

- **Long-run marginal cost**--the costs of providing flights for foreign and commercial users, which include the operational cost of an additional flight, plus a capital charge for a replacement orbiter spread over 4 flights per year ($76 million per flight);

- **Full operational cost**--includes operational costs only ($84 million per flight).

- **Full cost less development**--includes all total average costs except research and development ($106 million per flight); and

- **Full cost**--includes all total average costs, both past and future ($150 million per flight).

Assumptions made concerning three controversial factors especially affect the results. These factors and assumptions are:

- The shuttle flight rate (particularly for full-cost prices). The base case assumes 24 flights for 1989.

- The discount and depreciation rates used to calculate the annual capital charge (for the prices in which these charges are included). The base case uses a 4 percent real interest rate and a 25-year system life.

- The accuracy of NASA's operational cost estimates and the division of operational cost between fixed and variable costs. The base case uses the NASA total operational cost and divides it equally between fixed and variable costs.

The two marginal costs are lower than the three full costs because the marginal costs exclude fixed costs that do not change as additional flights are flown. The base case estimate for the short-run marginal cost is $42 million per flight--between a low estimate of $28 million per flight (roughly NASA's estimate) and a high estimate of $71 million per flight. The actual cost in 1989 will depend on the flight rate between now and then and upon how well NASA has estimated future operational costs. The estimate for the long-run marginal cost ($76 million per flight) is higher than the short-run estimate, reflecting the fact that providing the shuttle service to foreign and commercial users requires capital as well as operational expenditures. This cost, therefore, includes an annual capital charge based on the $1.7 billion replacement cost of an orbiter, in addition to the operational costs that are contained in both marginal costs.

Each full-cost price rises significantly as the estimated number of flights flown decreases, because fixed costs--either operational or capital--must be spread over a smaller base. For example, if 18 rather than 24 flights were flown in 1989, the highest full-cost price would increase from $150 million per flight to $186 million; with only 12 flights, it would increase to $258 million.

PRICES AND POLICY OBJECTIVES

The second key issue for shuttle prices is how prices affect the nation's space objectives. These objectives can be grouped into six areas:

- **National Security**--ensure access to space for the Department of Defense;

- **National Prestige**--maintain a strong U.S. role in space technology and in the development of space;

- **Research**--encourage both applied and scientific research in space;

- **Cost Recovery**--full recovery of public costs for the use of the space shuttle by commercial firms and foreign governments;

- **Efficiency**--encourage the efficient use of the space shuttle system; and

- **Commercialization**--encourage the commercial use of space, including:
  --existing commercial activities in space,
  --new commercial activities, and
  --a strong domestic private launch industry.

Cost recovery, efficiency, and commercialization will be dramatically affected by the new pricing policy (see Summary Table). While the cost of the shuttle is not the only determinant of success in reaching these objectives--the overall demand for launch services and the cost of the private launch alternatives are two others--shuttle costs play a significant role. A central conclusion of this analysis is that no one price can serve all these objectives equally well.

Cost Recovery and Efficiency

The shuttle system is not a conventional enterprise. In particular, many of its costs remain fixed regardless of the number of flights. These high fixed costs make the goals of cost recovery and efficiency mutually exclusive. Specifically, because of high fixed costs, the cost of providing an additional shuttle launch is significantly less than the average cost of a launch. Thus, recovering average costs does not lead to efficient pricing and efficient pricing does not result in full-cost recovery.

The short-run marginal-cost price, $42 million per flight, sacrifices the goal of cost recovery to ensure that the shuttle has sufficient customers to fly at a high rate. This price depends on the existence of excess capacity in the shuttle system. It essentially forgives shuttle users from having to repay the system's fixed costs, and implicitly holds full use of the shuttle to be a pre-eminent policy objective. A shuttle price set at this level would have no net budgetary implications. But to the extent that costs prove to have been underestimated, the federal government could end up subsidizing foreign and commercial users.

SUMMARY TABLE. PRICING OPTIONS

Pricing Policy	Definition of Cost	Price Per Flight in 1989 (millions of 1982 dollars) With 24 Flights	With 18 Flights	Policy Implications
Marginal Cost Prices				
Short-Run Marginal Cost	Variable operational costs.	42	42	Maximum use of shuttle. Likely end to domestic expendable launch vehicles (ELVs). Direct competition with Arianespace. If NASA's costs are underestimated, revenues will not cover cost. High flight rate encourages future expansion.
Long-Run Marginal Cost	Variable operational costs, plus a capital charge for an orbiter dedicated to foreign and commercial flights.	76	76	Shuttle should maintain current market share and generate net federal revenues. Domestic ELV firms have little chance of success.
Full-Cost Prices				
Full Operational Cost	All operational costs. Approximation of proposed NASA policy for 1989 through 1991.	84	98	Largely the same as for long-run marginal price.
Full Cost Less Development	All operational costs, orbiters at replacement cost ($1.7 billion each), plus other investment but excluding research and development.	106	128	Shuttle will lose part of its market share unless Arianespace increases its price as well. Prospects for domestic ELVs improved but still uncertain. Less than full use of shuttle.
Full Cost	All operational costs, plus all investment valued at historic costs.	150	186	Shuttle losses all but specialized foreign and commercial payloads--flight rate will be below efficient level. Reduced net federal revenues. Domestic ELVs will do well, particularly if Arianespace increases price. Investors in new space processing may reduce planned spending. Little immediate need to expand shuttle system.

SOURCE: Congressional Budget Office.

NOTE: Estimates reflect base-case assumptions about interest rate and depreciation. Alternative assumptions would generally result in higher costs for options with capital costs. Operational costs based on estimates by NASA.

The price based on long-run marginal cost, $76 million per flight, adds the perspective that serving the foreign and commercial market requires a price to cover capital as well as operating costs. It also might be prudent to overestimate rather than underestimate public sector marginal cost when the public and private sectors compete. From a budgetary perspective, the concept of a long-run marginal-cost price provides a litmus test to help determine the need for an additional orbiter. If the shuttle is fully booked at the price based on long-run marginal cost, then a new orbiter could be acquired with the confidence that its users would pay its costs (already reflected in the capital charge included in the shuttle price). But, as with the short-run marginal-cost option, the advantages of a long-run marginal-cost price will not be achieved if costs are underestimated dramatically.

The prices of $150 million (full cost) and $106 million (full cost less development) are high enough to permit full-cost recovery if and only if 24 flights are flown in 1989. Proponents of full-cost prices point out that they are equitable in two ways. First, if foreign and commercial users are charged less than full costs, they will reap, but not pay for, the benefits of the past expenditures that went into the shuttle and its technology. Second, full-cost prices are more comparable to the cost structures faced by competitive launch operators in the private sector.

A long-run equity argument can also be made. NASA developed the shuttle program to provide a viable means for the commercial development of space. By 1991, the last year of the new pricing policy, the shuttle program will be entering its third decade. It can be argued that, since the experimental phase is over, the shuttle should recoup all of its costs, and that, if it cannot, then a different approach to space transportation should be pursued for payloads that can use expendable launch vehicles (ELVs). Full-cost prices also might reduce long-run spending on the shuttle program because they would discourage use of the shuttle and thus reduce pressures to expand capacity.

The Long-Term Development of Space

At its conception, the shuttle's low projected costs led planners to believe that it ultimately would replace ELVs. But these low costs did not materialize, and ELVs continue to be a viable option for many space payloads. Currently, the shuttle's ELV competitors include Arianespace (an enterprise backed by the 11 nations of the European Space Agency) and several private U.S. firms. The ELV industry offers launch services with rocket technologies--the U.S. Delta, Atlas Centaur, and Titan and their European relative, Ariane--directly or indirectly developed by U.S. government efforts. Arianespace has priced its services to be competitive with the shuttle and intends to win a third of the launch market over the next decade. Private U.S. ELV firms claim that both the shuttle and Arianespace charge below-cost prices and that, if the full cost of service were reflected in their prices, private ELVs would prove competitive.

A short-run marginal-cost price is the most direct way to encourage use of the shuttle. But existing U.S. ELVs would not be able to match such a low price, and competition would focus on the Ariane rocket. Although the response of Arianespace is hard to predict, continued subsidies by its European supporters appear likely. As a result, the commercial market would probably continue to be shared between Arianespace and the shuttle, but with the shuttle gaining some relative advantage.

The implications of a very low shuttle price for commercialization are mixed. The domestic ELV industry simply could not survive and the potential entry of other nations (Japan, for example) might be discouraged. Firms investing in shuttle-related launch technologies would benefit most, including private firms designing upperstage rockets to lift into higher orbits payloads placed in low-orbits by the shuttle. Investors interested in new space processing techniques would also be encouraged, perhaps overly so since the price would make no allowance for recapturing capital costs.

Without a more extensive analysis of demand and the costs of shuttle competitors, it is difficult to evaluate the relative prospects of domestic ELVs, Arianespace, and the shuttle, if NASA should charge a price based on long-run marginal costs or full operating costs. Many analysts, however, believe that while a long-run marginal-cost price is low enough to allow the shuttle to compete effectively with Arianespace, it is substantially too low for domestic ELVs to survive. Alternatively, under a full-cost price (and perhaps a full-cost price less development), the ELV industry would be able to compete directly with Arianespace and the shuttle. While the domestic ELV firms would have a difficult time matching Arianespace's price, they would have real incentives to invest additional funds in improving their rockets (or in developing new ones). From this perspective, the long-term commercialization of space would be best served by launch prices that reflect full costs, unsubsidized by the federal government.

These benefits could be jeopardized, however, if Arianespace undercut a full-cost shuttle price with a subsidized, predatory price. If investors perceived that Arianespace would use its government subsidies to prohibit the entry of American ELVs into the launch industry, then the development of the domestic industry could be thwarted. Thus, in addition to a higher shuttle price, an aggressive trade policy that seeks to eliminate Arianespace subsidies might be a necessary precondition to investment in American ELVs.

OTHER FACTORS

A significant aspect of pricing policy concerns the time for which the price remains in effect. NASA has proposed a three-year policy, covering 1989 through 1991. The rationale is that price stability is desirable from a marketing standpoint and that the detailed engineering and construction work on communication satellites must start at least three years before launch. A very long lead time, such as the six years from now until 1991, greatly increases the likelihood of errors in forecasting costs and demand. One alternative to the proposed policy would be to establish a pricing principle, use it to set a price for 1989, and then to update the price each year using NASA's most recent information on costs and flight rates.

CHAPTER I

INTRODUCTION

Since 1972 the National Aeronautics and Space Administration (NASA) has spent $25.7 billion to develop, build, and operate the space shuttle and its support facilities. 1/ Through fiscal year 1990, the annual shuttle budget is projected to be about $2 billion. The shuttle system, called the Space Transportation System (STS) by NASA, is a significant public investment designed to serve the space transportation needs of the federal government, private firms, and foreign governments. In order to recoup at least part of this cost, NASA must charge for the use of the shuttle. Prices, which must be set well ahead of actual launch, can be based on a variety of costs. This paper investigates the alternative cost bases and discusses how the different prices NASA might charge would achieve the nation's space policy goals.

The space shuttle program was approved for development in 1972 as the nation's major effort in manned space operations, following the successful completion of the Apollo Program. NASA originally proposed to build both a fully reusable shuttle (technically called an orbiter) and a permanently manned space station. Largely because of budgetary concerns, this proposal was cut back to developing a partially reusable shuttle, which would serve as a first step toward building a space station. 2/ Because the shuttle would be reusable, NASA originally thought it would be a cheaper means of transportation than traditional rockets, also called expendable launch vehicles (ELVs). In turn, these lower prices would help encourage commercial development of space.

NASA divides shuttle users into three major groups: U.S. civilian research agencies, including NASA itself; the Department of Defense (DoD); and foreign governments and commercial users. 3/ A further distinction could be made between foreign and commercial users that are already mature commercial enterprises--communications satellites and remote-sensing satellites--and so-called "infant industries," such as materials

1. Unless otherwise stated, all dollar amounts in this report are expressed in 1982 dollars.

2. The shuttle design was also modified to accommodate the needs of the Department of Defense (primarily a wider shuttle payload bay and greater maneuverability in landing).

3. Both foreign governments (except for European governments which use Arianespace) and foreign enterprises use the shuttle. Hereafter, "foreign" will encompass both these users.

processing and pharmaceutical manufacture. In this study, the term foreign and commercial market will be applied to the mature technologies only.[4] Most of these commercial payloads can also use ELVs, the only alternative to the shuttle for placing satellites in orbit. Because of this competitive means of transport, most commercial payloads are sensitive to the price charged for shuttle services.

In 1977, four years before the first flight and six years before the shuttle entered commercial operations, NASA issued its first pricing policy for shuttle launch services. Because of the long lead time required to design a satellite and integrate it with a launch vehicle--generally two to four years--pricing policies must be established well in advance of launch dates. The base price of $38 million per flight and additional user fees and insurance charges established at that time covered flights from 1983 through 1985. Customers paid a portion of the base price, depending on the share of the orbiter's capacity taken up by their cargo. Because the price was derived from NASA's projected total costs, it also was used to value the launch services provided to DoD.

In 1986 a higher, Phase II price of $71 million per flight will take effect. This price, however, reflects only part of the system's operating costs and none of its capital depreciation. NASA has recently proposed a Phase III pricing policy for launches from 1989 through 1991, which will raise the per flight price to $87 million. This third price is projected to cover operational costs only. The Administration is expected to issue its recommendation on this proposal this spring.

WHY IS THE PRICE IMPORTANT?

The price NASA charges for shuttle services is important because of its effects on the budget and its influences on the success of the shuttle program in meeting its major objectives. The shuttle price determines how much, if any, of private-sector shuttle costs are subsidized by the general taxpayer. Less directly, it helps to determine what costs are charged to the DoD budget function.

More important, the shuttle price is a key factor in determining the resources the nation devotes to space, and whether these are provided by

4. NASA subsidizes flights for the infant industries through Joint Endeavor Agreements, which outline cost sharing between NASA and private firms and anticipate future full-price launch services if the new technologies prove viable.

the public or private sector. For example, while a high price will discourage the shuttle's full use, it can also encourage private firms to provide competing services. Further, by influencing how often the shuttle system is used, the price will affect the decision to expand the system in the future (for example, by investing $1.7 billion to build an additional orbiter). In the long run, the resource allocation role played by the shuttle price will help to determine how and when the commercial development of space occurs.

The shuttle launch price is not of equal importance to each of the nation's space objectives. Regardless of the price charged commercial and foreign customers, the shuttle system probably will fly at least 12 to 15 flights annually from 1989 through 1991 (NASA projects 24 flights). 5/ This flight rate appears adequate to meet the vague, but important, goal of maintaining U.S. national prestige in space technology. Similarly, a flight rate of 12 to 15 launches annually would contribute substantially toward meeting the nation's objectives in space science research. A significant portion of the shuttle's national security mission also could probably be met with a flight rate lower than the 24 projected by NASA. The average cost of meeting either research or national security objectives, however, will fall as more flights are flown, or as fees charged to foreign and commercial users generate revenues in excess of the cost of service.

The shuttle price is particularly significant with regard to the objectives of cost recovery and space commercialization. 6/ The effect of any particular shuttle price on either objective not only is difficult to gauge, but also is the substance of the current policy debate. For instance, it can be argued that a substantial price increase could encourage private U.S. companies to enter the market and push the U.S. government out of the commercial launch business. On the other hand, a very high NASA price could turn the launch market over to the shuttle's major current competitor, the European-backed Arianespace, and to such potential foreign competitors as the Japanese.

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5. According to current NASA projections, the combination of NASA and DoD requirements will account for about 20 flights per year from 1989 through 1991. Foreign and commercial users are estimated to demand another four flights per year, for a total of 24. NASA, however, has overestimated demand in the past, as discussed later in this chapter.

6. Cost recovery was a criterion in both the 1977 and 1982 pricing policies. National Security Directive 94, "Commercialization of Expendable Launch Vehicles," (May 16, 1983), indicated that full cost recovery should be the cost base for shuttle prices after 1988. NASA views its Phase III pricing policy as consistent with that directive.

This analysis of shuttle costs and their relation to price illustrates the trade-offs that exist among a variety of space policy goals--encouraging the commercialization of space, recovering shuttle costs, and efficiently using the shuttle system, for example. In selecting a shuttle pricing policy, the Congress and the Administration also will be setting priorities among space policy objectives.

History of NASA Pricing

The cost and engineering analysis undertaken by NASA to develop the first shuttle pricing policy suggested that a single price could satisfy the whole array of budgetary, commercialization, and efficiency objectives. The Phase I price was calculated by estimating the average total operating cost for the 572 shuttle flights that NASA predicted would be flown from 1980 through 1991, and then adding 50 percent to the result as a contingency. Additional fees were added for insurance and "... a pro rata share of the depreciation of facilities and equipment and the amortization of the investment in the orbiter fleet." 7/ This Phase I price was in NASA's estimation high enough to cover operational, capital and insurance costs, but low enough to attract foreign and commercial users. In fact, rather than subsidizing space transportation for private interests, the first analysis of price and cost indicated that the shuttle price, $38 million per flight plus a user fee and an insurance charge, would generate revenues in excess of its cost. In turn, this could have allowed the system to be expanded at private, rather than public, expense.

As unforeseen technical problems developed, the shuttle program met neither its cost nor flight-rate goals. By 1980 NASA's estimate of the number of flights through 1991 had fallen from 572 to 487 and, in combination with design changes and inaccurate cost estimates, this drove the per flight cost up by 73 percent. 8/ NASA now estimates that the demand for the shuttle from 1980 through 1991 will be only 165 flights, or 30 percent of the 1977 estimate. The flight rate continues to be a key uncertainty because both the physical capability of the shuttle fleet to fly 24 times a year and

7. C.M. Lee and B. Stone, "STS Pricing Policy," *The Space Transportation System: A Review of its Present Capability and Probable Evolution*, AIAA/DGLR/BIS Space Systems Conference, Washington, D.C., October 18-20, 1982, p. 1.

8. See the Comptroller General, *NASA Must Reconsider Operation Pricing Policy to Compensate for Cost Growth on the Space Transportation System*, Report to the Congress of the United States (February 23, 1982), p. 7.

the existence of sufficient demand to require 24 flights have been questioned.

Higher shuttle costs increase the difficulties of achieving particular objectives with any specific shuttle launch price. The first analysis of shuttle prices foresaw a definite and substantial cost advantage for the shuttle compared with ELVs. Once this advantage was lost, a low (below average cost) shuttle price could be criticized for subsidizing the public-sector in competition with private interests, while a high shuttle price could be faulted for discouraging full use of an important national asset. Although the original shuttle pricing policy seemed to rule out a conflict between cost recovery and competitive pricing, the current debate focuses on precisely this point.

The Phase II price increase for flights from 1986 through 1988, formulated in 1982, reflected the strains caused by cost increases above the 1977 estimates. The price of $71 million per flight accounted for the increased cost of some shuttle components and a lower flight rate, 311 as opposed to 572. To offset these increases and to meet increasing domestic and foreign competition, this price was based on what NASA termed "out-of-pocket" costs (the average cost of hardware consumed in the launch process plus marginal service costs but excluding capital costs). Thus, in its Phase II pricing policy, NASA retained the goal of cost recovery, but changed its definition of costs.

The Worldwide ELV Industry

The resilience of ELVs as a competitive launch alternative to the shuttle is also an important consideration in setting shuttle prices. The viability of ELVs stems more from increased shuttle costs than from technical developments in rocketry or investment in new facilities. ELV competitors include Arianespace (the operator of Ariane, the European ELV) and several domestic ELV firms, including those that use the Delta and the Atlas-Centaur rockets. Technically, these rockets are very similar, although the American ELVs evolved from rockets built in the 1960s while Ariane was developed in recent years. The Ariane, which is launched from French Guyana, has a 12 percent to 15 percent performance advantage compared with launches from Florida, because its location near the equator provides a faster launch velocity as a result of the earth's rotation. Although the stated long-term goal for Ariane is a one-third share of the non-Communist world's market for space payloads, it now carries close to 40 percent of recent commercial launches, thanks to aggressive pricing and continued technical improvements.

The private domestic ELV industry has yet to win a launch bid. According to these firms, the major obstacle impeding their success is subsidized public sector competition, namely NASA and Arianespace.[9] NASA, for its part, responds that the technologies likely to be employed by domestic ELV firms have already been deeply subsidized, and that these firms should either be forced to pay for past government support or to compete with the shuttle as currently priced. Moreover, NASA and a different group of domestic private firms contend that the real investment in space commercialization is occuring in technologies which complement rather than compete with the shuttle. According to this view, private firms and space commercialization would be hurt rather than helped by a high shuttle price.

The conflicts surrounding the Phase II policy discussion have increased as the pricing policy for the 1989-1991 period is being formulated. A high shuttle price might better serve some policy objectives--such as cost recovery, encouraging private entrants to the domestic launch industry, and ensuring that the public sector does not overinvest in additional capacity. Other objectives, such as encouraging the use of the shuttle's unique capabilities and ensuring full use of the shuttle system's capacity, could be better served by a lower shuttle price. The optimism of the 1977 pricing policy analysis and the possibility it offered of a single price to meet a diverse set of general and specific objectives is all but gone. Instead, in choosing among different pricing policies, a choice must be made among different policy objectives.

THE SHUTTLE MARKET

Cost is not the sole consideration in formulating and evaluating pricing policy options for the shuttle system. Equally important are assumptions about the demand for launch services and the price offered by competing services. Although neither is the subject of intensive analysis in this study, a perspective on both is necessary to compare different pricing policies.

Demand for Launch Services

NASA's projections of the demand for the shuttle launch service is referred to as the "mission model." The model adds up individual payloads and converts them to equivalent shuttle flights. The model then presents the annual number of flights accounted for by the major shuttle customer

9. American ELV firms have been active in presenting their view of shuttle pricing to the public. Transpace Carriers Inc., the operator of the Delta rocket, has initiated a formal trade compaint currently being pursued by the U.S. Special Trade Representative.

groups--NASA and other civilian agencies, the Department of Defense and foreign and commercial users. For the period in which the proposed Phase III pricing policy will be in effect, 1989 through 1991, NASA expects to book fully its annual flight rate of 24, as shown in Table 1.

Over the period covered by the Phase III pricing policy, the total supply of launch services from all sources is likely to exceed the total demand for them. From 1989 through 1991, the entire foreign and commercial launch market is usually estimated to be around 20 payloads or the equivalent of six to eight shuttle flights. NASA projects the shuttle will provide between two and four of these flights per year. Considering new investment at the Arianespace facility and anticipated European government demand, Arianespace could offer the equivalent of 3.5 shuttle flights to the foreign and commercial market. Finally, the private U.S. firms that could become serious ELV competitors, could, at a minimum, serve the entire anticipated market. These estimates suggest a buyer's market for foreign and commercial users of launch services.

Because former projections of both private and government demand have been greater than actual launch requirements, demand could be less than anticipated, thus increasing the prospective oversupply of launch services. The most conservative projections of 1980's demand, made in the

TABLE 1. NASA SHUTTLE FLIGHT PROJECTIONS
(In equivalent flights per year)

Customer	1989	1990	1991
NASA and Other Civilian Agencies	6.8	9.3	8.3
Department of Defense	13.8	9.2	10.2
Commercial and Foreign	2.0	4.2	4.2
Reflight Opportunities [a]	1.4	1.3	1.3
Total	24.0	24.0	24.0

SOURCE: National Aeronautics and Space Administration.

a. As yet unallocated flights to allow for schedule slippage.

1970s, consistently proved to be double the demand that materialized. Although there are reasonable explanations for this overestimation (primarily related to the survey methods), the fact remains that demand usually has been overestimated in the past.

Demand is probably overestimated today. Through the early 1990s, communications satellites will dominate the foreign and commercial launch market. Demand could be depressed by the excess capacity of communication satellites already in orbit or by new earth-based technologies, such as fiber optic cables. On the public side, overestimation of demand can be caused by undue optimism about federal funding for research payloads, or by the tendency of defense and intelligence planners to assume the worst about key intelligence satellites in orbit and to schedule replacement launches sooner than they are required. 10/

The prospect of a slack launch market has two implications for the shuttle system. First, the shuttle could have significant excess capacity to offer the market if civilian government and DoD demands are less than projected. Second, other launch services are likely to be extremely price competitive. The space community generally ranks the new price proposed by NASA ($87 million) above Arianespace and below prospective domestic ELV firms. This proposition assumes that Arianespace's costs continue to be subsidized and that a modest degree of as yet unrealized success is experienced by private ELVs. At the highest and lowest definitions of cost in this analysis, the shuttle's position is clear: a full-cost price of $150 million per flight would limit the NASA share of the foreign and commercial market to those payloads specifically designed to fly on the shuttle and would make questionable the future of shuttle-only payloads for mature market applications. A low short-run marginal cost price of $42 million for shuttle launches would retain, and probably expand, the shuttle market share, rendering private ELV firms uneconomic and leaving Arianespace hard-pressed to maintain its target of serving 33 percent of the market. At prices in between these extremes, NASA's proposed option among them, the outcome of the competition among payload launch suppliers would be unclear.

Supply of Shuttle Flights

This study focuses on cost, a key determinant of the price at which NASA will supply launch services. NASA estimates of operational costs for the

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10. See, for example, Subcommittee on Space Science and Applications, *Review of Space Shuttle Requirements, Operations, and Future Plans* (October 1984) pp. 23-24.

1989-1991 period are based on assumed flights of 140 from 1985 through 1991 and 24 annually from 1989 through 1991.

This assumption is contentious. Even if demand does not limit total shuttle flights from 1985 through 1991, questions have been raised concerning the number of flights that could be flown each year by the four orbiters currently in the shuttle fleet. A 1983 study by the National Research Council was less confident than NASA of the capability of the current fleet to achieve 24 flights annually. 11/ The study concluded that a low conservative estimate of the fleet's capability was 17 flights per year; a 25-flight level was labeled optimistic. With a fifth orbiter added to the shuttle fleet, the study found that a low conservative estimate was 22 flights a year and an optimistic estimate was 31 flights, compared with NASA's goal of 24 annual flights.

Over the 1985-1991 period, a lower number of total shuttle flights would raise the shuttle's operational cost by increasing individual unit costs of significant parts, such as external tanks or solid rocket boosters. The estimated cost of these items in the 1989-1991 period assumes that the experience gathered from flights in former years will have driven down costs (called the "learning curve" in economic language). If this experience is not obtained, NASA's assumed cost reductions might not be achieved. While this analysis recognizes that some operational costs will be saved by flying fewer flights, it makes no attempt to reestimate the higher unit costs resulting from lost learning in years before 1989.

11. National Academy of Sciences, National Research Council, Committee on NASA Scientific and Technological Program Reviews, *Assessment of Constraints on Space Shuttle Launch Rates* (1983), pp. 8-9.

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CHAPTER II

THE COSTS OF THE SHUTTLE

Before fiscal year 1983, the nation invested $17.8 billion in development and testing of the shuttle system. For the first three years of operation, fiscal years 1983 through 1985, an additional $10.5 billion will be spent, half to operate the shuttle and half on facilities, equipment, and capability development. For the next five years, 1986 through 1990, spending of $10.4 billion is projected, some $9.6 billion to operate the system and $0.8 billion to continue to develop the system capability.

This chapter breaks down these budget expenditure data and translates them into cost categories appropriate for economic analysis (see following box).

EXPENDITURES ON THE SHUTTLE SYSTEM: PAST AND PROJECTED

Past and projected spending for the shuttle system can be divided into four major categories:

- o Design, development, testing and evaluation, which ended in 1983;
- o Construction of facilities;
- o Production of the orbiter and system capability; and
- o Operations, which began in 1981.

Table 2 shows actual spending on these categories from fiscal years 1972 through 1984, and projected spending from fiscal years 1985 through 1990. Before shuttle operations began in 1983, outlays in the above first three categories accounted for $17.8 billion. Of this total, 75 percent went to design, development, testing, and evaluation (DDT&E). These expenditures ended in 1983 when the shuttle became operational. Operational expenditures began in 1981 for flights to be undertaken in 1983 and beyond. On average for 1983 through 1985, the Congress authorized $3 billion annually for the shuttle system, divided equally between operations and capital spending to improve capabilities. By 1990 the operations portion of the shuttle system budget will dominate, accounting for more than 95 percent of the projected budget of $2 billion.

FROM BUDGET EXPENDITURES TO ECONOMIC COSTS

These budget numbers cannot be used alone to estimate the cost of the shuttle. Only operating expenditures correspond to an annual cost in

GENERAL 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 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. 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 costs** 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 construction, 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 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.

the economic sense, and even these estimates require adjustment for the three-year period over which the cost of a shuttle flight is incurred and reimbursements for the flight are received. For example, the fiscal year 1983 budget included $1.4 billion (in 1983 dollars) for shuttle operations. This expenditure did not, however, represent the economic cost of the shuttle flights undertaken in 1983. The long lead times necessary to plan a

TABLE 2. ACTUAL AND PROJECTED SPENDING ON THE SHUTTLE SYSTEM (By fiscal year, in thousands of 1982 dollars)

Fiscal Year	DDT&E [a]	Construction	Production	Operations	Total
Actual					
1972	0	40,481	0	0	40,481
1973	0	58,368	0	0	58,368
1974	216,393	108,897	0	0	325,290
1975	1,406,526	136,129	0	0	1,542,655
1976	2,540,765	78,586	0	0	2,619,351
1977	2,088,802	60,365	108,865	0	2,258,032
1978	1,898,462	103,469	60,522	0	2,062,453
1979	1,712,918	41,896	496,224	0	2,251,038
1980	1,339,136	42,017	906,963	462,768	2,750,884
1981	1,040,642	12,532	1,093,048	577,968	2,724,189
1982	894,000	20,050	1,282,750	734,860	2,931,600
1983	0	25,700	1,634,629	1,354,000	3,014,329
1984	0	73,300	689,815	2,364,167	3,127,282
Projected					
1985	0	37,900	556,545	1,934,105	2,528,550
1986	0	39,200	325,000	1,935,720	2,299,920
1987	0	40,700	175,000	1,937,113	2,152,813
1988	0	42,100	65,000	1,930,973	2,038,073
1989	0	43,700	25,000	1,930,483	1,999,183
1990	0	45,200	25,000	1,929,170	1,999,370

SOURCE: Congressional Budget Office based on NASA data.

a. Design, development, testing, and evaluation.

flight and integrate payloads with the orbiter required expenditures as early as 1981. For the same reason, the 1983 budget for shuttle operations included funding for flights to be flown as late as 1985. Thus, an additional step in establishing the cost of the shuttle in any one year is to identify the operational costs for that particular year's flights. This analysis relies on NASA cost estimates for these data. (See the Appendix for a discussion of how NASA's budget figures are related to the costs for particular flights.)

A more significant problem of translating budgetary outlays into economic costs arises because $20 billion, or 79 percent of the cumulative spending on the shuttle system through fiscal year 1984, was invested in capital assets (through the DDT&E, construction, and production accounts). For an economic analysis of cost, this investment must be translated into an annual capital charge, in contrast with budgetary authorizations in the year the investments were made.

If the shuttle were operated as a private business or a regulated utility, the annual cost of service would include a capital charge, which would be included in the price paid by customers. Without inclusion of this charge, the owners of the asset would not receive an adequate return on their investment. The shuttle is not strictly comparable to a private enterprise or a regulated utility because it is a very high-risk venture, generates social benefits that are difficult to anticipate or quantify, and has been designed to accommodate a set of needs--such as those required by the Defense Department--not required by commercial users. Nevertheless, one view of the annual cost of the shuttle would capitalize--that is, include as capital costs--all preoperational and ongoing investments in the shuttle, including research and development spending. It would also include the cost of funds or interest costs tied up in the system before its commercial operation began. This last point, the cost of funds, is also pertinent to investments made since 1983 in assets that will become operational in several years. 1/

The capital charges estimated in this analysis need to be examined carefully on their own terms and in comparison with corresponding estimates for actual and potential shuttle competitors. The Arianespace cost data do not include a capital charge, nor is it clear that the rough order-of-magnitude estimates for the capital costs of private domestic ELV entrants

1. The shuttle system orbiters are the best example to illustrate this point. NASA currently estimates that, if a new orbiter were to be built--an expenditure opposed by NASA--seven years would pass between the time spending began and the orbiter became operational. But a dollar spent on a new orbiter could have been used in some alternative way. Thus, while this "interest" on funds used to build the shuttle system is not included in NASA budgets, it is a legitimate "cost" of the shuttle program.

incorporate the value of past or ongoing public investments made in their behalf, such as R&D expenditures on the Delta rocket.

Valuing the Investment in the Shuttle

A myriad of factors influences how investments in capital assets are included in annual costs. The shuttle system was constructed over the last 12 years and should be operational over an even longer period of time in the future. Calculating the value of this investment requires a discount rate (or interest rate) to account for the cost of devoting resources to the shuttle instead of other activities; a depreciation rate, to account for the decrease in the shuttle value through time; and a procedure to value the stock of shuttle assets in each year of the system's operational life.

Discount Rate. The investment in the shuttle should provide some return, if only because the funds could have been used in some other enterprise or activity. Just as the cost of any other input into the shuttle should be covered, this return would repay society for the use of its taxes. Economists call this return a "social discount rate," one that sets the rate of imputed profit that the shuttle should earn. But how large should this rate be? Considerable disagreement exists concerning the appropriate level. The analysis presented here uses a range of estimates from 4 percent to 10 percent in excess of inflation. [2] The lower value is consistent with the position that the discount rate should only account for the postponement of consumption implied by investment. The higher end of the range is consistent with the view that the discount rate should include provision for risk and thus approximate the private-sector rate. [3]

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2. All discount rates used in this paper are expressed in real (adjusted for inflation) terms.

3. The case for the lower rate is made in Kenneth Arrow and Robert Lind, "Uncertainty and the Evaluation of Public Investment Decisions," *American Economic Review, 60,* (June 1970), pp. 364-378. Arrow and Lind argue that the risk of investing in public goods such as the shuttle is so broadly spread among taxpayers that the value of unanticipated gains or losses to the individual is zero. Therefore, the social discount rate only need incorporate time preference. A criticism of this approach focuses on the issue of dividing and assigning the profits of a public good, which in its purest sense is indivisible and cannot have its profits assigned; see Kenneth A. Shepsle, "Risk and the Discount rate of Investment Yielding Public Goods: The Arrow Lind Theorem Reconsidered," in Gordon Tullock and Richard Washer, eds., *Policy Analysis and Deductive Reasoning* (Lexington, Massachusetts: Lexington Books, 1982), pp. 167-178. The high discount rate position argues for the inclusion of a risk factor in the public discount rate so that there is not overinvestment in public goods relative to private goods. See Jack Hirschleifer, "Investment Decision Under Uncertainty: Application of the State Preference Approach," *Quarterly Journal of Economics, 80* (May 1966), pp. 252-277.

The discount rate enters into the calculation of both the value of the shuttle assets and the annual total cost of the system. The rate is applied to investment funds during the gestation period to represent the cost of not using these resources in some alternative way. [4] For example, the spending on construction of facilities undertaken in 1972 is increased by the discount rate for the intervening eleven years between the time the investment was made and the time system became operational. This accounts for the cost of tying up funds in the shuttle during that period. Table 3 presents interest

TABLE 3. SHUTTLE SYSTEM NON-OPERATIONAL EXPENDITURES AND INTEREST COSTS, FISCAL YEARS 1972-1982 (In millions of 1982 dollars)

Type of Cost	Cost
Design, Development, Testing and Engineering	13,138
Production	3,948
Construction of Facilities	703
Total	17,789
Interest Costs	
Low rate (4 percent)	3,561
High rate (10 percent)	10,332
Total Expenditures and Interest Costs	
Low-rate case	21,350
High-rate case	28,122

SOURCE: Congressional Budget Office.

4. The capital cost estimates assume that investment in each year after 1982 is capitalized in the following year, adding to the system stock of assets depreciated in use. During the years of gestation, an interest charge is levied on the investment flow.

cost estimates for the nonoperational expenditures on the shuttle, assuming a low and high discount rate. The interest costs can be substantial. At a discount rate of 4 percent compounded annually, the value of shuttle system assets is $21.3 billion, even though the total expenditure on the assets was only $17.8 billion. At a higher discount rate of 10 percent, the value of the investment rises to $28.1 billion.

The discount rate also turns this total capital asset value into an annual capital charge that can be included in the annual total cost estimates of the shuttle system. The concept of the discount rate in this calculation is identical to its role in calculating the value of past shuttle investments. The stock of capital assets--facilities, equipment, and scientific and technical know-how--tied up in the shuttle represents resources that society could have used in some alternative way. The application of the discount rate to the value of the system's capital assets accounts for this opportunity cost in the annual cost of the system. This annual capital charge is discussed later in this chapter.

Depreciation. While the discount rate is applied to measure the cost of the resources tied up in the shuttle system, the depreciation rate measures the physical wear and tear, inflation, and obsolescence. This analysis applies a range of constant annual rates of depreciation from 4 percent per year to 10 percent per year. 5/ These correspond to an economic life of 25 years and 10 years, respectively. An additional choice must be made between valuing current assets at their historic acquisition costs or their prevailing replacement costs. Whenever possible, replacement cost is preferred to historic cost. 6/

A range of depreciation rates is used because the actual life of the shuttle system investment is unknown. The most prominent assets of the shuttle system, its four orbiters, are conservatively estimated to have a useful life of 100 flights. NASA officials, however, have indicated that each orbiter could fly as many as 400 flights. Actual experience has yet to confirm these or any other estimate. But at some point, the technology embodied in the existing fleet and the other components of the system built around it will become obsolete. This factor alone would require that a

5. The constant rate of depreciation applied in this analysis is a geometric depreciation pattern, as opposed to the more commonly used straightline depreciation pattern. Because neither is to be preferred theoretically, a geometric pattern is used here because of its analytical convenience.

6. The most significant issue here is the cost of an additional orbiter, the value of which is arguably of importance to foreign and commercial pricing decisions in the 1989-1991 period.

depreciation charge be levied against the shuttle system to account for its technical aging. In the extreme, even if the real value of the system was constant through time and in actual use, and then instantaneously fell to zero, an annual depreciation charge would have to be assessed. 7/

Annual Capital Charges

The annual capital charge included in the shuttle costs will vary significantly depending on the choice of discount rates. Depreciation rates have a much smaller influence. Table 4 shows estimates of the annual capital charges for 1985 through 1990. If a high discount rate is chosen and the assets of the system are depreciated over ten years, a capital charge of $5.1 billion would be assessed to the entire shuttle system in 1985. A lower discount rate and slower depreciation lower the capital charge to $1.8 billion.

TABLE 4. ANNUAL CAPITAL CHARGE UNDER ALTERNATIVE DISCOUNT AND DEPRECIATION RATE ASSUMPTIONS (By fiscal year, in billions of 1982 dollars)

	1985	1986	1987	1988	1989	1990
Discount Rate 4 Percent						
Depreciation rate 4 percent	1.8	1.8	1.7	1.6	1.6	1.5
Depreciation rate 7.7 percent	2.4	2.3	2.1	2.0	1.8	1.7
Depreciation rate 10 percent	2.8	2.6	2.3	2.1	1.9	1.7
Discount Rate 10 Percent						
Depreciation rate 4 percent	4.0	3.9	3.8	3.7	3.5	3.4
Depreciation rate 7.7 percent	4.7	4.4	4.1	3.8	3.5	3.3
Depreciation rate 10 percent	5.1	4.6	4.2	3.8	3.5	3.1

SOURCE: Congressional Budget Office.

7. For discussion of this "one-horse-shay" depreciation pattern see Charles Hulten and Frank Wykoff, "The Measurement of Economic Depreciation," in Charles Hulten, ed., *Depreciation, Inflation, and the Taxation of Income from Capital* (Washington, D.C.: The Urban Institute Press, 1982), pp. 81-125.

The six combinations of discount and depreciation rates presented in Table 4 show a wide range of capital charges for each year from 1985 through 1990. In order to simplify the analysis that follows, the 4 percent discount/4 percent depreciation rate will be used as a base case. It should be borne in mind, however, that alternative discount and depreciation rates would result in different imputed annual capital charges.

OPERATIONAL COSTS

The operational costs of the shuttle have played a key role in NASA pricing policy since 1977. According to NASA definitions, operational costs include the following:

- o **Consumables**, the materials and services used in a flight, including orbiter hardware spares, crew equipment, maintenance of the main engines, the solid rocket boosters, the external tanks, propellants, ground support equipment spares, and contract administration.

- o **Launch operations support** at the Kennedy Space Center; and

- o **Flight operations support** at Kennedy, the Marshall Space Flight Center, the Johnson Space Center, and the global tracking network. 8/

NASA projected operation costs for 1985 - 1990 are shown in Table 5.

The flat trend in total operational costs shown in Table 5 belies the expected improvement in shuttle cost performance during the next six years. Although total operational costs change little, the average operational cost per flight is expected to drop as the number of flights increases. Thus, the NASA average operational cost per flight fell from $338.5 million in 1983 to $268.9 million in 1984. Because the number of flights is expected to increase from four in 1984 to 24 in 1989 and continue at that rate through 1991, the average operational cost per flight is expected to decline to $83.6 million by 1990. The bulk of this improvement is realized because the flight rate is increased each year and the fixed portion of operating costs (over 65 percent of total operating costs in 1989 by the NASA reckoning) is spread over a larger number of flights. The remainder of the improvement is accounted for by the "learning" that accompanies flight experiences, pri-

8. Barbara Stone, "Understanding the Cost Bases of Space Shuttle Pricing Policies for Foreign and Commercial Customers," *Journal of Parametrics*, Vol. 3, No. 1 (1984) pp. 1 - 6.

TABLE 5. PROJECTED TOTAL OPERATIONAL COST, FISCAL YEARS 1985-1990 (In thousands of 1982 dollars)

	1985	1986	1987	1988	1989	1990
Boosters Solid Rocket	445.5	364.8	449.4	450.8	453.6	453.6
External Tanks	284.9	355.2	411.6	411.7	396.0	372.0
Launch Operations	298.1	376.0	287.7	324.3	338.4	352.8
Propellants	24.2	26.0	32.0	24.0	22.0	22.0
Flight Operations	301.4	334.4	350.7	340.4	331.2	333.6
Orbiter Hardware	135.3	153.6	163.8	170.2	163.2	158.4
Crew Equipment	29.7	35.2	35.7	36.8	45.6	79.2
Main Engine	30.8	35.2	33.6	36.8	45.6	79.2
Administration Contract	7.7	8.4	8.8	9.0	9.0	9.0
Research and Program Management	207.9	190.4	178.5	179.4	177.6	172.8
Network Support	16.5	24.0	31.5	34.5	36.0	36.0
Total	1,782.0	1,909.0	19,849.0	2,021.5	2,013.0	2,005.7

SOURCE: NASA for 1982 dollar per flight data. Total cost data derived by CBO by multiplying the NASA per flight estimates by total number of flights per year, including those launched from Vandenberg Air Force Base. NASA does not bear all of these costs of operating the shuttle. Specifically, launch operations and propellants are not covered by NASA for three flights in 1986, three flights in 1987, one flight in 1988, and four flights each in 1989 and 1990. The other components of cost are covered by NASA for all flights.

marily in the areas of external tank and solid rocket booster production and refurbishment of the shuttle main engines. 9/

As noted in Chapter I, the NASA estimate of operating costs has been questioned in the past. A 1982 General Accounting Office report cited design changes, new requirements, and optimistic inflation estimates as reasons for a consistent underestimation of total and average operational cost. 10/ This analysis accepts the current NASA estimates of total operating cost for 1985-1990. The maturing of the program and previous errors probably have made realistic and accurate cost estimation more probable than in the past. In any case, an item-by-item cost review is beyond the scope of this study. Moreover, this analysis is based on NASA's target of 24 flights per year. Changes in the expected number of flights and their effect on shuttle costs will be discussed later.

THE TOTAL AND AVERAGE COSTS OF THE SHUTTLE SYSTEM

The total annual cost of the shuttle is the sum of annual capital costs and annual operational costs. Table 6 shows the estimates for total costs for the 1985-1990 period. The average total cost per flight, assuming the most recent projected NASA flight rate, is also shown.

The most significant insight derived from these total cost estimates is the relatively high fixed-cost character of the shuttle system. For example, for 1985 the capital charge cost of $1.8 billion, which does not vary with the flight rate and is thus fixed even using the lowest discount and depreciation rate, accounts for 50 percent of total costs.

9. By using the NASA operations cost data for 1989-1991, this analysis accepts the NASA estimates of the annual flight rate and of the fall in per unit cost, or learning curve, associated with the growing cumulative volume of shuttle flights. As indicated in Chapter I, there is reason to suspect NASA will not meet its flight rate goals, which in turn will push the cost of major operational expenses above projected levels. In the analysis of the 1989 per flight costs which follows, a lower than expected flight rate in that year will cause an increase in average total cost per flight. (In economics, this is represented as a movement up the negatively sloped average total cost curve.) If the flight rate in prior years is not achieved, average total cost also will increase because the learning during this period will be lost. (This can be thought of as an upward shift of the entire average cost curve, rather than a movement along the average cost curve.)

10. Comptroller General, General Accounting Office, "NASA Must Reconsider Operations Pricing Policy to Compensate for Cost Growth on the Space Transportation System," Report to the Congress of the United States, February 23, 1984.

Using higher values of discount and depreciation (10 percent and 10 years, respectively) increases this percentage to 74 percent as the capital charge increases from $1.8 billion to $5.1 billion. When the NASA estimate of the portion of fixed operational cost (roughly two-thirds of operational cost if at least eight flights are flown) is added to fixed capital charge costs for the base case, the percentage of total costs that are fixed increases from 50 percent to 85 percent in 1985. The following chapter develops the implications of this characteristic of the shuttle for the cost analysis need to formulate and evaluate pricing policy.

TABLE 6. ESTIMATED TOTAL AND AVERAGE COSTS FOR THE SHUTTLE, FISCAL YEARS 1985-1990 (In millions of 1982 dollars)

	1985	1986	1987	1988	1989	1990
Capital Charge a/	1,803	1,760	1,707	1,647	1,586	1,529
Operational Cost b/	1,782	1,909	1,985	2,021	2,013	2,005
Total Cost	3,585	3,669	3,692	3,668	3,599	3,534
Average Cost per Flight	326	229	176	159	150	147
Number of Flights	11	16	21	23	24	24

SOURCE: Congressional Budget Office and NASA.

a. Assumes a 4 percent discount rate and a 4 percent depreciation rate.

b. NASA for 1982 dollar per flight data. Total cost data derived by CBO by multipling the NASA per flight estimates by total number of flights per year, including those launched from Vandenberg Air Force Base. NASA does not bear all of these costs of operating the shuttle. Specifically, launch operations and propellants are not covered by NASA for three flights in 1986, three flights in 1987, one flight in 1988, and four flights each in 1989 and 1990. The other components of cost are covered by NASA for all flights.

CHAPTER III

ALTERNATIVE COST BASES FOR SHUTTLE PRICING POLICY

Economic analysis can help identify the costs relevant for choosing a price for foreign and commercial shuttle users. Because the shuttle is a high fixed-cost system in which the average cost per flight continuously declines as the number of flights increases, however, the same body of theory offers no clear guidelines as to what kind of pricing policy should prevail.

NASA has undertaken a detailed cost analysis each time that it has recommended a shuttle pricing policy. The NASA estimate of shuttle costs from 1989 through 1991 will be a significant determinant of the price to be established for that period. But the new policy will probably be more influenced than its predecessors by considerations beyond the cost of providing shuttle launch services to foreign and commerical buyers. This chapter presents an analysis of shuttle cost bases pertinent to pricing policy.

Two types of cost bases for pricing policy are analyzed--marginal costs and full costs. In Chapter IV, these different cost bases are examined in the context of the several goals of the space program.

BASE CASE

In the preceding chapter, a range of estimates was developed to accommodate different opinions about appropriate discount and depreciation rates. In this chapter, ranges are also used to divide operational costs and capital charges into fixed and variable components. Ranges are used rather than single points to allow for differing but reasonable assumptions, as well as to acknowledge the uncertainty inherent in estimating the costs of a technically complex and risky enterprise some four or more years in the future. But, for simplicity, the bulk of the discussion will focus on a base case. The key assumptions underlying the base case estimates are as follows:

- 24 flights are flown in 1989;
- A 4 percent discount rate and 4 percent depreciation rate (25-year life) are used to assess the annual capital charge for the shuttle system;

- Design, development, testing, and evaluation costs are fully included in the capital charge, except where otherwise noted;

- The NASA estimate of total operational cost is split equally between fixed and variable costs (as opposed to the NASA estimate that roughly two-thirds of operational costs are fixed);

- The replacement cost of an orbiter is $1.7 billion, the annual capital charge for which is spread over four flights per year;

- Short-run marginal operational costs are constant after eight flights.

All of these assumptions are subject to question, some more so than others. Some analysts might choose a higher or lower discount rate. As indicated in Chapter I, it is uncertain whether the space market or the shuttle's operational capability can support 24 flights in 1989. Failure to approach the planned flight rate between now and 1989 could increase all shuttle operational costs, or unforeseen problems could dramatically increase shuttle costs regardless of the flight rate. Many of these assumptions, therefore, are varied later in this analysis.

This chapter develops estimates of five different concepts of cost on which shuttle prices could be based. They are:

- **Short-run marginal cost**, or the costs of an additional shuttle flight.

- **Long-run marginal cost**, or the cost of allowing foreign and commercial users access to the shuttle.

- Three definitions of **full cost**, in which

  --all costs are included;
  --all costs (except research and development) are included; and
  --only operational costs are included (the NASA definition).

Table 7 presents estimates for these five concepts of shuttle costs under the base case assumptions. The remainder of this chapter explains how these estimates were obtained.

MARGINAL COSTS

Economic theory suggests that resources are used most efficiently when the price of a service equals the cost of providing an additional, or marginal, unit of service. When price exceeds this marginal cost, society foregoes benefits because consumers are willing to pay more for the additional unit of the service than the value of the resources that went into providing it. Conversely, if marginal cost exceeds price, resources used to produce the service would be better employed in providing some alternative good or service. Because the marginal cost includes the depleted resources necessary to provide the last measure of service, it could include capital as well as operational costs. Marginal costs, however, do not include fixed costs or past or anticipated losses that will be incurred regardless of whether or not the marginal unit of service is provided.

Regardless of whether or not efficient pricing is the objective of policy, knowing the costs that indicate an efficient price--that is, the marginal costs--provides a useful reference point in setting prices to achieve other objectives, such as cost recovery or a specific degree of space shuttle price competitiveness with foreign or domestic expendable launch vehicles. In order to identify marginal costs, the total cost estimates presented in Chapter II must be broken down into fixed and variable costs.

TABLE 7. ALTERNATIVE COST BASES FOR SHUTTLE FLIGHTS, BASE CASE ASSUMPTIONS (In millions of 1982 dollars)

Cost Bases	Cost per Flight
Full Cost	
Average total cost, including all capital costs	150
Average total cost, less research and development	106
Average operational cost (the NASA base)	85
Marginal Cost	
Long-run marginal cost	75
Short-run marginal cost	42

SOURCE: Congressional Budget Office.

Fixed and Variable Costs

Analyzing shuttle marginal costs requires separating the shuttle's fixed costs (costs that will be incurred regardless of the number of flights) from its variable costs (costs that increase as service is increased). This division depends on how the "unit" of shuttle service or output is defined. Several alternatives can be used, including the launch of a single payload, a single flight, or a group of flights that serve a relatively small additional group of users (the foreign and commercial consumers).

Each definition implies a different split between fixed and variable costs, and suggests a different time perspective for the analysis of cost. For example, if the unit of output is defined as a single flight, the costs associated with that additional flight can be identified. In this case, marginal cost would reflect only the cost of the rockets, fuel, maintenance, and the processing needed to prepare the flight. On the other hand, if the shuttle's capacity were sufficient only to serve U.S. scientific and defense needs, the costs incurred to produce service for the foreign and commercial segment of the market would increase. In this case, the marginal cost of providing an additional unit of output is substantial and includes sizable capital costs. In the single flight case, the ratio of fixed to variable costs is higher, and the time period over which these fixed, variable, and marginal costs are incurred is short. In the market segment case, the period of analysis must include the time to construct additional facilities and expand the orbiter fleet, and more costs elements are variable. The efficient price of shuttle services under this definition of output would be higher, reflecting the higher assessment of marginal cost. The range of estimates for these two alternative specifications of marginal cost, short-run and long-run, are shown in Table 8.

Regardless of the unit of output, the bulk of 1989 shuttle capital costs are fixed. The entire capital cost is fixed if the unit of output is defined as a single payload or a single flight. The preponderance of capital costs is also fixed, if the marginal service is defined as the capacity to fly 4 to 6 flights above the 18 to 20 flights necessary to meet projected U.S. government demand. But if providing these additional flights for commercial and foreign payloads were to tax the current capacity of the system, either by accelerating the rate at which existing capacity was worn out or by requiring an expansion of capacity, part of the capital costs would be considered variable rather than fixed. This possibility is accounted for by the long-run marginal-cost estimate.

The major contributor to shuttle marginal costs--long-run or short-run--are those operational costs that increase as more flights are flown. NASA estimates that 1989 operational costs will total $2.0 billion, and that two-thirds of this total is fixed. The NASA estimate of fixed cost has been criticized as too high, primarily because of skepticism concerning the rate of 24 flights per year. To account for differing opinions concerning how much of operational costs is fixed, the NASA estimate of two-thirds of operational costs is treated as the high end of a range, and 25 percent represented as a low end. The base case assumes that half of operational costs are fixed.

Short-Run Marginal Costs

The base case estimate of short-run marginal costs is obtained by assuming that 50 percent of 1989 operational costs vary as the flight rate changes. Using this assumption, total variable costs will be $1.0 billion annually. The base case estimate of short-run marginal cost, $42 million per flight, is obtained by dividing the total variable cost of $1.0 billion by 24 flights. This

TABLE 8. MARGINAL COST: RANGE OF ESTIMATES (In millions of 1982 dollars)

Cost Bases	Cost per Flight
Short-Run Marginal Cost	
Low	28
Base case	42
High	71
Long-Run Marginal Cost	
Low	62
Base case	76
High	105

SOURCE: Congressional Budget Office.

marginal cost is assumed to be constant across all 24 flights, an assumption made in the absence of cost data based on actual experience. NASA cost estimates indicate that the marginal cost of an additional shuttle flight changes by the same amount if at least eight flights are launched annually. 1/

The range of short-run marginal cost for 1989 is obtained by changing the ratio of fixed to variable operational costs. When this assumption is changed, short-run marginal costs will range from $28 million to $71 million per flight, again assuming 24 flights per year. 2/

Long-Run Marginal Costs

The estimates of short-run marginal costs were developed for a single flight. The estimates of long-run marginal costs take a different perspective: that the additional unit of output is the capacity to serve the additional class of foreign and commercial users. Serving this additional market segment might require additional capital expenditures. The long-run marginal-cost estimate, therefore, regards some capital costs as variable costs.

The long-run marginal-cost estimate is the sum of short-run marginal cost plus a charge equal to the capital charge on the asset value of a replacement orbiter averaged over four flights per year. Under base case assumptions, long-run marginal costs are $76 million per flight. But a range of estimates can be obtained by varying a number of factors: the division of operational costs into fixed and variable components, the depreciation rate and discount rate employed, and the number of flights over which the capital charge is spread. When these assumptions are varied, long-run marginal-cost ranges from $62 million to $105 million per flight.

1. As more of a service is provided, there is no reason to expect that each increase in service will be provided at the same cost as the previous increase; thus there is no inherent reason that marginal cost should be constant. But within specific ranges of output, however, the cost of increasing output might change at a constant rate, particularly if capacity constraints are not reached. A manufacturing facility, producing at less than full capacity with constant prices for labor and material, provides a good example.

2. The high end of the short-run marginal-cost range is explicitly based on the 25 percent/75 percent operational cost split between fixed and variable cost. However, the high-end variable cost can also occur if costs prove higher than expected, perhaps because the flight rate in 1985 through 1988 was less than anticipated. NASA suggests that the marginal cost of shuttle services to the foreign and commercial market is probably closer to the $28 million low range, in part because the cost of integrating commercial payloads with the shuttle is substantially lower than that of scientific or military payloads.

FULL COSTS

Economic theory defines a full-cost price as one that covers the average total cost of producing the volume of products or services brought to market. The full-cost alternatives for shuttle prices differ on the basis of what is included in or excluded from the cost base. Table 8 shows the alternative full-cost bases. The highest full-cost base, $150 million per flight for 24 flights, holds the shuttle to the standard of a private firm and includes all of the system development costs (including the $9.9 billion spent for design, development, testing, and evaluation--DDT&E--plus interest spent from 1972 through 1982).

The second estimate of full cost (average total cost less development) takes account of the very high level of risk associated with the development of the shuttle and of the consideration that replacement rather than historic cost is the most appropriate way to value assets in calculating a capital charge. Arguably, the $9.9 billion spent on DDT&E should be excluded from the shuttle asset base because it represents a uniquely public research effort, which the private sector would be unlikely to undertake because of its riskiness, long pay-off period, and social benefits too diverse for a private investor to capture. Excluding the shuttle's development expenditures leaves the other system assets as the base from which a capital charge is derived. The system fleet of four orbiters constitutes the bulk of these assets. NASA currently estimates the cost of an orbiter to be $1.5 billion. If, as in the past, these funds are spent over seven years, an additional $0.2 billion in interest charges accumulates, increasing the total replacement cost of an orbiter to $1.7 billion. If the other assets of the system are represented by the $0.8 billion spent on construction of facilities through 1984 and the projected $0.7 billion in further investments through 1989 (assumed to be capitalized in the year in which it is invested), the base case assumptions result in a capital charge of about $22 million per flight and an average total cost (less development) of $106 million (consisting of average total operational cost of $84 million, plus the per flight capital charge of $22 million).

The lowest full-cost base--average operational cost--is $84 million, and excludes all expenditures other than those necessary to fly 24 flights in 1989. This cost base is closest to the one used by NASA.

NASA interprets a full-cost pricing policy differently from the full-cost estimates provided in this analysis. The NASA full-cost base for pricing policy is essentially total operational costs for 1989 through 1991 divided by the 72 flights planned for those years. The result is a figure of $84 million per flight. Like the CBO cost bases for pricing, the NASA estimate assumes operational costs fall as the cumulative volume of flights increases from 1986 through 1989. Unlike the CBO estimate, no capital charge for previous investment is included. The NASA full-cost price is presented here is a point estimate only.

A common characteristic of all of the full-cost prices is their sensitivity to the flight rate. Full-cost prices change dramatically as the number of flights change, as Table 9 shows. In the base case, the highest full-cost price is $186 million if 18 flights are flown. If 24 flights are flown, this price falls to $150 million. The lower price per flight is attributable to spreading fixed costs--operational and capital alike--over a greater number of flights, rather than a lower variable cost per flight.

TABLE 9. FULL-COST PRICES UNDER VARIOUS SHUTTLE FLIGHT RATES (In millions of 1982 dollars)

Full-Cost Prices	Number of Flights 12	18	24
Average Total Cost, Including All Capital Costs	258	186	150
Average Total Cost, Less Research and Development	170	128	106
Average Operational Cost (The NASA Base)	126	98	84

SOURCE: Congressional Budget Office.

CHAPTER IV

POLICY OPTIONS

No single shuttle pricing option stands out as clearly superior either on economic principles or on its ability to satisfy all objectives for the shuttle program. Indeed, sound arguments and counter arguments can be made for all the cost bases discussed in Chapter III. The price eventually approved by the Congress will depend on the relative importance assigned to each of the different objectives for the nation's space program. Any given price policy is sure to conflict with one or more of these objectives.

POLICY OBJECTIVES

The major objectives for the space shuttle program can be grouped in six categories:

- **National Security**: Ensure access to space for the Department of Defense.

- **National Prestige**: Maintain a strong U.S. role in space technology and in the development of space.

- **Research**: Encourage research activities in space--both applied and scientific.

- **Cost Recovery**: Ensure full-cost recovery for use of the shuttle by commercial firms and foreign governments.

- **Efficiency**: Encourage the efficient use of the space shuttle system.

- **Commercialization**, which has several, sometimes inconsistent, components:

  --Encourage existing commercial activities in space;

  --Encourage the development of new commercial activities in space; and

  --Encourage a strong domestic expendable launch vehicle (ELV) industry.

Some of the most important objectives--DoD access to space and many scientific missions--are linked to the shuttle price only in the sense that activity in these programs is subject to overall budgetary constraints. Other objectives--most important, encouraging the efficient use of the shuttle system, promoting commercial activity in space, and maintaining a domestic ELV industry--depend greatly on price. One of the higher full-cost prices might be required to ensure that a domestic, private ELV industry can compete with the shuttle. But there still would be no guarantee that U.S. rockets could compete successfully against Ariane. Lower marginal-cost prices are the best way to ensure efficient use of the shuttle; if full-cost prices were charged, the shuttle system underutilized compared to its capacity and the added resources could be needed to fly it. But the fact that the shuttle system is a public asset in competition with the private sector argues for reliance on higher long-run rather than lower short-run marginal costs, even if significant excess capacity exists at that higher price.

Moreover, the link between price and policy objectives is not always clear. Depending on the time horizon, some objectives could be achieved in different ways under either a low or a high price. Over the next few years, for example, a relatively low shuttle price, such as one based on short-term marginal costs, would provide the most encouragement for commercial development of space. In the longer run, however, a higher price could create an incentive for private firms to develop new, and perhaps less expensive, space vehicles.

Table 10 summarizes the ability of the major pricing options to meet different objectives for the nation's space program. The rest of this chapter expands on the link between various shuttle prices and space objectives.

EFFICIENCY AND COST RECOVERY

In a conventional enterprise in a competitive economy, efficiency and cost recovery inevitably go hand in hand. Firms seek to recover their costs plus whatever profits the market will bear. But if profits expand beyond some level, competitors initiate price competition until the price of any good covers only its costs of production. Covering costs, however, is not the standard that a firm uses to decide how much to produce. Instead, the firm compares the cost of producing an additional, or marginal, unit of service and the market price; if an additional unit of production will fetch more than the marginal cost of producing it, the firm will provide it. But because the production capacity of the conventional enterprise is limited (as is the

TABLE 10. PRICING OPTIONS

Pricing Policy	Definition of Cost	Price Per Flight in 1989 (millions of 1982 dollars) With 24 Flights	With 18 Flights	Policy Implications
Marginal Cost Prices				
Short-Run Marginal Cost	Variable operational costs.	42	42	Maximum use of shuttle. Likely end to domestic expendable launch vehicles (ELVs). Direct competition with Arianespace. If NASA's costs are underestimated, revenues will not cover cost. High flight rate encourages future expansion.
Long-Run Marginal Cost	Variable operational costs, plus a capital charge for an orbiter dedicated to foreign and commercial flights.	76	76	Shuttle should maintain current market share and generate net federal revenues. Domestic ELV firms have little chance of success.
Full-Cost Prices				
Full Operational Cost	All operational costs. Approximation of proposed NASA policy for 1989 through 1991.	84	98	Largely the same as for long-run marginal price.
Full Cost Less Development	All operational costs, orbiters at replacement cost ($1.7 billion each), plus other investment but excluding research and development.	106	128	Shuttle will lose part of its market share unless Arianespace increases its price as well. Prospects for domestic ELVs improved but still uncertain. Less than full use of shuttle.
Full Cost	All operational costs, plus all investment valued at historic costs.	150	186	Shuttle losses all but specialized foreign and commercial payloads--flight rate will be below efficient level. Reduced net federal revenues. Domestic ELVs will do well, particularly if Arianespace increases price. Investors in new space processing may reduce planned spending. Little immediate need to expand shuttle system.

SOURCE: Congressional Budget Office.

NOTE: Estimates reflect base-case assumptions about interest rate and depreciation. Alternative assumptions would generally result in higher costs for options with capital costs. Operational costs based on estimates by NASA.

capacity of any factory, farm, or office), the costs of producing additional output rise as output increases. Thus, once the forces of competition act themselves out, firms produce until their marginal costs rise to the level of market prices, and market prices fall until they recover the costs of production (average total costs) and no more.

But the shuttle system is not a conventional enterprise. It differs, most notably, in that it has a very high fixed-cost component. These high fixed-costs make the two goals of cost recovery and efficiency diverge. Specifically, because of high fixed costs, the marginal cost of providing launch services is significantly lower than the average total cost. Thus, recovering costs does not lead to efficient pricing. This section examines this duality in greater detail.

Short-Run Marginal Cost

The short-run marginal-cost price, $42 million per flight, sacrifices the goal of cost recovery. It essentially forgives foreign and commercial shuttle users their share of the system's fixed costs. But the short-run marginal-cost price is the price that will encourage the most efficient short-term use of the shuttle. This outcome depends on a specific and restrictive set of circumstances:

- NASA's cost and flight rate estimates are accurate; and
- The shuttle system capacity is in excess of that required by the government, and foreign and commercial users will demand that excess capacity at the marginal cost price.

Under these circumstances, a short-run marginal-cost price will induce greater demand for shuttle service while recovering the additional costs borne by the government in providing service to the foreign and commercial users. The efficient use of the shuttle will result because only those users who derive benefits in excess of the cost of an additional shuttle flight will demand such a flight.

This result, however, depends on the underlying assumptions. Consider the capacity issue. NASA depicts the shuttle system's current rate of capacity as 24 flights per year. In fiscal year 1984, only 4 shuttle launches were made and, as previously indicated, some observers have raised serious doubts about the ability of the current four-orbiter fleet to achieve the 24 flight rate. If the effective capacity is less than 24 flights per year, capacity problems could appear sooner than expected. In addition, plans for the space station call for use of at least six shuttle flights a year by the early 1990s, a level that is sure to strain the capability of the system even if current projections for commercial and foreign payloads turn out to be too optimistic. Moreover, if the Strategic Defense Initiative is pursued, then Department of Defense needs might place additional pressures on the system. In sum, it can be argued that the assumption of excess shuttle capacity might be valid for only the next few years.

If the projected excess capacity does not materialize, then a price based on short-run marginal costs could be so attractive that demand could exceed the shuttle's capacity. The immediate purpose of this price is to cover the additional budgetary cost of foreign and commercial flights. But by encouraging higher use of the system, a short-run marginal-cost price could increase the need for further investment in the shuttle, and in doing so, lead to higher future costs. But these increased costs would not be reflected in the short-run marginal-cost price. Thus, this price delivers efficiency benefits only as long as excess capacity exists on the shuttle system.

Long-Run Marginal Cost

The price based on long-run marginal costs, $76 million, poses much of the same efficiency and cost recovery trade-offs as the short-run marginal-cost price. It shares the same flight rate and cost estimates. But the long-run marginal cost takes into account that the ultimate cost of serving the foreign and commercial market might exceed its short-run cost, because serving this market would ultimately demand new capital expenditures.

The long-run marginal-cost estimate recognizes the possibility that shuttle capacity might be taxed. It includes, therefore, a capital charge based on the cost of a replacement orbiter spread over four foreign and commercial flights per year. This charge approximates the additional capital cost of servicing this market segment. As such, the cost can as easily be thought of as representative of all of the future investment costs likely to be incurred in serving the foreign and commercial market rather than the cost of adding an additional orbiter.

The cost of an orbiter is a good proxy for estimating the future investment costs that might be incurred in serving the foreign and commercial market. First, the orbiters are the major capital asset of the system. Second, even though NASA currently opposes procurement of an additional orbiter, it is probable that a demand for 24 flights per year in the late 1980s --possible only if foreign and commercial flights are flown--would require one. This last point is consistent with the National Research Council evaluation of the shuttle flight rate. This study concluded that, under a reasonable set of assumptions, it would be optimistic to assume the 24 flight target could be reached using only the current four-orbiter feet. There is also a judgmental aspect to including a capital charge in marginal cost. This judgment recognizes that, when the public and the private sectors are in competition, it is prudent to overestimate rather than underestimate public-sector marginal costs.

Finally, and perhaps most important, the long-run marginal-cost price provides an excellent litmus test to determine whether an additional orbiter would be required. If shuttle users book fully the system's capacity at the long-run marginal-cost price, then a new orbiter could be acquired with the confidence that its users would be willing to pay its costs (which would already be reflected in the shuttle price). The long-run marginal-cost price, therefore, furnishes a unique efficiency benefit: it presents the correct signal about the possible expansion of the shuttle system.

The direct budgetary consequences of the long-run marginal-cost price are more positive than the short-run estimate. At a price of $76 million per flight, roughly $30 million per flight will be returned as net federal revenues--if, and only if, the NASA flight rate and cost estimates hold.

Full-Cost Prices

The three full-cost prices have the same qualitative effects on cost recovery and efficiency, but differ in degree. Each is likely to leave the shuttle with excess capacity. Each requires foreign and commercial users to pay a price above the marginal cost of the service provided, however defined, and thereby to contribute to the fixed costs of all shuttle flights.

Most important, establishing a high full-cost price equal to the average total cost of 24 flights is likely to result in an annual flight rate below this number of flights. This would occur because the foreign and commercial market is sufficiently price sensitive to switch to alternative launch services (ELVs) at a high shuttle price. Thus, full-cost prices might not lead to complete recovery of all shuttle program costs, and they could result in underutilization of the shuttle. But full-cost prices would greatly spur incentives for shuttle competitors, both foreign and domestic.

Proponents of full-cost prices point out that they convey an equity advantage. If foreign and commercial users are not charged a full-cost price, then they would reap the benefits of the massive expenditures that went into the development of the shuttle and its underlying technology. In this way, these users will "free ride" the costs of the shuttle's development. But this equity advantage might be hard to obtain, because foreign and commercial users might switch to alternative launch suppliers if a full-cost price was charged. Moreover, charging the full-cost price would needlessly discourage use of the shuttle, since the full-cost price is substantially above either the short-run or long-run conception of the marginal cost of shuttle services.

A different equity argument can also be made. NASA developed the shuttle program with a goal of providing a viable means for the commercial development of space. By the end of the period covered by the Phase III pricing policy, the shuttle program will be entering its third decade. It can be argued that, after twenty years, the shuttle should recoup all its costs from non-U.S. government users, and that, if it cannot, then an entirely new approach to space development should be pursued for payloads that can be accommodated by ELVs. This underlying view of full-cost pricing holds that, at some point in government efforts towards commercializing technologies, the technologies must stand on their own and recoup all of their costs. Proponents of this view would allow the shuttle system to fail in the commercial market and let Arianespace and potential U.S. ELV competitors divide the launch market. (The shuttle, in fact, would continue to cater to the needs of a highly specialized market segment that requires payload retrieval or manned in-flight work, capabilities unique to the shuttle.)

COMPETITION AND COMMERCIALIZATION

Beyond the cost recovery and efficiency effects of shuttle prices are the policy objectives of remaining competitive with foreign launch services, providing an opportunity for private domestic ELVs to enter the market, and the role of the shuttle system and NASA in the ultimate commercialization of space. In Chapter I, a perspective was presented on the demand for launch services and the relative cost competitiveness of private ELVs, Arianespace, and the shuttle. More extensive analysis of both issues is necessary to draw firm conclusions on the probable effects of alternative pricing policies in these areas. Nevertheless, enough is known now to comment on the broader implications of the pricing alternatives for the three policy objectives.

Marginal-Cost Based Prices

A short-run marginal-cost price is the most direct way to encourage use of the shuttle. Existing domestic ELVs would not be able to match such a price, however, and competition would focus on Arianespace. Although the response of Arianespace is hard to predict, continued subsidies by its European supporters must be considered likely. As a result, the commercial market would probably continue to be shared between Ariane and the shuttle, with the shuttle obtaining a high market share of at least 50 percent.

Without a more extensive analysis of demand and the cost of shuttle competitors, it is difficult to evaluate the relative prospects of domestic ELVs, Arianespace, and the shuttle, should a long-run marginal cost (closest to the NASA full operating cost price) be used to price shuttle services. Many analysts, however, believe that a long-run marginal-cost price is too low for domestic ELVs to survive, but low enough to allow NASA to compete effectively with Arianespace.

A more speculative question is how either marginal cost price will contribute to the long-run goal of lowering space transportation costs. The case can be argued either way. A low price, leading to a fully utilized shuttle, could create strong groundwork for a "Shuttle II" system to be built by NASA, with the explicit goal of lowering transportation costs. But a contrary argument holds that, if the possibility of a private launch industry is foreclosed by a low shuttle price, the best prospect for cheaper space transportation in the long term--that is, through the diverse experimentation that would accompany private sector involvement--would be dashed.

Full-Cost Prices

The principles behind the two higher full-cost recovery pricing options (with and without DDT&E) are based on reducing or eliminating the subsidy required from the general taxpayer. These alternatives represent an attempt to reach the average price level that a private firm would require in order to finance the capital costs of developing a shuttle system and expanding its capacity.

Because both higher full-cost prices would be substantially above the prices that NASA has charged in the past or proposes for the future, their policy implications are significant. First, Arianespace might not raise its prices to match either new shuttle price. As a result, the shuttle might capture only those payloads that exceeded Ariane's capacity. Because no apparent technical or financial barriers exist to prevent the expansion of Ariane's capacity beyond its current six to seven launches a year, the shuttle could be limited to military or government research payloads and those commercial payloads that required work by astronauts or had to be returned from space. Thus, the shuttle would lose most of the existing commercial market, although it would continue to capture those market segments that had to meet U.S. security requirements or that needed the shuttle's unique capabilities.

Second, the American ELV industry would be encouraged to compete directly with Arianespace. While existing ELV firms (those using the Delta and Atlas-Centaur rockets) would find it difficult to match Arianespace's price, they would have real incentives to invest additional funds in improving these rockets. In addition, new firms might be able to raise funds to test new rocket concepts. Although the chances of any single firm succeeding might be limited, the potential long-run payoffs from innovation, experimentation, and the subsequent lower cost of space transport would be substantial. These benefits could be jeopardized, however, if Arianespace were to undercut U.S. ELVs with a subsidized, predatory price. If potential investors perceived that Arianspace would use its government subsidies to prohibit the entry of U.S. ELVs, then the development of the American ELV industry could be thwarted. An aggressive trade policy that seeks to eliminate Ariane subsidies might be a necessary precondition to investment in domestic ELVs.

OTHER ASPECTS OF PRICING POLICY

The pricing policy involves more than just determining the amount to be charged for each launch. Key factors include the flexibility that NASA provides itself in negotiating prices and payment terms with its customers. All past NASA prices have been set at least four to six years in advance and for amounts that could be adjusted for general inflation only. When originally determined in 1978, this policy provided a guaranteed price to NASA's customers and thus helped NASA to market the shuttle during its early years of development. Moreover, NASA's early price was substantially less than costs of competitive systems. Now, with active competition from Arianespace and potential competition from domestic ELVs, such a policy merely ties NASA's hands in competitive bidding for commercial payloads. Arianespace, or any other competitor, knows in advance exactly how much of a discount it must offer in order to secure a particular bid. Further, as cost estimates and demand projections change, a fixed long-term price could lock NASA into prices that are substantially below actual costs (as in the past) or above them.

NASA's recent pricing proposal attempts to remedy some of these problems by providing the NASA Administrator with the option to charge a price that is within five percent of the official price. But customers will still know NASA's lowest possible price in advance, and might insist on receiving this price. Moreover, the policy is still set up to six years in advance (for 1991) and is locked in for three years at a time. Thus, the Congress could consider allowing NASA greater flexibility in determining prices.

Such flexibility has drawbacks, however. It would make the shuttle program harder to budget because it would add an element of uncertainty to its receipts. Unless subject to some targets for total shuttle receipts, flexibility would encourage shuttle administrators to discount its services. On the other hand, pricing flexibility might send strong signals to Arianespace, and to the governments that subsidize it, to discontinue their subsidies, since they could be matched by the shuttle in selected instances. For these reasons, price flexibility could help create a "level playing field" in the market for launches, and would, therefore, encourage the development of the domestic ELV industry.

NASA also requires payment spread over the 33 months before launch. This is a fiscally conservative policy, since roughly two-thirds of the operating costs for each launch occur in the year of the launch (see the Appendix). The cash flow gains to the federal government from having reimbursements paid before expenditures appear relatively modest, particularly since none of the past pricing policies has recovered the shuttle's costs. A change in payment policy could help to offset a higher price.

APPENDIX

APPENDIX

THE RELATIONSHIP BETWEEN THE NASA BUDGET AND SHUTTLE COST FIGURES

The flight cost figures used in this study are not identical to the figures that appear in the NASA budget. The logical step of comparing any given fiscal year's costs and budget figures will most likely lead to confusion as they often bear little resemblance to one another. This appendix notes the differences between these figures and the problems encountered when converting one to another.

THE NASA BUDGET

The annual NASA appropriation reflects the estimated net obligations to be incurred during agency operations for the fiscal year. To determine gross obligations, NASA estimates the total amount of funding required to carry out its programs during the upcoming fiscal year. Estimated reimbursements from the Department of Defense (DoD) and foreign and commercial customers are then subtracted from that amount to arrive at the anticipated funding requirements.

Three major points must be kept in mind when comparing NASA budget and shuttle cost figures:

- o Obligations incurred in one fiscal year are spent out over several years;
- o Appropriation amounts reflect anticipated gross obligations adjusted for reimbursements; and
- o Reimbursements are received over a three-year period beginning two fiscal years before the year in which the launch is to take place.

Other considerations exist, but they are not nearly as important for the purposes of this study.

The following example demonstrates the distinctions among shuttle costs, budget costs (outlays), reimbursements, obligations, and unobligated balances. The example is for the operational costs of a launch in fiscal year 1989. The figures used are taken from NASA cost projections.

Table A-1 illustrates the manner in which costs are incurred over a number of years for a particular launch. The total funding required for solid rocket boosters, for example, is requested for the first year in which funds will be needed (1988). Of the $18.9 million request, $4.6 million will be spent in 1988. This figure will show up as a cost (outlay) in the 1988 NASA budget, while the remaining $14.3 million is recorded as obligations. These obligations are carried into the next year when they are spent. The expenditures are recorded as costs (outlays) in the 1989 budget, while obligations are reduced by that amount. Table A-2 summarizes this process.

TABLE A-1. COST DATA BASE: COST OF FLIGHT IN 1989
(By fiscal year, in millions of 1982 dollars)

Costs	1987	1988	1989	1990	Total 1987-1990
Solid Rocket Boosters	--	4.6	14.3	--	18.9
External Tanks	3.4	10.9	2.2	--	16.5
Launch Operations	--	--	14.1	--	14.1
Propellants	--	--	1.1	--	1.1
Flight Operations	--	6.9	6.9	--	13.8
Orbiter Hardware	1.7	3.4	1.7	--	6.8
Crew Equipment	--	--	1.5	--	1.5
Space Shuttle Main Engine	--	0.7	0.7	0.5	1.9
Contract Admin.--	0.1	0.3	--	0.4	
Research and Program Management	--	--	7.4	--	7.4
Network Support	--	--	1.5	--	1.5
Total	5.1	26.6	51.7	0.5	83.9

SOURCE: National Aeronautic and Space Administration.

The NASA appropriation request is based anticipated net obligations to be incurred in a fiscal year. Net obligations are the difference between projected gross obligations and expected reimbursements. Reimbursement begins 36 months before the launch date and consists of six payments, the final one being made three months before the launch. Reimbursements for a launch do not coincide with the associated shuttle costs, which further blurs the relationship between budget and cost figures. In any one year, appropriations do not reflect the actual costs of a given launch, as shown in Table A-3.

TABLE A-2. OUTLAYS AND OBLIGATIONS ASSOCIATED WITH AN 1989 LAUNCH (By fiscal year, in millions of 1982 dollars)

	1987	1988	1989	1990	Total
Funding Required	23.3	35.0	25.6	--	83.9
Outlays	5.1	26.6	51.7	0.5	83.9
Obligations	18.2	26.6	0.5	--	45.3

SOURCE: Congressional Budget Office.

While costs and obligations and reimbursements eventually net out, the appropriation figure that appears in the annual budget gives no hint of what underlies it. In fiscal years 1987 and 1989, the appropriation figures imply that the cost of the launch is negative, an absurd result. This is a prime example of the problems that can be caused when unadjusted budget figures are used to evaluate shuttle pricing.

A final difficulty, though less troublesome than those already noted, is inflation. NASA sets shuttle prices for three-year periods and does so well in advance. This necessitates inflation projections using a fiscal year 1982 base. These projections almost always differ from actual inflation rates.

TABLE A-3. COSTS AND REIMBURSEMENTS ASSOCIATED WITH AN 1989 LAUNCH (By fiscal year, in millions of 1982 dollars)

	1987	1988	1989	Total
Costs and Obligations	23.3	35.0	25.6	83.9
Reimbursements a/	27.9	28.0	28.0	83.9
Appropriation Required	-4.6	7.0	-2.4	00.0

SOURCE: Congressional Budget Office.

a. Estimated reimbursement pattern of six equal payments.