Chapter 5

SPACE TRANSPORTATION

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SPACE TRANSPORTATION

INTRODUCTION

Space transportation is an industry in which the U.S. Government has acted both as the primary seller and the primary buyer. But over the last 10 years the European Space Agency (ESA) has developed the Ariane launcher, and in 1980 the corporation Arianespace was formed to market Ariane launch services. Taken together, these events have ended the U.S. monopoly in commercial launches. Now that the Space Shuttle has been certified "operational" and the U.S. Government has, for the most part, terminated its use of the present fleet of expendable launch vehicles (at least for civilian launches), private U.S. firms may take over their operation. In addition, recent activities of some small U.S. firms suggest that a new generation of low-cost, low-capacity ELVS could soon be competing in the launch vehicle market. Thus, the National Aeronautics and Space Administration (NASA) monopoly in U.S. commercial launches may be ending as well.

Although NASA and Arianespace compete for launch customers, neither has had much difficulty filling current flight manifests. However, the entry of additional launch service providers over the next 5 years could lead to a situation where launch service capacity exceeds demand. In the past, space transportation policy in the United States has focused on development of new technology. The emergence of foreign competition and the interest of the U.S. private sector in providing launch services require a reassessment of the Government's role as space transportation service provider.

This chapter assesses the challenges of international competition and the opportunities for future cooperation in the international space transportation industry. It gives additional consideration to the role the private sector may play in developing a space transportation industry based on the principles of competition and open entry.

THE SPACE TRANSPORTATION INDUSTRY

The Providers of Space Transportation Services

National Aeronautics and Space Administration

When NASA was established in 1958 it was charged with responsibility for the " . . . development and operation of vehicles capable of carrying instruments, equipment, supplies, and living organisms through space."[1] The launch vehicles that NASA developed (through contracts with private manufacturers) created the opportunity for commercial space endeavors. Until the establishment of Arianespace, NASA was the only seller of commercial launch services. The U.S. manufacturers of expendable launch vehicles (ELVs)–although they are "commercial companies"-have not sold vehicles except through NASA.

In a typical pre-Shuttle commercial transaction, the buyer would contract with NASA to launch a payload–generally a communications satellite. NASA would then contract with one of the launch vehicle manufacturers for delivery of a launch vehicle; when it was complete, NASA would integrate the payload into the launch vehicle and supervise both launch and insertion of the payload into orbit. With a fully operational Shuttle, NASA no longer needs to order individual vehicles for each of its launches; its responsibilities for launch services have otherwise remained the same.

[1] National Aeronautics and Space Act of 1958, sec. 102(c)(3), 42 U.S.C. 2451.

NASA entered into its first launch services agreement in July 1961, with American Telephone&Telegraph (AT&T) for the experimental Telstar communication satellites.[2] Under this agreement AT&T financed, designed, and built the satellites and reimbursed NASA for the costs it incurred for the launch. NASA's policy then was to recover incremental, "out-of-pocket" costs associated with the launch and not the "sunk" costs associated with the development of the vehicle or of the terrestrial support facilities. Since that time, NASA has continued to provide launch services on expendable vehicles for its own missions and, on a "reimbursable basis, " for other U.S. Government users, foreign governments, and private entities.[3] The current pricing policy for the Shuttle-although similar to the policy for ELVs—raises a number of specific problems which are discussed in detail below.

Provision of a reliable vehicle is only one element of a launch service. Launch pads must be built and special facilities must be provided for integrating the payload and the launch vehicle. Equipment and personnel must be available for tracking and control of the vehicle after launch, and pre- and post-launch safety procedures must be developed and implemented. The complex technical nature of launch services, the need for elaborate terrestrial facilities, and the high cost of operations have, until 1982, prevented any challenge to NASA's monopoly in free world space transportation services.

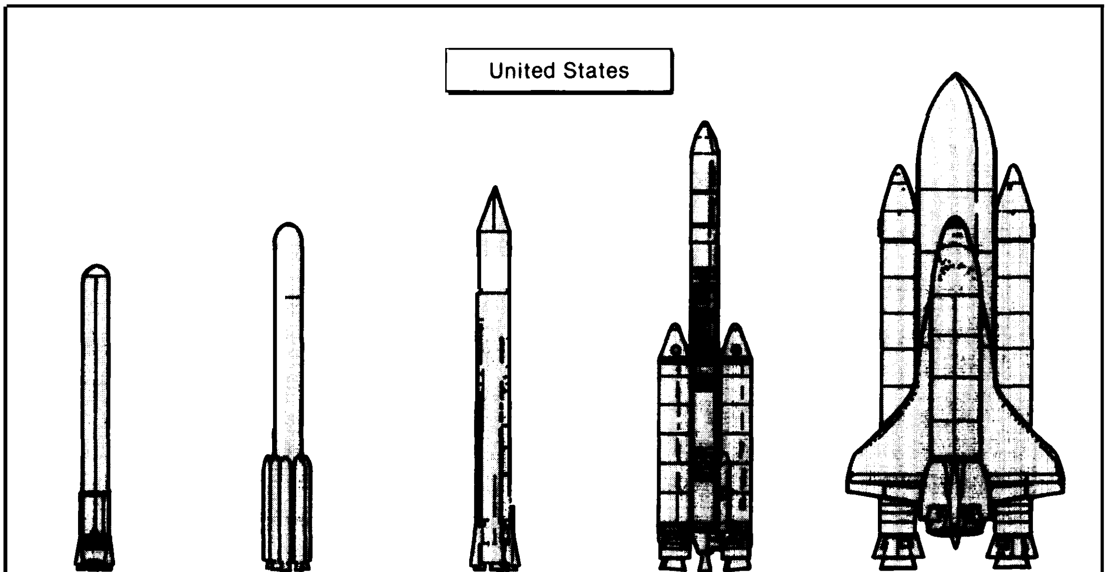
NASA has used the following vehicles to launch commercial payloads (fig. 5-1):

Delta: When NASA modified the Thor IRBM in 19s9 to produce the Delta it was thought to be only an interim launch vehicle. However, with 177 launches to date–94 percent of which have

[2]The Space Industrialization Act of 1979: hearings on H.R. 2337 before the Subcommittee on Space Science and Applications of the House Committee on Science and Technology, 96th Cong., Ist sess. p. 85 (1979) (Statement of Dr. Robert A. Frosch).

[3]Although it was NASA's policy to recover incremental, "out-of-pocket" costs in 1961, this later was changed to recovering "all reasonable costs." Launch services provided on a "reimbursable basis" implies, then, a recovery of "all reasonable costs. "

Figure 5-1.—U.S. Launch Vehicles



	Class	Scout-D	Delta 3920	Atlas-Centaur	Titan 34D	Space Shuttle
P/L Wt	LEO	440 lb	7,800 lb	12,000 lb	33,000 lb	65,000 lb
	GEO-transfe	—	2,800 lb (PAM)	5,200 lb	10,000 lb (IUS)	27,000 lb (Centaur)
	GEO-circula est	—	1,300 lb (PAM)	2,600 lb	5,000 lb (IUS)	13,000 lb (Centaur)
IOC		Operational	Operational	Operational	Operational	Operational

been successful–the Delta has become the most-used U.S. launch vehicle. The Delta has been constantly upgraded by its manufacturer, McDonnell Douglas, during its 25-year history and presently performs at nearly 30 times its original payload capacity. The Delta 3920/PAM-D, which began service in 1982, is capable of launching payloads of 2,800 pounds to geostationary transfer orbit.[4]

The Delta can be used with a two- or three-stage configuration. The first stage, or booster, is an elongated Thor missile with Castor IV solid strap-on motors. The second stage (the Delta stage) is a liquid stage with restart capability. First- and second-stage guidance is accomplished by an inertial guidance system mounted in the second stage. The Delta third stage can be a solid rocket motor with spin stabilization, or the Shuttle-compatible payload assist module (PAM) (discussed below). This interchangeability made the Delta the obvious choice as backup vehicle during the early Shuttle program. NASA no longer books satellites on the Delta, either as primary or backup vehicles. As of January 1985, there were four Delta launches left on NASA's books.

Atlas-Centaur: The Atlas-Centaur is a 2.5-stage vehicle which uses liquid oxygen and kerosene as propellants in the Atlas booster and liquid oxygen and liquid hydrogen in the Centaur upper stage.[5] Based on the Atlas ballistic missile, the Atlas rocket was first used as a space booster in 1958. NASA first used the present Atlas-Centaur configuration in 1966, to launch the Surveyor lunar-landing spacecraft. Since this time, the Atlas-Centaur has been used for low-Earth-orbit (LEO), lunar, planetary, and synchronous transfer orbit missions. This vehicle can launch 2,600 pounds to geostationary orbit (about 5,000 pounds to geostationary transfer orbit; see footnote 4) and has a 91 percent success rate with 53 launches.

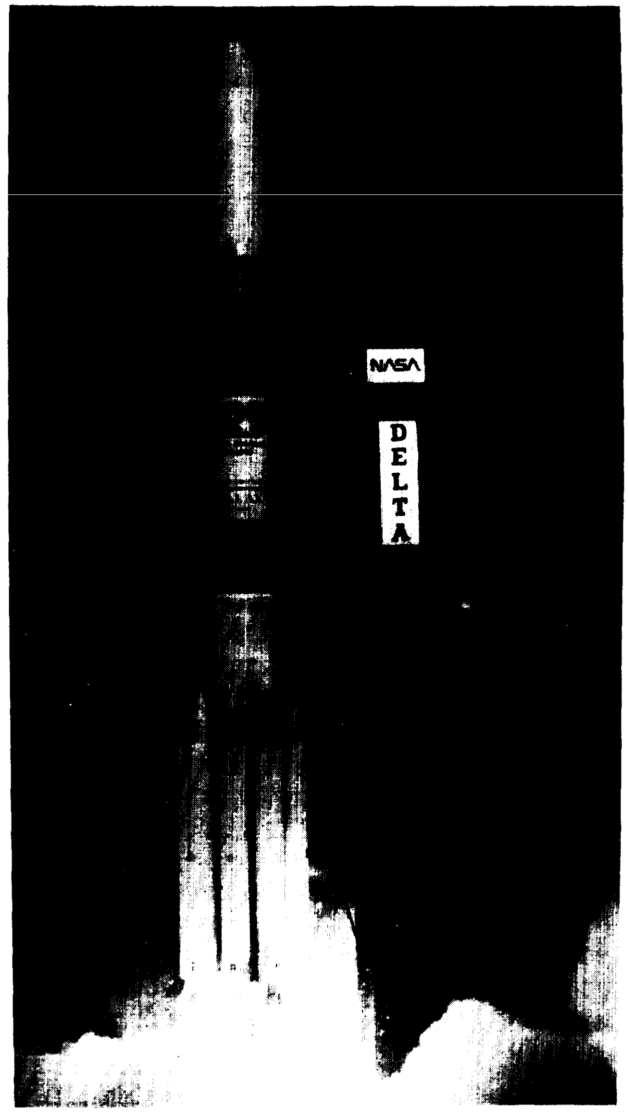


Photo credit: McDonnell Douglas

Delta Launch Vehicle

Atlas-Centaur performance was improved in 1982 to enable it to launch the INTELSAT V satellites. General Dynamics' Convair Division, the manufacturer of the Atlas-Centaur, had planned to add strap-on boosters like those used on the Delta to increase performance. In order to com-

[4] The Delta and Titan ELVs and the shuttle-PAM and shuttle-TOS combinations all require apogee kick motors; therefore in this report their capabilities are given as pounds to geostationary transfer orbit. These upper stages place about twice as much weight into geostationary transfer orbit as eventually reaches geostationary orbit. For example, the PAM-D can place about 2,800 pounds into geostationary transfer orbit, but only 1,350 pounds into geostationary orbit. The Centaur stage of the Atlas-Centaur ELV, the Shuttle-Centaur, or Shuttle/TOS-AMS, and the Shuttle-I US do not require separate apogee kick motors; the capabilities of these vehicles are given as pounds to geostationary orbit.

[5] The Atlas is referred to as a one-stage booster because it shuts down and jettisons two of its three engines during its flight. See: R. Teeter, "U.S. Capability for Commercial Launches, " AIAA Space Systems Conference, Oct. 18-20, 1982, Washington, DC, AIAA-82-1789, p. 1.

pete for smaller payloads, General Dynamics also considered developing a tandem adapter and a stretched payload shroud to allow the Atlas-Centaur to carry two Delta-class satellites or one PAM-DII or Ariane-4 class satellite. As a result of NASA discontinuation of Atlas-Centaur bookings, such modifications may depend on General Dynamics' success at marketing this vehicle commercially. As of January 1985, there were six Government-contracted Atlas-Centaur launches left.[6]

Titan: Designed by the Air Force to meet its own needs, the Titan has not, to date, been used as a commercial launch vehicle, although several firms have expressed interest in offering a "commercial" Titan launch service. The Titan has been configured in several different ways since the vehicle was first manufactured under contract by Martin Marietta in 1955. One of its current configurations, the Titan IIIC, is a three-stage solid-and-liquid-propellant launch vehicle. Its central core is composed of two liquid stages. Two 120-inch-diameter, solid-propellant motors are added as an "O stage. " The final or third stage, called the transtage, contains an inertial guidance system and altitude control system. The transtage has a multistart capability and provides the propulsive maneuvers for achieving a variety of circular and elliptical orbits. Titan IIIC can launch multiple payloads to the same or different orbits on the same launch and can place about 6,000 pounds into geosynchronous transfer orbit.

The Titan IIID is a two-stage solid-and-liquid-propellant launch vehicle. it is essentially a Titan IIIC with the transtage removed. This vehicle was designed to launch heavy, low-altitude payloads for the military. It can place about 30,000 pounds into LEO.

The Titan 34D, (considered for possible commercial use) is similar to the Titan IIIC and can use the transtage, the Boeing inertial upper stage (IUS, discussed below), the Centaur, or the TOS/AMS upper stages (discussed below). As a result, the Titan 34D can be used as a backup vehicle for Shuttle upper stage payloads. It is capable of launching about 4,0OO pounds into geostationary orbit.

ELV Derivations: The Air Force has announced plans to purchase a fleet of 10 ELVs as a backup and/or complement to the Shuttle fleet.[7] General Dynamics and Martin Marietta each received contracts to study a larger launcher based, respectively, on the Atlas and the Titan. The Air Force declared the Titan-derivative the victor in this initial competition; in a second round, undertaken at the insistence of NASA, the Air Force recommended the Titan-derivative over the proposed SRB-X, an ELV based on Shuttle hardware.[8] These possible derivations are mentioned because, when developed, a commercial version could very well emerge.

Shuttle? The Shuttle is the world's first partially reusable, manned, launch vehicle. The prime contractor is Rockwell International. The Shuttle system consists of an orbiter with 3 liquid-fuel engines, two solid rocket boosters and a large external fuel tank (ET). The orbiter is about the size of a DC-9 jet and carries both the crew and payload, When fully developed it will be able to place 65,000 pounds into low-Earth orbit (LEO) and return payloads up to 32,000 pounds,

The Shuttle is launched by the combined firing of the liquid fuel engines on the orbiter (which are fed by the ET) and the solid rocket engines. The solid rocket casings are parachuted back to Earth and land in the ocean to be recovered and reused. On all Shuttle flights to date or planned, the ET, when nearly empty, is released just before orbital insertion so as to be destroyed on its reentry trajectory by atmospheric friction. However, one or more ETs may eventually be orbited as components of (or raw materials for) permanent LEO infrastructure.[10]

6 Ibid. Of the six satellites manifested on Atlas-Centaur, three are U.S. Navy Fltsatcoms and three are INTELSAT VA communication satellites.

7 "Commercial ELV Competition Planned by Air Force, " *Aerospace Daily*, Feb. 22, 1984, p. 289.

8 *Space Business News*, Jan. 14, 1985, p. 1; see also 'presidential Directive Expands U.S. Space Launches Spectrum, " *Aviation Week and Space Technology*, Mar. 4, 1985, pp. 18-20.

9 See generally: H. Allaway, "The Space Shuttle At Work," NASA, Washington, DC, 1979, NASA SP-432.

10 *Civilian Space Stations and the U.S. Future in Space* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-STI-242, November 1984), pp. 77-82.

Multiple payloads–e.g., communication satellites, the ESA-developed Spacelab, or various experimental pallets–can be carried in the Shuttle's 15 x 60-foot cargo bay. '[11] When in orbit, payloads can be lifted out of or hauled into the cargo bay by the remote manipulator. This 50-foot robot arm was designed and built by Spar Aerospace under contract to the National Research Council of Canada.

Shuttle Upper Stages: The Shuttle carries its payloads only to low-Earth-orbit; to reach the higher orbits in which most communication satellites are placed an additional upper stage must be used. McDonnell Douglas manufactures one upper stage family called the payload assist module (PAM).[12] There are currently two versions of this stage designed to place payloads into geostationary transfer orbit; PAM-D, which has a capacity of 2,800 Ibs, and PAM-DI 1, which has a capacity of 4,0OO Ibs.

The PAM-DII is used only with the Shuttle, while the PAM-D can be employed either with the Shuttle or as the final stage of a Delta.[13] For Shuttle use, each system has an expendable stage consisting of a spin-stabilized solid rocket motor, spacecraft fittings, and the necessary timing, sequencing, power, and control assemblies. Also required is a spin system to provide stabilizing rotation, a separation system to release and deploy the stage and spacecraft, and the necessary avionics to control, monitor, and power the system. A cradle structure is also necessary to hold the PAM and its spacecraft in the Shuttle bay.

The cost of a PAM-D upper stage system is approximately $7 million to $8 million (1984 dollars) for a launch in 1987.[14] Costs may vary depending on whether it is a first or a repeat launch for a customer, because initial launches require additional preparation such as structural analysis. As of January 1985, a total of 26 PAM upper stages have been launched. With the exception of the 17th and 18th launches, all were successful.Is

Photo credit: National Aeronautics and Space Administration

Shuttle launching Satellite Business Systems communication satellite. PAM upper stage is attached below satellite.

Another upper stage, the inertial upper stage (I US), was developed by Boeing, primarily for the Air Force.[16] The I US, when used with the Shuttle, should be able to place about 5,000 pounds into geostationary orbit. It is a two-stage solid-propellant, three-axis-controlled, inertially navigated upper stage. The I US was designed originally as an interim vehicle that would bridge the gap between existing expendable upper stages and the reusable space tug desired by NASA. When it became apparent that the space tug would not be developed in the foreseeable future, the "interim

11 The Shuttle is large and powerful enough to hold five Delta-class satellites. However, due to center-of-gravity problems, and limitations imposed by tracking facilities and the insurance market, it is unlikely that the Shuttle will carry more than three or four satellites at one time.

12 Also referred to as the spinning solid upper stage or SSUS. See generally, "Using the Space Shuttle," Rockwell International, 1982, p. 12.

13 E.H. Peterson and R. J. Thiele, "PAM Commercial Upper Stages for Space Access, " (Huntington Beach, CA: McDonnell Douglas Astronautics Co., August 1982), MDAC Paper G8920, p. 1-2.

14 "McDonnell Douglas Sees 50 PAM-Ds Sold by 1990," *Aviation Week and Space Technology,* June 25, 1984, pp. 169-171.

15 Ibid.

16 E. L. Bangsund, "IUS Status and Growth Potential, " Boeing Aerospace, Headquarters Space Division, 1982, IAF-82-05.

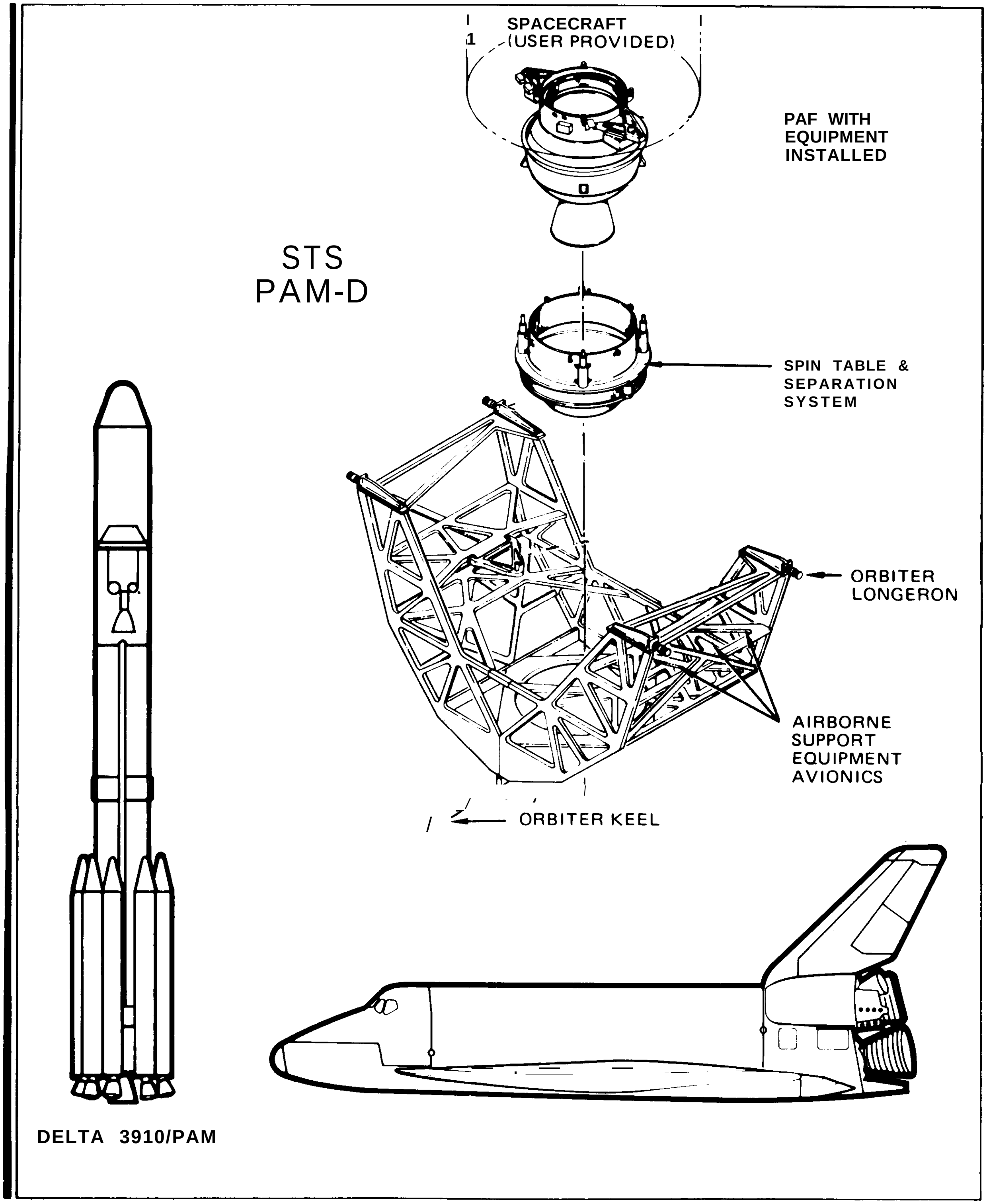


Photo credit: National Aeronautics and Space Administration

The PAM-D was designed to be compatible with both the Shuttle and the Delta in order to provide a backup capability for early Shuttle missions.

upper stage" gradually evolved into the present "inertial upper stage." The IUS can be used on the Shuttle or the final stage of the Titan 34D. NASA plans to use the IUS only to launch the Tracking and Data Relay Satellite System (TDRSS) satellites, after which it will rely on the Centaur upper stage. The Air Force will continue to use the IUS for its launches at an estimated cost of $60 million per flight.

The Centaur G and G-prime upper stages are wide-body derivatives of the upper stage of the expendable launch vehicle, the Atlas-Centaur.[17] These upper stages are under development by General Dynamics for NASA and the Air Force. The Centaur G will be capable of placing about 10,000 pounds into geostationary orbit from the Shuttle. The Centaur G-prime is to be used on the International Solar Polar Mission, and for the Galileo Jupiter probe, both planned for 1986. This stage will be capable of placing about 14,000 pounds into geostationary orbit.

Believing that the IUS would be too expensive for commercial users and that the PAM-D and DII are too small for the large communication satellites of the late 1980s, a private corporation, Orbital Sciences Corp., is working on an upper stage called the Transfer Orbit Stage (TOS).[18] The TOS would be able to place about 13,000 pounds into geostationary transfer orbit and is less expensive than the IUS. The prime contractor for the TOS is Martin Marietta.

Orbital Sciences Corp. also plans to offer an Apogee and Maneuvering Stage (AMS); a bipropellant propulsion module which, depending on the weight of the payload and the desired orbit, will operate independently of, or with, the TOS. OSC intends to charge about $30 million to launch IUS-class payloads.[20]

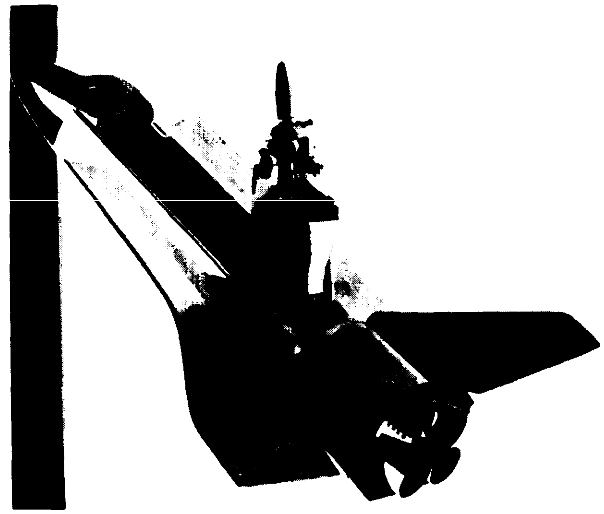


Photo credit: National Aeronautics and Space Administration

Artist's conception of the proposed Shuttle launched Centaur Inertial Upper Stage

Aerojet Tech Systems is also undertaking development, with in-house funds, of a high-performance, all-liquid upper stage, called the Liquid Propulsion Module (1PM). The basic model is tailored for launching up to 3,500 pounds to geostationary orbit; by using tandem stages it would be capable of launching up to 8,500 pounds to geostationary orbit. Aerojet's goal is to offer this stage commercially by 1987 for $10 million. Its engine is derived from the Shuttle Orbit Maneuvering System Engine.

Astrotech Space Operations is another firm interested in entering the IUS-class upper stage market for commercial and military payloads. Astrotech and its prime contractor, McDonnell Douglas, hope to develop a liquid-propellant upper stage (Delta Transfer Stage) capable of placing as much as 7,500 pounds into geosynchronous orbit or 20,000 pounds into geosynchronous transfer orbit. The Delta stage, as currently envisioned, would be Shuttle- and Titan-compatible and would cost in excess of $30 million.[21]

[17] E. H. Kolcum, "NASA Weighs Greater Role for Centaur," *Aviation Week and Space Technology*, July 25, 1983, p. 60.

[18] D. Dooling, "Business Graduates Plan New Shuttle Stage," *Space World*, March 1983, p. 29.

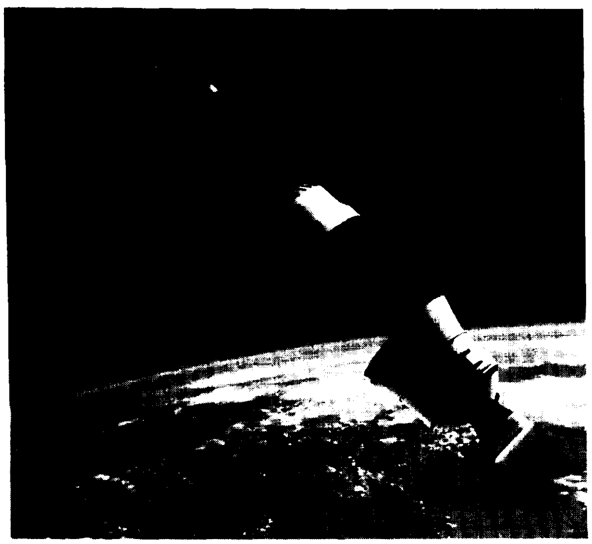
[19] The TOS was fully financed by a $50-million R&D limited partnership, the largest private financing of any commercial space endeavor to date.

[20] "Orbital Sciences Offers Upper Stages," *Aviation Week and Space Technology*, June 25, 1984, pp. 108-113.

[21] "Astrotech Sees Military Uses for Stage," *Aviation Week and Space Technology*, June 25, 1984, p. 158.

Photo credit: Boeing Co.

IUS and attached tracking and data relay communications satellite being launched from the Shuttle.



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Arianespace

Since the early 1960s, Europe has attempted to mount a coordinated space program to ensure European participation in the economic, scientific, and political benefits of space activities and to compete with the United States and the Soviet Union. The latest and most successful organization is the European Space Agency (ESA), which was founded in 1975.[22] ESA inherited the programs and facilities of its predecessor organizations, the European Space Research Organization (ESRO), the European Launcher Development Organization (ELDO), and the European Space Conference (ESC).[23] ESA'S most important launch program to date has been development of the Ariane vehicle.

Ariane 1 is a three-stage ELV with an advanced liquid-oxygen/liquid-hydrogen third stage. This vehicle was only the first in a series of as many as five models; successive designs will improve payload capacity and performance through the 1980s. With Ariane 2 and 3 already operational, the ESA member states have approved a program to develop Ariane 4 as well as the HM-60 engine, an essential component of the Ariane 5.[24] Ariane 1 is capable of placing about 3,800 pounds into geostationary transfer orbit, Ariane 2, about 4,400 pounds, Ariane 3, about 5,200 pounds, and Ariane 4, about 9,200 pounds. With the successful launch of an Ariane 1 on May 23, 1984, the Ariane vehicle entered into commercial service (see table 5-1). Previous flights had been developmental (LO1 -L04) and promotional (L5-V8). The first Ariane 3 was successfully launched on August 4, 1984. The first flight of Ariane 4 is expected in 1986. A variety of designs for Ariane 5 are being debated, including a manned Shuttle-type system called "Hermes" (fig. 5-2).

Using a dual launch system, the Ariane is capable of carrying two payloads on each flight. Launches are made from the French-owned, ESA-funded Kourou spaceport in French Guiana, South America. Currently, the one pad at Kourou will allow only five or six flights a year; a new

[22]ESA has 11 full members—Belgium, Denmark, France, West Germany, Ireland, Italy, the Netherlands, Spain, Sweden, Switzerland, and the United Kingdom–and three associate members-Austria, Canada, and Norway. (See ch. 3 for a discussion of ESA.)

[23] For a description of European space activities prior to and following the formation of ESA, see: *Civilian Space Policy and Applications* (Washington, DC: U.S. Congress, Office of Technology Assessment, OTA-STI-177, June 1982).

[24]Gibson, Roy, "Europe-Towards a New Long-Term Programme," *Space Policy* (1: 1), February 1985, p. 5.

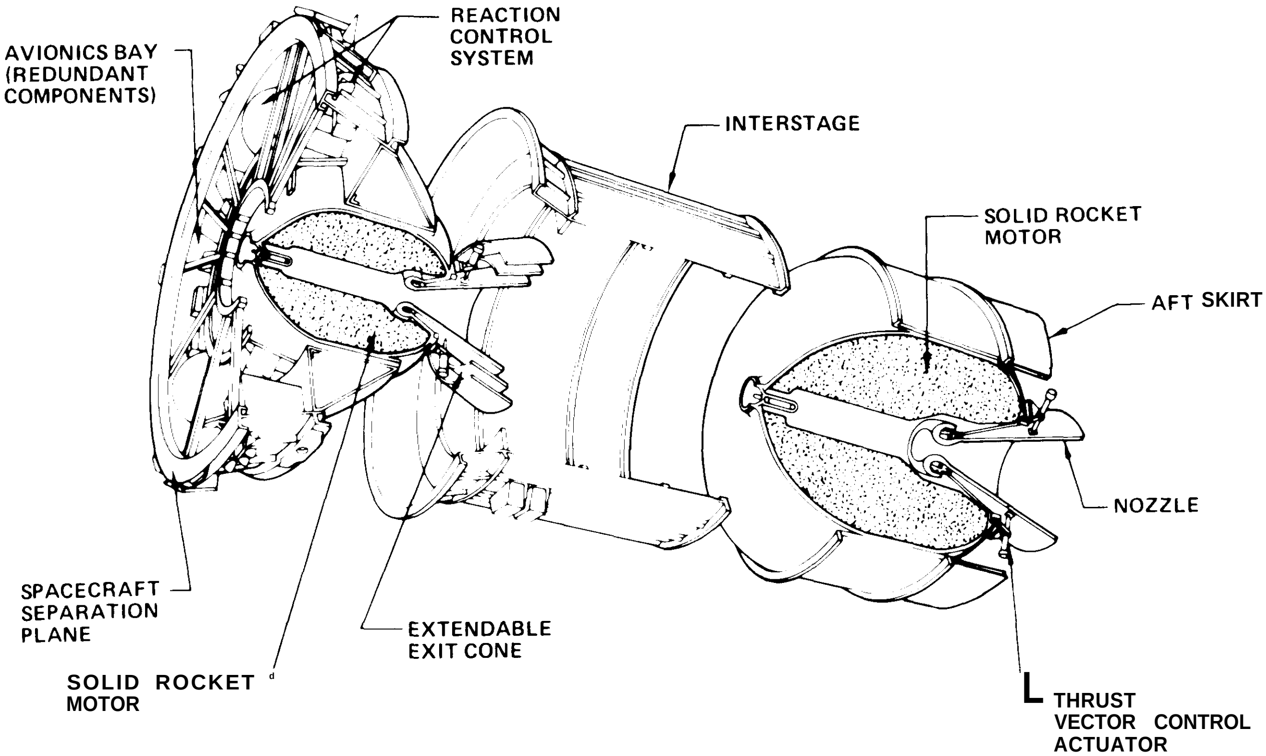

Photo credit; Boeing Co.

Inertial Upper Stage

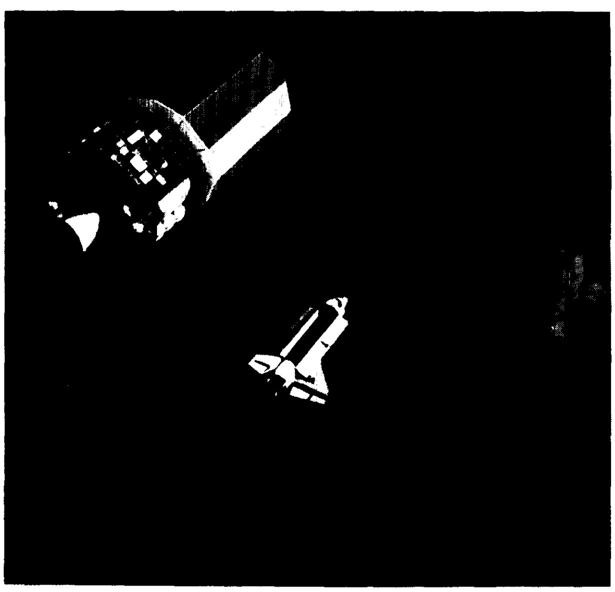

Photo credit: McDonnell Douglas

Artist's conception of Delta Transfer Stage

pad in 1985 will allow about 10 annual au riches. As of January 1985, there have been 1 Ariane launches, of which two have been fain res (table **5-1).**

Realizing that commercial operations would be difficult if the 11 ESA nations had to agree unanimously to every business decision, ESA and CNES (the French national space program) established a quasi-private corporation called Arianespace to produce, finance, market, and launch Ariane vehicles. ESA and CNES remain responsible for development of future Ariane vehicles and for operation of the Guiana spaceport. Arianespace S.A. is incorporated in France (March 1980) and owned by firms from the states that funded Ariane's development, by CNES, and by European banks. French investors (including CNES, which is the largest single shareholder with 34 percent) own 60 percent; West German investors own 20 percent; and the remainder is split

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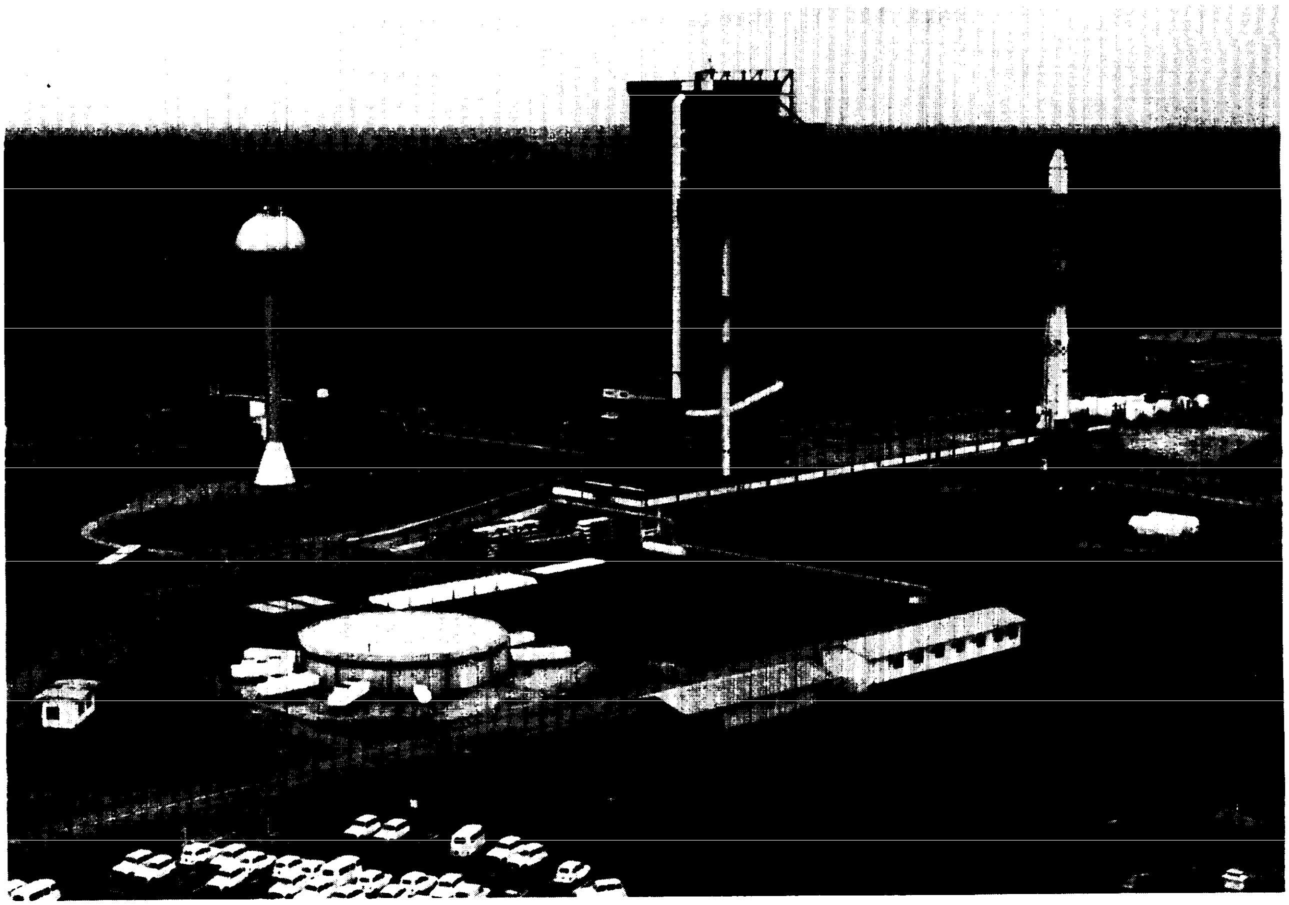


Photo credit: European Space Agency

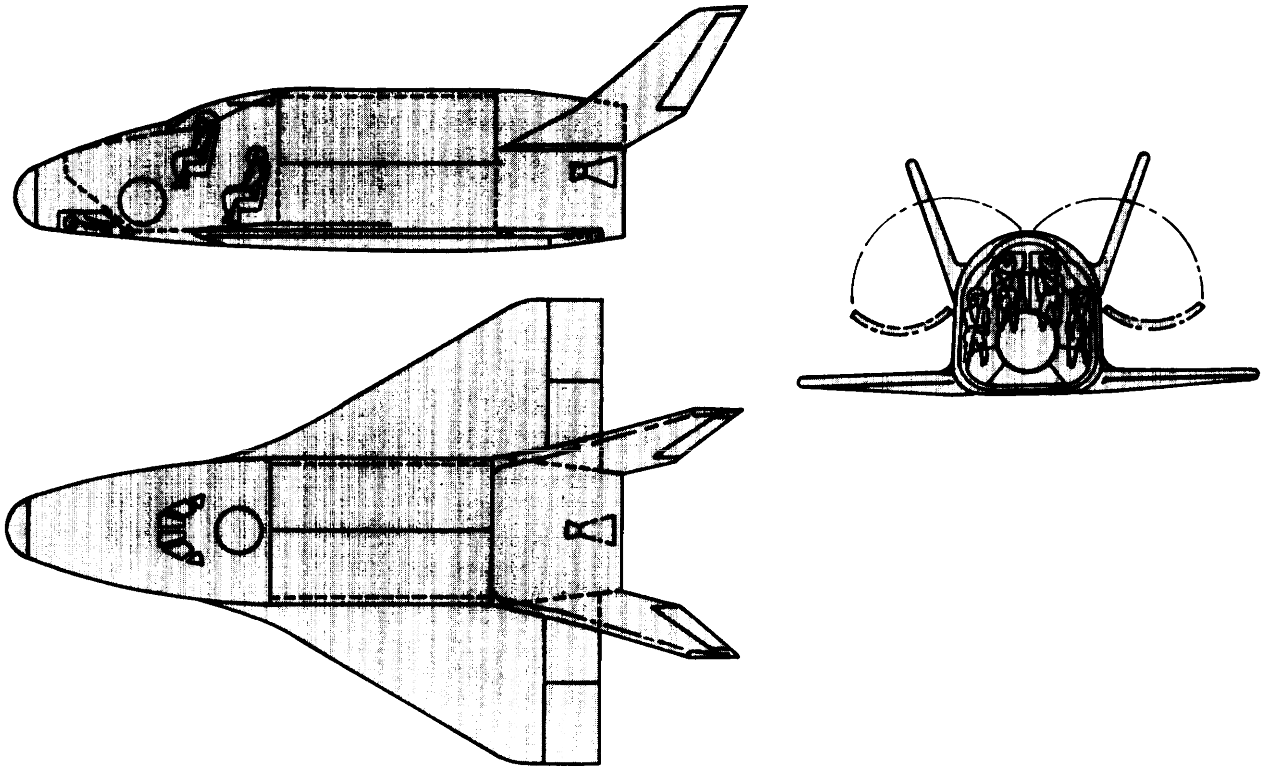
Ariane L1 on ELA1

Table 5-1.—Ariane Flights

Flight reference	Date	Launcher	Payload	Comments
Development flights:				
LO1	**Dec. 24, 1979**	**AR 1**	**Technological Capsule (CAT)**	**Success**
L02	**May 23, 1980**	**AR 1**	**AMSAT-FIREWHEEL**	**Failure (Viking engine instability)**
LO..	June 19, 1981	**AR 1**	**CAT + APPLE + METEOSAT**	**Success**
LO..	Dec.20, 1981	**AR 1**	**CAT + MARECSA**	**Success**
Promotion flights:				
Lo.	**Sept** 10, 1982	AR1 (SYLDA)	**MARECSB/SIRIO**	**Failure (third-stage Turbo pump)**
Lo.	**June 16, 1983**	**AR1 (SYLDA)**	ECS-1/OSCAR	**Success**
L7.	**Oct. 19, 1983**	**AR1**	INTELSATV-F7	**Success**
V8	**Mar.5, 1984**	**AR1**	INTELSATV-F8	**Success**
Arianespace commercial *flights:*				
V9	**May23, 1984**	**AR1**	SPACENET1	Success
Vlo	**Aug.4, 1984**	**AR3(SYLDA)**	ECS-2/TELECOM 1A	Success
VII	*Nov.* **10, 1984**	**AR3**	SPACENETF21MARECS 62	Success
V12	**1985**	**AR3(SYLDA)**	ARABSAT/SBTS-I	—

SOURCE" Arianespace, Inc

Figure 5=2.—The Hermes Spaceplane (conceptual design)



SOURCE: CNES

among the other ESA nations, A U.S. subsidiary (Arianespace, Inc.) was chartered in November 1982.

Potential Government Sellers

A number of countries have, or are developing, launch vehicles which would enable them to enter the launch vehicles market (figs. 5-3a and 5-3 b):

SOVIET VEHICLES[25]

The Soviets have developed a number of expendable launch vehicles; the most commonly used is the Sapwood-A launcher, a derivative of an ICBM design dating back to the mid-l950s. As presently modified, the Sapwood-A can launch Soyuz manned vehicles of about 15,000 pounds to low-Earth-orbit. The larger Proton-D launcher can carry about 44,000 pounds to low-Earth-orbit and has been used to launch the Salyut space stations. Recent reports indicate that the Soviets are developing both a Saturn-class vehicle capable of placing 300,000 pounds into low-Earth-orbit and a reusable space vehicle similar to the Shuttle.[26]

Although the Soviets have long had a reliable fleet of launch vehicles they have only recently

[25]The Soviet Union does not name or identify its launch vehicles. Soviet surface-to-surface missiles are assigned numbers with the prefix SS by the U.S. military. When such missiles are seen often enough to be identified by military branches of the NATO powers, code names such as Sandal, Skean, or Sapwood are assigned. (The Proton, not having been developed as a missile, does not have an SS or code-S designator.) In order to convey more information about the Soviet vehicle and its various stages, TRW developed the system of using capital letters for the first stage, numbers for the upper stages and small letters for the final stage. Both the letter and code designators are used here. For a detailed discussion of Soviet launch activities, see: *Soviet Space Programs, 1971-1975,* Staff Report for Senate Committee on Aeronautics and Space Sciences, Congressional Research Service, August 1976.

[26]" Soviets Said to Remove Camouflage Nets From New Launch Vehicles," *Aerospace Daily,* Dec. 14, 1983, p. 227; See also: D. Doder, "Soviets Say They Plan to Build Space Shuttle," *The Washington Post,* Dec. 13, 1983, p. A 10, c. 1; See also, "Soviets Ready New Boosters at Tyuratam," *Aviation Week and Space Technology,* Aug. 27, 1984, pp. 18-21.

Photo credit: *Ariane*

Kourou, French Guiana V1O launch, August 4, 1984. Arianespace/ECS-2 Telecom 1-A

made an attempt to enter the international launch services market. In June 1983, the Soviets requested that their Proton launcher be considered as a candidate to orbit INMARSAT's second-generation communication satellites.[27] At the time of the Soviet announcement, the other candidate launch vehicles were the Shuttle, Ariane, Atlas-Centaur, Delta, and Titan. The INMARSAT council accepted the Soviet request and informed its satellite contract bidders that they must design their spacecraft for compatibility with at least two of the six launchers and that one of their selections had to be the Proton, Shuttle, or Ariane.[28]

[27] J. M. Lenorovitz, "INMARSAT Adds Proton to Booster List," *Aviation Week and Space Technology,* Aug. 1, 1983, p. 16; see also, "Soviets Provide Data to Guide INMARSAT in Launcher Decision," *Aviation Week and Space Technology,* Aug. 8, 1983. p 22. It should be noted that the Soviet Union is a member of INMARSAT (see chs. 3 and 6).

[28] *Aviation Week and Space Technology,* Aug. 1, 1983, p. 17.

The Soviets have quoted a launch price of approximately $24 million (current year dollars) for the Proton; this is less than the price of either the Space Shuttle or the Ariane.

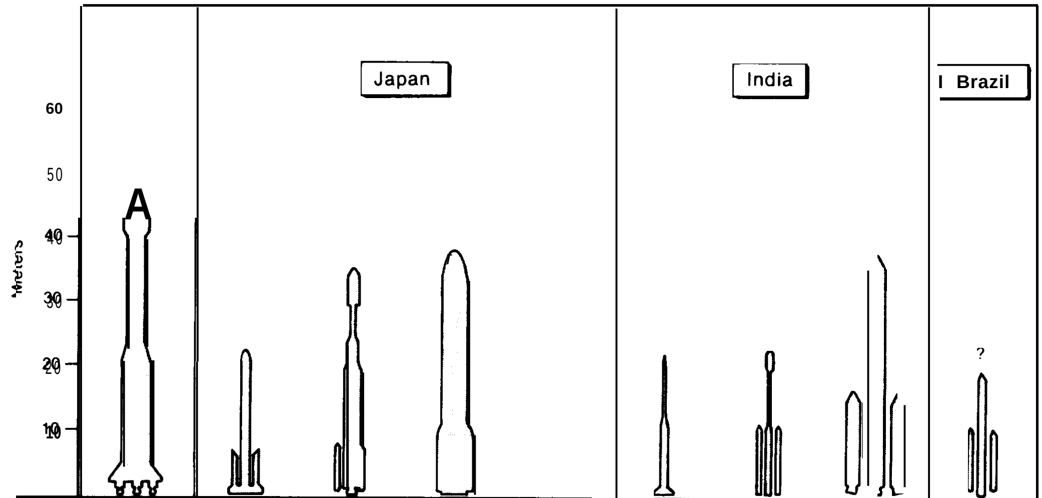
Soviet willingness to specify the launch site (Tyuratam) and to provide technical data concerning the Proton suggests that they are serious about the INMARSAT offer. It seems unlikely that a more general entry into international launch vehicle competition will be forthcoming. Although the Soviets possess the technology to compete with NASA and Arianespace or with U.S. commercial firms, they will probably never become an important provider of commercial launch services: first, the Soviets would have to allow Western scientists and businessmen to supervise the assembly, testing, integration, and launch of their satellites; second, it is unlikely that the United States, or any Western government, would allow sophisticated communication satellites to be exported to the Soviet Union; and third, it is unclear whether financing and insurance could be obtained for a Soviet launch.

JAPANESE LAUNCH VEHICLES

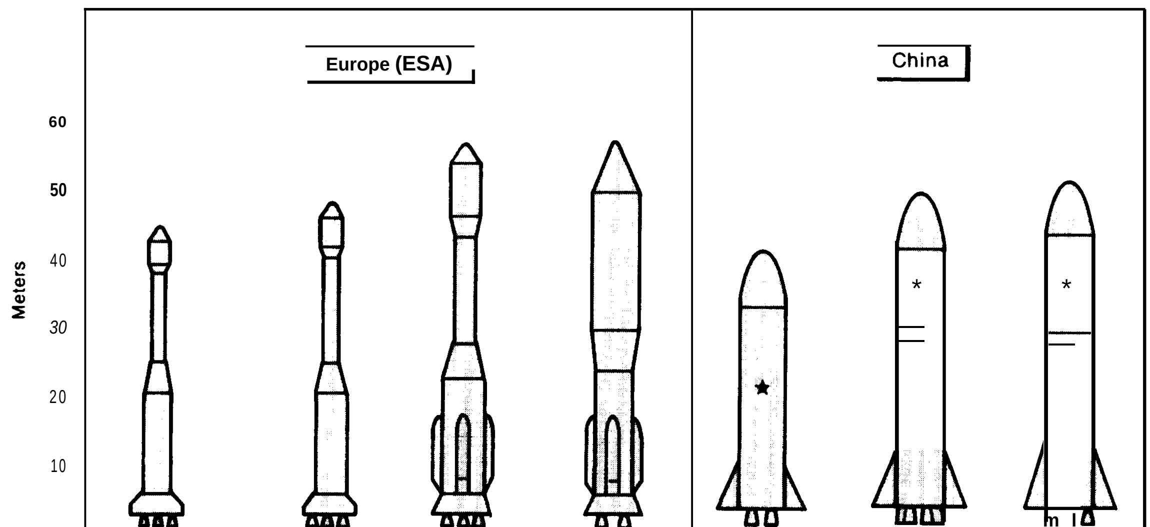
Beginning in the late 1950s and through the 1960s, the Institute of Space and Aeronautical Sciences (ISAS), developed the Kappa and Lambda series of solid-fuel sounding rockets, which were used for Japanese scientific and applications experiments. The difficulties of rocket development were exacerbated by inadequate guidance and stabilization technology, the result in part of a self-imposed reluctance to fund technologies that might be perceived as having military applications. ISAS went on to develop orbital rockets; the first successful 50-pound test satellite was launched by an advanced Lambda in February 1970. The Mu-class orbital launcher achieved its first success in 1971 and continues to be operated by ISAS from its Kagoshima test range. Nissan Motors is currently designing an advanced version of the Mu, the M-3-kai-l, which will be used for Japan's first planetary exploration missions in the mid-1980s, including a planned Halley/Venus mission in 1985.

In 1969, the National Space Development Agency (NASDA), assumed primary responsibility for launcher development for applications satel-

Figure 5-3.—Foreign National Comparative Launch Vehicle Development



Class	(Reference) Ariane 2/3	M	N-1/2	H-I	H-II (Ariane Class)	SLV-3	ASLV	PSLV	SOND IV
P/L wt LEO		660 lb			(?)	80-100 lb	300 lb	1,300 lb	440-660 lb 450 ml
P/L wt GEO		—	250-500 lb	1,200 lb	(?)	—	—	—	
IOC		Operational	Operational	1985	1990's	)peratlonall	1982	1988	1990's



Class	Ariane 1	Ariane 2/3	Ariane 4	Ariane 5	CSL-1	CSL-2	CSL-3
P/L wt LEO	4,000 lb	5,000 lb	30,000 lb	(?)	370 lb	2,600 lb 95 mi	
P/L wt GEO	3,600 lb	4,400-5,200 lb	9,200 lb	(?)			860 lb
loc	Operational	Operational	1985	1990-1994	Operational	Operational	1985

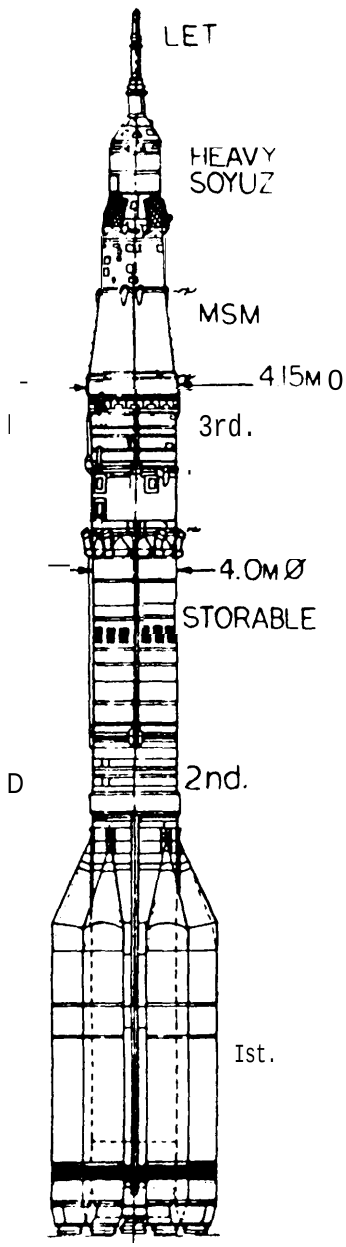


Photo credit: C. P. *Vick*©

Soviet launcher

lites. Instead of attempting to develop further versions of the Mu launcher, NASDA decided to purchase U.S. Delta launcher technology. The U. S.-Japanese Agreement on Space Activities, signed on July 31, 1969, gave Japan access to this technology (subject to certain limitations, which are discussed below). As a result, Japan developed the N-1 launcher, which is capable of lifting over 500 pounds into geostationary transfer orbit. The N-1 consists of a Thor first stage, built in Japan by Mitsubishi Industries under license to McDonnell Douglas, a Japanese-developed liquid-fuel second stage, and a U.S. Thiokol third stage. Approximately 67 percent of the **N-1** is supplied by Japanese firms.

A more powerful version, the N-11, had its first successful test flight in February 1981, and is capable of lifting about 1,500 pounds into geostationary transfer orbit. The major differences from the N-1 are use of additional solid-fuel strap-on boosters and replacement of the Japanese-designed second stage by an improved version of the Aerojet-General (U. S.) second stage used on the Delta. As a result the Japanese contribution to the N-11 is only 56 percent. For the late 1980s and the 1990s, the Japanese have a new booster, the **H-1,** under development. The major innovation is a planned liquid oxygen-liquid hydrogen second stage to be built by Mitsubishi. The initial version of the H-1 will be able to place about 2,400 pounds into geostationary transfer orbit; a recently funded follow-on version, the H-11, will have even greater capacity (in the early 1990s).2'3 The H-1 will use an inertial guidance system instead of the radio guidance of the N-1 series.

The Japanese have not announced plans to offer commercial launch services. At present, Japanese launch capabilities are restricted not only by technology, but also by agreements with the Japanese fishing industry which allow missiles to be fired only at two times of the year, January-February and August-September. In addition, the U.S.-Japanese agreements which cover the transfer of Delta technology prevent its transfer to third

[29] "Japan Funds Launcher, Satellite Development," *Aviation Week and Space Technology,* Feb. 13, 1984, p. 125.

countries or its use for launching third-country payloads. The H-11 launch vehicle, which will be designed and built entirely with Japanese technology, will not be similarly restricted.

CHINESE VEHICLES

The Peoples Republic of China's (PRC) launch technology has been derived from the Soviet Union, primarily the SS-4 (Sandal) medium-range liquid-fueled missile. The design for these missiles was given to the Chinese in the late 1950s before relations between the two countries deteriorated.

The Chinese launched their first satellite, the 380-pound China 1, in April 1970, with a CSL-I (Long March 1) launcher. Starting with China 3 in 1975, launches were made with the FB-I (Storm) vehicles, a version of the CSS-X-4 ICBM, which is equivalent in size to the U.S. Atlas. The FB-1 can launch about 2,600 pounds into low-Earth-orbit.

The Chinese are known to be working on a new launcher, the Long March 3, that would use the two stages of the FB-1 plus a liquid oxygen-liquid hydrogen upper stage. If successful, this would make them third in the world, after the United States and ESA, to use high-energy cryogenic fuels. The Long March 3 would be capable of launching about 3,080 pounds into geostationary transfer orbit.

China is planning to accelerate its international cooperative efforts in space, and it has announced that it is ready to discuss Long March launch services with interested customers .30

INDIAN LAUNCH VEHICLES

India began to work on its first launch vehicle, the SLV-3, in 1973. It is is a four-stage, inertially guided, solid-propellant rocket designed to lift 80 to 100 pounds to low-Earth-orbit. The SLV-3 successfully launched a 75-pound RS-1 technology demonstration satellite in July 1980.

The Indians are developing the ASLV, which will be able to lift about 300 pounds into low-Earth-orbit. The first launch of the ASLV is planned for 1985 or 1986. The ASLV will continue to use solid propellant for the main motors, as does the SLV, but will have two solid-propellant strap-on boosters. The PSLV, a vehicle planned for development in the late 1980s or early 1990s, will be similar to the ASLV but may use the Viking engine (currently used on the Ariane) as its second stage and will be able to launch 1,300 pounds into low-Earth-orbit. Long-term plans call for development of a SPSLV capable of low-Earth-orbit launches of 7,50O pounds. It is unlikely that India will be able to compete with NASA or Arianespace in the next two decades.

BRAZILIAN VEHICLES

Brazil has developed a family of solid-propellant sounding rockets called the Sonda; the latest of these—the Sonda Ill—is a two-stage rocket which can carry payloads of about 130 pounds to altitudes of 380 miles. Several variants of the Sonda are now operational and regularly used for meteorological observation and atmospheric testing. Although these rockets lack the power to place a satellite into orbit, current plans call for development of more powerful boosters.

Potential Non-Government Sellers

U.S. PRIVATE SECTOR ACTIVITIES

Three types of private sector launch activities are currently under way in the United States: firms which want to market one of the existing ELVS (Delta, Atlas-Centaur, or Titan), firms which want to develop new, low-cost expendable launch vehicles, and those marketing upper stages for use with the Shuttle.

When NASA announced in 1983 that it was seeking private sector operators for the Delta and the Atlas-Centaur, five firms expressed interest in marketing these vehicles.[31] However, when NASA published its official solicitation for proposals, only two companies responded with firm offers. General Dynamics' Convair Division, the current manufacturer of the Atlas-Centaur, was the only company to express interest in that vehicle. Transpace Carriers, inc., was the only company to re-

[30] "China Offering Space Launch Services to International Users," *Aviation Week and Space Technology,* Apr. 8, 1985, p. 25.

J' "Five Firms Seek NASA ELVs," *Space Business News,* July 18, 1983.

quest the right to operate the Delta line. McDonnell Douglas Astronautics, the manufacturer of the Delta, did not bid on this vehicle.

The Titan was not included in the NASA solicitation because it is an Air Force vehicle. Prime contractor Martin Marietta has expressed interest in marketing the Titan as a military backup for the Shuttle.

Several private U.S. companies are developing small expendable launch vehicles. Most notable are Space Services Inc. (SS1) of Houston, TX, and Starstruck, Inc. (formerly Arc Technologies) of Redwood City, CA.

[n September 1982, SS1 flew a successful suborbital flight of its Conestoga 1 vehicle, demonstrating payload spin-up and separation capabilities. This vehicle was an adaptation of the Minuteman 1 second-stage motor and did not have the ability to achieve orbit. The Conestoga II being developed by SS1 will be able to place small payloads into low-Earth-orbit. The Conestoga II will be a multistage vehicle based on the Thiokol solid-rocket motors presently used as strap-ens for the Delta.[32] [33]

Starstruck is presently developing a hybrid solid/liquid-fueled rocket engine for its Dolphin launch vehicle, which may be launched from the open seas.[34] In June 1983, Starstruck successfully tested key propulsion and electronic systems, and in August 1984 conducted a successful test launch. Eventually, Starstruck hopes to
in the market for geosynchronous payloads 1,300 to 1,500 pounds.[35] However, the company has had major financial, technical, and organizational problems recently and it is not clear that it will remain in business. [36]

As discussed above, there are five families of Shuttle upper stages either existing or under development in the United States—PAM, I US, Centaur (under development), TOS (under development), and the Delta Transfer Stage. Although it is possible that any of these might be sold commercially, only the PAM (McDonnell Douglas), the TOS (Orbital Sciences Corp./Martin Marietta), and the Delta Transfer Stage (Astrotech, McDonnell Douglas) were developed as private initiatives. The I US was developed for the Air Force by Boeing, and the Centaur is being developed under a joint NASA-Air Force contract by General Dynamics. There might be little competition between these upper stages because they are designed to serve different weight classes of satel-

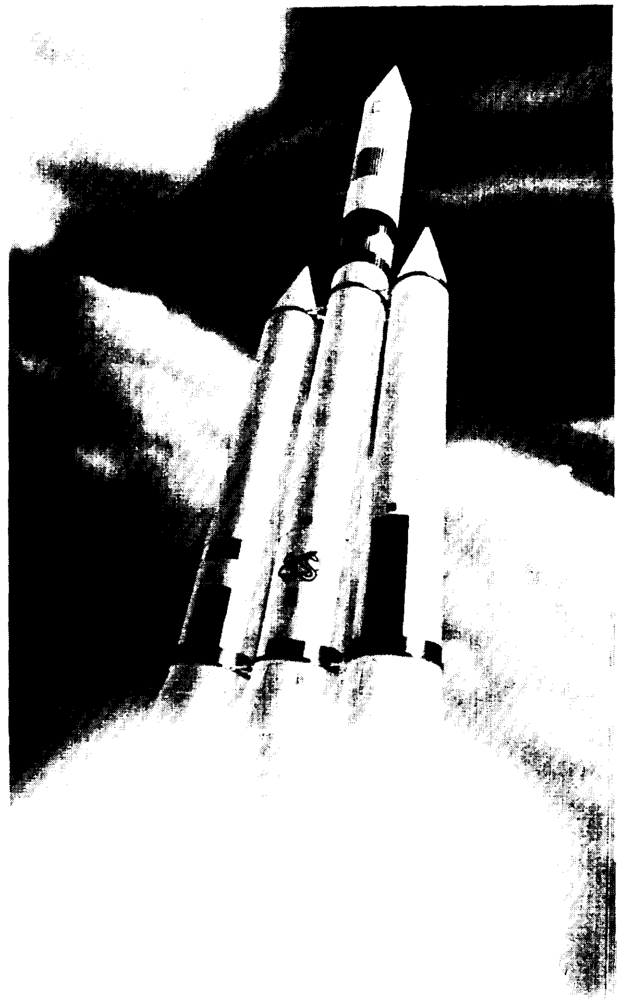


Photo credit: Space Services Inc.

Artist's depiction of SS1's Conestoga II

[32] Space Services Inc., press release, Sept. 8, 1983. See also, "SSI Selling Conestoga 1-6," *Space Business News,* Aug. 13, 1984.

[33] SSI has a contract to launch the cremated remains of humans into orbit in an orbiting mausoleum. The firm awaits DOT approval to do so. See "SS1 Awaits DOT Mission Approval," *Space Business News,* Jan. 28, 1985, p. 1.

[34] J. Levine, "Shooting for Outer Space," *Venture,* October 1983, pp. 116-117.

[35] "Arc/Starstruck Plans Three Tests in '83," *Space Business News,* July 18, 1983, p. 6.

[36] See, for example, "Reorganization Gives New Life to Starstruck," *Space Business News,* Oct. 22, 1984, pp. 2-3.

lites. Their approximate capacities to geostationary orbit are: PAM-D—1 ,400 pounds, IUS—5,000 pounds, TOS–5,000 pounds, Delta Transfer Stage–7,500 pounds, Centaur—10,000 to 14,000 pounds. Although the I US and TOS/AMS are in the same weight class, the currently planned TOS should cost substantially less than the IUS.[37]

The only potential foreign participation in the Shuttle upper stage market is the Italian Research Interim Stage (I RIS).SB The IRIS is being developed by the Italian Government and aerospace industries and should be able to launch 1,900 pounds to geostationary transfer orbit or about 900 pounds to geostationary orbit. The limited capacity of the IRIS will prevent it from launching even small Delta-class communication satellites; however, it may be ideal for scientific satellites and small commercial satellites should a market develop for these. The first flight of the IRIS is planned for November 1986.

FOREIGN PRIVATE SECTOR

In the late 1970s, a private West German firm, OTRAG (Orbital Transport-und-Raketen Aktiengesellschaft), announced its plans to offer private launch services. However, political complications with the West German Government, combined with the company's inability to find a permanent location for its launch pad, have so far prevented OTRAG'S success. OTRAG plans to create a family of vehicles using clusters of identical liquid propulsion units; such units would be added or subtracted to match the payload weight. Their smallest model would be capable of launching a 440-pound payload to an altitude of 31 miles and their largest vehicles would be able to carry a 1,1oo-pound payload to 174 miles. OTRAG successfully tested a two-unit rocket in 1977 and a four-unit rocket in 1978. Eventually, OTRAG hopes to create a vehicle in the Ariane class; however, its present activities are limited to launching sounding rocket-class vehicles from Sweden's Kiruna launch site.[39]

Bristol Aerospace, Ltd., of Canada, has also announced plans to offer a low-cost commercial launch vehicle.[40] Bristol currently manufactures the Black Brant sounding rocket, which has been used for research by several space agencies including NASA and ESA. Bristol plans to develop a solid-propellant vehicle capable of placing 500- to 1,700-pound payloads into low-Earth-orbit and payloads of up to 800 pounds into geosynchronous orbit. The company hopes to conduct flight tests in 1988 and to begin commercial launch activities by 1990.

Buyers of Space Transportation Services

At present, the three primary purchasers of space transportation services are the military, national and cooperative space programs, and communication satellite service providers. Activities of the military and of the various national and cooperative space programs will account for over 75 percent of the total demand for launch services over the next decade. Although these activities are numerically the largest, they raise few international competitive issues. In the United States, most NASA and Department of Defense (DOD) payloads will fly on the Shuttle. A number of DOD payloads will fly on an ELV designated as a Shuttle backup. The payloads of ESA and the ESA member states will most likely fly on Ariane unless—as in the case of Spacelab—the unique capabilities of the Shuttle are necessary. **International commercial competition in space transportation will take place primarily with regard to large communication satellites launched to geostationary orbit.**

Outside the Soviet bloc, the buyers of civilian communication satellites can be divided into three submarkets: U.S. communications carriers, global international satellite organizations, and considered together, foreign national and regional satellite systems.

U.S. Communications Firms

Of these submarkets, that of U.S. communications carriers is by far the largest. U.S. commu-

[37] PAM and TOS upper stages only go to geostationary transfer orbit. Figures given here assume an appropriate apogee motor.

[38] E. Vallerani, F. Veresio, and L. Bussolino, "IRIS—A New Italian Upper Stage System, " 34th Congress of the International Astronautical Federation, Oct. 10-15, 1983.

[39] J. Lenorovitz, "Otrag Prepares for Full Launch Service, " *Aviation Week and Space Technology,* Sept. 12, *1983,* pp. 77-78.

[40] "Expendable Launch Vehicle," Bristol Aerospace Ltd., 1983.

nications and satellite manufacturing firms such as AT&T, RCA, Western Union, ITT, Satellite Business Systems, American Satellite, Ford Aerospace, and Hughes now own 21 geosynchronous communication satellites, used primarily for domestic U.S. communications. In limited but growing numbers, they are also used for transborder communications between the United States and North and South America and the Caribbean.

Up to the present, forecasters have been optimistic regarding the continuing need for launch services to put U.S. communications satellites in orbit. One indication supporting this prospect are the 81 pending and approved applications filed with the Federal Communications Commission (FCC) to construct and launch satellites, and to receive orbital locations. Two studies done for NASA have also concluded that the demand for launch services for communications satellites would remain strong.[41] One estimated that 61 U.S. communications satellites would be launched during the 1986-89 period, with 68 more launched before 2000; the other that between 97 and 163 U.S. domestic communications payloads would be launched between 1984 and 1999.

Recent events, however, put these optimistic projections in doubt. First, the expected surge in demand for direct broadcasting satellites has failed to materialize. Second, current substantial excess satellite capacity (see ch. 6) may delay or deter firms from proceeding with announced plans. Third, in the late 1980s and 1990s, communications carriers are expected to have large fiber optic networks in place that will compete with satellite communications in virtually all applications except point-to-multipoint, sparse area, and some mobile communications. While the outcome of this technological competition cannot now be clearly foreseen, fiber optic cables and other terrestrial modes linked to fiber optic local area networks will almost certainly carry some traffic that satellites heretofore had been expected to carry. Optimistic projections of the number of communications satellite launches, therefore, should be treated with considerable skepticism.

included in the forecasts is launch demand generated by satellite replacement. Because communications satellites typically have design lives of less than 10 years, most of the satellites that are expected to be in orbit or launched before the end of 1985 will therefore cease operation before 1995 and, if replaced, will generate demand for launch services.

The Shuttle, Ariane, Delta, Atlas-Centaur, and Titan launch vehicles could all meet the needs of U.S. communication satellite system operators. The Shuttle, although more sophisticated than its competitors, has no special advantage in launching satellites to geostationary orbit, If all these vehicles are equally reliable, the choice of launcher will be based primarily on: 1) the price of the vehicle, 2) the reliability of the launch schedules, 3) the relative simplicity of planning, documenting, and processing their payloads.[42]

INTELSAT and INMARSAT

The International Telecommunications Satellite Organization (INTELSAT) and the international Maritime Satellite Organization (INMARSAT) maintain global communications systems. INTELSAT, which also provides space segment capacity for many countries that do not have national systems, currently has 15 satellites in orbit, 8 of them large INTELSAT V satellites, which were launched by Atlas-Centaur and Ariane from 1980 through 1984. Current plans are for INTELSAT to launch 13 satellites in the 1985-87 period. If all are launched as planned, six of them will be INTELSAT V satellites, and seven will be INTELSAT Vls. The latter series of satellites are very large and will be able to carry approximately 40,000 separate simultaneous telephone conversations. Still on the drawing board is an INTELSAT VII series.

Whether all the INTELSAT Vls will be launched as planned is in some doubt. INTELSAT transatlantic and transpacific satellites will compete with undersea fiber optic cables, several of which are

[41] *Outside Users Payload Model*, Battelle's Columbus Laboratories, NASA contract NASW-338; June 1983. For a more complete discussion of the demand for communication satellites see ch. 6.

[42] *NASA Advisory Council Study of Effective Shuttle Utilization*, NAC Task Force for the Study of Effective Shuttle Utilization, Nov. 17, 1983,

planned for the late 1980s and early 1990s. In addition, some competition from private U.S. satellite systems is likely to emerge. Although INMARSAT is purchasing its own system of satellites, it currently leases capacity from INTELSAT and other systems.

Satellites of the INTELSAT 1, 11, and 111 series were launched on the Delta; satellites of the INTELSAT IV and V series were launched on the Atlas-Centaur. To satisfy political pressures that have arisen since the development of Ariane, INTELSAT now intends to distribute its business between U.S. and European vehicles, The Ariane has been used to launch an INTELSAT V, and the Shuttle will be used for the initial INTELSAT VI launch.

As a result of the projected size of the next generation of INTELSAT satellites (I NTELSAT VI will weigh 4,800 pounds in orbit) the only vehicles that could launch them are the Shuttle, Ariane-4 (under development), Atlas (improved version not developed), and Titan.

Foreign Satellite Systems

This category includes both the satellites of individual foreign countries (private or government owned) and organizations established to provide services to regional groups of countries. In addition to voice communication, such systems provide TV distribution, maritime communication, data transfer, and direct broadcast TV,

At present, Canada, France, Great Britain, Indonesia, Japan, the Middle East countries (Arabsat), and NATO all have operational systems. Other planned but not yet operational systems include: ITALSAT (Italy), MORELES (Mexico), SBTS (Brazil), AUSSAT (Australia), ECS (Eutelsat), LUXSAT (Luxembourg), and STW (China). Current users of the INTELSAT system may convert to national or regional satellite systems if they experience a dramatic increase in traffic volume or it becomes politically or economically desirable to exercise greater control over their communications network (see ch. 6).

Battelle has estimated that between 1983 and 1998 anywhere from 110 to 176 satellites will be launched for foreign national or regional communications.[43] Countries that have the ability to place large payloads into geostationary orbit will presumably use their own launch vehicles, For example, the Europeans will favor the Ariane rocket. Countries such as Japan and China, which have at present only a limited launch capability, will within 10 years probably be able to launch large communication satellites to geostationary orbit.

Countries which do not possess an independent launch capability will, like the U.S. domestic communications suppliers, be concerned with the price, schedule, reliability, and processing simplicity of individual launchers. The availability of favorable financing and/or trade offsets (particularly for developing countries) may also be an important consideration .44

In addition to communication satellites, other space activities such as remote sensing (ch. 7), materials processing (ch. 8), and navigational satellites (app. C) may require commercial launch services. Many activities conducted in low-Earth-orbit might be launched not only with the Shuttle, Ariane, Delta, Titan, and Atlas, but also with the new generation of low-cost privately developed launch vehicles and with the vehicles of Japan, China, and perhaps Brazil and India. Current demand for such activities is limited; however, together they constitute a significant uncertainty in future launcher demand estimates.

The Shuttle, because it allows human interaction with and retrieval of payloads, has a decided advantage over other launch systems for manufacturing in space. Unless the Ariane is substantially modified—a subject which has been discussed within ESA—it cannot compete with the Shuttle for MPS and other payloads that require human interaction. Other ELVS are equally disadvantaged in comparison to the Shuttle.

[43]Battelle, op. cit., note 41.

[44]Rainbow Satellite Inc.'s decision to launch two communication satellites on the General Dynamics Atlas-Centaur is a good example of the value of creative financing. In order to insure that Rainbow's launch business did not go to either NASA or Arianespace, General Dynamics agreed to provide $2oO million in financing for Rainbow and to give "a back-up commitment for all of the capacity" of one of the satellites. See: *Space Business News,* July 16, 1984, p. 1.

COMPETITION IN SPACE TRANSPORTATION

The entrance of ESA's Ariane rocket into the international marketplace brought an end to NASA's monopoly in commercial space transportation services. This fact, combined with the development of the Shuttle and the potential entry of other new launch vehicles, has created a situation where, for the first time, supply cou/d significantly exceed demand in the space transportation service market. Prior to these two occurrences, vehicles were manufactured and consumed as they were needed; therefore, the supply of launch services was always roughly equivalent to the demand for that service. Depending on the size of demand for satellites, NASA and the other launch service suppliers may find themselves in a situation where they must compete for a limited number of payloads.

Development of Competition

Access to space via a capable and reliable launch vehicle is important to the technological and commercial goals of all nations that may wish to orbit satellites. The desire of some nations to develop an indigenous launch capability derives from three considerations: first, a lack of confidence that launch services would be available when needed and without restriction from the United States or the Soviet Union; second, an interest in enhancing national prestige by demonstrating the technical virtuosity required to maintain an independent launch service; and third, an intention to participate in any economic gain to be derived from a wide range of commercial space services. Some newly industrialized countries, may also desire to acquire launch vehicle and precision guidance and control technologies for use in military ballistic missile systems.

Some European countries–particularly France–have always been reluctant to concede to the United States a monopoly in launch vehicles. Consequently, U.S. hesitation before launching the French-German Symphonic communications satellite in 1971 strengthened European determination to develop an autonomous launch capability.[45] The **decision to build the Ariane launch vehicle was a declaration of political and technological independence from the United States.**

In Japan, space technology has been identified as an area of future economic significance. A 1981 report by the Ministry of International Trade and Investment (MITI), emphasized the export potential of space technology and concluded that an indigenous space industry is vital because:

> **As unilateral introduction of technologies from foreign countries is getting more difficult, it is necessary to strengthen Japan's own bargaining power through accumulation of necessary technological know-how.** [46]

With a smaller economic and technical base to draw from than either the United States or Europe, and lacking the major military program to ensure political and financial support, the Japanese launcher program has relied on close cooperation with the United States.

Brazil, India, and China are also developing their own launch capabilities–for many of the reasons mentioned above. All three countries possess a strong desire to be technologically independent from the developed world, to gain any economic benefits that derive from the application of space technology, and to be regarded as belonging to the prestigious club of "space powers." Although the launch vehicles being developed in these countries are at present somewhat limited, their political importance will probably assure their continued existence. In some respects, national launch vehicle programs can be compared to national airlines—some are conducted primarily for profit, others play the role of enhancing "prestige" and "national self-image."

To date, competition in launch vehicles has been limited to those developed by governments. The fact that private or semi-private launch services will soon be available introduces a different kind of competition into this market. On May 16, 1983, the president announced that the U.S. Government fully endorsed and would facilitate the commercial operation of expendable launch ve-

[45] *Civilian* **space** *Policy and Applications,* op. cit., p. 363.

[46] *Report of the Deliberation Council on Basic problems in the Space Industry,* MITI, **Apr. 20, 1981.**

hicles (ELVs) by the private sector.[47] He assigned the Department of Transportation the task of assisting commercial ELV operations and recommending necessary regulatory, policy, and treaty changes. Subsequent legislation (Public Law 98-575), signed into law on October 30, 1984, confirmed and strengthened the previous Executive Order. Whether such private sector participants can compete with Government-supported launch vehicles and services has yet to be demonstrated.

Assessment of Demand

Because U.S. space transportation policy will significantly affect the supply of launch vehicles, it is important to give some consideration to the worldwide demand for launch services. NASA hopes that the four-orbiter Shuttle fleet will be able to provide **24** launches per year by 1988, and Arianespace hopes to be able to launch 10 Arianes per year by that time. Experts disagree about whether the demand for launch vehicles will exceed the supply. They further disagree about what, if any, public policies to pursue to affect supply and demand.[48] Estimates of demand must be viewed with caution since they are, at bottom, only "best guesses." Such estimates will be affected by changes in:

- **U.S. and foreign government space activities**–Building a space station, pursuing planetary exploration, or pursuing additional military activities in space will increase the demand for launch services.
- **Space** policy–Encouraging or subsidizing commercial activities such as remote sensing or materials processing in space could increase demand.
- **Space** technology-Satellites with longer lives could reduce the need for new satellite launches; new technologies such as DBS may increase the demand for new launches.
- Terrestrial technologies–Use of fiber optics may reduce the demand for communication satellites; technologies such as genetic engineering might reduce the desirability of conducting biological and materials research in space.

[47] White House press release, May 16, 1983.

[48] The question of whether or not NASA should be competing for commercial launches is discussed in the policy options.

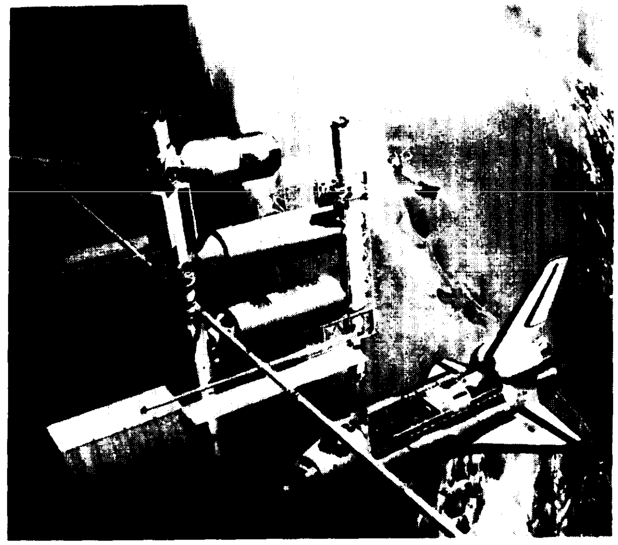


Photo credit: National Aeronautics and Space Administration

Artist's depiction of a Shuttle paying a visit to a Space Operations Center (SOC) in Earth orbit.

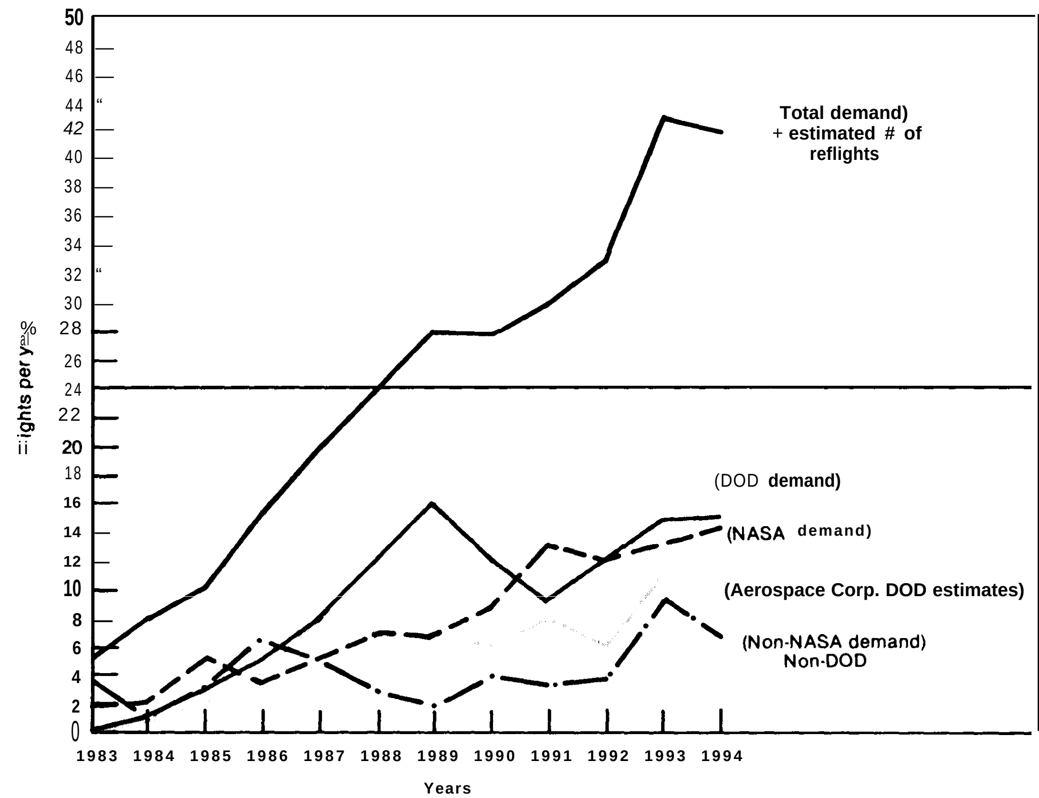
The results of the Rockwell International (fig. 5-4) and the Battelle (fig. 5-5) assessments of future launcher demand are presented below to illustrate the connection between the demand for launch vehicles and U.S. space policy.[49] OTA has not conducted an independent appraisal of either of these studies; and therefore offers no opinion as to their validity. They are included here to provide a rough quantitative dimension to this discussion.[50]

- **Result 1:** If the Shuttle fleet can provide **24** flights per year and the Ariane 10 flights per year, and the Rockwell projection of total demand is correct or low, then by 1988 additional launch capacity will be needed. This could be supplied by U.S. commercial or foreign ELVS or additional orbiters.

[49] See also: *Projection of Non-Federal Demand for Space Transportation Services Through 2000: An AIAA Assessment for the Office of Science and Technology Policy of the White House*, American Institute of Aeronautics and Astronautics, Jan. 19, 1981; *Systems Analysis of National Space Launch Possibilities*, The Aerospace Corp., March 1983; "United States Commercial Expendable Launch Vehicles, " General Dynamics, 1982; *Assessment of Constraints on Space Shuttle Launch Rates*, National Research Council, Committee on NASA Scientific and Technological Program Reviews, April 1983.

[50] These analyses are based on the Shuttle reaching 24 flights per year and Ariane reaching 10 flights per year, assumptions that remain to be proven by experience. Some analysts doubt that NASA will be able to reach that level of flights before 1990.

Figure 5-4.-Projection of Future Space Shuttle Demand Rockwell International



Rockwell International's *Projection* ***of Future*** **Space** ***Shuttle Traffic*** *Demand,* **(July 1963).**

Time period: **1963-1994 (shown here 1964-1994).**

Scope: All NASA, DOD, commercial and foreign (non-Soviet) space transportation demand.

Key ***assumptions:*** • Payloads booked on **U.S. ELVs** would fly on them

• Payloads for Japan and China would fly on their own national vehicles **unless specifically booked** *elsewhere*

• **The Ariane will fly full. (5 launch 19S4-5; 10 launches 1986-1994)**

• **Model includes funded, extensions or follow-ons and potential new missions.**

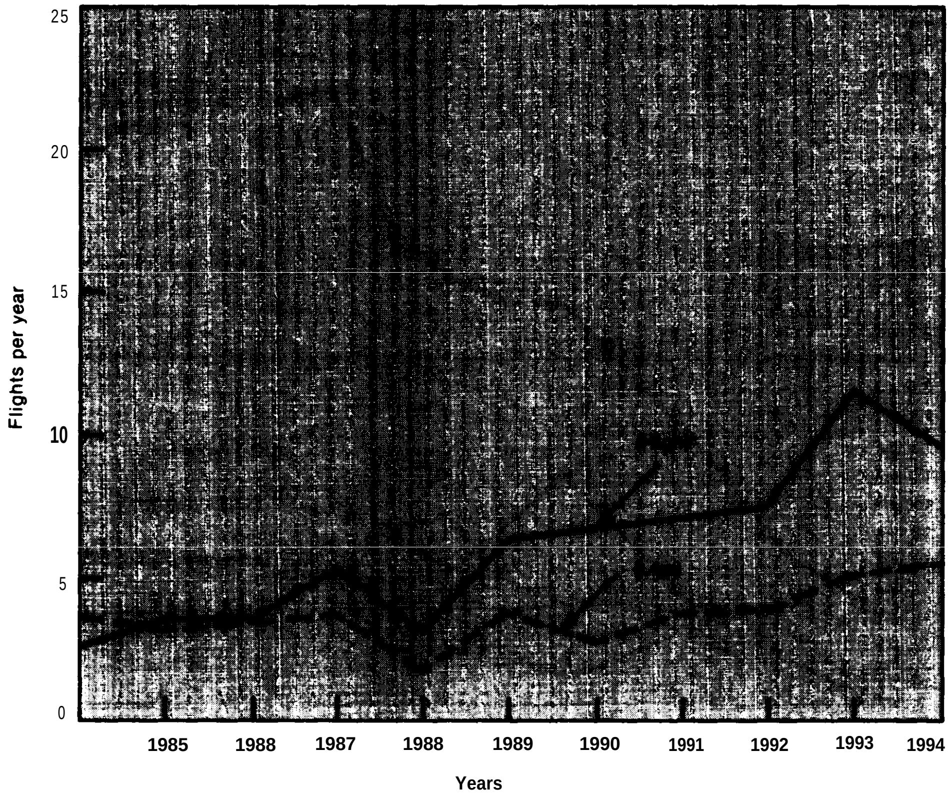
"Equivalent Shuttle Flights:" All **payloads characterized in terms of equivalent Shuttle payloads.**

- **Result 2:** Starting with the assumptions listed in Result 1, if the Rockwell projection for DOD demand is overstated (as has been suggested by an Aerospace Corp. study),[51] *and/or,* some DOD payloads continue to fly on ELVS, then the Shuttle and Ariane could probably meet the total launch demand through **1994.**
- **Result 3: If** the Rockwell and Battelle estimates of non-NASA, non-DOD demand are accurate, but Rockwell's NASA and DOD estimates are both overstated, then the Shuttle and Ariane will create a surplus of launch capacity through 1994. Neither U.S. commercial nor other foreign ELVS would be necessary to satisfy total launch demand,

If the demand for launch services were unlimited the United States would be well-advised to pursue a policy of encouraging both Shuttle use and the commercialization of ELVS. With the demand for launch services uncertain, the questions become more complex. Should the Shuttle be allowed to compete with private firms for a limited number of commercial launches? If the demand for launch services exceeds the Shuttle's capacity, should additional orbiters be purchased, or should ELVS be used to fill the gap? If the Shuttle fleet is diminished by a catastrophic accident or unforeseen technical problems, how is the de-

[51] *Systems Analysis of National Space Launch possibilities,* op. cit.

Figure 5-5.-Outside Users Payload Model Battelle's Columbus Laboratories (nominal non.NASA, non.DOD demand)



Battelle's *Outside Users Payload Model* (June 19S3).
Time period: 1983-1998 (shown here 19S4-1904).
Scope: All known non-NASA, non-DOD reimbursable payloads scheduled to be flown by non-soviet-bloc countries.
Key assumptions: • Shuttle and Ariane successful and price competitive
• U.S. commercial ELVs not considered
• Space station not considered
• No revolutionary technical, economic or social developments
"Equivalent Shuttle Flights:" All payloads characterized in terms of equivalent Shuttle payloads.

mand for launch services to be met? In the long run, will private ELVs or the Shuttle prove to be the more cost-effective way to meet the additional demand? Unless additional orbiters or ELVs are ordered, will the production lines for either remain open? Given the U.S. Government's commitment to the space station and other space goals, is cost effectiveness an important short-term consideration?

The primary focus of this study is international competition and cooperation; therefore, many of these questions are beyond the scope of this report. Those that pertain directly to international competition are discussed in greater detail in the policy options that follow.

Nature of Competition

Although there are a number of potential entrants, current competition in space transportation is predominantly between the U.S. Government-supported Shuttle and the European government-supported Ariane.[52] The Shuttle and Ariane are competing primarily for the launch of large geosynchronous communication satellites. A recent study conducted for NASA estimated that from 1983 to 1998 there will be between 103 and 163 non-NASA, non-DOD payloads for which NASA and Arianespace are in direct competi-

[52] Competition between U.S. upper stage manufacturers is to a great extent dependent on, and subsidiary to, the Shuttle successfully competing with other launch vehicles.

tion.[53] (See figs. 5-6 and 5-7.) Of this number, the study estimated that between 29 and 72 payloads would go to Arianespace. [54] That is a loss of between one and two dedicated Shuttle flights per year over a period of 15 years.

The primary advantages of the Shuttle are that it is manned, reusable, and able to retrieve and deploy large objects in low-Earth-orbit. Normally, none of these advantages is important when communication satellites are launched to geosynchronous orbit. * Its primary disadvantages are that schedules have slipped about 1s percent each year, raising questions of reliability and planning, and that documentation and integration are more complex and expensive than those of Ariane. These particular disadvantages are quite important to commercial launch customers. As a result, the Ariane launch vehicle, which is less sophisticated than the Shuttle, is capable of competing with the Shuttle for payloads. (In addition, Ariane competes well with the Shuttle on the basis of price.) For the same reasons, private U.S. ELVs, which are technically comparable to Ariane, can also compete with the Shuttle.

The technical comparability of the Shuttle and Ariane with respect to launching communication satellites has focused competition primarily on launch price and financing.[55]

Current pricing policies have occasioned complaints of unfair competition on both sides of the Atlantic and generated considerable unrest among private U.S. ELV manufacturers. In a state-

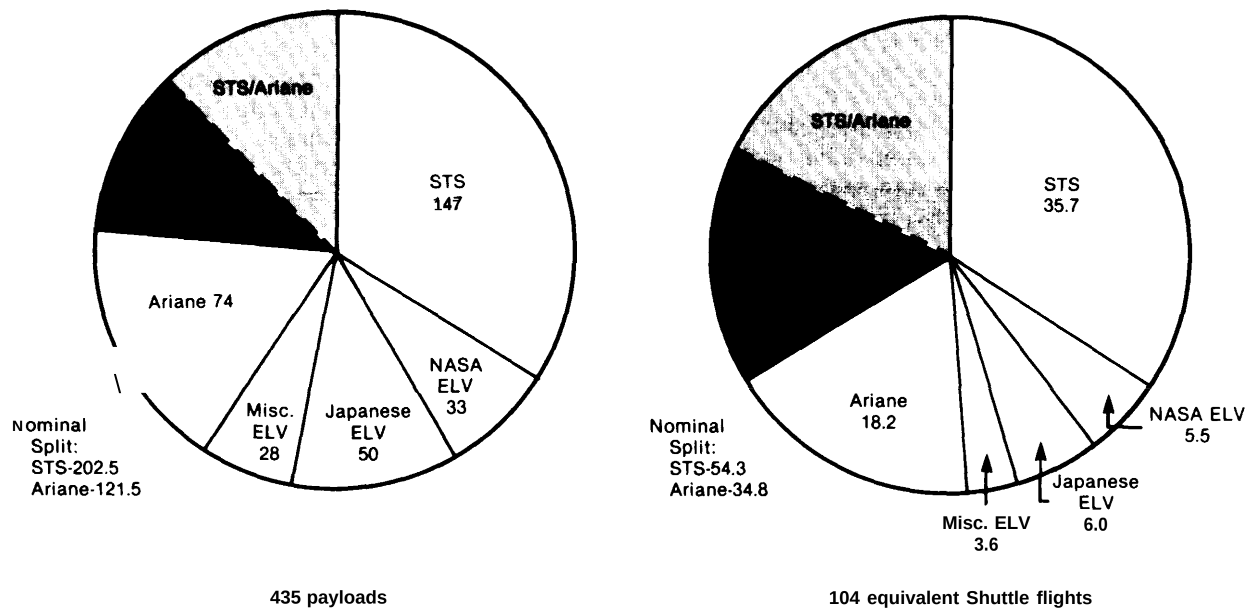
[53] *Outside Users payload Model,* op. cit.

[54] In 1984, Ariane and the Shuttle each took about half of the commercial space transportation market.

*However, when certain types of malfunctions occur, in either the satellite or its upper stage, astronauts or payload specialists may be able to repair the malfunction or retrieve a satellite that has gone into an anomalous orbit. An example was the recent retrieval of the Westar and Palapa spacecraft after their PAM-D stages failed. See "Astronauts Deploy, Retrieve Satellites, " *Aviation Week and Space Technology, Nov. 26,* 1984, pp. 20-23.

[55] Should a U.S. commitment to a space Stati On or an increase in military space activities reduce the number of commercial Shuttle flights, or should a catastrophic failure reduce or ground the Shuttle fleet, availability would become a more important factor than price or financing.

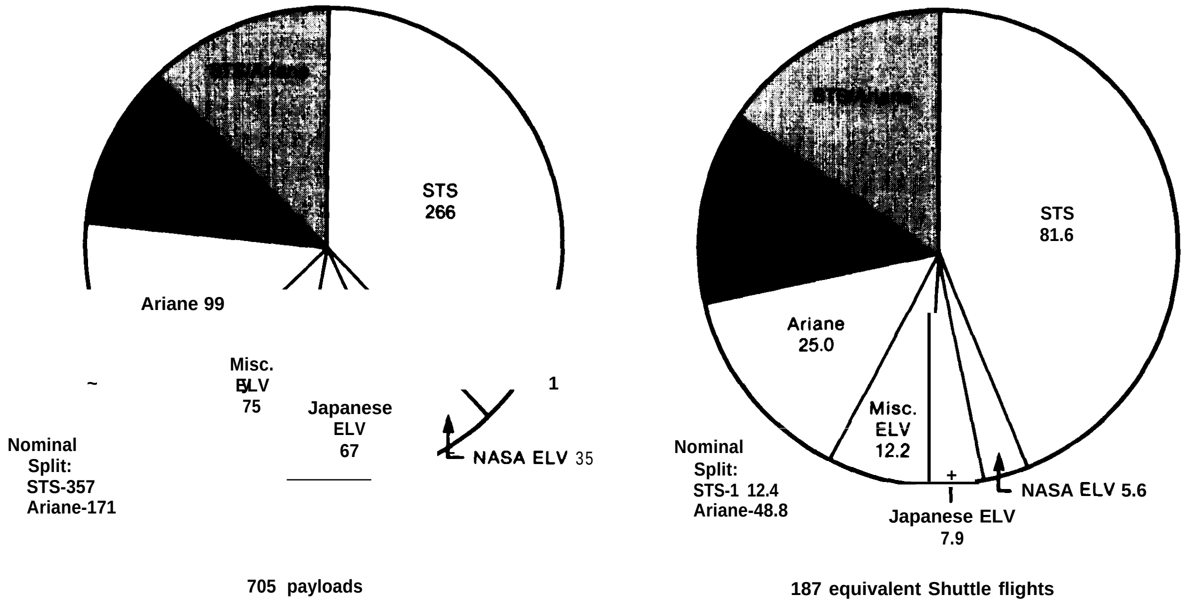
Figure 5-6.—Low Model Market Share by Launch Vehicle



Assumes 75% average Shuttle load factor

SOURCE: Outside Users Payload Model Battelle Columbus Laboratories (NASA contract NASW-338), June 1963.

Figure 5“7.–High Model Market Share by Launch Vehicle



Assumes 75?40 average Shuttle load factor

SOURCE: Outside Users Payload Model Battelle Columbus Laboratories (NASA contract NASW-338), June 19S3.

ment before the Senate Commerce Committee, NASA Administrator James Beggs cautioned:[56]

> The French are pricing their service very, very competitively. As a matter of fact, they have set the price very close to Shuttle-type pricing. They are, without any question, subsidizing that, because their **costs are not down. With respect to the cost per launch and the financial terms . . . they are more than competitive with us . . (T)hey are formidable competition, and we are not taking them lightly.**

The Europeans take exception to suggestions that the Ariane is unfairly being subsidized. Frederic D’Allest, President of Arianespace, testified before a Senate subcommittee:[57]

> **There is no transfer of money between Arianespace and ESA and the other European organizations other than the payments due to Arianespace within the framework of the launch services contracts . . .**
>
> **When establishing Arianespace, we succeeded in convincing ESA and its member States that the STS (Space Transportation System) pricing policy during the first 3 years of its operations involved a huge subsidy, thus creating an unfair competition. In response, it was agreed that for the European payloads launched before mid-1 986, the standard price negotiated with ESA . . . would include a 25-percent extra charge to support the company.**
>
> **We consider, and hope you will consider, that these practices are not very sound, as they charge the research and development programs on both sides of the Atlantic, instead of charging the users who reportedly look to gain great financial profit from their commercial applications.**
>
> **As long as the STS production and operation costs do not reflect realistically the STS pricing policy, we shall claim some support through the European payloads launch prices, to ESA and its member States.**

The principal complaint of the Europeans has been that the Shuttle price–unlike the price charged for U.S. expendable vehicles, which was based on the recovery of “all reasonable costs’ ’–bears little relationship to the cost of

[56] NASA Authorization for Fiscal Year 1983: Hearings before the Subcommittee on Science, Technology, and Space of the Senate Committee on Commerce, Science, and Transportation, 97th Cong., 2d sess., February 1982, Statement of Hon. James A. Beggs, p. 41.
[57] Ibid., p. 170, statement of Frederic D’Allest.

operating the Shuttle. The price currently charged by NASA for a Shuttle launch was developed in 1975 and was designed, in part, "to effect early transition from expendable launch vehicles.[58] At the time, NASA felt that Shuttle costs would fall as they gained more experience with the system and the flight rate increased. It was assumed that there would be a tendency among users to delay Shuttle use in order to take advantage of the lower prices in later years.[59]

In order to overcome this tendency, NASA based the Shuttle price on the estimated 12-year average cost of the program. As a result, cost of launching a Delta-class payload to geosynchronous orbit on the Shuttle was about one-half of what it would have cost to use an expendable Delta.[60] The initial price for a dedicated Shuttle bay was $18 million in 1975 dollars or about $40 million in 1984 dollars.[61] Although exact, per flight, Shuttle costs (recurring costs per flight, refurbishment, support facilities, and personnel) are difficult to calculate, it has been estimated that each of the five Shuttle flights in 1983 cost $375 million.[62]

In 1981-82, when NASA began to reassess its pricing policy, several U.S. customers had already switched from the Shuttle to Ariane. NASA felt that a pricing policy based on current Shuttle costs would lead to "an unacceptable commercial and foreign users price.[63] NASA does plan to raise the price for a dedicated Shuttle launch in 1985 to $38 million 1975 dollars (about $80 million in 1984 dollars). President Reagan's policy statement of May 16, 1983, declared that after 1988 NASA should charge a "full cost recovery" price[64]. If prices continue to fall as experiencxe is gained with Shuttle operations, the 1988 price could still be as high as $100 million to $150 million in 1984 dollars.

As described above in Frederic D'Allest's statement, the ESA nations also felt that the early success of Ariane could not be assured if the price were based entirely on launch costs. An Organization for Economic Cooperation and Development (OECD) study has estimated that the Ariane is priced at about two-thirds of its cost.[65] The commercial Ariane price is approximately $54 million, or $25 million to $30 million per customer for dual launch. This is purportedly a temporary promotional price to be followed by a "more normal cost coverage basis. " ESA States pay a 25 percent additional charge to support the Ariane program.

Price competition between Shuttle and Ariane has made it difficult for private sector ELVS to enter the market. In an attempt to alter the current situation, Transpace Carriers, Inc., seller of the commercial Delta launch vehicle, filed a complaint with the Office of the U.S. Trade Representative charging that Aria nespace was engaged in predatory pricing. The complaint, filed under Section 301 of the U.S. Trade Act of 1974, stated that Arianespace charged prices to U.S. firms that were 25 to 33 percent lower than those charged to ESA members, and that as a result of this practice TCI had lost sales to Arianespace.[66]

In its petition, TCI asked that the President seek the immediate discontinuance of the two-tiered pricing policy; the elimination of the cost-free or below-cost support in facilities, services, and personnel; and the subsidization of mission insurance rates. Pending the cessation of these practices, the complaint requested the President to retaliate by prohibiting Arianespace from advertising and marketing its services in the United States and by imposing economic sanctions against the goods and services of the Member States of ESA.

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[58] C. M. Lee and B. Stone, "STS Pricing Policy," AIAA Space Systems Conference, Oct. 18-20, 1982, Washington, DC, p. 1.

[59] Ibid., p. 2.

[60] Ibid.

[61] Based on an escalation rate of 2.192 from 1975 to 1984. Note that this is the price for a "dedicated payload bay"; a Delta-class satellite would only take up about 25 percent of the bay, and therefore the price to launch this payload would be about 25 percent of the "dedicated payload bay" price.

[62] James Abrahamson, testimony before the Subcommittee on Space Science and Technology, February/March 1984, p. 584.

[63] Lee and Stone, Op. Cit.

[64] White House Press Release, May 16, 1983.

[65] OECD, *Trade in High-Technology Products, The Space Products Industry,* Paris, 1985.

[66] See "U.S. Space Launch Services Company Brings Unprecedented Complaint Against Europeans," *U.S. Import Weekly,* vol. 9, June 6, 1984, p. 1088. The complaint stated:

> As a beneficiary of such subsidy practices Arianespace has been able to offer launch services to U.S. companies and third country customers at rates which are substantially less than those charged to Member States of ESA and substantially below those prices that Arianespace would be able to charge in the absence of subsidization. This unfair competitive advantage has resulted in lost sales to petitioner and price suppression, if not depression, of bid prices. Furthermore, it poses a serious threat to the establishment of a United States commercial launch services industry.

Responding to the TCI complaint, Erik Quistgaard, ESA Director General, announced that his agency was willing to talk to the U.S. Government in an attempt to "create conditions for healthy competition" in launch services.[67]

To summarize, the price for an Ariane launch has been set so as to compete effectively with the Shuttle. The ESA nations, in order to assist in this goal, pay more for a flight than would the purchaser of a commercial launch.

The Shuttle price rests heavily on the following reasoning. First, in the absence of commercial payloads the Shuttle would fly anyway. As a consequence, NASA charges customers only for the amount that their payload adds to the cost of flying all Government payloads for a given period and not for a portion of the total cost of an individual flight. Second, the cost of flying the Shuttle will decrease substantially as experience is gained. By spreading the average cost over a number of years and projecting a rapid decline in Shuttle launch prices, the near-term average cost can be kept low. As a result of current NASA/ESA price competition, launch service purchasers (largely satellite communication service providers) are benefiting—at least in the early years of Shuttle operations–from substantial government subsidies for each launch.

Given the commitment of the United States and the European nations to the success of their respective vehicles, these pricing structures are defensible; they do, however, raise substantial barriers to the commercial success of any private ELVS. Assuming a 65,000-pound capacity and an $80 million (1984 dollars) price per launch, the Shuttle can place a Delta-class payload into low-Earth-orbit for about $1,200 per pound. However, because the full payload capacity is rarely used and in order to reach geosynchronous orbit communication satellites require the additional weight of upper stages and cradle structures, the Shuttle cost of placing a payload into orbit is about $10,000 to $20,000 per pound depending on the upper stage (see table 5-2). This is compared to the approximate per pound cost of a Delta ($24,000), an Atlas-Centaur ($25,000), or the Ariane 3 ($20,000).

At current prices, the Shuttle is less expensive than any of the ELV alternatives; however, this advantage will be lost as Shuttle prices increase. At $125 million per dedicated launch, the Shuttle is competitive though not preferable to the ELVS; at $150 million per launch the Shuttle ceases to be financially attractive for payloads not requiring human interaction.[68]

NASA has expressed concern that it cannot effectively compete with the Ariane because of the favorable financing that Arianespace has been

[67]"ESA Replies to Charges on Arianespace Pricing," *Aviation Week* and *Space* Technology, July 2, 1984, pp. 22-23.

[68]Prices given here are approximations, supplied to illustrate the Shuttle's competitive position vis-a-vis ELVs. Such estimates do not reflect the dynamic nature of the launch vehicle industry. NASA maintains that Shuttle prices will fall substantially as experience is gained. It is also possible that less expensive upper stages or orbital transfer vehicles will be developed, thereby reducing the cost to geostationary orbit. Both General Dynamics (Atlas-Centaur) and Transpace Carriers Inc. (Delta) have stated that commercial competition and private sector efficiencies will reduce the cost of ELV launches.

Table 5-2.—Transportation Costs to Geosynchronous Orbit (approximate)

ELVS			Shuttle				
Vehicie	Maximum payload (lb to GEO)	Cost/ib to GEO	Vehicle	Maximum payload (lb to GEO)	Cost/lb to GEO $83M price	$125M price	$150M price
Deita	1,350	24,000	PAM-D	1,350	17,000	24,000	28,000
Atias-Centaur	2,600	25,000	[a]PAM-DII	*2,000*	*17,000*	*23,000*	*27,000*
Ariane 3	2,700	20,000	[a]PAM-A	2,200	*17,000*	*24,000*	*28,000*
Titan 34 D/IUS	5,000	31,000	Shuttie/IUS	5,000	30,000	38,000	43,000
Titan 34 D/TOS[b]	6,400	17,000	Shuttie TOS	6,800	14,000	19,000	22,000
Ariane 4	4,500	19,000	Shuttle/Centaur	14,000	9,000	12,000	14,000

[a]OTA figures.
[b]Transfer Orbit Stage.

SOURCE: M. C. Simon and O. Steinbroun, "The Economics of Space Development," General Dynamics, Convair Division, October 1983, p. 3.

able to offer its customers. **The Ariane payment schedule requires that a company pay 20 percent of the cost 30 months prior to launch; the balance is spread over 5 years at low interest rates** while the satellites are in orbit earning revenue (table 5-3 and fig. 5-8). Typically, Arianespace will finance 80 percent of the cost, of which 80 percent of the debt will be at a subsidized rate.[69] The remaining 20 percent of the 80 percent financing would be at market rates.

Although NASA cannot provide financing and requires that the entire cost be paid prior to launch, it can, with the help of the U.S. Export-Import Bank (Ex-lm), offer financing similar to that of Arianespace in foreign, non-EEC (European Economic Community) countries.[70] Recently, the Ex-lm Bank agreed to guarantee 85 percent of costs to be incurred by Mexico for a Shuttle launch; this allowed the Private Export Funding Corp. (PEFCO) to provide the funding for this

[69] In one example, 64 percent of the subsidized debt was at 9.5 percent (from Compagnie Francaise d'Assurance Pour Le Commerce Exterieur) and the remaining 16 percent was at 10.5 percent; this resulted in a blended subsidized rate of 9.75 percent. See *NASA Advisory Council Study of Effective Shuttle Utilization,* Nov. 17, 1983, p. 30.

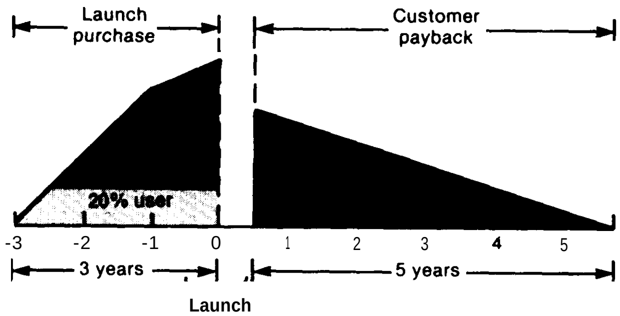
[70] Ibid., p. 30.

Table 5-3.—NASA vs. Arianespace Financing (1982 $M) (FY 1982-85 pricing)

NASA's STS		Ariane
Total launch price:		
SBS	$12.65	$22.0
iNTELSAT	$28.34	$39.6
Prelaunch payments required (S6S example):		
36 months	$ 0.1	
33 months	1.25 (l 0"/o)	
27 months	1.25 (lt)°\o)	$4.4 (20°/0) due 30 months prior to launch
21 months	2.13 (17°/0)	
15 months	2.13 (17°/0)	
9 months	2.9 (230/.)	
3 months	2.9 (23Yo)	
	$12.65 (lOO°/o)	
Postlaunch payments—none		*80°/0* balance—payments begin 6 months after launch, spread over 5 years at 5-100/0 interest

SOURCE: D. A Bletsos, *The Current Status and Future Outlook of Foreign Space Transportation Programs,* Rockwell International Shuttle Orbiter Division

Figure 5-8.—Arianespace Financing



- Arianespace gets paid up front
- Financing by FrenchlGerman banks
- Rates negotiable (typically 9-10°/0)
- Payback out of revenues—starts 6 months after launch

transaction.[71] Similar NASA/Ex-lm packages have been proposed for Australian and Colombian payloads. A recent report by the NASA Advisory Council stated:[72]

> In **virtually all cases the difference between Shuttle and Arianespace rates and terms were not significant. Except for the loss of a Brazilian launch due to a development loan and offsets, NASA has not lost any launch business due to more competitive financing.** Based on recent discussions with senior officers of the Ex-lm Bank, there is every indication that the Ex-lm will be responsive to export financing for non-EEC countries, particularly when there is competitive European export financing involved (emphasis added).

When dealing with EEC countries, neither NASA nor Arianespace can employ subsidized financing. EEC export agencies will not provide subsidized financing to other EEC members, and, in the absence of such subsidized financing, the Ex-Im bank will not become involved. In any case, since European nations will almost certainly choose to support the Ariane program, there will probably be no significant number of Shuttle sales to EEC countries.[73]

[71] PEFCO is owned by 52 U.S. banks and manufacturers. Its function is to provide funding against Ex-lm-guaranteed paper. Its rates are essentially the prevailing market rate for U.S. Government-guaranteed obligations plus a commitment fee and arrangement fee.

[72] Ibid.

[73] Special Circumstances may make possible a limited number of sales of Shuttle services to EEC members. For example, British Skynet military satellite will fly on the Shuttle in 1986.

Arianespace has its strongest potential advantage in U.S. domestic markets. Here, it can provide 80 percent financing at a subsidized rate (currently 12.4 percent), and the Ex-Im Bank will not step in because the customers are U.S. nationals. In examining this issue, the NAC report acknowledged that it was a potential problem, but noted that:

> . . . **Arianespace financing up to this point did not present a big enough discount off the advertised Arianespace price to affect significantly and adversely NASA's marketing of the shuttle.**
>
> **However, this could become a serious competitive disadvantage in the future if prices equalized. '4**

In summation, current international launch vehicle competition has been between government-supported vehicles and has focused almost exclusively on price. To date, sales have been sought to ensure maximum use of the Ariane and the Shuttle and there has been little opportunity for profit taking.[75] In this environment, the successful entry of commercial, nongovernment-supported launch vehicles seems unlikely.

Effects of Competition

Foreign launch vehicles can reduce the demand for U.S. Government and private sector launch vehicles in two important ways: 1) by flying their own and regional payloads, and 2) by marketing their services internationally. Reductions in demand caused by the former will be difficult, if not impossible, to offset by altering present U.S. practices or policies. Other governments willing to expend the human and economic resources to develop their own launch capabilities can, of course, work toward satisfying all of their indigenous launch needs and may capture some portion of the overall world demand for space transportation services. However, the resulting losses to the United States are likely to be small, because the vast majority of nations will continue to be launch service consumers rather than producers.

There is substantial difference of opinion regarding the effect that the marketing of foreign launch systems may have on U.S. space transportation services. Under these circumstances, perhaps the most useful approach is to lay out possible effects that international competition in space transportation may have, with a view to setting boundary conditions for an appropriate policy response. Possible effects are:

- **Reduced demand for the Shuttle:** A substantial reduction in demand would occur only if an international provider were to offer equivalent services to users at significantly lower prices. Now it is already the case that the prices charged to users do not recover the Shuttle's operating and maintenance (O&M) costs, and Rockwell International, the manufacturer of the Shuttle, has argued that, with only four orbiters and a low annual flight rate, these costs probably cannot be significantly reduced (fig. 5-9).[76] With Shuttle prices set to rise over the next few years in order to more closely approximate average operating costs, there is every likelihood that international providers may capture an increasing share of the market for users whose spacecraft do not require hum.. intervention in orbit. However, this result, in itself, is not a simple economic negative, for the prices charged for an all-commercial flight do not recoup the costs of making the flight.

  With these new facts in view, the Office of Management and Budget (OMB) has stated that the Shuttle's primary goal is to meet U.S. Government needs, not those of foreign governments or the private sector. Therefore, the price charged to non-U.S. Government users should reflect the true "additive costs" of flying them on the Shuttle and should serve to "minimize the overall cost to the Federal Government of meeting its own needs.''" In a letter to NASA

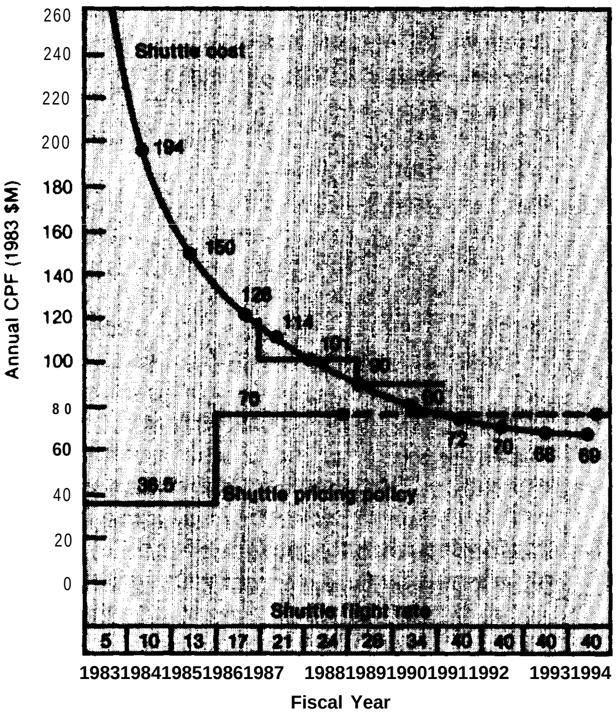
[74] Ibid.

[75] Arianespace claims that in 1985 it made a profit on its commercial launch activities. See *Space Commerce Bulletin*, vol. II, No. 1, Jan. 18, 1985, p. 3.

[76] "Economic Comparison: Shuttle-only Fleet vs. Shuttle/Commercial ELV Mixed Fleet," Rockwell International Space Transportation & Systems Group, May 17, 1983.

[77] Letter from David A. Stockman, Director, OMB, to James M. Beggs, NASA Administrator, June 14, 1982; See also C. Covault, "Shuttle Fund Policy Stirs Concern at NASA," *Aviation Week and Space Technology*, Oct. 18, 1982.

Figure 5-9.—Rockwell International Estimates That the Shuttle is Most Economical Over ELVS at High-Volume Operations



(Shuttle cost data from NASA independent assessment, April 1982)

SOURCE: "Economic Comparison: Shuttle-Only Fleet vs Shuttle/Commercial ELV Mixed Fleet," Rockwell International Space Transportation and Systems Group, May 17, 1983.

Administrator James M. Beggs, OMB Director David Stockman stated:78

> . . . (T)he appropriate price for excess Shuttle launch capacity after 1985 would appear to be one that:
> - Is the highest price at which sufficient users will be available to utilize the excess capacity of the Shuttle system after USG [U.S. Government] user needs are met.
> - At least covers the additive costs of the USG to operate the Shuttle system for non-U.S. Government users.
> - Does not in itself lead to the demand for funding of additional capacity by the USG (e.g., additional orbiters, ground support systems).

According to OMB'S view, a reduction in non-U.S. Government demand for Shuttle services resulting from foreign competition would require no policy change. Indeed, the Stockman letter implies that if Shuttle launch costs were to rise as a result of a reduction in demand, then the price charged to non-U.S. Government users should also be increased.

On the other hand, it should be pointed out that such a price increase might lead to a further reduction in demand, thus setting up a vicious cycle. In economic terms, this result might make sense, but there is a political price to be paid, namely that the commercial market may come to see the Shuttle as vehicle of last resort, rather than vehicle of choice. [n that case, the Shuttle might be perceived as increasingly irrelevant to the commercial development of space.

- **Loss of revenue:** A 1982 NASA report stated that: "The present projection of capital lost to Ariane is estimated to be approximately $3 billion total through 1984, if every compatible U.S. customer used Ariane."[79] There is considerable question as to the significance of this finding. It should be noted that this is a potential loss of income, not a real loss to NASA, since none of the "out-of-pocket" costs associated with each additional commercial flight would be incurred. Therefore, the actual "loss" to NASA would be limited to the amount of "revenue" which would have been derived from each Shuttle launch and the potential costs of a less-than-optimal use of the Shuttle fleet. Since the cost of an additional Shuttle flight still exceeds the revenue produced by that flight, the marginal value of additional flights is debatable. In addition, there is no reason to believe that Ariane will capture "every compatible customer." Current Shuttle manifests do not reflect an exodus to Ariane; it will probably be the early 1990s before Arianespace can handle more than 10 flights per year. Therefore loss of revenue does not seem to be a major problem requiring immediate policy attention.

78 Ibid.

79 *Analysis of Policy Issues,* NASA, August 1982, p. 78.

- **Loss of technological leadership:** A recent National Academy of Public Administration report warned that the loss of U.S. leadership in space technology "would be felt acutely on the economic front.[80] The report compared space to the electronics and communications fields where the United States once held a dominant position and cautioned that foreign competitors have "increased their public expenditures for space programs in recognition of the benefits of such endeavors to the strengthening of their national economies." Broadly taken, this is sound advice. However, with specific reference to space transportation it loses some of its urgency. The Shuttle is, and will be for some time, the most sophisticated and capable space vehicle flying. Ariane, Shuttle's main competitor, challenges the Shuttle in only one important area—the placement of satellites into geostationary orbit.
- **Loss of prestige:** The perception that the United States is first among space powers is an important advantage, albeit difficult to define. The United States has had enormous influence on the international application of space technology. This is particularly true with regard to satellite communications and remote sensing, where the United States not only developed most of the technology but also played a major role in establishing the institutions by which it was shared.

  Some diminution of the world's regard for U.S. technological prowess is certain to occur as alternatives to U.S. launch vehicles begin to appear. However, the United States may offset such changes by taking a leadership role in defining the organizational structure of the future space transportation industry. Major questions regarding the roles that governments and the private sector will play in this industry, the need for international regulation, and the usefulness of competition have yet to be answered. Space transportation is an infant industry; the United States, as its most important actor, still exerts considerable influence. It is appropriate that the United States exercise its leadership to ensure that this industry matures in a manner consistent with long-term U.S. trade objectives.
- **Hindrance of private sector entry:** The current Shuttle pricing policy, not foreign competition, is the most important barrier to U.S. private sector entry. Though the private firms–using current ELVs–should be able to compete on technical grounds with Government-backed launch services, they are not now financially competitive. Although the price for a Shuttle launch will be raised by NASA in 1985 and probably again in 1988, private operators may not be able to keep current ELV production lines open. Should the Air Force decide to purchase private launch vehicles to complement the Shuttle, the chosen company would be in a good position for successful "commercial" operation. Firms such as Starstruck and SS1, which do not compete for the same class of payloads as Ariane and the Shuttle, may not be affected by Government pricing policies.[81]
- **Secondary effects (e.g., loss of satellite sales, etc.):** Although foreign competition may not cause serious disruption of the Shuttle program, it may have indirect effects on other U.S. industries. A 1982 NASA policy report cautioned:[82]

  > The loss of launch operations to foreign competition can have important secondary effects. Foreign candidates for launch services are candidates for U.S. development of their satellite and of any related ground stations. When the direct effects are totaled, the estimate of the direct losses to the U.S. economy is very close to $4 billion over (a 12-year period).

  Although it is possible that Arianespace, or some other foreign organization, might eventually offer an attractive "package deal" including both satellite and launch vehicle, current buying practices do not indicate a cause for concern. Recent examples of satellite double-booking on both the Shuttle and Ariane and the successful entry of Japan into the ground station market indicate that price and product quality remain the primary concern of the buyer.

[80] *Encouraging Business Ventures in Space Technologies,* National Academy of Public Administration, May 1983, p. 6.

[81] It should be noted, however, that Ariane and Shuttle can both carry small payloads along with larger ones. Their prices for such services could be substantially lower than the private operators could afford to charge.

[82] *Analysis of Policy Issues,* op. cit.

COOPERATION IN SPACE TRANSPORTATION

In the heyday of the Apollo program, President Nixon in 1968 impaneled a Space Task Group to develop future goals for the U.S. space program, One of the recommendations of the Space Task Group (STG) was that the United States:[83]

> (U)se (its) space capability not only to extend the benefits of space to the rest of the world, but also to increase direct participation by the world community in both manned and unmanned exploration and use of space.

More specifically, the STG advocated a national commitment to what would eventually become the Space Shuttle.[84] As conceived by the STG, the Shuttle program would be an international cooperative effort with possible European design and construction of major subsystems. In 1970 and 1971, NASA discussed the possibility of a European contribution to a variety of cooperative ventures including the space transportation system. While Shuttle design options were proliferating and tradeoffs were being made internally among NASA, OMB, and Congress, NASA tried to include the Europeans in the program. However, in view of the difficulty of resolving emerging conflicts within U.S. agencies, simultaneous negotiations with a multinational European group seemed out of the question.

To prevent the total exclusion of the Europeans from Shuttle activities, NASA suggested that they might develop the "space tug." This potential role was the subject of extensive discussions lasting almost 2 years. As the final design approach to the Shuttle became fixed in the spring and summer of 1972, the role of DOD in supporting Shuttle development became more important. When the Space Task Group had identified the Shuttle as the next major technological development in space, DOD had not been an enthusiastic supporter. It was only with the aid of policy guidance from the President (i. e., that the Shuttle was a "national" system that would serve both DOD and civilian payloads) that DOD requirements were brought into the design process. Although NASA had primary responsibility for Shuttle development, the President decided that for political and economic reasons visible DOD interest and contribution to the Shuttle would be desirable.

DOD involvement in Shuttle design resulted in a further reduction of the European role. Some DOD missions would require the addition of an upper stage to place payloads into their desired orbits. The European space tug was originally intended to serve this function. But, because of the sensitive nature of certain of these payloads, DOD decided to take responsibility for the upper stage development. As a result, the United States discouraged European development of a tug and urged them to redirect their efforts toward what was to become the Spacelab.

Thus, in 2 years, the United States went from its initial encouragement of substantial international cooperation in space transportation system development to a position in which only payloads were being discussed. This change in position left segments of the European space community suspicious of U.S. intentions and disturbed by its peremptory behavior.

Against this background, future cooperative activities in space transportation must overcome major economic and political hurdles. First, the military security sensitivities which prevented the Europeans from building the space tug still exist and would presumably inhibit other types of cooperation. Second, both Europe and Japan foresee possible constraints on their full development of competitive commercial spacecraft and services (e.g., communication and remote-sensing satellites) if they do not also have control of an independent launch capability for such spacecraft. Both Europe and Japan have active aerospace industries increasingly capable of competing in the world markets. Finally, the Europeans are particularly sensitive to the prospect

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[83] " The Post-Apollo Space Program: Directions for the Future, " Space Task Group Report to the President, September 1969, p. 10.

[84] The "space shuttle" endorsed by the STG was a concept rather than a specific design. It was merely one part of a set of space activities which included a space station, an integrated transportation system and a vigorous program of advanced technology development. The integrated transportation system included the basic shuttle, an orbital transfer vehicle, and a reusable nuclear stage for larger, manned systems and for follow-on lunar or planetary missions. All of these systems were to satisfy three basic characteristics— "commonality, reusability, and economy. "

that any cooperative launching enterprise with the United States would depend on budget support that cannot be guaranteed.

The ability to reduce costs significantly is one reason why nations might wish to cooperate on the development and/or operation of launch vehicles. It is expensive to develop and maintain an efficient, low-failure-rate launching service to geostationary orbit. Subsidized and inefficient launch vehicles may keep aerospace employment high and help to support production costs, but are a drain on the economy.

Despite the pull of potential cost savings, the future of cooperative space transportation research will be further limited if the private sector can successfully offer launch services. international cooperation would most certainly involve government activities that would provide competition to private firms. It is unlikely that the United States will find reason to engage in international development programs in space transportation.

The U.S./Japanese agreements of 1969, 1975, and 1980 provide a different example of international cooperation.[85] Under these agreements the United States allowed U.S. firms to provide the Japanese Government—or firms working under contract to the Japanese Government–with launch vehicle equipment and technology. Although the individual agreements differ slightly, taken as a whole, Japan agreed: 1) to use the technology for peaceful purposes, **2)** not to transfer the technology to third countries, 3) to use the technology exclusively for the launch of satellites for the Japanese National Space Development Agency, and 4) not to launch projects for third countries. As a result of these agreements, U.S. firms have played and will continue to play an important role in Japanese launch vehicle technology (see table **5-4).** This type of cooperation might be used successfully as other nations begin to develop indigenous launch vehicles.

[85]See generally, "Space Cooperation: Agreement Between the United States of America and Japan, " July 31, 1969, T. I.A.S. 6735.

CURRENT POLICIES

As a corollary to the development of the Shuttle, NASA had planned to phase down and eventually terminate ELV programs; this plan was endorsed in the President's July 4, 1982, policy statement.[86] As a result of early Shuttle successes, NASA declined to order new Delta or Atlas-Centaur vehicles after 1982. Early in **1983,** the Department of Defense also announced that it was stopping production of the Titan vehicle.*'

When it appeared that NASA and DOD would no longer fund ELV procurement, several private firms expressed interest in providing this service on a commercial basis. They encouraged the White House to develop a policy in support of their efforts. On May 16, 1983, the Reagan Administration announced that "the U.S. Government fully endorses and will facilitate commercial operations of Expendable Launch Vehicles (ELVS) by the U.S. private sector." One of the basic goals of the President's ELV policy was to "ensure a flexible and robust U.S. launch posture to maintain space transportation leadership." Although not cited as one of its major goals, the President's statement did observe that: "Each commercial launch conducted in the United States, rather than by foreign competitors, would strengthen our economy and improve our international balance of payments. "

The ELV policy further emphasized that the Shuttle is the "primary launch vehicle for the U.S. Government" and that it would also continue to be available for domestic and foreign commercial users. NASA has interpreted this to mean that the Government will not only take care of its own needs, but also participate actively as a compet-

[86]White House Fact Sheet: National Space Policy, July 4, 1982.

[87]The DOD decision to launch all payloads on the Shuttle is being reconsidered. The Air Force recently asked Congress to approve procurement of 10 upgraded Titan or Atlas-Centaur vehicles to be launched two each year for 5 years. Although claiming strongly to support the Shuttle, the Air Force has stated that ELVs are necessary to provide "assured access to space. " See: *Aviation Week and Space Technology:* Mar. 5, 1984, p. 19; Apr. 16, 1984, p. 17; Apr. *30, 1984,* p. *25; Aerospace Daily,* Mar. 23, 1984, p. 129; *Defense Daily,* Feb. 28, 1984, p. 317.

Table 5-4.—Companies That Contribute to Manufacturing Japanese Launch Vehicles
(U.S. corporations are given in parentheses)

Covered work	Vehicle N-1	Vehicle N-11	Vehicle H-1
Vehicle integration	MHI (M DC)	MHI (MDC)	MHI
First stage:			
Airframe	MHI (MDC)	MHI (MDC)	MHI (MDC)
Main engine	MH1/IHI (RIC)	MH1/IHI(RIC)	MHUIHI(RIC)
Vernier engine	IHI (RIC)	IHI (RIC)	IHI (RIC)
Strap-on booster	NM (TC)	NM (TC)	NM (TC)
Second stage:			
Airframe	MHI (MDC)	MHI (MDC)	MHI
Engine	MHI (RIC)	IHI (ATC)	MHI, IHI
Reaction control system	IHI (TRW)	IHI (ATC)	IHI (TRW)
Third stage:			
Airframe	MHI(MDC)	MHI(MDC)	MH\NM
Motor	NM(TC)	NM(TC)	NM
Satellite fairing	MHI(MDC)	MHI(MDC)	MHI(MDC)
Onboard equipment:			
Guidance and control equipment	NEC(HONEYWELL~ JAE,MHI (MDC)	MHI(MDC)	JAE, NEC, MH~MPC, MSS
First/third-stage telemeter	MELCO	MELCO	MELCO
Command destruct receiver	NEC(MMAE)	NEC(MMAE)	NEC(MMAE)
Second-stage telemeter and pulse transponder	NEC(MMAE)	NEC(MMAE)	NEC

Abbreviations:
ATC: Aeroject TechSystems Co.
HONEYWELL: Honeywell Inc.
IHI: Ishikawajima-Harima Heavy Industries Co. Ltd.
JAE: Japan Aviation Electronics Industries Co. Ltd.
MDC: McDonnell Douglas Corp.
MELCO: Mitsubishi Electric Corp.
MHI: Mitsubishi Heavy Industries, Ltd.
MMAE: Motorola Military and Aerospace Electronics Inc.
MPC: Mitsubishi Precision Co. Ltd.
MSS: Mitsubishi Space Software Co. Ltd.
NEC: NEC Corp.
NM: Nissan Motor Co. Ltd.
RIC: Rockwell International Corp.
TRW: TRW Inc.
TC: Thiokol Corp.

NOTE: Names of overseas companies given in parentheses are firms from which NASDA'S contractors get cooperation in the manufacture by means of technical assistance, production licenses, or hardware supply.

SOURCE: National Space Development Agency.

itor in the overall launch market. **The President's policy encourages "free market competition among the various systems and concepts within the U.S. private sector," yet the policy fails to recognize that the Government-owned Shuttle is one of the main competitors for private sector ELV activities. Therefore, "free market competition" between private ELV suppliers may be meaningless if ELVs are noncompetitive vis-a-vis the Shuttle.**

Notwithstanding its support for ELVS, the policy stated that the price for Shuttle flights "will be maintained in accordance with the currently established NASA pricing policies" through 1988. After this time, " . . . it is the U.S. Government's intent to establish a full cost recovery policy for commercial and foreign STS flight operations. " If the price of a Shuttle launch were increased before 1988 to reflect actual costs, including depreciation, current ELVs might have a better chance of competing for a share of the commercial market. Such a price increase might be damaging to Shuttle-related commercial activities such as privately developed upper stages and various MPS-related activities.

his unclear what effect such an increase would have on the demand for Ariane launches. It is possible that an increase in Shuttle prices would drive some customers to U.S. ELVs or to Ariane,

If, as has been suggested by some analysts, the Ariane price was chosen to be competitive with the Shuttle, an increase in Shuttle price might result in a like increase in the price of an Ariane. In any case, since "full cost recovery" will not be the Shuttle pricing policy until 1988, it is uncertain whether the Titan, Atlas-Centaur, and Delta launch vehicles will be able to sustain launch activity to see them through to this time. Therefore, commercial U.S. ELVS may not be an important participant in the global competition for launch services.

FUTURE POLICY OPTIONS

The United States does not lack the "means" by which to engage in successful private or government-supported international competition in space transportation; what it lacks is a national consensus concerning the "ends" of such competition. The development of foreign space transportation systems has caused considerable–and often unwarranted—concern in the United States. It is true that foreign competition will reduce the demand for Shuttle launches and for private ELVs; whether this requires an immediate policy response depends entirely on the constraints that the Government imposes on NASA and the incentives it offers the private sector. The following discussion analyzes several different policy options that have been proposed for the U.S. space transportation system.

Option 1:
Use the Shuttle primarily for launching Government payloads

Should the U.S. Government compete **in the international launch service market?** The United States could adopt the policy that the primary role of the Shuttle is to launch U.S. Government payloads. Such a position might rest on the ideological conviction that, except in rare instances, the Government should not undertake activities that compete with the private sector. Alternatively, since commercial payloads launched on the Shuttle involve some degree of Government subsidy, such a policy might flow from a desire to reduce the cost to the taxpayer of operating the space program. OMB has indicated its support for such a policy :[88]

> **Generally speaking, when circumstances justify the funding and management of an operational system by the U.S. Government that is also sought by nongovernment entities, the U.S. Government should limit its role to making available system capacities which exceed its own needs.**

Under the OMB approach, NASA would not regard itself as being in competition with foreign or domestic launch services. To the extent that excess capacity existed, it would be sold "so as to minimize the overall cost to the federal government of meeting its own needs in the long run." The existence of foreign and private U.S. vehicles would be important only insofar as they affected the price at which this excess capacity could be sold. OMB suggested that an appropriate price would be "the highest price at which sufficient users will be available to utilize the excess capacity." Limited competition from foreign and private U.S. suppliers would allow NASA to charge a high price for launch services; aggressive competition would limit the price that NASA could charge and still sell all of its excess capacity.

Under a policy of noncompetition, an increase in Government launch activities could significantly reduce commercial Shuttle operations. For example, the decision to build a space station or to increase military activities in space might limit the space available on the Shuttle for commercial launches. OMB suggested that the Shuttle price should not "in itself lead to the demand for funding of additional capacity by the U.S. Government." This would indicate that, with a very limited capacity, NASA would discourage commercial Shuttle use by charging higher prices. The OMB position does not consider the possibility that an increased Shuttle flight rate might increase efficiency and reduce costs for all users.

To summarize, a policy that restricted the Shuttle primarily to Government payloads would likely have the following results:

- eliminate NASA as a major supplier of commercial launch services;
- reduce the likelihood that additional orbiters will be needed in this decade;
- increase the likelihood that the U.S. private sector could make an early and successful entry into the launch service market;
- potentially reduce the cost of operating the overall Shuttle program by requiring fewer flights; and
- increase the demand for, and potential commercial success of, the Ariane launch vehicle.

[88] Stockman Letter, Op. cit.

Option 2:
Capture a high percentage of commercial launches with the Shuttle

This would appear to be the current U.S. policy. Two reasons are often stated for a strong U.S. competitive posture: to maintain its leadership role in the development and application of space technology, and to ensure foreign technical and financial support for future U.S. space activities. In addition, being regarded as first among the Free World space powers carries important international political and psychological advantages.

A recent NASA Advisory Council report on the Shuttle found that:[89]

> **The overwhelming positive appeal of the Shuttle lies in current NASA pricing policy, designed to make the Shuttle competitive to currently available expendable boosters. Commercial success of STS hinges on continuation of this margin.**

In accordance with the Council's report, a policy decision has been made to pursue international launch opportunities aggressively. This decision entails a commitment to continue the current practice of subsidizing the Shuttle's commercial payloads, as well as a requirement that greater attention be paid to Shuttle marketing. The NASA Advisory Council report stated:

> **There was general agreement in the Task Force that an intensive high level marketing effort on behalf of Shuttle utilization is warranted. In this context, marketing means to develop and implement a broad scale and long range plan to involve increasing numbers of users in the exploration of the STS capabilities. It thus involves market analysis, planning, advertising, customer service, financing, and insurance, to name a few areas. It must be a high level, strongly led effort, with the active participation of NASA top management to the Administrator level.**

The NASA Advisory Council report identified "the emergence of increased competition" as one of the primary reasons for pursuing a bold marketing strategy.

To summarize, current policy encouraging the Shuttle to capture a high percentage of commercial launches, will likely have the following results:

- increase the demand for Shuttle services;
- create a need for additional orbiters in this decade;
- potentially increase the cost of operating the overall Shuttle program;[90]
- decrease the likelihood that the U.S. private sector could make an early and successful entry into the launch services market; and
- reduce the demand for, and the potential for commercial success of, the Ariane launch vehicle.

Option 3:
Encourage private launch activities

When the National Aeronautics and Space Act was written in 1958, it was assumed that the Government would be the prime launch authority. The NAS Act stated:[91]

> **The Congress further declares that such (aeronautical and space) activities shall be the responsibility of, and shall be directed by, a civilian agency (NASA) exercising control over aeronautical and space activities sponsored by the United States."**

The NAS Act refers to the private sector as potential NASA contractors but does not mention their independent participation in space activities.[92] It may be assumed from the historic U.S. dependence on a private sector economy that expectations of private launch services were implicit in U.S. space policy, subject only to satisfying the applicable health and safety regulations. More recently, statements of national space policy by both the Carter and Reagan Administrations have highlighted the importance of private sector space activities. For example, President Reagan's Statement on Space Policy of July 4, 1982, declared:

[89] "Study of Effective Shuttle Utilization," report of the NASA Advisory Council Task Force, Nov. 17, 1983.

[90] Some analysts believe that an increase in Shuttle flights will, through a combination of learning curve efficiencies and economies of scale, actually reduce the cost of operating the Shuttle.

[91] National Aeronautics and Space Act of 1958, sec. 102(b), 42 U.S.C. 2451.

[92] Ibid., sec. 203(5).

> The U.S. Government will provide a climate conducive to expand private sector investment and involvement in space activities . . .

Can the U.S. private sector, encouraged by the U.S. Government, be competitive with foreign, government-supported launch systems? This is a point on which there is significant disagreement both in the U.S. Congress and in the private sector. In the U.S. air transportation industry, however, private U.S. firms have successfully competed with foreign government-owned, often subsidized, firms. Private U.S. firms, using current ELV technology, could probably compete successfully against foreign launch vehicles such as the Ariane.

It is uncertain whether U.S. firms will be able to compete against both foreign ELVs and the U.S. Government's Shuttle. A decision to support private launch activities aggressively would most certainly require either limiting the number of commercial payloads carried on the Shuttle or raising the Shuttle launch price. On this subject, the NASA Advisory Council report stated:[93]

> The potential for the successful privatization of ELVs was considered fairly low by the Task Force. It seems probable that following divestiture by NASA of an ELV to an entrepreneurial company, that company would exert every effort to cause the Shuttle pricing to be revised upward in order to make the ELV more competitive. This would run counter to the Shuttle pricing policy and its objectives.

It is possible to argue by analogy to the postal service that the Government and the private sector might coexist as launch service providers. The majority of the mail in the United States, by law, can be handled only by the U.S. Postal Service; however, private firms are allowed to provide numerous specialty services. If NASA continues to pursue commercial payloads aggressively, it is conceivable that some private sector firms might be able to market expendable launch vehicles to customers who needed unique services such as rapid launches or payload delivery to non-Shuttle orbits. It is doubtful, however, that the near-term demand for such "specialty services" will be sufficient to sustain even a single private firm.

At present, the United States is attempting to pursue policies that simultaneously seek to encourage the entry of the private sector into the launch services market and to maximize the use of the Shuttle for commercial launches. If the demand for launch services were to increase dramatically, it might be possible to maintain both positions; since this is unlikely in this decade, the United States must choose which of these two courses it intends to follow.

To summarize, a policy that encouraged the participation of the Private sector with expendable launch vehicles would likely have the following results:

- encourage the formation of an internationally competitive U.S. space transportation industry;
- reduce NASA's role in space transportation and the demand for Shuttle launches;
- reduce the likelihood that additional orbiters will be needed in this decade;
- potentially reduce the cost of operating the Shuttle program; and
- increase the demand for, and the potential commercial success of, the Ariane launch vehicle.

Option 4:
Use the Shuttle to meet all current and future U.S. space objectives

The Shuttle is not "just another launch vehicle." It is a unique tool for conducting manned activities in space that until now were not possible. It is also a technology in which this Nation has invested over $15 billion. The NASA Advisory Council recently expressed their concern that the U.S. commitment to the Shuttle might be wavering:[94]

> We sensed a great pressure within the government to find some way to make the STS "pay its way" . . . We are concerned that preoccupation with this thrust may distort our national priorities in space. In our view the Shuttle is a great national asset in its own right, and is essential to pursuit of civil and military objectives in space.

[93] "Study of Effective Shuttle Utilization," op. cit.

[94] Ibid.

It is possible to conceive of a space transportation policy built around the expansion of space activities through the Shuttle, Having recently made the decision to encourage Shuttle-related commercial activities, to build a space station, and to use the Shuttle for military space activities, this Nation has already made a substantial commitment to Shuttle operations. It is reasonable to argue, as NASA has often done, that commercial space operation should be coordinated so as to contribute to overall national space goals, including in this case the success of the Shuttle program. If current Shuttle-use policies were combined with a more vigorous attempt to enlist commercial communication satellites (perhaps at the expense of developing a reusable orbital transfer vehicle for payload delivery to geostationary orbit) and an increased level of effort (and of expenditure) for scientific and new commercial payloads such as materials processing, Shuttle utilization might remain the most important single element in future space policy decisions.

Under such a policy NASA would not be limited to flying Government payloads, since it would be desirable to direct the energies of the private sector into Shuttle-related activities. However, capturing a large number of communication satellite launches with the Shuttle would not be the only purpose of such a policy; it would also require a commitment to NASA programs and research activities that would create new sources of demand for Shuttle services. Such a policy would rest on the belief that, if the benefits of "space industrialization" are to be realized, the Shuttle, is indispensable.

Competing with foreign launch vehicles would not be the primary reason for such a policy. Capturing a large number of commercial payloads might be useful if it created pressure to "Shuttle-optimize" satellites and other cargo. Conceivably, a strong movement in this direction could, as NASA had hoped in the past, render ELVs obsolete.

A policy that sought to maximize Shuttle use would have to overcome a number of important domestic and international barriers. Domestically, there is considerable support for a policy to encourage a private ELV industry. There are some compelling arguments in support of this position. There is also substantial national interest in reducing the Federal deficit and, therefore, Government expenditure; this includes expenditures for the space program. Though NASA argues that revenue from commerical flights will eventually reduce the cost of operating the Shuttle, critics charge that, for the foreseeable future, such activities only add to the cost of the space program.

Even though the Shuttle is technologically superior to the Ariane and other potential foreign competitors, as long as these competitors can launch payloads at a price that bears a reasonable relationship to the cost, they will continue to do so. For this reason, it is unlikely that foreign equipment manufacturers will "Shuttle-optimize" future satellites and other space cargo; likewise, U.S. equipment manufacturers are unlikely to build "Shuttle-only" equipment as long as the space transportation market includes both the Shuttle and ELVS.

To summarize, a policy that encouraged the maximum use of the Shuttle for all types of missions would likely have the following results:

- increase the likelihood that the Shuttle will play a major role in the successful exploitation of outer space;
- create a need for additional orbiters in this decade;
- decrease the likelihood that the U.S. private sector could make a successful entry into the launch service market;
- greatly increase the cost of operating the Shuttle program (as well as other NASA programs); and
- reduce the demand for, and the potential commercial success of, the Ariane launch vehicle.