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International Competition For Satellite Launch Services

A Case Study by Wayne T. S

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INTERNATIONAL COMPETITION FOR
COMMERCIAL SATELLITE LAUNCH SERVICES

SUMMARY

Since the launch of Sputnik in 1957, the use of space for practical applications has grown tremendously. Satellites have revolutionized communications, weather forecasting, navigation, exploration for naturual resources and other activities, and the use of satellites continues to grow. Concurrent with the growth in satellite uses has been an expanding requirement for satellite launch services in the free world, particularly for communications satellites. In 1985 this market generated about $500 million in revenues, and it is projected to double in size over the next decade.

The National Aeronautics and Space Administration (NASA) dominated the launch market through the 1970s, but now shares it on an almost equal basis with the European Space Agency (ESA). The ESA began to penetrate the launch market in 1980 by establishing an organization called Arianespace, whose sole purpose is to market and operate satellite launch services. Arianespace currently has three different launch vehicles in operation, and has undercut NASA's launch prices.

Over the next decade Arianespace in all likelihood will increase its share of this market, perhaps up to two-thirds. The competitiveness of Arianespace will be enhanced primarily through a decrease in commercial launch services provided by NASA. NASA is phasing out its Delta and Atlas-Centaur expendable launch vehicles and intends to rely totally on the shuttle fleet for all of its launch requirements. The recent Challenger disaster has left NASA with three shuttles which, under the most optimistic of circumstances, could make a total of 18 flights per year. A large percentage of these flights will be needed for U.S. Government programs. At the same time, the Europeans are improving their own launch capabilities by adding new, larger launchers, and by increasing their launch rate.

It is possible that one or two other competitors could enter the launch market in the next decade. The nation that appears to have the best opportunity to do so is Japan, which is scheduled to have a domestically-designed medium-lift launch vehicle available in 1992. Japan's current launch vehicle is based on U.S. technology, and because of licensing agreements cannot be used to launch satellites for other countries.

It is less likely that the Soviets or the Chinese will enter the market. For the Soviets to do so, they would have to open major sectors of their space program to the public and overcome technology transfer restrictions. Neither is likely to occur. China has just recently developed the capability to launch communications satellites, and the reliability of its new launcher has not been established. Another limiting factor is that this launch vehicle does not have the capability to place medium and large-sized

communications satellites into orbit. China's remote location from the satellite market is another impediment. India and Brazil will not have launch vehicles capable of orbiting communications satellites during the next decade.

There is a growing possibility that one, and at the most two, U.S. private companies attempting to enter the commercial satellite launch market will succeed. Those with the best chances are Transpace, Incorporated, which was awarded marketing rights by NASA for the Delta launcher; General Dynamics, which is negotiating with NASA for marketing rights for the Atlas-Centaur launcher; and Martin-Marietta which produces the Titan series of launch vehicles.

Wayne T. Strand
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INTRODUCTION

This research paper examines the space programs of various nations and organizations to assess their capabilities to compete for commercial satellite launch services. For years the U.S. had the leadership position in this market, but now shares this position with the West Europeans. NASA had planned on capturing up to 75 percent of the market over the next decade and had used that plan to help justify 24 shuttle flights per year by 1990. The loss of Challenger, however, leaves NASA with a capability to achieve 18 flights per year under the most optimistic conditions. Most of this launch capability will be needed for government payloads. Unless NASA takes some immediate action to augment its launch capabilities, its share of the launch market will continue to decrease.

This report is based on an extensive review of literature addressing space programs, and on interviews with officials in NASA and the Department of Transportation (DOT). It is intended for people involved with foreign affairs, and in particular those conducting business with the Soviet Union, West European countries, Japan, the People's Republic of China, India, and Brazil. The report should also be of interest to people following international space developments, and technology transfer and trade issues.

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THE SATELLITE LAUNCH MARKET

Since the launch of the first artificial satellite by the Soviets in 1957, the number and uses of satellites have grown tremendously. In mid-1985 the North American Aerospace Defense Command reported that there were over 1,520 satellites in orbit, and many of them still operating. That number does not include those which have decayed and been destroyed upon reentering the earth's atmosphere, or that have been retrieved from space.

Satellites are used to perform a variety of functions. Some are referred to as "applications" satellites and are used for communications, weather forecasting, earth resources sensing, and aids to navigation. Others are used for scientific research and support to national security programs. Different types of satellites operate at different altitudes. For example, communications and most weather satellites operate in geosynchronous orbit at an altitude of approximately 22,300 miles above the equator.[1] At this altitude the satellite orbits at a rate equal to the earth's rotation, allowing it to stay positioned over a constant point on the earth's surface. Earth resources satellites operate in sun-synchronous (polar) orbit at altitudes ranging from approximately 100 to 500 miles. The orbit paths are inclined in longitude which allows them to operate over the target areas during periods of sunlight. Other satellites operate in low-earth orbit at altitudes ranging from one to several hundred miles. Their orbits are not synchronized with the presence of sunlight.

In the commercial world, communications satellites are by far the largest revenue earners, and therefore the focus of the satellite launch market. Commercial communications satellites had their origin in the U.S. Communications Satellite Act of 1962 which established the first private space venture -- the Communications Satellite Corporation (COMSAT). COMSAT was given the charter to provide domestic satellite communications. In 1972, the Federal Communications Commission authorized U.S. common carriers--such as Western Union and AT&T--to set up and operate satellite systems for domestic communications on a competitive basis. Satellite communications organizations and networks similar to these have been established by other countries, both in the developed and the Third World.

Since the first communications satellite was placed in orbit in 1964, over 105 others have been launched. Today they account for most international phone calls, and many television programs are relayed, processed, or distributed via satellite. Communications satellites also perform other functions such as transmitting data for morning newspapers, radio stations, weather services, and computers.

The capabilities and size of communications satellites have grown along with the uses. The first Intelsat satellite, launched in 1964, had a capacity of 240 voice channels and one television channel. Intelsat VI, scheduled for launch this year, has 30,000 voice channels and four television channels. The first communications satellite, SYNCOM 1, weighed about 86 pounds. As higher capacity launch vehicles have become available, satellites have increased in size, with Intelsat VI weighing over 4,600 pounds. Even larger satellites, on the order of three or four tons, are projected for the 1990s.

Earth resources satellites represent another potential source of revenue in the commercial sector, albeit much smaller in size than the satellite communications business. These satellites use sensors that record different degrees of reflective or radiation energy from features on the earth's surface. This data, which is transmitted electronically to ground receiving stations, can be manipulated with computers to compare and contrast the characteristics of natural and manmade features. This information is useful in mineral and hydrocarbon exploration, land-use planning, pollution control, and other applications. To date, NASA has launched and operated five of these satellites (the LANDSAT program). The NASA program for LANDSAT was to be commercialized, but bureaucratic wrangling and funding difficulties have stalled the transition.

While the U.S. program has stagnated, other countries are moving forward with their earth resources satellite programs. The French SPOT system should become operational this year, and another European group has a competing system in advanced development. Two resource satellite programs are underway in Japan, and India and Brazil are working on programs.

Although this sector of the commercial space market is small, it could develop rapidly as more governments and private organizations become aware of its potential capabilities. Improvements are being made in the quality of images and in data manipulation which will further enhance its potential.

The size of the future satellite launch market is critical to those organizations competing in the satellite launch business, or with plans to do so. The estimates that are available for the communications market vary widely. On the high side is a 1984 Arianespace estimate of 250 satellite launches between 1985 and 1991. A 1985 article in Macleans magazine cites some experts estimating that communications satellites will require about 70 launches per year. More conservative estimates center around 20 communications satellite launches per year. A statement made in 1984 by then Director of NASA Beggs projected that the market is not likely to be much more than 20 per year. A 1985 article in Financial Times quotes government and telecommunications companies stating that roughly 20 communications satellites are expected to be launched annually over the next few years. And another article, in a 1985 National Journal publication, states that expendable launch vehicle manufacturers expect 100 communications satellites to be launched over the next 15 years.

Based on a number of factors, the estimate centering around 20 per year appears to be more accurate than the higher ones. One factor is that communications satellites now in development will have much more capacity than those currently operating, and consequently fewer will be needed. Second, there is unused capacity available on some satellites. Third is that the orbit used by these satellites is crowded, both in terms of space and frequency. And, land-based, fiber optics communications systems are expected to increase sharply in the 1990s and will compete with the satellites.

The earth resources satellite launch market currently is very small, about one per year. If, however, the educational process underway is successful as are efforts to improve image quality and data handling capabilities, this market could grow to two or three launches per year.

Some communications satellites and almost all of the other types of satellites currently in use are owned and operated by government organizations. Those countries with launch capabilities will continue to use their own assets for their satellite launches. Those countries without launch capability, however, will seek services in the satellite launch market.

FACTORS AFFECTING SELECTION OF A SATELLITE LAUNCH SERVICE

Selection of a launch service by a commercial satellite customer is a compromise of cost, complexity, availability, reliability, and occasionally political and trade considerations.

- Cost. Launch costs are dependent on the size of the satellite and the altitude of the orbit required (Large satellites launched to geosynchronous orbit require larger--and more costly--launch vehicles than do smaller satellites launched to the same orbit.) Launch costs can be split if two or more satellite customers can share the same launch vehicle.

- Complexity. The complexity of the launch vehicle technology is an important consideration. Some launch vehicles incorporate simple, proven technology, whereas others use complicated technology which increases the risk of failure. The complexity of the launch operation is another factor. Boosters that can launch satellites directly into orbit generally have a better chance of success than those requiring a series of separate maneuvers.

- Availability. The design and fabrication of a satellite is a multi-year and multi-million dollar venture. Consequently, the satellite owner wants to get the satellite into orbit and operating as soon as possible so that it can begin generating revenue.

- Reliability. Reliability of the launch vehicle has gained importance over the last several years. In 1984 and 1985 seven satellites were lost during launch operations, costing the insurance underwriters $625 million. As a result, some underwriters have withdrawn from the market, and those that remain have reduced coverage and increased premiums to 30 percent of satellite cost. As a result, at least one satellite customer launched without insurance, and others may be forced to do the same.

- Political and Trade Considerations. To date the Western countries have not launched any satellites for Communist countries. The only free-world country which has used a Communist country--Russia--for launch services is India, which enjoys a close political relationship with the Soviets. Within the free world, the U.S. and West Europeans are the principal satellite launch customers. In the past, the West Europeans have placed pressure on ESA member nations to use launch services available through Arianespace. This has not always worked, however, as some European countries have contracted with NASA for launch services. Likewise, some private American firms have contracted with Arianespace.

The selection factors described above will dictate where satellite customers will seek launch services. The relative importance of each, however, will change with developments in the various space programs.

NATIONS AND ORGANIZATIONS WITH SPACE PROGRAMS

Six individual nations and one consortium of nations have space programs. The individual nations are the U.S., the Soviet Union, Japan, The People's Republic of China, India, and Brazil. West European nations have combined their separate programs into one--the European Space Agency. A small number of private organizations are attempting to develop space programs, and several others have plans to do so. The private organizations are focused on providing launch services.

To assess the current and future capabilities of these nations and organizations to compete in the commercial satellite launch market, the space programs of each were examined. Specific aspects of the programs reviewed were their historical development, current and future launch vehicle capabilities, and major program goals over the next decade. The nations and organizations are presented in order of their overall space program size and capability.

UNITED STATES

The U.S. space program was given organizational structure in 1958 with passage of the National Aeronautics and Space Act. This Act established NASA and gave it responsibility for the civilian space program.[2] Responsibility for the military space program was given to the Department of Defense (DOD), with the Air Force acting as executive agent. The Space Act also established the goals for the space program, with scientific research, technological development, and practical civilian and military applications serving as the cornerstones.

In 1961, the NASA program was given a big boost when President Kennedy received congressional support for the Apollo program, which was intended to land the first man on the moon. The Apollo program was the single-most important space initiative for the U.S. in the 1960s, culminating in the first lunar landing by man in July 1969.

There were, however, other important space developments for the U.S. in the 1960s. A number of separate launch vehicle developments were consolidated into a series of rockets that formed the backbone for space launches from the early 1960s into the mid-1980s. They are the Scout, Delta, Atlas, and Titan series. The U.S. was the first country to develop and use high-energy, cryogenic (liquid hydrogen-liquid oxygen) fuels, and rocket motors that could be shut off and restarted. It also launched a series of satellites which significantly improved communications, navigation, weather forecasting, and other activities. And a number of scientific probes were launched into deep space to return data about other planets.

The progress and successes of the U.S. space program in the 1960s, however, had a large price tag. At the peak of the program, one percent of the U.S. Gross National Product was committed to the space program, with NASA receiving almost three-quarters of the funds. And, NASA had as many as 400,000 people in government and private industry dedicated to its space program, with an estimated additional 200,000 committed to the military sector of the program.

In the 1970s, the U.S. space program lost some of the momentum developed in the 1960s. NASA's budget leveled off and, to a small degree, was eroded by inflation. And, the DOD was commanding larger shares of the funds, accounting for about 45 percent of total space expenditures in the late 1970s. Manned missions ended with the launch of Skylab in 1973. Much of NASA's activity was directed towards the development and launching of larger, more sophisticated applications satellites, and launching more capable scientific payloads into deep space. The need for manned flights was not forgotten, however. Development of a reusable space transport system--the shuttle--began in 1972 and continued through the 1970s. The shuttle was intended to serve as the primary launch system for the U.S. in the 1980s and 1990s.

In the 1980s NASA's space program has achieved some successes, suffered some losses, and has come under increasing criticism. The shuttle program became operational in 1981, and until the Challenger disaster in January 1986, had achieved a string of 24 successful flights. Critics, however, point to the five year delay in its development and the billions of dollars in cost overruns.

NASA also has come under criticism in the area of space commercialization. In a study completed by the congressional Office of Technology Assessment (OTA) in the early 1980s, NASA is cited for "a loss of significant revenue opportunities" in the increasingly lucrative space business "as well as potential loss of prestige and influence". It blamed the dilemma on "the lack of consistent long-term goals and clear policy initiatives". And in a 1985 report, OTA states that NASA by itself is not well equipped either to promote or to regulate growth in the commercial exploitation of space.

The Administration has taken several steps in the past two years to provide direction and assistance to the civilian sector of the space program. In 1984, the President approved a National Space Strategy aimed at giving the U.S. the lead role in the age of space commercialization. Also in 1984 the Commercial Space Launch Act was passed which gave the DOT responsibility for assisting private U.S. companies entering the satellite launch market. This Act is intended to assure that adequate launch services are available to those corporations intent on using space for commercial purposes.

The Space Launch Act has not yet resulted in any private concern entering the satellite launch market, but it has caused some bureaucratic problems between NASA and DOT. The DOT, along with at least one private company, has called into question the use of the

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shuttle to earn revenues, and the subsidization of shuttle launch rates which makes it difficult, if not impossible, for private enterprises to compete. Another government action in 1984 was National Security Directive 144 which charged NASA with establishing a price policy whereby full costs of shuttle operations would be recouped. Price hikes are scheduled for 1986 and 1989. One other government decision which impacts on NASA's program was a compromise reached in 1985 which allows the DOD to keep a limited but independent launch capability, rather than relying totally on the shuttle for launch services.

Two major goals for NASA in the 1990s are to develop and launch a space station by 1994, and to develop a trans-atmospheric vehicle. A more immediate concern, however, is how NASA can expand its launch capability, given the loss of Challenger and an earlier decision to phase out all expendable launch vehicles (ELVs) in the mid-1980s. Each of these three activities will require large sums of money and come at a time when most federal government programs are about to be frozen or reduced in size.

Organizational Structure and Facilities

Planning, coordination, and control of NASA programs occur at its Washington headquarters. Nine major field installations provide research and development, launch operations, and flight tracking, control and communications support to NASA's programs. In 1985 approximately 135,000 people in government, academia, and industry were involved in NASA programs.

NASA's primary launch facility is the Kennedy Space Center. Both ELVs and the shuttle are launched from there. A second shuttle launch facility is nearing completion at Vandenberg Air Force Base in California. NASA has two smaller launch facilities--one at Wallops Island, Virginia and the other a sea-based platform at San Marcos, off the east coast of Africa. Space tracking, control, and communications are located at the Johnson Space Center; it is supported by a large network of ground-based tracking and communications facilities located throughout the world.

Launch Vehicles

Since the late 1950s, NASA has relied primarily on three series of ELVS--the Scout, Delta, and Atlas. All three have undergone upgrades since becoming operational and are still in use. Only the Delta and Atlas-Centaur are used for satellite launches, and they are scheduled to be phased out by mid-1987.

Delta. Since reaching operational status in 1960, the Delta has been the workhorse of the space program, accounting for over 180 launches and achieving a success rate of over 94 percent. Its primary mission has been to carry scientific, weather, communications, and earth resources satellites into orbit. Only one Delta remains in NASA's inventory, and it is scheduled to be launched in mid-1986. The production line has been shut down by McDonnell Douglas, and exclusive rights to market the Delta were given to Transpace, Incorporated in 1984.

The Delta program was the first contract let by NASA to develop an ELV. Since its initial design it has undergone a number of upgrades. The current version uses liquid propellants in its first two stages, and a Payload Assist Module (PAM)--which is attached to the payload--as its third stage. (The PAM is being used on some shuttle payloads.) The first stage is augmented by nine solid propellant strap-on boosters. With the PAM, the Delta can lift up to 2,800 pounds into geosynchronous transfer orbit.

Atlas-Centaur. The Atlas-Centaur has been NASA's primary launch vehicle for intermediate-sized payloads to low-earth and geosynchronous orbits, and for interplanetary missions. Since reaching operational status in 1966, over 80 Atlas-Centaur launches have occurred, and it has achieved a success rate of about 90 percent. This vehicle has accounted for one-third of all communications satellites launched by the U.S., and was the booster used to soft-land the first spacecraft on the moon. Only two Atlas-Centaur vehicles remain in inventory, one scheduled for launch in mid-1986 and the other in mid-1987. The production line at General Dynamics has been shut down, but the Centaur second stage is still being produced for use with some shuttle payloads. Exclusive rights to market the Atlas-Centaur have been awarded to General Dynamics.

The Atlas-Centaur is the second launch vehicle to be based on an Intercontinental Ballistic Missile (ICBM). The Atlas-Agena was the first. It has two stages, both using liquid propellants. Unlike the first stage, however, the second stage uses high-energy cryogenic fuels, the first launch vehicle to do so. The technology for the second stage was developed under the direction of NASA's Lewis Research Center in Cleveland. The Atlas-Centaur also has a stop-start capability, the first launch vehicle to do so. It is capable of placing 10,000 pounds into low-earth orbit, over 4,100 pounds into geosynchronous transfer orbit, and 2,000 pounds on an interplanetary trajectory.

Shuttle. The shuttle, or Space Transport System, was designed to be NASA's major launch vehicle for the 1980s and 1990s, carrying civilian, military, and government payloads into low-earth orbit. The first shuttle flight occurred in April 1981, and the system was declared operational after the fourth flight in July 1982. Each orbiter is designed to accomplish 100 flights before being retired. Five shuttle orbiters have been built, but only three are operational. One was used as a testbed and Challenger was destroyed in the January 1986 disaster. The production line at Rockwell International is being shut down, but NASA has stockpiled extra major components of the shuttle to be used as spares.

The shuttle consists of three major components--the orbiter which carries the crew and cargo; the external tank which carries the high energy cryogenic fuels; and two large, solid rocket boosters. The overall height of the shuttle system is 184 feet, and it weighs over 2,245 tons at lift-off. The orbiter can carry up to a seven-person crew, and has a cargo bay about 60 feet long and 15 feet wide. The shuttle system is able to carry up to 65,000 pounds into an orbit ranging from 115 to 250 miles, depending on cargo weight and other variables. Most shuttle flights carry a variety of payloads, fitted together to best utilize the shuttle's space and lift capabilities.

Many of the payloads launched on the shuttle are sent into geosynchronous orbit or are launched into interplanetary trajectories. These spacecraft require independent rocket stages which are attached to them and ignited after launch from the shuttle.

The number of shuttle flights has been pared back significantly since NASA made its first projections. In 1976, NASA projected 572 flights by four shuttles over a 12 year period. By January 1985, the number had been reduced to 227. During the first five years of the program, 25 shuttle launches have occurred, including the ill-fated last flight of Challenger, a number far below the 1985 projection. NASA had projected 24 flights per year by 1990, based on a four-shuttle fleet and a reduced turn-around time from 100 days in 1983 to 28 days. Since the loss of Challenger, NASA now projects (optimistically) a maximum of 18 flights per year.

Outlook

The most immediate problem facing NASA is to determine what caused the Challenger disaster, make the necessary fixes, and get the shuttle flying again. Even with a quick resolution of the problem, NASA's launch program will suffer serious delays. Some sources state that flights will not resume until October 1986 at the earliest, and could be delayed up to several years. One scientific project--a probe to study Halley's Comet--has been cancelled and two others--Europe's Ulysses mission to study the sun and the U.S. Galileo mission to Jupiter--in all probability will be postponed. The big losers, however, will be the commercial customers who receive a lower priority for launch services than do government programs. Government programs--especially those of DOD--already command an important percentage of NASA's launch assets and will require additional future launch services for the Strategic Defense Initiative and the space station. In 1985, NASA had firm contracts for 34 commercial satellite launches and reservations for almost 100 others. Some of these customers will be forced to seek launch services elsewhere.

There are some options available to NASA for increasing its launch capability, but each has some drawbacks and requires funds currently not included in NASA's budget. One option is to build another shuttle. The components intended to serve as spare parts could be used to begin construction. It would take an estimated three to five years before the new orbiter became operational, however, and would cost more than the $1.5 billion price tag for each of the other shuttles.

Another option is for NASA to reverse its decision to phase out the use of ELVs. The Centaur stage for the Atlas booster and the PAM stage for the Delta launcher are still being produced for use with the shuttle, and production lines for other Atlas and Delta components could be reopened. This option, however, would place NASA in direct competition with Transpace, Incorporated and General Dynamics which plan to enter the launch market with these boosters. A different angle of this option would be to follow DOD's lead and use converted Titan 2 ICBMs for launch vehicles. This action, however, would also place NASA in competition with private companies attempting to enter the launch market.

A longer range option is to accelerate the pace of development of the trans-atmospheric vehicle, which is scheduled to replace the shuttle in the late 1990s. To do so would allow NASA to move away from the 1950s and 1960s technology incorporated in the shuttle and ELVs. It would not help NASA's immediate problem, however, and would cost large amounts of money to develop the necessary technology.

Another factor that could hurt NASA's bid for commercial satellite launch services is price hikes for shuttle launches scheduled in October 1986 and again in 1989. (The price hikes do not include recovery of the shuttle development costs which were on the order of $10 billion.) Currently NASA is charging $38 million for a full shuttle cargo bay. Because several payloads can be carried on each shuttle, costs for most satellites range from about $13 to $19 million with another $7 million required for the PAM or Centaur stage needed to boost the satellite into its proper orbit. In October 1986, NASA will begin charging $71 million (in 1982 dollars) for a full cargo bay. In 1989, the base price for a full cargo bay will increase to $74 million (in 1982 dollars), with cargo space available for commercial payloads being auctioned off to the highest bidder. The auction process will work to the advantage of the larger companies which will be in a better position to pay higher launch costs.

The $74 million floor price for shuttle launches will fall short of full recovery costs. In testimony before Congress in 1984, NASA stated that each shuttle flight now costs about $150 million. NASA projected that the costs would be reduced significantly when it reached a launch schedule of 24 flights per year in 1989. This projected launch schedule, however, was based on a fleet of four orbiters, and acquisition of up to 75 percent of the commercial launch market.

SOVIET UNION

In 1957, the Soviets shocked the world when they placed the first manmade satellite into orbit. Their space program achieved another first in 1961, when they launched the first man into space. The Soviets have continued to make important strides in their space program, in both manned and scientific and applications satellite sectors. By 1986, the Soviets are estimated to have launched more than 2,400 payloads into space, compared to about 1,150 for the U.S. Their rate of launches continues at a high level, with about 100 per year compared to about 20 per year for the U.S.

The Soviets publish little data on their space launches, but Western observers estimate that about two-thirds of them are related to military programs. They probably include functions such as photographic, communications, and electronic intelligence collection; the establishment of communications nets for command and control; and more recently, space weapons.

To date the Soviets have for the most part relied on derivatives of ballistic missiles for space launchers. Three of the launcher systems are based on medium range ballistic missiles (MRBM), and one is a modified ICBM. Westerners believe that only one operational launcher system--the Proton--was designed specifically for the space program. (A space launcher much larger than the Proton was developed, but due to several disastrous launch failures it never reached operational status.) Because the Soviets have trailed the West in the miniaturization of hardware, most of their space launchers have large lift capabilities to carry heavy payloads into space.

The Soviets have not publically stated future goals for their space program. It is apparent, however, that some major new developments will occur in the late 1980s. The Soviets have three new launch vehicles under development, the largest of which will have a lift capability in the range of the U.S. Saturn V rocket. A shuttle strikingly similar to ours in size and configuration should also be operational, and the Soviets have already accomplished several flights of a small space plane. There also has been talk about a large and permanent Soviet space station for applications work, scientific observation of the stars, and to serve as an assembly, check-out and launch point for deep space flights. (Their February 1986 launch of a space station module may be part of this program.)

Another possibility is more aggressive Soviet attempts to enter the satellite launch market. In the late 1970s, the Soviets made overtures to Western Europe to launch satellites, and to provide a backup capability to the Ariane program. The overtures were turned aside. In the early 1980s, the Soviets made a bid to launch one of three International Maritime Satellite Organization (Inmarsat) payloads. The U.S., however, blocked the move because it would mean transferring American advanced technology to Soviet soil. Inmarsat, of which the Soviets are the fifth largest shareholder, chose instead the European Ariane and the U.S. shuttle. Inmarsat did, however, identify the Soviet Proton booster as a contender for the next generation of satellites scheduled to be launched in the 1990s.

The Soviets have not published data on the cost of their space program. However, some Western analysts familiar with both the Soviet and U.S. space programs believe that the USSR program has cost at least as much as that of the U.S. (about $200 billion through 1985). They also believe that current costs per year are about the same as those for the U.S.--on the order of $18 billion per year.

Organizational Structure and Facilities

Little unclassified information is available regarding how the Soviet space program is organized and which facilities support the program. The Soviet Academy of Science is reported to play a part in planning the program, and the Strategic Rocket Forces probably are responsible for providing launch vehicles and conducting launch operations. In all likelihood a number of other government ministries and agencies are involved in the space effort. Some U.S. experts believe there are about 600,000 people currently involved in the Soviet space program, based on the high degree of activity currenty underway.

Three launch complexes support the Soviet space programs. One is located at Tyuratam in Central Asia. It reportedly supports manned, lunar, planetary, and some communications satellite launches. Another launch complex is located at Plesetsk in northwest Russia. It is reported to be used for launching communications, weather, and navigation satellites. The third site is at Kapustin Yar in Central Russia. It is used for sounding rockets and small orbital launches.[3] The Soviets claim to have a network of satellite tracking and control sites across the country as well as about ten space support ships.

Launch Vehicles

The first launch vehicle believed to be used by the Soviets for their space program is based on the SS-6 MRBM. It is estimated to have the capacity to place up to 16,500 pound payloads into low-earth orbit (data on capabilities to carry payloads to higher orbits is not available). This launch vehicle, designated the A-class, has accounted for almost 40 percent of all payloads. The B-class launch vehicle is based on the SS-5 ballistic missile. It has not been used since 1977. The C-class booster is based on the SS-4 MRBM and is capable of placing 2,200 pounds into orbit. The F-class is based on the SS-9 ICBM. It is capable of placing up to 9,900 pounds into low-earth orbit. The D-class is the Proton launch vehicle, developed specifically for the space program. It is 185 feet high, estimated to have a lift-off weight of about 740 tons, and is estimated to be capable of placing 45,000 pounds into low-earth orbit and 3,300 pounds into geosynchronous transfer orbit. The Proton has accounted for over 80 space launches. All of these launch vehicles use liquid propellants, none of which are high-energy, cryogenic fuels.

Currently, the Soviets have three new launch vehicles under development, all intended specifically for use with their space program. A medium-sized launcher appears to be about 215 feet high and is estimated to have a lift-off weight of about 440 tons. It is estimated to be capable of placing 33,000 pounds into low-earth orbit. One of the new large launchers may be about 230 feet high and have a lift-off weight around 2,200 tons. Estimates place its payload capability at 66,000 pounds for low-earth orbit. The other large launcher may be as high as 315 feet. No data is available on lift-off weight. It will have six boosters attached to the core vehicle and may have a capability of placing 330,000 pounds in low-earth orbit. (Data is not available on launch capability to geosynchronous orbit for any of the three.) All three launch vehicles should be operational by the late 1980s. One of the large boosters probably will serve as the launch vehicle for the Soviet shuttle.

Outlook

The Soviets certainly have the technical capability necessary to compete in the commercial satellite launch market. They have launchers capable of placing small and medium-sized satellites into geosynchronous orbit, and other launchers under development which could handle the large satellites projected for the 1990s. And, they appear to have the production capacity and launch infrastructure necessary to accommodate their own launch requirements as well as some for other countries. The shuttle under development will also give them the capability to compete against the U.S. shuttle for payloads requiring human presence in space.

Despite these current and potential capabilities, there are some serious constraints that the Soviets would have to overcome to enter into the commercial satellite launch competition. One is the heavy veil of secrecy the Soviets place over most sectors of their space program. To enter the market the Soviets would have to provide potential customers with accurate and specific data on their launch vehicles and schedules as well as on launching operations. And, they would have to allow access of satellite technicians to their launch facilities for checkout and integration operations (the only non-Communists reported to have had some degree of access to Soviet space facilities are the Indians).

Another constraint is the one of technology transfer. The U.S. and other Western nations have strict restrictions against their high technology getting into the hands of Soviet-bloc countries. Most free-world satellites are built by U.S. or West European countries and include state-of-the-art technology. It is highly unlikely that these restrictions will be eased. If these satellites were shipped to the Soviet Union for launch it would be extremely difficult, if not impossible, to deny access of the technology to the Soviets.

Marketing strategies and insurance are other obstacles. The Soviets would have to develop shrewd marketing schemes to compete, particularly against the Europeans, and offer the necessary insurance arrangements. It is unlikely that they would be able to do this in the immediate future. The one factor that the Soviets have in their favor in this arena is launch price. In their bid for launch of the Inmarsat satellites, the Soviets underbid both the Europeans and the U.S. With total government control of their space program, they could easily continue to underbid their competitors.

EUROPEAN SPACE AGENCY

Following the Soviet and U.S. successes in space in the late 1950s, the Europeans recognized the gap that had developed between their space activities and those of the other two nations. Discussions began in the early 1960s to form a European space program. It was not until 1964, however, before agreement was reached, and two organizations were formed--one to carry out scientific studies in space and the other to develop launch vehicles.

In the late 1960s and early 1970s, it became apparent to the Europeans that each organization was expanding into areas outside of its original charter, that international rivalries were hamstringing sectors of program development, and that there was a need to consolidate all space activities into one umbrella organization. As a result, in 1975 the ESA was formed.

The ESA consists of 11 member-nations, with three other nations closely associated with the organization. The mission of the ESA, as described at its 1980 convention, is "to provide for and to promote, for exclusive peaceful purposes, closer cooperation among European states in space research and technology, and their space applications, with a view to their being used for scientific purposes and for space applications systems". Motivation behind this mission is the desire to build a complete space program independent from the U.S. and USSR, and to compete in the space business for satellite launch services.

A new organization--Arianespace--was created in 1980 whose sole purpose was to market satellite launch services and operate the launcher program. The Ariane 1 launcher, which began initial development in 1973 and had its first test launch in 1979, became the first launch vehicle for marketing services. In 1980, agreement was reached in the ESA to begin development of two larger launch vehicles, designated Ariane 2 and 3. These launchers were required to keep pace with the growing size of communications satellites, and to provide the capability to launch two satellites with one vehicle. Both are in operation. Two new Ariane launchers are in development--the Ariane 4 which will be capable of launching medium and large-sized satellites into geosynchronous orbit, and the heavy lift Ariane 5 which is capable of placing very large satellites into geosynchronous orbit. The first launch of the Ariane 4 is scheduled for 1986 and the Ariane 5 is scheduled for launch in 1995.

Arianespace already has become a competitive force in the launch market. It has pulled even with the U.S. shuttle in commercial satellite launches, and has firm contracts for almost one-half of the satellite launches scheduled through 1995.

In 1985, the ESA had an operating budget of about $800 million. Costs are expected to rise to about $1.4 billion per year by 1990 to fund the development of the Ariane 5, build a module for the U.S. space station and fund the accelerating satellite launch program. Costs could increase even higher if ESA proceeds with its plan to develop a shuttle vehicle (Hermes) in the 1990s for use with the Ariane 5.

Organizational Structure and Facilities

The 11 ESA member-nations are--in rank order of participation--France, West Germany, the United Kingdom, Italy, the Netherlands, Spain, Sweden, Switzerland, Belgium, Denmark, and Ireland. Three other nations--Austria, Norway and Canada--are closely associated with the ESA. The organization maintains close contact with a large number of other nations as well as with European industrial, scientific, and banking groups.

The ESA has an overall staff of about 1,360. The ESA Council, which operates at the Agency headquarters in Paris, is responsible for developing policy and setting budgets. Three major ESA centers are located in other parts of Europe which are responsible for satellite design, fabrication, and operations.

Arianespace is headquartered near Paris and has a branch office in Washington, D.C. to serve its North American customers. It was created in 1980 under the aegis of ESA by 36 main European manufacturers of aerospace and electronics equipment, 13 large European banks, and the French National Center for Space Studies. Its specific duties include managing and financing the Ariane production program, operating the launch facility near Kourou, French Guyana, and marketing launch services. France is the major shareholder of Arianespace (60 percent) and West Germany the next largest shareholder (20 percent). Other members are Belgium, Denmark, Ireland, the United Kingdom, Italy, the Netherlands, Sweden, Spain, and Switzerland.

The Kourou launch facility became operational in 1968, when it was used to launch a small French rocket. It contains a large launch preparation area and 15 launch pads. About 700 people are employed there with 45 percent of them recruited from Europe. The ESA provides two-thirds of the operating budget and France paying the other third. Kourou is ideally suited for satellite launches due to its proximity to the equator. Launches at or near the equator are more efficient due to the greater "sling" effect of the earth's rotation at this latitude.

Launch Vehicles

The Ariane 1 development program was commissioned in 1973 at a meeting of representatives from 10 European countries. The goal was to develop a launch vehicle for applications satellites already under development in Europe. The first launch of the Ariane 1 occurred in 1979. It has three stages, uses liquid fuels, and has a height of 155 feet and a lift-off weight of approximately 210 tons. It is capable of placing about 8,000 pounds into low-earth orbit and 4,000 pounds into geosynchronous transfer orbit. Through September 1984, there were nine Ariane 1 launches--two of which failed.

Discussions to develop follow-ons to the Ariane 1 began in 1978, and the decision to go forward with the program was made in 1980. The main objective of this program was to increase the Ariane capability to launch payloads into geosynchronous transfer orbit and to provide it with a dual launch capability. The Ariane 2 is an upgraded version of the Ariane 1. It is 161 feet high, has a lift-off mass of 219 tons, and is capable of placing up to 4,800 pounds into geosynchronous transfer orbit. The Ariane 3 has the same Ariane 2 core vehicle but with strap-on boosters attached. It has a lift-off mass of 237 tons and is capable of placing 5,700 pounds in geosynchronous transfer orbit.

Eighteen months after the decision to proceed with Ariane 2 and 3 development, another decision was made to begin work on the Ariane 4. The Ariane 4 is being designed to have six performance options, based on the number of strap-on boosters attached. Depending on payload requirements, launch capability to geosynchronous transfer orbit can range from 4,200 to 9,200 pounds. Maximum lift capability to low-earth orbit is 18,000 pounds. The first Ariane 4 flight is scheduled for mid-1986.

Development is underway on a very large launch vehicle. It is designated Ariane 5 and scheduled for launch in 1995. Goals for the Ariane 5 are to launch very large satellites, reduce launch costs from those of the Ariane 4, and achieve a reliability factor equal to that of the U.S. shuttle. It will also be capable of placing large sections of the European module for the U.S. space station into orbit, and launching the Hermes shuttle should it be developed. The Ariane 5 is designed to place up to 16,000 pounds in geosynchronous transfer orbit and up to 30,000 pounds into low-earth orbit. It will use high energy cryogenic propellants, have two large, solid propellant strap-on boosters, a height of 171 feet, and a lift-off mass greater than 500 tons.

Outlook

The Europeans already have achieved notable success with their space program and they face a bright future. They have achieved good reliability with their launchers (12 successes out of 15 flights) and have captured about half of the free-world satellite launch market from the U.S. Their competitiveness with the U.S. is certain to increase since the Challenger disaster. Their position will be further enhanced once the Ariane 4 and Ariane 5 become operational, and the rate of launches per year increases.

Since the first Ariane launch, the Europeans have placed 12 commercial satellites into orbit (compared to 30 by the U.S. during the same period). Through 1995, Arianespace already has firm contracts to launch 30 satellites--almost half for U.S. customers--and options on 11 others (NASA has firm contracts for 34 satellites with reservations for about 100 others). In 1984, they declared their first profit on revenues of $74 million and expect revenues to reach $500 million per year by 1990.

Currently, Arianespace charges about $1 million less per satellite launch than NASA does for the shuttle (about $25 million versus $26 million). It also is discounting up to an additional $3 million to U.S. customers to gain more entry into that market. In all likelihood, Arianespace will raise its launch prices as those for the U.S. shuttle increase. They will, however, probably continue to keep them below those of the shuttle.

Besides lower launch prices, there are several other attractions of the Arianespace program over that of the shuttle. One is that Ariane launch vehicles place satellites into geosynchronous transfer orbit, versus low-earth orbit for the shuttle. Therefore, less fuel is needed to boost the satellite into its permanent position. This fuel saving can extend the life of the satellite up to a year, earning additional revenue for its owner. Another advantage is that the satellite payload does not have to be at the launch site until seven to nine days before launch, a shorter time than required for shuttle payloads. This decreases personnel costs and lessens the chance of damage to the satellite.

JAPAN

Japan's space program began in the mid-1950s with the launching of small sounding rockets. In 1964, the Institute of Space and Aeronautical Science (ISAS) was formed to develop a series of sounding rockets for scientific study of near space and of the sun. In 1966, ISAS launched a rocket to 1,100 miles, and in 1970, launched Japan's first test satellite into orbit.

In 1969, Japan formed another space organization--the National Space Development Agency (NASDA). This organization was created to develop applications satellites, and launchers to get them into orbit (ISAS retained responsibility for scientific study of space). To date NASDA has designed and built several of its 30 plus satellites, and has accounted for about half of the launches.

Japan's space program has been heavily dependent upon U.S. technology. Most of its applications satellites have been built in the U.S., and the two launch vehicles used by Japan to place its satellites into orbit--the N-1 and N-2--are basically Japanese-built versions of the U.S. Delta rocket. By agreement with the U.S., in return for technology and assistance, Japan cannot use the N-1 and N-2 to launch satellites for other countries, nor can it transfer any of the technology to other countries.

Japan's rationale for developing its space program is based on three factors--national prestige, the fact that the development of space technology has direct application in other sectors of industry, and long-range defense applications for national security. The goal of its space program for the remainder of this century is to break its dependence upon the U.S., and to build space systems that can be used to compete in the growing space business. To that end, Japan is developing a launch vehicle--the H-2--which will be 100 percent Japanese. It plans to launch about 50 applications satellites, with most being fabricated in Japan and several being in the two-ton class. Japan also plans to launch about 30 scientific satellites, and participate in the U.S. space station program. And, it is scheduled to put an astronaut on a shuttle flight in 1988.

Japan spent about $450 million per year on its space program in the first five years of the 1980s. Over the next 15 years Japan's space budget will be between $8 and $10 billion, with more than 80 percent of it going to support NASDA applications programs. The two items with the largest price tags are the H-2 which will cost about $800 million to develop, and the construction of a laboratory module for the U.S. space station which will cost between $800 million and $1.5 billion.

Organizational Structure and Facilities

A five-man Space Activities Commission, which reports directly to the Prime Minister's Office, has overall responsibility for Japan's space program. The ISAS resides in the Ministry of Education and draws on Japan's universities for technological expertise. Its specific responsibilities are to develop satellites and payloads for scientific missions, develop launchers for these missions, and to support simple meteorologial missions. The NASDA resides in the Science and Technology Agency and is responsible for developing communications, broadcasting, meteorological, and remote sensing satellites; developing launchers for these satellites; and overall management of spacecraft tasking and control.

Japan has a number of centers used to support its space program. The Tonesgashima Space Center is the largest facility, and is used by NASDA to launch satellites. It is located about 590 miles southwest of Tokyo off the island of Kyushu. A $200 million launch facility is under construction at Tonesgashima for use by the H-2 booster. The ISAS has its own launch facility at Kagoshima, located about 500 miles southwest of Tokyo. Both launch facilities have their own radio and optical tracking systems, and are supported by a network of supporting tracking facilities located in other parts of Japan and as far away as the southern Pacific Ocean. The Tsukuba Space Center is responsible for satellite integration and test operations and overall control of tracking operations. Other facilities perform such functions as propulsion design and testing, earth observation analysis, and data integration and evaluation.

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Launch Vehicles

The first launch vehicle developed by NASDA for applications satellites was designated the N-1. The first N-1 launch occurred in 1975 with the seventh and last launch occurring in 1982. The N-1 had three stages--the first two being liquid fueled and the third using solid propellants. It was 108 feet high, had a lift-off weight of about 90 tons, and was capable of placing a 285 pound payload into geosynchronous orbit and a 880 pound payload into low-earth orbit. The N-1 and its successor, the N-2, are basically Japanese versions of the U.S. Delta rocket built under license by the Japanese.

The N-2 is an upgraded version of the N-1. Propellant capacity of the first stage was increased by 30 percent, the second stage was improved, and the third stage was enlarged. Additionally, the number of strap-on boosters was increased from three to nine. With these modifications, the N-2 has a height of 115 feet and a lift-off weight of 135 tons. The N-2 is capable of placing a 770 pound satellite into geosynchronous orbit, and a 4,400 pound payload into low-earth orbit. The first N-2 was launched in 1980, and the last launch is expected to occur in the late 1980s.

Planning for larger launch vehicles began in the late 1970s and resulted in the commission of two development programs. One is the H-1 which the Japanese plan to use as the primary launcher in the late 1980s and early 1990s. The other is the H-2 which will become operational in 1992.

The H-1 is intended to fill the gap between the N-2 and the H-2. It will have three stages; the first is the same as that of the N-2, the second stage will use high energy cryogenic propellants, and the third stage will use solid propellants. The H-1 will have a height of 130 feet and a lift-off weight of 140 tons. It will be capable of placing a 1,200 pound satellite into geosynchronous orbit and 4,400 pounds into low-earth orbit. The first launch is scheduled for 1987. The most important feature of the H-1 is that it will use high energy cryogenic fuels, the fourth to do so. (The others are the U.S., West Europeans, and the Chinese.)

The H-2 is in development and will be Japan's first totally domestically designed and built launcher. The H-2 will have two stages. The central core of the first stage will use high energy cryogenic fuels and have two solid propellant strap-on boosters attached to it. The second stage will be a scaled-up version of the H-1's second stage. The overall height of the H-2 will be 157 feet, and it will have a lift-off weight of 281 tons. It will be capable of placing up to 4,400 pounds into geosynchronous orbit and 14,000 pounds into low-earth orbit. The first flight of the H-2 is scheduled for 1992.

Outlook

Japan has the technological expertise and the industrial base necessary to successfully develop the H-1 and H-2 vehicles, as well as a variety of applications satellites. The Japanese will not, however, be able to compete in the satellite launch business until the H-2 becomes operational. Once the H-2 becomes operational, they plan to compete directly with the U.S. and Western Europe in the space market, concentrating on the Asian and Pacific regions.

There are limitations to the degree that Japan will be able to compete internationally for launch services. One is a projection that by the early 1990s, some satellites will weigh three to four tons, more than the H-2's launch capability to geosynchronous orbit. Consequently, Japan will be forced to compete in that sector of the market which concentrates on small and medium-sized satellites. Another factor is the number of H-2s planned to be built each year. Some sources have stated that Japan plans to produce only a few H-2 launchers per year. These H-2s probably will be needed to launch Japanese satellites. Another constraint is that the current space program only allows for launches during two periods each year. This restriction is caused by the necessity to close fishing areas in the launch trajectory flight path, and to reimburse the fishermen for their losses during these periods.

CHINA

The Chinese established their aeronautics industry in 1956 to develop aircraft and rocket systems. China received a small amount of assistance from the Soviets until 1960, when the two countries terminated their relationship. In 1964, the Chinese launched their first booster, patterned after the Soviet SS-4 ballistic missile. In 1965, China established a program designed to launch domestically designed and produced satellites with its own rockets. The first satellite launch occurred in 1970, when booster stages from a missile placed a 380-pound satellite in low-earth orbit. The next major step in their program occurred in 1975, when the Chinese launched their first recoverable satellite, the third country to accomplish this feat.

In 1980, the Chinese launched a new booster--designated the CSL-2--which uses the first two stages of their indigenously designed ICBM. And in 1984, they launched their first CSL-3, based on the CSL-2 first two stages with a high-energy cryogenic propellant used for the third stage. With this launch, China placed its first satellite into geosynchronous orbit.

China's space program is designed to benefit both the military and civilian sectors. In the 1970s and early 1980s, most of China's 15 or so satellites were probably used by the military for photo reconnaissance, scientific, and meteorological purposes. China has since made public its plans to use the space program to improve civilian communications, television and weather forecasting services.

In 1979, China opened parts of its space program to Western countries, and has since established cooperative agreements with the U.S., France, the United Kingdom, West Germany, and Italy. These cooperative agreements are aimed at drawing China's space industry closer to that of the West, and to exchange data and services for everyone's benefit. (There have even been discussions with NASA about a Chinese astronaut flying aboard a shuttle flight in the late 1980s.) And in 1984, China declared its intention of competing with the U.S. and West Europeans in the satellite launch services market.

Organizational Structure and Facilities

Data on the organizational structure and facilities of the Chinese space program is scarce. That information which is available has been gleaned from U.S. and European space experts who visited China in 1979 and the early 1980s. These sources indicate that a number of ministries, responsible for different institutes and centers, are involved in the program. Overall responsibility is reported to rest with the State Council, with various commissions responsible for planning activities and different ministries serving as executive organs. The lead organization may be the Ministry of Astronautics. The Defense Ministry reportedly is responsible for the development of launchers and for launch operations. Other organizations involved in the space program are reported to be the Chinese Academy of Sciences, the Academy of Space Technology, the Institute of Telecommunications Technology, and the Central Meteorological Bureau.

Even less data is available on facilities involved with the program. Rocket engine production and booster assembly for the CSL-2 are reported to occur at Xinxin. Satellite design and fabrication are reported to occur in Beijing and Chang-hai. Major test facilities are located in the Beijing area. Two launch facilities exist. One is at Shung-cheng-Tzu which has been used for years for missile and spacecraft launchings. A second launch facility is reported by the Chinese to be located in southwest China. Its exact location has not been released. The new facility offers advantages over Shung-cheng-Tzu for launches to geosynchronous orbit because it is located closer to the equator.

Launch Vehicles

The Chinese have developed three launch vehicles--the CZ-1, the CSL-2, and the CSL-3. The CZ-1 was declared operational in 1970, when it launched China's first satellite into low-earth orbit. It is about 108 feet high and has a lift-off weight of approximately 95 tons. It is reported to be capable of placing a 880-pound satellite into sun-synchronous orbit, and up to 1,320 pounds into low-earth orbit. The CZ-1 is probably a derivative of their IRBM.

The CSL-2 was declared operational in 1974. It is about 104 feet high and has a lift-off weight of approximately 210 tons. The CSL-2 is reported to be capable of placing up to 4,400 pounds into sun-synchronous orbit and up to 6,600 pounds into low-earth orbit. It uses the first two stages of the CSS-4 ICBM.

China's first launch vehicle, capable of placing a satellite into geosynchronous orbit, is the CSL-3 (also known as the Long-March 3). This launch vehicle was declared operational in 1984 when it was used to place a 925-pound communications satellite into geosynchronous orbit. The CSL-3 has three stages; the first two are the same as those of the CSL-2, but the third stage uses high-energy cryogenic propellants. It is 142 feet high and has a lift-off weight of nearly 222 tons. In addition to its capability to place payload into geosynchronous orbit, it is able to lift up to 8,900 pounds into low-earth orbit.

Outlook

China has developed launch vehicles capable of competing in the international satellite launch services market and has declared its intention to do so. Information regarding the capabilities of China's launch vehicles is being distributed, and China has stated that it is ready to discuss launch services with potential customers. The Chinese have stated that they are willing to allow Westerners to visit their launch site. And, they do not believe transport of satellites from the West to China would be an insurmountable problem. China has not yet announced launch fees or marketing arrangements.

Whether or not China can compete with the U.S. and Europe for satellite launch services remains open to question. China's CSL-3 has a limited lift capability to geosynchronous orbit, and could only be used for launching small satellites. Launch schedules and reliability of the launch vehicle are other important factors. Satellite owners will expect convenient launch dates. The CSL-3, however, has only recently become operational and does not appear to be being produced in moderate or large numbers. And, it is too early for the CSL-3 to have established a track record for reliability. China's remote location, relative to the satellite market, is another problem. Customers in need of satellite launch services may be wary of the distance and length of time required to get their payloads to the launch facility, thereby increasing the possibility of damage to the satellite.

INDIA

The roots of India's space program were established in the early 1960s when small sounding rockets began being launched to study the earth's ionosphere. It was not until 1971, however, that India developed a national space program. The goal of the program was to establish an independent capability to build its own satellites and to launch them into orbit with its own rockets. India has been successful in meeting major aspects of this goal. It has designed and built satellites, developed a launch vehicle to put small satellites into low-earth orbit, and established an extensive command and control infrastructure to operate its programs. Developments underway are designed to replace Western-built, multipurpose satellites with domestically built ones, and to develop a launch vehicle capable of placing payloads up to 2,200 pounds in sun-synchronous orbit.

The stated motivating factors driving India's space program are the need to improve communications, acquire better weather data, and develop its natural resources. National prestige has been an important unstated factor. In developing its space program, India has relied on assistance from the USSR, the U.S., Europe, and Japan. Primary assistance came from the Soviets, who established joint working groups with the Indians in 1972, launched India's first satellite in 1975 (free of charge), launched two other satellites for India in subsequent years, and flew an Indian cosmonaut with a Soviet spacecraft crew in 1984. The Europeans allowed India to participate in the development of the Ariane launcher, and launched an Indian-built communications satellite for them in 1981. The U.S. has built three multipurpose satellites for India, launched two Indian satellites, and is scheduled to launch a third one in 1986.

The Indian space program cost about $325 million from 1963 to 1980. They have budgeted $1.1 billion for the 1980s. No data is available for the space program budget in the 1990s.

Organizational Structure and Facilities

The Indian Space Commission was established in 1971 to promote the development and application of space science and technology to the overall benefit of the nation. The Space Commission is responsible for framing the policy of the Department of Space (DoS), formulating the space budget, and implementing all government policies related to space.

The DoS is responsible for executing space activities through the Indian Space Research Organization (ISRO). The ISRO, which is headquartered at Bangalore, operates four centers--the Space Application Center (SAC), the ISRO Satellite Center (ISAC), the Vikram Sarabhai Space Center, (VSSC) and the SHAR Center. The SAC, located at Ahmedabad, is responsible for identifying and implementing space applications. The ISAC, located at Bangalore, is the primary facility for the operation of India's satellites. The VSSC, located at Trivandrum, is the largest of the centers. It is responsible for research and development of propellants, propulsion systems, rocket hardware, on-board and ground-based electronics, and payload test and evaluation. The SHAR center, located on Sriharikota Island north of Madras, is India's principal launch facility. It also has responsibility for the production of propellants and managing India's network of 36 satellite ground control facilities. These four centers and other supporting facilities employ about 10,000 people.

Launch Vehicles

India's initial rocket development was centered on the production of small, French-designed sounding rockets. In 1967, India launched its first domestically designed and fabricated sounding rocket. Progressively larger and more capable sounding rockets have been developed through the 1970s.

The development of a launcher designed to place a small payload into low-earth orbit began in 1973. This launcher, designated the SLV-3, has four stages, is 74 feet high, weighs over 17 tons, and uses solid propellants. Although design and development of the SLV-3 were done by the Indians, 15 percent of its parts are imported. Its first test in 1979 was a failure. A second launch in July 1980 was successful in placing a small domestically-built experimental satellite into low orbit. (The successful 1980 launch was hailed by India as the major milestone in its space program, as India became the first Third World nation to develop such a capability.)

An improved version of the SLV-3, augmented by two solid propellant strap-on boosters, is scheduled to be built in the late 1980s. It will weigh about 35 tons and is designed to carry a payload of 330 pounds into low-earth orbit.

The focus of current launcher development is on a larger rocket, designated the Polar Space Launch Vehicle (PSLV). The PSLV will have four stages, with the third stage being fueled with liquid propellants. It will be about 145 feet high, weigh about 275 tons, and is designed to carry 2,200 pounds into sun-synchronous orbit. The first test launch is scheduled for 1988.

Outlook

India has not yet expressed any interest in competing for satellite launch services for other nations. Currently, it is still attempting to develop its PSLV, and no announcement has been issued concerning development of a launcher capable of placing payloads into geosynchronous orbit. Instead, India's focus is on developing and launching remote sensing, meteorological, and geodetic satellites for its own purposes.

India's space program has not hit any severe budget constraints to date, and appears to be proceeding on schedule. The government has answered internal criticism regarding the value of the space program by stating that investment costs for the program can be regained within three years through applications and benefits acquired from its satellites.

BRAZIL

Brazil's space program began in the mid-1960s with the launching of small sounding rockets. Since then, Brazil has launched rockets of increasing size and capability. It now has a launcher under development that will be capable of putting satellites into sun-synchronous orbit. Brazil's near-term goal is to build its own meteorological and earth resources satellites and to launch them with its own rockets by the early 1990s. A longer-term goal is to launch its first domestically-built communications satellite around the year 2000.

The motivating factors behind Brazil's space program are national prestige, a quest for leadership in South America, a desire to further develop its technological base, and a need to use space as an aid in the development of its resources and economic infrastructure. In pursuit of its space program, Brazil has drawn on technical expertise from the U.S. and France, and has established cooperative programs with the U.S., France, West Germany, and the Peoples' Republic of China. Through these cooperative programs, Arianespace launched a Canadian-built satellite for Brazil in 1985, and an earth resources satellite is scheduled to be launched by the U.S. for Brazil in 1987. Brazilian ground facilities are to be used to help track Ariane launches, and a Brazilian astronaut is scheduled to be aboard a U.S. shuttle flight in 1987.

Data on the cost of the Brazilian space program is scarce, and what is available varies sharply. Estimates for total program costs since the mid-1960s range from a low of $500 million to a high of $6 billion.

Organizational Structure and Facilities

The heart of Brazil's space program is located at Sao Jose dos Campos, just outside of Sao Paulo in the country's high technology and defense industrial center. The Aerospace Technical Center (CTA), which is under military control and run by the Brazilian Aeronautics Ministry, is responsible for the development of launch vehicles and launching operations.

The satellites are being designed and built by the Space Research Institute, located adjacent to the CTA. This institute is subordinate to the civilian National Research Council. Work is progressing on the two weather and two earth resources satellites scheduled for launch by the early 1990s.

Brazil's rocket launching operations have occurred at Barreisa de Inferno, in the northeastern sector of the country. This launch site, however, has been considered too small and surrounded by a too populated area to allow for the expansion necessary for Brazil's growing space program. As a result, a new launch facility is being constructed at Alcantara, located on a remote peninsula in northeastern Brazil. It is estimated to cost about $60 million and is scheduled to be ready in the late 1980s, in time for the testing of a new launch vehicle.

Launch Vehicles

DECLASSIFIED

The Brazilian launcher program consists of five projects--the Sonda I, II, III and IV and a satellite launching vehicle (VLS). The Sonda I, II and III are sounding rockets, the largest of which (Sonda III) is capable of launching a 130 pound payload to an altitude of about 375 miles. The Sonda I was first launched in 1970, and the Sonda II and III were first tested in the mid-1970s. The Sonda IV, like its predecessors, uses solid propellant and is designed to carry a 1,100 pound payload to an altitude of 400 miles. It was first launched in November 1984. It took 10 years to develop, is 36 feet high, and weighs seven tons.

The Sonda IV will serve as the basic rocket unit for the VLS, the first Brazilian launcher capable of placing a satellite in orbit. The first stage of the VLS will be a cluster of four Sonda IV rockets, with another Sonda IV serving as the second stage. The third stage of the VLS will use a more advanced technology (probably liquid propellants). The launch vehicle will be almost 80 feet high and weigh about 44 tons. Brazil is scheduled to launch its first payload with the VLS, a 450 pound instrumentation package, in 1989. Plans are to use the VLS to launch the meteorological and earth resources satellites into sun-synchronous orbit by the early 1990s.

Outlook

Although Brazil has made steady progress in developing its space program, in all likelihood it will not have the capability to compete in the satellite launch business through 1995. Even if the VLS proves successful, it will initially be dedicated to launching domestic satellites. And, it does not have the capability to place satellites into geosynchronous orbit which disqualifies it from the communications satellite market. The Brazilians plan to move to liquid-fueled rockets in the future for development of a larger launcher, but this will require them to develop a whole new technology at additional costs.

There are several important issues which may affect the pace of Brazil's space program. Brazil's massive foreign debt has already caused delays in the development of the Alcantara launch facility, and there is much public debate concerning monies being spent on a space program while sectors of the economy and sections of the country need funds for development. And, the transition of the Brazilian Government from military to civilian rule also worries the space industry. Some believe that the space program, which received considerable direction and funding from the military-controlled government, will receive less of both from the civilian government.

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PRIVATE ORGANIZATIONS

At least seven nongovernment organizations have attempted--or are attempting--to enter the launch market. Only three of them, however, appear to have any chance of success. They are Transpace, Incorporated, General Dynamics, and Martin-Marietta. One company--Starstruck--is still attempting to gain the necessary financial base before it begins design of a new launch vehicle. It is doubtful that Starstruck will be in a position to compete during the next decade. Three others--Space Services, Incorporated, Pacific American Launch Services, and the German-based Orbital Transport and Raketen AG are now concentrating on other types of launch services.

Most of the private organizations initially were motivated by what they saw as a lucrative and growing market for satellite launch services. The U.S. organizations were given additional encouragement in 1984 when President Reagan, in his State of the Union address, called "space America's next frontier and U.S. companies interested in putting payloads into space must have ready access to private sector launch services". Passage of the Commercial Space Launch Act and issuance of the National Security Directive 144 were seen as actions which would benefit private launcher organizations.

In spite of the President's speech and the two government actions, none of the private enterprises have been able to enter the commercial satellite launch market. Price policies of NASA and Arianespace are one reason. Private organizations accuse both NASA and Arianespace of receiving government subsidies for their launch programs, thereby allowing them to charge prices that do not reflect full operating costs. Another factor is that even though the launch market is growing in size, it is not that large. To date, NASA and Arianespace have been able to provide the necessary launch services, and before the Challenger disaster, it appeared that the two organizations would continue to fulfill market requirements. A third factor is that large amounts of capital are required to establish and maintain launcher production, to develop or rent launch facilities, and to execute the launches. Consequently, the necessary financial backing must be found, and an adequate number of customers must be obtained to establish a rate of at least several launches per year.

The fortunes of one, and possibly two, of these companies, could soon change, however. The Challenger disaster is causing delays in the shuttle program which could stretch into several years. The only other launch service currently available to satellite customers is the Ariane. The Ariane program, however, is heavily booked for the next several years, and does not appear to have the surge capability to accommodate all shuttle launch customers.

A short description and status of each of the three contenders follows:

Transpace, Incorporated (TCI)

TCI was created in 1982 by a former NASA official. In May 1984, it was awarded exclusive rights by NASA to the Delta launcher providing two conditions could be met. One is that TCI must develop the necessary financial backing required to operate, and the other is that it must line up at least three customers. The initial deadline given to TCI to meet these conditions was 1 October 1984. TCI was unable to meet the deadline, and since then, a number of new deadlines have been established. It now appears that TCI is close to gaining the financial backing required to compete, and is actively pursuing customers. It must move quickly, however, because the Delta production line has been closed by McDonnell Douglas.

In 1984, TCI filed a complaint with the U.S. Government about unfair pricing policies of Arianespace; specifically, that Arianespace was able to provide predatory prices to its customers due to government subsidies, and that unfair discounts were being provided to lure U.S. customers. In July 1984, the U.S. Trade Representative Office agreed to investigate the charges. In July 1985, President Reagan turned down TCI's petition for trade relief, stating that all national space programs are subsidized in some way, and that the European practice is not much different from that of the U.S. TCI has stated that to make a profit it would have to have enough customers for five Delta launchings per year and charge at least $27 million per launch.

General Dynamics

General Dynamics, which produces the Atlas-Centaur launcher, has been negotiating with NASA for the rights to market the launcher. The Atlas-Centaur, like the Delta, is being phased out by NASA. Two advantages that General Dynamics has over TCI are that it has a large financial base, and that the Atlas-Centaur is capable of placing larger payloads into orbit than the Delta. Like TCI, however, General Dynamics is concerned about the low pricing policies of NASA and Arianespace, and the limited size of the market. On the latter point, General Dynamics was concerned whether or not NASA could execute 24 shuttle launches per year as planned, and what percentage of shuttle cargo space would be used for Strategic Defense Initiative and space station payloads. Time also is running out on General Dynamics because some of its key subcontractors have shut down their production lines, and unless it can line up some customers, it will soon have to shut down its production line. Once these facilities are shut down it would be a difficult and costly venture to reopen them. General Dynamics has stated that for it to make a profit, a minimum of four launches per year would be required at $65 million each.

Martin-Marietta

Martin-Marietta may be in the best position to compete with NASA and Arianespace. It produces the Titan series of launchers which have been used by NASA to a limited degree and is still in use by the DOD. Martin-Marietta is converting Titan ICBMs into launch vehicles for the DOD and was recently awarded another contract by the Air Force to develop a new, complementary ELV. Consequently, Martin-Marietta will keep its production lines open, giving it time to develop a strategy for entering the satellite launch business. It plans to examine the market with its whole family of Titan launchers.

CONCLUSIONS

Currently, competition for commercial satellite launch services is limited to two organizations--NASA and Arianespace. Three other countries--the Soviet Union, China and Japan--have the necessary launch vehicle capability to compete, but for different reasons have not been able to enter the market. The major constraints working against the Soviets are the degree of secrecy surrounding their space program, denial of the necessary access by foreigners to their launch facilities, and technology transfer restrictions. China has just recently developed the capability to launch to geosynchronous orbit. Its launch vehicle--the CSL-3--is only capable of placing small satellites into orbit, appears to be being produced in limited numbers, and has not established a record of reliability. The remote location of China's new launch facility from the satellite producers is also an obstacle. Japan is constrained by licensing agreements with the U.S. which prohibit it from launching satellites for other countries.

Privately-owned organizations have not yet entered the market for other reasons. Some have not been able to develop the required launcher technology; others have not been able to generate the necessary capital. Deflated launch costs offered by NASA and the Europeans, and uncertainties over the size of the market have been other constraints.

The West Europeans were able to penetrate what was once a totally-controlled NASA market through several measures. One was a clear goal established by ESA to compete in the market, and the establishment of Arianespace, an organization whose sole responsibility is to market and operate satellite launch services. Another is the development of a family of launch vehicles with varying capabilities. These launch vehicles, which are designed solely for satellite launches, offer advantages over NASA's shuttle program in simplicity, efficiency, and cost. Another important factor is the Arianespace practice of undercutting NASA's launch prices, and offering special discounts to U.S. customers.

Since the first Ariane launch in 1979, Arianespace has placed 12 commercial satellites in orbit, compared to 30 by NASA for the same time period. Launch services currently contracted through the mid-1990s are about even: 30 for Arianespace and 34 for NASA. NASA does have a large advantage over Arianespace for more tenuous launch orders--almost 100 compared to 11.

Over the next decade, the satellite market is expected to expand to about 20 commercial launches per year, and to generate revenues of approximately $1 billion. Arianespace in all likelihood will capture a larger share of the market--possibly up to two thirds of it--and some small sectors of the market could go to one or two other nations or private companies.

A number of factors will affect the competition for the market. The most important is the loss of Challenger, reducing NASA's shuttle fleet to three. The reduction in the size of the fleet comes at the same time that NASA is phasing out the Delta and Atlas-Centaur ELVs. Unless NASA takes some immediate action to augment its launch capability, most of its remaining launch capability will be devoted to U.S. Government space programs, leaving little for commercial customers. Another factor that will work to the benefit of NASA's competitors is price hikes scheduled for shuttle payloads in October 1986 and again in 1989. The 1986 price hike for full shuttle bay will jump to $71 million (in 1982 dollars), almost double the current cost. The 1989 increase will set the floor price at $74 million (in 1982 dollars), with limited shuttle capacity auctioned off to the highest commercial bidder.

The projected diminished commercial launch capability of NASA and the price hikes for shuttle launch services will benefit Arianespace the most. Currently, Arianespace is producing four to five launch vehicles per year, but is planning to produce six to eight in 1987. And, the Ariane 4 should be operational by that time, enhancing Arianespace's capability to bid for larger satellites.

The nation that appears to have the best opportunity to enter the launch competition is Japan. In 1992, its domestically designed and built H-2 launcher should be operational, eliminating the current U.S. licensing constraints. To make any appreciable dent in the market, however, Japan will have to expand its rate of launcher production and eliminate the barriers to the number of launches that can occur each year. wrong

The chances for the Soviets or Chinese to enter the market are less likely due to the same reasons that are currently keeping them out. And, India and Brazil will not have launch vehicles large enough for communications satellites. wrong.

There is an increasing possibility that one--and at the most two--private U.S. companies could enter the market. It is doubtful that the U.S. will not try to retain an important share of the commercial satellite launch business, either through NASA or through private U.S. companies. The companies that stand the best chance are Transpace, Incorporated, General Dynamics, and Martin-Marietta.

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FOOTNOTES

1. Oftentimes, these satellites are initially launched to a geosynchronous transfer orbit. Transfer orbit is highly elliptical, with an apogee equal to geosynchronous orbit and perigee of only several hundred miles altitude. A small rocket motor or thrusters attached to the satellite are used to boost the satellite to its final position.

2. This research paper concentrates on the NASA program, with only references made to the military sector as necessary.

3. Sounding rockets are used for scientific investigation of the atmosphere and ionosphere. They are smaller in size than launch vehicles used to place satellites in orbit.

SELECTED BIBLIOGRAPHY

BRAZIL

Brazil's Space Program Prepares to Launch 4 Satellites by 1993, The Washington Post, 26 November 1981.

Brazil Plans to Enter Space Age with Launchings This Decade, Associated Press, 11 July 1982.

Brazil Set to Join the Space Superpowers, New Scientist, 26 August 1982, p. 555.

Brazil Plans to Launch its Own Satellites in 1990s, Aviation Week and Space Technology, 9 July 1984, p. 60.

Brazil Pursues Dream in Space: Rocket Launch a Milestone, The Washington Post, 13 December 1984.

Brazil on the Doorstep of Space, Associated Press, 15 January 1985.

Brazil's Move Toward the Stars, Defense and Foreign Affairs, April 1985, p. 12.

DOD IR 6-809-037381, Brazil/Space Program Notes, May 1981.

DOD IR 6-809-067582, Brazil Space Effort, September 1982.

Per Ardua Ad Astra * for Brazil's Space Giant, Defense and Foreign Affairs, April 1985, p. 12.

The Talk of Alcantara: The Space Age Descends on a Backwater in Brazil, The New York Times, 18 July 1985.

CHINA

China Offers Space Launch Services, Aviation Week and Space Technology, 8 October 1984, p. 48.

China to Compete in Satellite Launchings, Financial Times, 4 February 1985, p. 14.

China Offering Space Launch Services to International Users, Aviation Week and Space Technology, 8 April 1985, pp. 25,26.

Nation Said to Rank High with 15 Satellites, China Report, JPRS-CST-84-030, 10 October 1984, p. 28.

EUROPEAN SPACE AGENCY

Arianespace Sets New Pricing Policy, Aviation Week and Space Technology, 23 July 1984, pp. 74, 78-79.

Arianespace: A Total European Space Capability, Telecommunications, August 1984.

Ariane Challenges U.S. on Satellites, Europe, January/February, 1985, pp. 22, 23.

Ariane Propels Europe Into Space Competition; NASA Losing Edge in Satellite Business, The Washington Post, 18 March 1985, p. A-6.

Ariane 5 and Colombus Spearhead New ESA Program, Aerospace America, April 1985, p. 24.

Ariane vs. the Shuttle: A User's Rationale, Aerospace America, May 1985, pp. 66-68.

Arianespace-Success for Europe, International Broadcasting, Vol. 6, June 1985, pp. 52, 54, 56.

Ariane Launches: Run of Successes is Broken, Nature, Vol. 317, 19 September 1985, p. 193.

Ariane: Rocket Company to Sell Insurance?, Nature, Vol. 317, 17 October 1985, p. 567.

Eurorockets Invading U.S. Market in Space, Christian Science Monitor, 8 July 1982, p. 1.

Europe's Competitor for Shuttle, The New York Times, 30 July, 1984, p. D-5.

European Nations Push Their Own Shuttle Program, Christian Science Monitor, 26 September 1984, p. 17.

Europeans Determine Ariane 5 Heavy-Lift Launcher Capabilities, Aviation Week and Space Technology, 15 April 1985, p. 55.

Europe Blasts Into the Space Business, Fortune, 27 May 1985, p. 138.

Forward to the Future, European Space Agency, 1985, Paris, France.

Giotto, ESA's Mission to Halley's Comet, European Space Agency, 1985, Paris, France.

In Harsh Light of Reality, The Shuttle is Being Re-evaluated, The New York Times, 14 May 1985, p. C-1.

Price Wars Reach Celestial Heights, Christian Science Monitor, 1 June 1984, p. 9.

Rocket Wars: How Europe May Zap America, High Technology, April 1983, pp. 50-56.

Space; A Developing Role for Europe, America Astronautical Society, 18th European Space Symposium, Vol. 56, 1983.

The New Satellite Race in Space, Macleans, Vol. 98, 1 July 1985, p. 58.

INDIA

DOD IR 2-252-001383, Soviet-Indian Cooperation in Space Exploration, 5 January 1983.

Domestic Civil Market Limited, Financial Times (London Edition), 23 May 1983, p. 13.

India Becomes 6th Country to Put Satellite in Orbit, The Washington Post, 19 July 1980, p. A-13.

India; Into the Space Club, The Economist, 26 July 1980, p. 40.

Indian Satellite Launch Marks Technology Gain, Aviation Week and Space Technology, 29 June 1981, p. 18.

Indian Space Program Continues Amid Controversy, Associated Press, 15 August 1982.

India Launches Satellite, United Press International, 17 April 1983.

India to Pursue Down-to-Earth Goals from 22,300 Mile Orbit, The New York Times, 29 August 1983, p. 8-6.

India Building a New Generation of Rockets, United Press International, 18 March 1984.

India Challenges Dominance, United Press International, 28 March 1984.

India Treads the Tightrope into Space, New Scientist, 29 November 1984, pp. 16-18

JAPAN

Japan's Space Effort Moves Toward Operations, Aviation Week and Space Technology, 14 March 1982, p. 112.

Japan Plans New Launches, 78 Satellites, Aviation Week and Space Technology, 22 August 1983, pp. 23, 24.

Japan Prepares for Next Space Phase, Aviation Week and Space Technology, 12 March 1984, p. 129.

Japan's Hopes Remain in Space, Financial Times, 2 May 1984, p. 11.

Japan's Space Race Struggle, The New York Times, 24 July 1984, p. D-1.

Japan Sets Sights on Prime Place in Space, Rueters LTD, 16 September 984.

Japan Pursues Role in Space, Electronics Week, 7 January 1985, pp. 32,33.

Japan Sets $645 Million Space Budget, Aviation Week and Space Technology, 18 February 1985, p. 24.

Japan's Space Program: A National Priority, Aerospace America, March 1985, p. 64.

Japanese Aerospace: Split Personality on the Mend, Aerospace America, March 1985, p. 48.

Japan to Push Applications, Booster Gains, Aviation Week and Space Technology, 18 March 1985, p. 130.

Japan Pushes to Catch Up in the Race for Space, Christian Science Monitor, 14 May 1985, p. 9.

Japan Outlines Space Plans, Flight International, 8 June 1985, p. 40.

Japan Develops Ambitious Space Station Plan, Space Business News, 1 July 1985, p. 5.

Japan Schedules First Flight of H-2 Launch Vehicle for 1992, Aviation Week and Space Technology, 21 October 1985, p. 127.

Outlook on Japan's Satellite Development, Satellite News, 9 July 1984, pp. 4, 5.

Overview of Japan's Launch Vehicle Programs, Electronics and Aerospace Systems Conference, Arlington, Virginia, 29 September-1 October 1980.

Users Challenging Policies of Japan, Aviation Week and Space Technology, 25 June 1984, p. 190.

SOVIET UNION

Cargo Space on a Soviet Rocket, Anyone? Business Week, 20 December 1982, p. 22.

Inmarsat Adds Proton to Booster List, Aviation Week and Space Technology, 1 August 1983, pp. 16, 17.

Launchers for Less: Russia Joins the Price War in Space, Business Week, 5 August 1985, p. 33.

Soviets Marketing Proton in the West, Aviation Week and Space Technology, 20 June 1983, pp. 18-20.

Soviet Military Power, U.S. Department of Defense, Fourth Edition, April 1985, pp. 54-59.

Space Race: Russia Takes Shocks in Stride, U.S. News and World Report, 31 October 1983, pp. 39, 40.

U.S. Says Nyet to Soviet Offer to Launch Western Satellite from Central Asia, Christian Science Monitor, 3 May 1984, p. 1.

UNITED STATES

Aerospace Facts and Figures, 1983/84, Aerospace Industries Association of America, Incorporated; Washington, D.C.

Challenger: Nothing Ends Here, Business Week, 10 February 1986, pp. 25, 26.

Commercial Launchers: Has U.S. Indecision Opened a Door to the East? Interavia Aerospace Review, August 1985, p. 873.

Competition Threatening U.S. Lead in Space, The New York Times, 26 July 1985, p. A-1.

Competition Clouds Outlook for Fifth Orbiter, Aviation Week and Space Technology, 18 February 1985, p. 24.

Congress Report Challenges NASA Space Station Plans, Rueters, 14 November 1984.

Defense Department to Retain Expendable Launchers as Backup to Shuttle, Aviation Week and Space Technology, 18 March 1985, p. 115.

Europe vs. America in Space, The New York Times, 17 March 1985, Section 3, p. 4.

High-Flying Rivals: U.S. Space Shuttle, European Rocket via to Put Things in Orbit, Wall Street Journal, 12 June 1984.

NASA Fact Book, National Aeronautics and Space Administration, September 1982.

NASA Striving for 24-Launch Goal After Fast Shuttle Pad Turnaround, Aviation Week and Space Technology, 13 May 1985, p. 78.

NASA Official Unsure of Need for New Shuttle, The Washington Post, 15 February 1986, p. A-9.

Ruptured Solid Rocket Motor Caused Challenger Accident, Aviation Week and Space Technology, 10 February 1986, pp. 19-24, 57-65

Shuttle Success Doesn't Deter Competition, Christian Science Monitor, 16 November 1984, p. 1.

Shuttle Faces Mounting Competition from America and Foreign Rockets, United Press International, 2 February 1985.

Shuttle Launch Pricing Issue Produces Diverging Opinions, Aviation Week and Space Technology, 18 March 1985, p. 137.

Shuttle Battles the Expendables, Aerospace America, May 1985, p. 16.

Shuttle Destroyed, Killing Crew; Manned Space Flights Halted, Aviation Week and Space Technology, 2 February 1986, pp. 16-29.

Shuttle Beset by High Cost, Bureaucracy, The Washington Post, 5 February 1986, p. 1.

The New Space Race: U.S.-Europe-Japan Rivalry, Christian Science Monitor, 15 June 1982, p. 1.

Using the Space Shuttle, Rockwell International, 1982.

White House to Put Shuttle Launchers on Auction Block at Minimum $74 Million, Communications Daily, Vol. 5, No. 150, 2 August 1985, p. 8.

PRIVATE ORGANIZATIONS

Business Briefs, Space Business News, 16 December 1985, p. 10.

Industry Observer, Aviation Week and Space Technology, 4 November 1985, p. 13.

NASA's Competitors Hit Turbulence, Space Business News, 6 May 1985, p. 2.

OTRAG Finds U.S. Interest, Space Business News, 2 July 1984, p. 2.

Pie In the Sky, Regardie's, October 1984.

Price Policy on Space Shuttle's Commercial Use Could Launch -- or Ground -- NASA's Rockets, Wall Street Journal, 21 March 1985.

Private Firms Eye the Space Trucking Business, High Technology, April 1983, p. 51.

Private Firms Want to Help Launch U.S. Commercialization of Space, National Journal, Vol. 17, 26 January 1985, p. 211.

Private Industry Looks to Space, United Press International, 10 May 1984.

Reagan's Plan to Have Private Industry Market Rocket Launchings Faces Delays, Wall Street Journal, 24 September 1984.

Space Burial Proposed, Flight, International, 9 February 1985, p. 3.

Space Markets; The Price of Beating Gravity, Interavia Aerospace Review, May 1985, p. 17.

Transpace Carriers: Private Sector to Launch Rockets, High Technology, June 1985, p. 75.

Trouble for Marginal Players, Wall Street Journal, 18 November 1985.

U.S. is to Investigate First Trade Dispute Over Rates in Space, Wall Street Journal, 11 July 1984.

[illegible] Satellite Launches, [illegible] Journal, [illegible] July [illegible]

[illegible] SOURCES

International Aerospace Review, AIAA Aerospace Assessment Series, Vol. 9, American Institute of Aeronautics and Astronautics, New York, New York, 1982.

Space Activities in the Eighties, European Space Agency, ESA SP 1012, Paris, France, [illegible]

Space Activities of the United States, Soviet Union, and Other Launching Countries/Organizations, 1957-1983, Congressional Research Service, [illegible], April 1984.

The Commercialization of Space, Department of State, INR Report [illegible], [illegible] 1984.

[illegible], November 198[illegible], [illegible]

The Launch and [illegible] of Spacecraft: An Insurance Perspective, Space Communication and Broadcasting, 0167-9368/83, pp. [illegible] (1983).

[illegible] of Commercial Satellite Communications, IEEE Transactions on Aerospace and Electronic Systems, Vol. AES-20, No. 4, July 1984, pp. [illegible]

[illegible] Launch [illegible], American Institute of Aeronautics and Astronautics, [illegible] Satellite Systems Conference, 19-22 March 1984.