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A Market Study on the Viability of Small Launch Firms

Allen George Dyer

A MARKET STUDY ON THE VIABILITY
OF SMALL LAUNCH FIRMS

by Allan George Dyer
BS, U. S. Military Academy, West Point, N.Y.

A Digest Presented to the Faculty of the Graduate School of the Lindenwood Colleges in Partial Fulfillment of the Requirements for the Degree of Master of Business

As the United States only launch vehicle program NASA's, Space Shuttle forced the shutdown of conventional launch vehicle operations. A system whose profitability depended on frequent use, but which, instead, incurred numerous launch delays, the Shuttle soon could not cover the cost of itself much less turn an profit. The French Ariane, albeit a simpler launch vehicle, soon successfully competed with the Shuttle for payloads.

The Reagan Administration, by various supportive measures, encouraged the market entrance of commercial launch firms. The Shuttle and Ariane, however, subsidized by their respective governments, set prices so artificially low that no large commercial launch vehicle company (e.g. McDonnell Douglas, General Dynamics) could hope to survive if they entered the market.

Nonetheless, in the early 1980's several entrepreneurs started small launch firms with the hope of placing small payloads into orbit at a cheaper price than the Shuttle could. The handful of these companies in existence today hope to be operational by the end of the decade. The grounding of the Shuttle fleet after the Challenger accident and the Ariane's technical difficulties may provide a valuable market opportunity for large and small commercial launch vehicles.

This study is a three part analysis to determine if the future market environment will allow a small launch firm to establish itself and capture a sector of that market. The primary thrust of this analysis addresses the market all launch vehicles serve: the satellites that require access to space in order to generate revenue. First, an analysis of the satellite population over the past ten years was conducted to determine trends in satellite use. Characteristics of satellites such as their categories, and their weights which are critical to small launchers were addressed in order to define a target market segment and to establish its growth based on the historical data. Next, an analysis of forecast satellite and launch vehicle use provided another basis to determine the need for small launchers. Satellites projected for the next ten years were associated with the most probable launcher that would be available at the time the satellite is scheduled to be orbited. This forecast supported the initial trend analysis. These projections are subject to a great deal of uncertainty because of the dynamic nature of the space business environment following the Challenger accident. Issues affecting the market forecast were addressed and include the Administration's future launch vehicle policy, the possibility of a replacement Shuttle, the final US space station configuration, the threat of foreign launch competition, the revival of expendable launchers and the demand for communication satellites. The likely course of action associated with each issue was determined and its impact was assessed against the projected trends and forecast. This information provided the most accurate forecast and was used in conjunction with representative data from several small launch firms to determine their profitability.

The study established that a small launch firm could not profitably operate without a significant investment of additional capital to upgrade its capabilities to a point where it could orbit moderate sized geosynchronous satellites. Currently and for the next eight years there will be on insufficient demand to orbit smaller satellites. Once the space station is deployed in the mid-1990's a change may occur and the need for transferring small payloads to the station may develop.

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Master of Business

COMMITTEE IN CHARGE OF CANDIDACY

Assistant Professor	Jack Kirk Chairperson and Advisor
	Clark Compton

DEDICATED TO THE MEMORY OF THE CHALLENGER

AND HER CREW

ACKNOWLEDGMENTS

Without the help and support of several persons this study would not have been possible. Professor Jack Kirk of Lindenwood College helped me immeasurably in the initial design of this study. A great deal of insight into the area of marketing was provided by Clark Compton. My classes with him sparked the idea which eventually developed into this project. Terrence Peterson's advice aided me greatly in defining and organizing this study. My wife Martina's love, support and encouragement were invaluable during the tough times and the late nights. Finally, I would like to acknowledge the selfless assistance of Jane Ellis who did the arduous work of typing and editing this study.

These people helped me immeasurably and without their participation this work would never have been completed.

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PREFACE

I have always maintained an interest in commercial space applications, which in the past few years have held tremendous promise. For my MBA culminating project I had difficulty focusing on a particular business problem which had not been thoroughly researched. In my graduate marketing course I completed a research paper on the French Ariane launcher as a successful competitor to the Shuttle. A simpler and more economical vehicle, the Ariane stole numerous payloads from the delay-prone Shuttle. My interest in the space transportation industry grew. Behind the calm governmental facade, I discovered a tremendous amount of political infighting between US Government agencies and NASA centering upon the competition between the subsidized Shuttle, the Ariane and US launch vehicles. I discovered that the builders of conventional launchers could not compete with government backed launch systems.

Small launch vehicle firms drew my attention. These firms with limited capital started by former NASA and aerospace firm employees began the development of small launch vehicles capable of orbiting light payloads. To date only one firm, Space Services Incorporated had successfully launched a rocket. Several firms have failed, while others continue work hoping to become operational in the near future. The question in my mind was - could a few of these small launcher firms survive. From this I derived the major thrust of my research to see if market conditions in the future will foster their growth of eventually choke them off.

My initial work went well until the Challenger accident on an ordinary January morning changed the entire perspective of the space program and commercial space ventures. To complicate matters a concise governmental space policy was never formulated. Uncertainty effectively tied the hands of the commercial space processing industry, large aerospace firms, foreign governments and small entrepreneurs. Confusion reigned in NASA, Congress, and the Administration. United States space policy never very cohesive in the past now came apart at the seams. The Administration, in an effort to pull things together in August, finally made several overdue decisions. One was to build another Shuttle, the other in September was to limit the number and types of commercial payloads on the Shuttle once it flew again. These events, unforseeable a year ago, had and will continue to have a significant impact on small launch firm operations.

The purpose of this study will be to examine in conjunction with demand what impact these issues and others in the marketing environment will have on small launch firms. This study will, in effect, take a snapshot of conditions and projections as they appear at the time of this study. The dynamic environment in which all commercial space ventures take place precludes anyone from being able to achieve anywhere near perfect accuracy in their projections. None foresaw the Challenger's demise, or seriously considered the possibility that four proven US launch vehicles in a row would fail and that the French Ariane would fail in the same period, shutting down Western launch capability. The best effort was made to provide a realistic, conservative projection in line with the belief that unforeseen events in the future will not be exceptionally favorable to space ventures in general and small launch firms in particular.

INTRODUCTION

THE ADVENT OF SPACE COMMERCIALIATION

CHAPTER 1

Man's entry into orbital space began in 1958 with the launching of Sputnik I by the Soviet Union. Since then hundreds of spacecraft have rocketed into earth orbit and beyond. These craft gradually increased in size and complexity and culminated in unmanned planetary spacecraft and manned flight to the moon. These formative years of the space program assumed an exploratory nature. Space represented a new environment about which man knew little in the late 1950s and early 1960s. Consequently, the early satellites primarily carried scientific instrumentation. This period, which ran until the early 1970s, was marked by several characteristics.

The United States and Soviet Union dominated the realm of space. No other nation had the engineering base and resources necessary for a credible space program. Another characteristic of this era was the dependence of other nations on either the Soviet Union or United States to launch their spacecraft. Though the United States agreed to launch the satellites of any Western nation with normal US relations, complications arose when stipulations went along with this service. The National Aeronautics and Space Administration (NASA) refused to launch two French Symphonie communications satellites unless significant restrictions were placed on their use. These satellites were launched only after the French conceded that they would not be used for commercial applications (Heydon, 1985).

This early period of the US and Soviet space program was further characterized by the evolution of manned space flight with man solely as a passenger to a role where man was an active participant culminating in the exploration of the moon. Scientific research led to practical applications through communications and weather satellites.

During this period the US national space program was controlled and regulated by the government through NASA. Private industry was not active in commercially developing space.

During the 1970's and early 1980's the situation changed dramatically. The US and Soviet Union no longer completely dominated the arena of space. China, Japan, and Brazil developed space programs. The European Space Agency (ESA) pooled the space interests, and the financial and industrial resources of several European countries. The cold war competition in space by the two great super-powers has been replaced by commercial competition between all spacefaring nations. This competition took several forms. The French SPOT satellite came into direct competition with the US LANDSAT remote sensing (detection of resources through satellite imagery) satellite system.

Today, foreign suppliers of ground station equipment in Germany, Canada, France and Japan compete directly with US firms abroad. Japan has developed a new communications satellite which could revolutionize that industry. The European Ariane launcher has lured customers away from the US Shuttle even prior to the Challenger accident.

The Europeans learned relatively early to develop launcher and satellite capabilities independent from the US. The US refusal to launch the French Symphonie satellites served to illustrate to the European space community the need for alternatives to US supplied services in such areas as space transportation. During the Carter Administration, due to budgetary pressures, the US bowed out of a joint solar-polar orbit mission with the Europeans, seriously degrading the overall project. Today, Europeans are dissatisfied with the return from their investment in the Shuttle program, the West German developed Spacelab module. This pressurized laboratory has been used more by the US than Europe. The European Space Agency (ESA) has demanded a more active role in the development and operation of a proposed US space station which is partially funded by ESA. The Europeans are intent on establishing an independent presence in space and plans are proceeding on a European heavy launch vehicle, spaceplane, and Columbus space station to be constructed after the US station is orbited.

American space objectives today still include man's presence in space, a program of scientific exploration and research, and practical application of the knowledge and technology gained. A national objective since the Reagan Administration took office is the commercialization of space through the participation of US business in establishing various industries and services in space. The total control of the national space program by the government has been replaced by the privatization of major functions that previously were the sole responsibility of NASA.

As an example, Lockheed assumed NASA's responsibilities at the Kennedy Spacecraft Center and was contracted to handle a major portion of the operations there. Recently, NASA turned over the control of the LANDSAT Earth Resources Satellite System to the Earth Observation Satellite Company (EOSAT). The US Government at one time even considered a proposal to turn over one or more Shuttle orbiters to a private firm for commercial launch services. The proposal was turned down based on the logic that the Shuttle is a national asset which promotes national interests, maintains the US presence in space, and in time of national emergency, might be called upon to conduct critical military missions.

The US Government has encouraged businesses to exploit the space environment in order to foster new industrial applications. New controlled processes could be developed to make stronger and more perfect materials. New pharmaceuticals are possible. Superior material for electronic equipment could be made along with an improvement in the usual applications in communications, weather prediction and global navigation. A commercial space policy developed by NASA and endorsed by the Reagan Administration has helped stimulate growth in commercial space activities.

COMMERCIAL SPACE POLICY

CHAPTER 2

NASA's space commercialization policy, formulated in 1983, is designed to aid companies, financial institutions, and entrepreneurs who would otherwise be unable to sustain the risk of investing their time, money and efforts in commercial space ventures. NASA's policy was formulated in conjunction with the Reagan Administration's Commercial Space Policy and is "designed to counter impediments to commercial space endeavors such as tax laws which have hampered space industrialization because they were written before the unique problems facing business were recognized" (Covault, 1984).

Various methods have been implemented to reduce the financial risk to commercial space venture companies. In seed funding, for example, NASA would pay a portion of a company's startup costs for a space venture to reduce risk. Firms receiving such funding would have placed a large amount of their own capital at risk. Another element of this policy would also allow NASA to purchase a portion of certain space-produced products as a means of providing market support when such products could be used by NASA.

Under the commercial space policy, attempts are being made to revise the tax code and investment credits in order to give companies with space ventures the same tax breaks as companies performing similar earth-bound services. The White House has ordered a review of tax regulations that unfairly discriminate against space commercialization ventures simply because commercial space ventures did not exist when those regulations were written. In addition to trying to eliminate this kind of discrimination, the Administration is working to change the tax code so that they would specifically benefit industries working in space. "A 10% investment tax credit currently unavailable to space commercialization ventures is being restructured with White House support to make it available to this new business area. Under existing law, objects launched into space are considered exports and therefore do not qualify"(Covault, 1984).

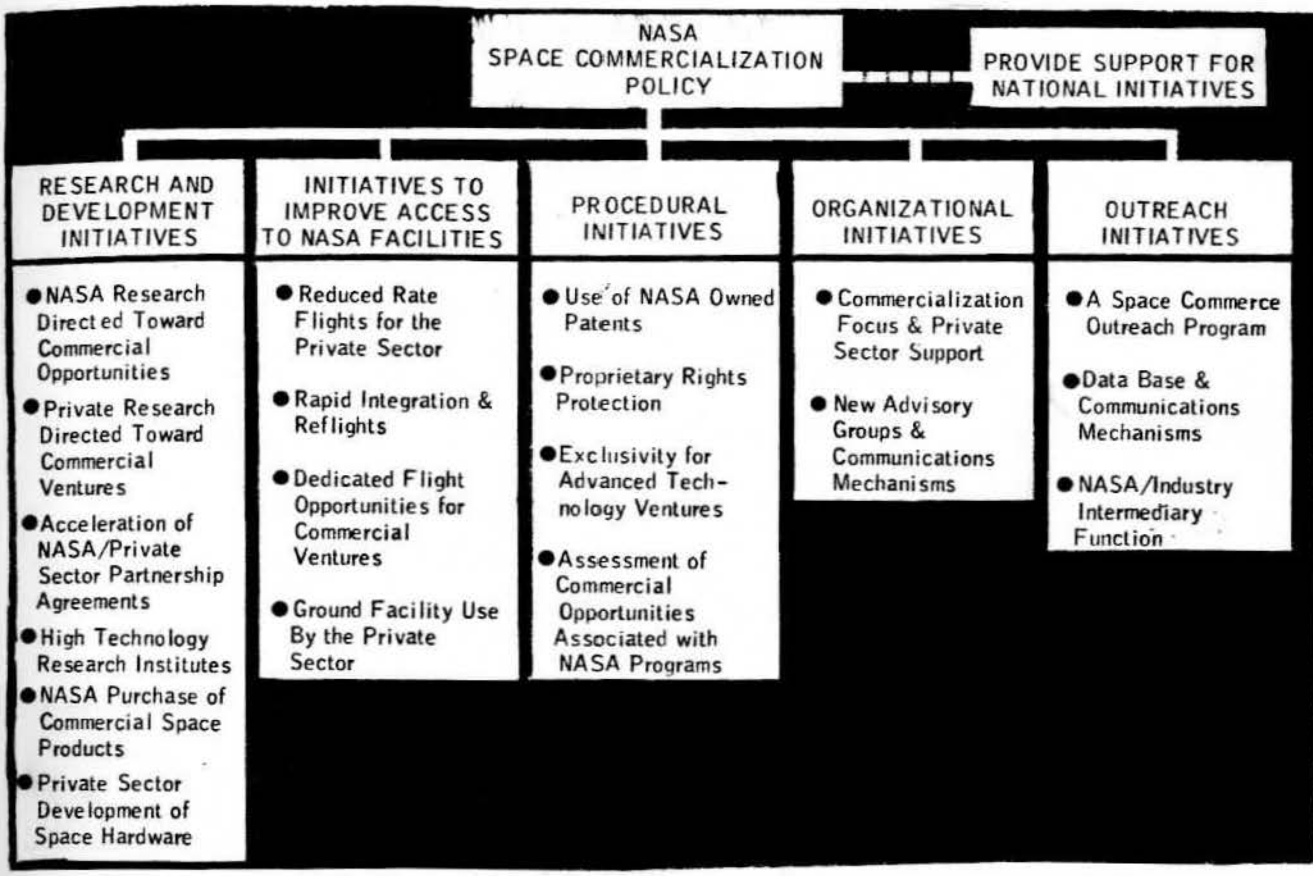
The Office of Commercial Programs was created in the Fall of 1984 and has served as the center for the government's outreach activities designed to provide a focal point for business to come to when they want to conduct commercial space ventures with NASA's aid. NASA, with its vast amount of knowledge and experience has agreed to share its expertise with a firm through various agreements. These agreements include:

1. Launch service agreements for a Shuttle flight.
2. Joint endeavor agreements which involve a combined research effort by the firm and NASA. No exchange of funds occurs. The firm pays the expense for requisite project research and development on earth and the construction of flight hardware, while NASA provides free shuttle flights for the project which must have already met certain basic criteria on technical

merit, innovation and acceptable business merit. While the company retains proprietary, patent and invention rights, NASA must receive enough data to evaluate the results of the endeavor.

3. Plans for an industrial quest investigator. This agreement permits a company scientist to work at company expense in a NASA experiment.
4. Technical exchange agreements for sharing data derived from ground-based research analysis. No flight is involved; expenses are paid by the company and the company's data and patent rights are protected (Covault, 1984).

The organization of NASA's Commercial Space Polcy is illustrated in Figure 1. It consists of five policy subsections and 19 initiatives that were to have been phased in over several years. NASA and other branches of the federal government have failed for the most part to enact these policies ("US Action on Command Space Policy Criticized by Current, Former Administration Officials", Aviation Week and Space Technology, 1986). A large portion of the space policy developed in 1984 is irrelevant in the post-Challenger accident environment. Commercial payloads have been given lowest



Figures 1. NASA's Commercial Space Policy contains nineteen initiatives designed to foster business involvement in developing commercial space applications.

NOTE. From "Unique Products, New Technology Spawn Space Business" by Craig Covault, 1984, AVIATION WEEK AND SPACE TECHNOLOGY, 47.

priority on the new Shuttle manifest. This alone negates the requirements under the heading "Initiatives to Improve Access to NASA Facilities" in the 1984 policy. L. J. Evans, the former NASA Deputy Administrator of Commercial Space and current President of the Center for Space and Advanced Technology Inc., indicated that out of the "nineteen NASA initiatives, six have been fully implemented, four partially, five have not been implemented and four have regressed in status. NASA is still unable to make prompt decisions resulting in an incredibly costly, bureaucratic and time consuming process to get cooperative agreements signed". (US Action on Command Space Policy Criticized by Current, Former Administration Officials", Aviation Week and Space Technology, 1986). The US government eventually will have to modify the Commercial Space Policy in light of recent developments and in the process redefine the role of NASA and the federal government with respect to the private use of space.

SPACE BUSINESS CATEGORIES

CHAPTER 3

David W. Thompson, President of Orbital Science Corporation, a firm which markets an upper stage vehicle for heavy satellites, said that six things characterize most space ventures at the Financing Business in Space Conference, March 27, 1984, in Arlington, Virginia.

First, space projects are capital intensive. Development costs of $25 million to $50 million as an absolute minimum, are required for the most modest ventures. Second, a longer period of time will pass before there is a return on investment. Three to four years will normally pass from a project's inception to launch, at which time a return may still be several years away. Orbital Science Corporation developed an upper stage for the Shuttle in the late 1970s. Its first use will occur around 1990. Several more customers will have to purchase the vehicle before a profit is possible around 1995. ("Investments", Commercial Space, 1985). For most investors there are better things to get into on earth while they wait for someone else to bring in a return from space. Third, like many other high tech ventures, space projects are associated with high levels of perceived and actual risks. These risks are related to the ventures inherent uncertainties, which are technical, market, operating, and political in nature. These factors can only be compensated for by projects with prospects for high return or exceptional long term growth. Financial experts, because of a lack of experience in space investments, have yet to establish a credible means of assessing risk for various space ventures. Fourth, space enterprises rely to a large part on high technology, which can act as a double-edged sword; while some investors are attracted to the glamour of space technologies, others are drawn elsewhere by the susceptibility of space ventures to unpredictable market and technical factors. The Shuttle, a marvel of technology, has by virtue of its failure and grounding stranded many programs dependent upon it for transportation. Fifth, space projects represent an exciting but unfamiliar area for private investors. Early stage investors are normally attracted by the excitement but the amounts invested are inadequate for the multistage financing required. Many investors will not be attracted to commercial space ventures without a significant amount of education on the economics and technologies of a space enterprise and a realistic prospect of very high financial returns. This is something that seems less likely until the US's space program has reestablished itself. Sixth, space projects can draw on a vast amount of managerial and technical talent. The quality of a project's management is a very significant factor in whether a project will draw the necessary investors. Excellent managerial and technical personnel are employed by both government and industry. A new venture is faced with the problem of attracting management and technicians from their current jobs. These factors are present to a greater or lesser degree in any industry associated with space. Generally these can be classified in one of three categories which are satellite construction and use, support services, and launch services.

SATELLITES

Satellites are classified according to function. There are four satellite categories: communications, remote sensing, material processing and space science. Space communications is the only substantial commercial exploitation of space to date.

Communications Satellites

Communications satellites represent the dominant transmission technology today. International and domestic communications satellites provide significant national support by supplementing cable and microwave transmission. Frequently, the same firms that carry data from one point to another also process the data, leading to the merger of these two formerly separate activities; telecommunications and data processing. In the United States, the largest US telecommunications corporations (AT&T, Western Union, IBM, RCA, ITT and GTE) offer domestic communications satellite services. Large firms, such as CITICORP and General Electric, have private satellite communications networks to support their operations. The big three communication satellite makers are Hughes, Ford Aerospace and RCA. They have captured most of the market and will continue to hold a sizeable portion for the rest of the decade.

Company	Country	Actual 1965-83	Planned 1984-89
Prime contractors:			
[First launch 1983 or before]			
Hughes Aircraft	United States	45	33
Ford Aerospace	United States	10	10
RCA Astro-Electronics	United States	9	27
TRW Defense and Space Systems	United States	8	0
British Aerospace Dynamics	United Kingdom	4	9
Melco/Ford Aerospace	Japan/United States	3	1
C.N.S.	Italy	1	1
Spar Aerospace/Hughes Aircraft	Canada/United States	1	3
Total		81	84
Additional prime contractors:			
[First launch 1984 or later]			
Eurosatellite	West European Consortium		5
Melco (Mitsubishi Electric Co.)	Japan		4
Toshiba/GE	Japan/United States		3
Spar Aerospace	Canada		3
Matra Space	France		2
Aerospatiale (with Ford Aerospace)	France/United States		2
Siemens/MBB/ERNO/AEG/ANT	West European Consortium		2
Total			21
Prime contractor not yet selected: [a]			45
Grand total		81	150

Table 1. Prime contractors for commercial communications satellites.

Note. From "World Communications Satellite Market Characteristics and Forcast", NASA Contract CR-168270, November 1983.

The communications satellite's commercial, political and regulatory environment are a complicated and treacherous area. The major issues are:

1. The International Telecommunication Satellite Organization (INTELSAT), a consortium of 109 nations has a monopoly on all international satellite communications. Several private US communications corporations have recently applied for authorization from the Federal Communications Commission (FCC) to launch satellites providing transatlantic

communications services. The US must decide whether it will continue support of INTELSAT as sole provider of intercontinental communications or whether it will allow US firms to launch and operate competitive satellites (Office of Technology Assessment, 1985).

2. In a related issue, other nations typically require that communications reaching their territories be handled by their governmental communications system and will accept communications traffic only from a designated US carrier. The US is working on bilateral negotiations with individual countries with the objective of obtaining access for additional US carriers. Multilateral negotiations also continue on a GATT (General Agreement on Traffic and Trade refers to a treaty adhered to by the code of 177 countries on trading services) agreement which will open communications by US carriers to several countries (OTA, 1985).

3. Satellite communications demand is increasing rapidly, but whether growth will continue through the 1990s remains uncertain. Fiber optic technology poses the greatest threat to the communication satellite industry. The first trans-Atlantic fiber optic cable is scheduled for operation in 1988. The ratio of communications satellites to fiber optics cables will depend on consumer preferences, business

incentives, industry structure and regulatory decisions (OTA, 1985).

4. The International Telecommunications Union (ITU), a United Nations Organization regulates space communications (i.e. setting telecommunications standards, allocating radio frequencies) to include allotting positions in geostationary orbit. Positions are now registered according to a policy of "first-come, first served." However, numerous Central American, South American and developing countries would like to change this to "a priori" allotments, whereby countries would be assigned slots (positions) in advance of actual need. The ITU periodically calls the World Administrative Radio Conference (WARC) into session. Through supposedly administrative in nature, the WARC during its last few sessions has taken on a decidedly political flavor with the third world nations pitted against the US. At issue is a reconsideration of international arrangements for planning the disposition of communications satellites in geosynchronous orbit. If the United States faces a limited allotment of geosynchronous slots, it may be forced to rent unfilled slots from other countries, substitute fiber optic cable capacity for lost satellite capability or deploy a new type of communications satellite which uses a new frequency

band (Ka band). Each alternative would incur additional costs (Rosemary, Kindel, 1983).

5. Congestion in geostationary orbit, primarily over the Western hemisphere in the C-frequency band (6/4 GHz) and Ku-frequency band (14/12 GHz) may create a market opportunity for Ka-frequency band (30/20 GHz) satellites in the 1990s. However, the deployment of Ka-band communications satellites entails several problems. The technology associated with this type of satellite is advanced, complicated and very expensive. C- and Ku-band ground equipment is incompatible with Ka-band equipment, increasing overall system cost.

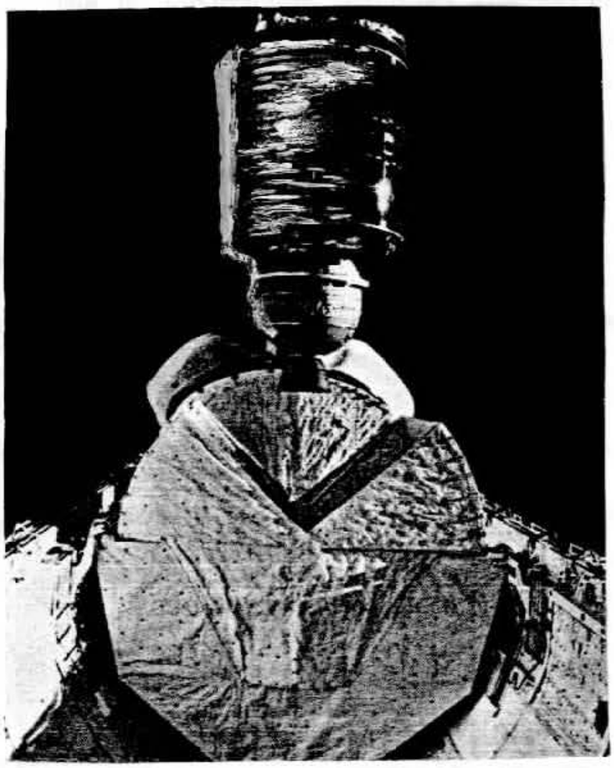


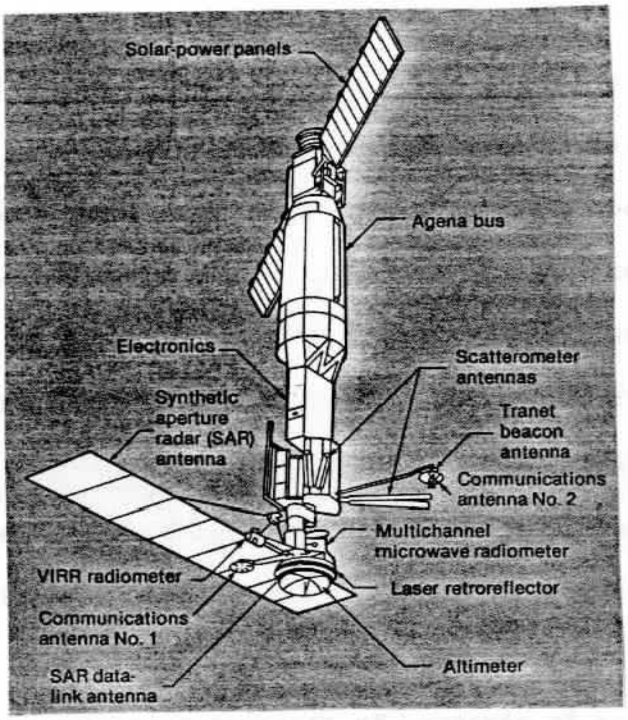
Figure 2. Shuttle launching Satellite Business Systems satellite from sunshield enclosure. A perigee kick motor is attached to place it in a higher orbit.

Communications satellites are the largest market in the satellite industry. While the demand increases for this method of information and data transmittal, there is no guarantee that continued growth through the 1990s will occur.

Remote Sensing Satellites

Remote sensing satellites view the Earth in various imaging mediums (i.e. visible light, microwave, infrared) for the purpose of investigating various aspects of the earth's composition, atmosphere and weather. These spacecraft have been used for weather prediction, mineral and petroleum prospecting, agricultural productivity, erosion control, and fishing management. The US Government through the National Oceanic and Atmospheric Administration (NOAA) will continue to operate the nation's weather satellites (advanced TIROS and GOES) since they benefit the nation as a whole. However, the US Government has transferred the LANDSAT system, which provides valuable data for the development and use of natural resources, to a private firm, the Earth Observation Satellite Company (EOSAT). When correctly interpreted, this data can aid in the prediction of mineral resources, ground water or the cause of agricultural problems. Separate firms market this data to other companies and foreign governments.

The US LANDSAT system, until the launch in 1986 of the French SPOT satellite, was the only commercial remote sensing system from which worldwide data was available. By 1990, other countries (to include Canada, France, and Japan) are expected to launch their own remote sensing satellites, lowering foreign demand for this service and providing multiple sources for this data.



<u>Figure 3</u>. SEASAT, Oceanographic remote sensing satellite.

<u>Material Processing Satellites</u>

Materials processing payloads offer the greatest promise for commercial success dependent upon the long term success of the Shuttle and the US space station. It involves the study of materials, from pharmaceuticals to ceramics, and the various processes which could be applied to these materials (i.e. melting, solidifying, electroplating) in the microgravity environment of space. This form of material development could lead to new or better quality products. The first commercial product from material processing, latex spheres produced during a shuttle flight and used to calibrate electron microscopes, have already been sold to the National Bureau of Weights and Standards. The commercial space policy treats this area of space business very favorably.

Material processing is a viable function for the US Shuttle since it normally requires the direct intervention of man to observe and control the various material processes. Another reason why the Shuttle is the ideal vehicle for material processing science is because of its ability to return the payload from orbit. Even when released in space, a material processing package can be picked up on a later shuttle flight. This is impossible for the standard launch vehicle.

Numerous material processing experiments are being funded by universities and industry. The recent shuttle disaster will put many of these projects on hold for two or more years. The material processing research of hundreds of companies to include John Deere, 3M, Bethlehem Steel, DuPont and Monsanto have been slowed significantly due to the inability to put payloads into orbit. This slowdown will allow competing companies time to develop Earth bound processes comparable to those conducted in space. Events prior to the Challenger loss were also disturbing. Fairchild Industries developed a satellite called LEASECRAFT which could have been deployed in orbit by the shuttle. LEASECRAFT would in essence have been leased from Fairchild with the renting company attaching onto LEASECRAFT a module with the material to be processed. A later shuttle flight would recover the material after it had been processed in space and would attach a material resupply module from the original or a new company wishing to use the satellite. Fairchild suspended further development of the spacecraft when no companies came forward to contract or use this satellite.

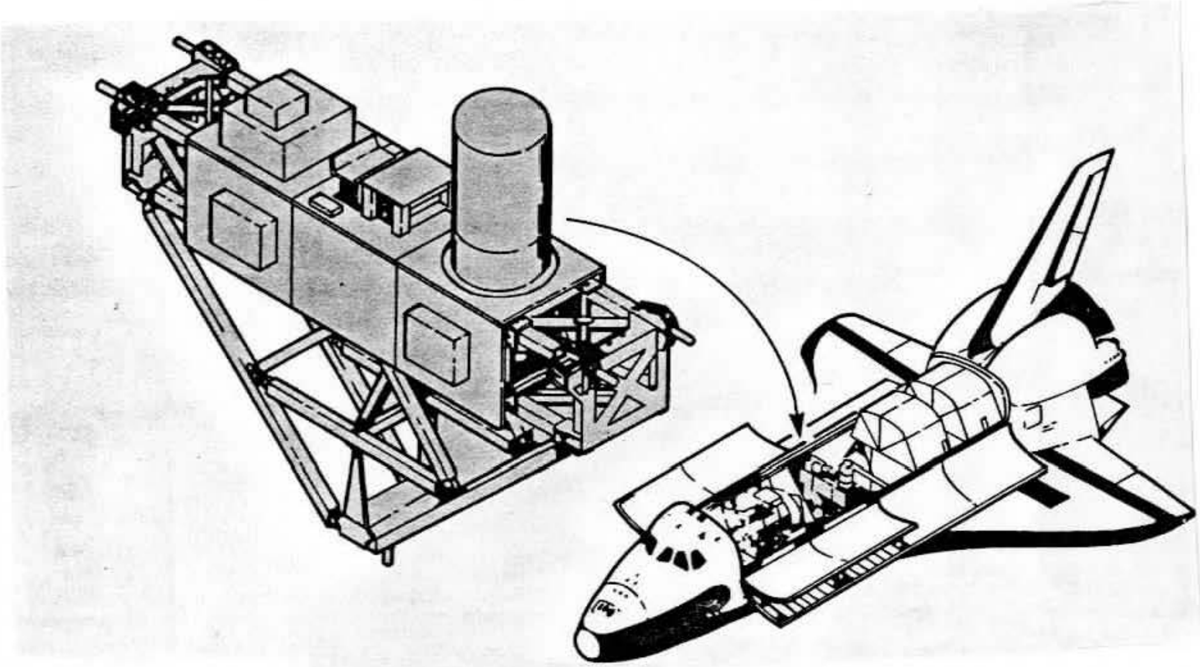


Figure 4. NASA's universities' or industries' material processing payloads can be mounted on this truss in the Shuttle's cargo bay.

Space Science Satellites

The final category of satellites are space science satellites, which as national or international vehicles to explore space, have little immediate commercial application. Examples which come to mind are the spacecraft sent by various nations to explore Halley's Comet and the Voyager craft which explored the outer planets. These craft are normally funded by the national government with the scientific instruments designed and constructed by universities and national laboratories. These vehicles are launched by the Shuttle or conventional launchers.

Figure 5. Japan's Susei spacecraft was one of several that were sent by West Germany and the Soviet Union to explore Halley's Comet.

SUPPORT SERVICES

It is evident that the various classes of satellites provide important services to the nation as a whole and opportunities for private sector commercial growth. In addition to the direct fallout from the use of a satellite, there is a vast industry supporting the operation of satellites, which include tracking stations, ground stations, payload servicing, recovery processing and launch services.

Tracking services consist of a network of stations which follow the satellite in orbit and receive data from and transmit commands to it. These stations are either government or privately operated. Several large electronics firms supply the equipment for these stations. NASA, in the future, will eliminate the need for most tracking stations in governmental, defense and some commercial communications networks by orbiting four large Tracking Data Relay Satellites (TDRS) equi-distant around the globe. Most telecommunications companies, companies with private networks and individuals will maintain stations for their satellites called Earth stations which vary in size from the cable television (CATV) satellite dish to the 30 meter dish antennaes ($2000 - $9 million). The current trend is toward higher-powered, more sophisticated satellites making possible smaller, less expensive, but technically advanced Earth stations that can be used for corporate data transmission and videoconferencing. Earth stations are supplied by 25 firms in seven countries (OTA, 1985). While foreign firms are allowed to compete in the United States, Japanese and European Economic Community (EEC) markets are effectively closed to the US due to trade barriers. In either case, by far the largest portion of the world market for Earth stations is currently in the United States. Nippon Electric Company (NEC), a Japanese firm, is the largest manufacturer of large Earth stations, having manufactured approximately one-third of all such stations around the world (OTA, 1985).

With the advent of regular operational shuttle flights, firms have provided services to those customers with payloads, to place on board. Commercial customers with large payloads, such as a communications satellite, have the option of having their payload processed by either NASA or Astrotech Space Operations which has excellent facilities and equipment adjacent to the Kennedy Space enter (Kolcum, 1985). For anyone wishing to orbit a smaller payload, several firms provide services to integrate it with the Shuttle. Instrumentation Technology Associates is the leader in this area integrating the customer's equipment to fit in NASA's payload modules and providing any additional support equipment required and technical advice. Shuttle customers range from high school experiments to the payloads of large corporations.

Numerous new firms have started based on the many opportunities resulting from support requirements related to space. In one area alone more than 40 commercial ventures are enhancing and interpreting LANDSAT and weather satellite data creating a multimillion-dollar industry that is continuously striving for new ways to make satellite imagery data more useful to crop market analysts, petroleum geologists and other users ("Fixing NASA", Time 1986).

LAUNCH SERVICES

An area which recently has been opened to the private sector are space transportation or launch services for commercial payloads. The US government has reassessed its traditional role as the sole provider of launch services and has opened this area to commercialization. Until the shuttle accident the primary competitors in the launch service market were the Shuttle and the French Ariane booster. Though the initial philosophy behind the Shuttle was a full recovery of launch costs by charging the customer the actual cost to launch his payload, pressure from the Ariane forced the Administration to subsidize the Shuttle and lower customer pricing in order to maintain a competitive edge. This has had an adverse impact on the launch vehicle firms currently in existence. The Shuttle's artificially low prices undercut the lowest price that could be offered by commercial launch vehicle firms, keeping them from entering the market.

The Administration policy on launch vehicle commercialization is ambiguous. "The President's policy encourages free market competition among the various systems within the US private sector, yet leaves the government-subsidized Shuttle as the main competitor to the private sector's efforts to market expendable launch vehicle services. Current and projected pricing policies... allow the Shuttle to compete with Ariane's prices ... however, these policies decrease the probability that US private firms will be economically successful in providing competitive launch services" (OTA, 1985). Recent events have changed the market outlook for these firms. NASA has come to the conclusion that without this industry the backlog of satellites will exceed shuttle capacity by a large margin. This paper will focus on a portion of that industry.

SPACE TRANSPORTATION SERVICES

CHAPTER 4

The Shuttle Transportation System, was originally developed for a number of good reasons:

1. It was less expensive to reuse valuable components of a rocket than to lose everything whenever it launched a payload.
2. Man would pilot the vehicle and would provide a problem solving element and greater flexibility than normally possible.
3. Rapid turn-around of a reusable vehicle would allow more flights during a single year than with expendable launch vehicles.
4. It seemed simpler and more economical to maintain one vehicle rather than a fleet of rocket boosters for the various payload weight classifications (Roland, 1985).

The Shuttle was envisioned as a cheap bus ride into orbit. Ideally these flights would pay for themselves by charging the customer for the flight. But because of cheaper access to orbit, flights would not be too costly. The initial analysis failed to accurately predict what would happen. An incredibly complex vehicle evolved since not only did it have to get itself into space, it also had to bring itself back in one piece like a high priced glider, something the expendable launch vehicle (ELV) did not have to do. The engines, a problem area, had to be built better to withstand numerous flights and the heat resistant tile problem delayed the program and further added to costs. Development of the shuttle cost $14 billion in 1985 dollars, still within budget. NASA's hopes of reducing the rates to orbit a pound of payload from $1000/lb for Expendable Launch Vehicles (ELV's) to $150/lb ($10 million Shuttle flight) vanished. In 1985 the Congressional Budget Office computed the cost of a flight using five preferred methods (Roland, 1985).

Accounting Method	Cost Per Launch	Cost per Pound*
Short-run marginal	$42 Million	$646/$893
Long-run marginal	$76 Million	$1,169/$1,617
Average Full Operational Cost	$84 million	$1,292/$1,787
Average Full Cost Less Development	$108 million	$1,662/$2,298
Average Full Cost	$150 million	$2,308/$3,191

*65,000 lb payload/ 47,000 lb payload

Table 2. Cost of a Shuttle flight based on five preferred cost analysis methods.

The interaction of man in certain aspects of space operations is essential. Several daring efforts have been made to recover or repair satellites which have malfunctioned or have been placed in the wrong orbit. Man's presence however, must be tempered by the added weight, complexity and cost of the overall vehicle; factors that are not considered in launching an ELV. Missions such as those involving material processing, biological or observation experiments, clearly require man's presence. Nonetheless, NASA still uses the Shuttle like an expensive bus service to haul ordinary communications satellites into orbit when they could more feasibly be launched on a less complex vehicle. Problems associated with the complexity of vehicles and operational and safety considerations for the men and women on board resulted in less flexibility in launch scheduling. While weather need only be good in the launch area for an ELV launch, it must be good at several emergency landing sites around the globe to launch the Shuttle. This plus equipment failures and the time needed to transport the vehicle when required from the California landing site to Florida decreased its ability to launch on a regular scheduled basis. A reduced number of flights increased the cost of each flight, which also increased the loss to the taxpayer. Experts placed the breakeven point at an impossible rate of 34 flights a year. Profitability studies of the Shuttle were based on the eventual launch rate of 60 flights a year. The maximum safe flight rate was achieved with nine flights in 1985 (Wilford & Broad, 1985).

The Shuttle replaced this nation's fleet of expendable launch vehicles. When the decision was made in the early 1970s to depend solely on the Shuttle for all military, government, commercial and foreign launches, it was defended on the basis of the projected high flight rates. The actual termination of ELV production was delayed as the Shuttle experienced program slips. If it were not for entry of the French Ariane NASA would have had a virtual monopoly on commercial launch services throughout the world during the 1980s.

Arianespace has the management responsibility for marketing, producing and launching the Ariane. The launch vehicle itself was developed by the French Space Agency Centre National d' Etudes Spatiales (CNES) and is financed by consortium of 50 companies and banks in eleven European countries. Some of the shareholders have contracts to produce various components of the vehicle. The Ariane, in addition to launching foreign payloads, is the prime launcher for the European Space Agency. A US aerospace company manager commented that "The Europeans combined the best of both worlds in the way they established the marketing organization for Ariane. The organization has the marketing freedom of a private organization, while enjoying the direct support of the necessary government agencies ("Competition", Fortune, 1985). Arianespace President, Frederick d'Allest is also the director general of the French Space Agency, CNES. This dual role gives d'Allest the advantage of being able to position Arianespace very well in the market through his CNES position and gives him a direct line to top government officials. "It would be the same as if the NASA Administrator were also the president of the commercial company building the Shuttle."("Competition", Fortune, 1985) This setup has reduced government red tape and brought success to Ariane when failure might have occurred.

France's Societe Europenne de Propulsion (SEP) manufactured a propulsion system that had twice failed on the Ariane (1980 and 1982). While the company was technically sound, it had difficulty with the swift rate of production, and, therefore, needed changes required for entry into commercial service. Consequently, SEP was made an affiliate of French engine producer, Snecma, and top management was realigned. D'Allest had a key role in SEP's merger with Snecma. His dual role allowed him to bring about change at the industrial level. The merger occurred because Snecma is the largest nationalized company in France, a holder of some of SEP's capital(Brady and Kindel, 1983).

Arianespace positioned its product to take advantage of the Shuttle's weak points. The vehicle itself is a moderately-sized expendable, launcher which is launched from near the equator (Kourou, French Guiana) where the earth's rotation helps push a greater weight into orbit. Being a far simpler vehicle, without man aboard, scheduling flexibility is increased, and technical and weather problems are far less likely to occur. The vehicle itself is significantly less expensive than the Shuttle, and, while it has suffered three launch failures, none has had the catastrophic results of the one Shuttle loss. The Shuttle was designed to launch almost any size spacecraft and the Ariane attempted to capture the market least suitable or cost effective for shuttle launch; the communications satellites.

Ariane, developed in 1979, penetrated this market in 1983. The International Satellite Corporation (INTELSAT) attempted to buy seven expendable vehicle launchers for their communications satellites from NASA. NASA could only provide four with expendable launchers and scheduled the remaining communication satellites on the shuttle which at that time had never flown and as behind schedule. INTELSAT opted to launch the excess on the Ariane. This decision by INTELSAT established the precedent for an alternative launch capability as a means of orbiting a satellite due to the unavailability of a single launch system and supplied the Ariane effort with the needed credibility. The basic Ariane vehicle has spawned a family of vehicles capable of launching heavier satellites.

Both the Shuttle and Arianespace are subsidized, one by the US Government, the other by ESA (Roland, 1985). The US Government paid for the development of the Shuttle ($10 billion) and ESA paid for Ariane's development ($1.5 billion). Beyond that Ariane pays for itself. Something the Shuttle has never done. Ariane launch prices include the costs of spare parts. Another thing impossible with the Shuttle. If Arianespace increases its launch rate the cost would come out of the company's pocket, while a Shuttle launch rate increase would see the money coming from the taxpayer.

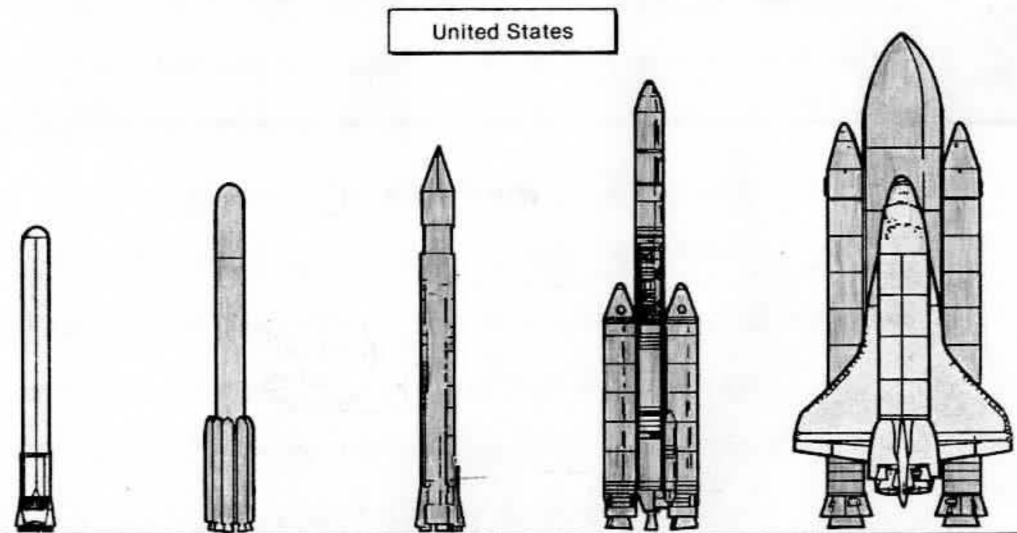
Ariane has tried to maintain prices competitive with the shuttle. The Ariane price to launch an INTELSAT satellite was $39.6 million compared with NASA's price of $28.34 million (Lenowitz, 1985). The Ariane however offered the advantages of greater flexibility and responsiveness; being able to launch the satellite well in advance of the Shuttle launch. A communications satellite cannot generate any revenue until it is in orbit. The delay by NASA may have been enough to overcome the price differential in favor of the Ariane as INTELSAT's launch vehicle. Compared to NASA Arianespace offers very favorable financing (See APPENDIX A).

Arianspace has captured between 30% and 50% of the communications satellite market in any one year and has developed a family of larger vehicles to retain and expand its market share. The final version, the Ariane 5 will represent a totally revolutionary vehicle design philosophy which will no longer maximize performance in terms of the number of pounds in orbit but rather will seek to minimize launch cost per pound orbited. This vehicle will be capable of not only placing France's mini-shuttle into orbit but fits well into the European strategy of gaining total autonomy from the US in the area of space flight and manned space stations.

Competition between the Shuttle and Ariane caused the Shuttle to artificially underprice the Ariane, eliminating all ELV firms from the market. Large ELV producers such as Martin Marietta, General Dynamics and McDonnell Douglas closed down production lines when they realized that they could not remain competitive. The Space Shuttle disaster has reversed some of that thinking.

The United States launch vehicle failure rate now is the worst since the early days of the space program. Two Air Force Titan 34Cs in a row have failed in placing Defense Department satellites in orbit. The destruction of the Challenger resulted in the loss of crew, communications satellite, orbiter, and has had the far reaching effects of indefinitely grounding the Shuttle and exposing severe managerial shortcomings in NASA. In May 1986 a Delta launch vehicle was destroyed with a weather satellite when control of it was lost. More recently a French

Ariane rocket failed with the subsequent loss of a powerful communications satellite. The Ariane like the Titan, Shuttle and Delta is grounded until the cause of the failure can be determined. The launch capability of the Western World has been shut down resulting in a growing satellite backlog. This backlog can become critical in the 1990s when the space station and major elements of the strategic Defense Initiative (SDI) are deployed. Efforts are being made to unload certain categories of commercial payloads off the Shuttle and onto ELVs. William R. Graham, the NASA administer at the time, ordered in March 1986 that no additional communications satellites be launched from orbiters once the existing contracts had been met. This forced NASA to end launch service negotiations with several customers (Saudi Arabia, Italy, the Mitsubishi/Ford Satellite Consortium, RCA, and British Defense Ministry) ("Washington Roundup" Aviation Week and Space Technology, 1986). President Reagan has enforced this decision with a directive prohibiting the future sale of shuttle services to certain commercial and foreign users. However, "NASA is unlikely to buy more expendable launch vehicles despite the payload backlog....because of budget constraints. NASA administrator James C. Fletcher has told Congress he expects the Defense Department and commercial operators to furnish the extra launch capacity that will be needed" ("Industry Observer", Aviation Week and Space Technology, 1986). The big three expendable launch vehicle producers, once considered outdated in light of the Shuttle, are gearing up to restart production. Martin Marietta, General Dynamics and McDonnell Douglas produce nearly all of the expendable launch vehicles used by the United States.



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

Figure 6. US launch vehicles include the four expendable launchers shown and the Shuttle.

The Air Force is Martin Marietta's primary launch vehicle customer. Various derivatives of their Titan Launch Vehicle have orbited Department of Defense (DOD) satellites. The Air Force was never totally sold on the Shuttle and preferred to rely more on ELVs. The Titan 34D launcher, the Air Force's workhouse orbits the majority of DOD satellites. With the Shuttle and Titan 34D (two failed in succession in 1985 and 1986) grounded the Air Force has requested that the production rate for the

Titan 34D-7 (an upgraded version of the Titan 34D) be increased from two to five vehicles per year. A second launch pad is planned to accommodate the increased launch rate. Additionally, 50 Titan 2s will be decommissioned as ballistic missiles in late 1987 and will be refurbished and upgraded to be used as space launchers for intermediate payloads (such as DOD meteorological and navigational satellites)(Lenowitz, 1985).

General Dynamics closed down production in the early 1980s when it felt that it could not hope to compete with the subsidized Shuttle and Ariane. It had produced the Atlas and the larger Atlas Centaur launchers. The Air Force still has approximately twelve Atlas Es and one Atlas H. Only three of the larger and more powerful Atlas Centaurs remain. They are scheduled to launch three Defense Department FLTSATCOM communications satellites in 1986 and 1987. General Dynamics plans to reopen its production lines, however, the first Atlas or Atlas Centaur would not be completed until 1988 because a greater period of time is required to construct the engines. Rocketdyne, the engine manufacturer, is shut down and would have to go through the expensive startup process. General Dynamics intends to produce 3 Atlas type vehicles in 1988 and 5 per year between 1989 and 1992. If additional tooling is acquired 9 vehicles could be produced in 1989 and 17 in 1990 and thereafter ("Expendable Launchers", Commercial Space, 1985).

McDonnell Douglas had also closed its production lines. Two Delta launch vehicles remain in the inventory. One is scheduled to launch a DOD payload in support of the Strategic Defense Initiative and the other is scheduled to launch a National

Oceanic and Atmospheric Administration GOES weather satellite. McDonnell Douglas faces similar problems as General Dynamics and by 1988 could achieve a production rate of 12 vehicles per year.

DATE	VEHICLE	PAYLOAD	LAUNCH SITE
1 May 86	DELTA	GOES-G	KSC (Failed)
August 86	ATLAS CENTAUR	FLTSATCOM-F	KSC Delayed
5 September 86	DELTA	DOD/SDI	KSC Success
17 September 86	ATLAS E	NOAA 10	KSC Success

Table 3. Actual and Planned ELV Launches for 1986.

Vought Corporation manufactures the Scout, a small rocket capable of putting small payloads into low earth orbit. It is not powerful enough to launch a satellite into geosychronous orbit. All twelve Scouts in the inventory are scheduled for DOD use. With the Shuttle and Ariane grounded at least for the major portion of 1987, ELV industries are firming up plans to reenter the market. Several very small fledgling firms, the focus of this study for the most part, have remained in the background working and waiting for the right opportunity to present their product.

SUCCESS	FAILURE	TOTAL	
DELTA	166	12	178
ATLAS CENTAUR	56	9	65
TITAN 34D	9	2	11
SHUTTLE SYSTEM	24	1	25

Table 4. Comparative ELV Success/Failure Rate.

The US Air Force in light of the launch vehicle crisis and the backlog of payloads has issued requests for proposals for a Medium Launch Vehicle (MLV) to launch payloads in the future. "One of the major thrusts of the MLV program is the strong Defense Department requirement to begin building the 18-satellite constellation for the NAVSTAR global positioning system (GPS)"(Smith, 1986). Several major launch firms have submitted their vehicles as candidates for the MLV. General Dynamics has proposed the Atlas Centaur, McDonnell Douglas has proposed an upgraded version of its Delta, and Martin Marietta has proposed the new Titan 4 as the MLV (Foley, 1986).

A new entrant is a Hughes Aircraft Co./Boeing Aerospace Co. proposal called the Jarvis (named after Hughes employee who was killed in the Challenger explosion). Its design combines the propulsion system from the Saturn moon rocket and the electronic systems and airframe from the Shuttle to form a very large vehicle. This booster is capable of launching multiple satellites with a combined weight of 85,000 lbs., 20,000 lbs more than the Shuttle (Smith, 1986). Whichever vehicle is chosen the MLV could expand its role to incorporate commercial payloads.

SMALL EXPENDABLE LAUNCH VEHICLE FIRMS

CHAPTER 5

There are several companies within the United States that are developing and/or marketing expendable launch vehicles in hopes of successfully entering the space transportation industry. They are Space Services Incorporated of Houston, Texas, Transpace Carriers Incorporated of Greenbelt, Maryland Pacific American Launch Systems Services of Redwood City, California and the American Rocket Company (Amroc) of Washington, D.C. Recently Starstruck Corporation of Redwood City, a very dynamic firm, which had tested a fully developed experimental launch vehicle went out of business.

Space Services Incorporated (SSI) headed by former Mercury astronaut Deke Slayton launched its own 36 foot rocket called Conestoga-1 on a 320 mile suborbital flight in September 1982. The Family of Conestoga rockets the firm plans to use are all built from proven off the shelf components and rocket stages. The vehicle is marketed among foreign countries and the Department of Defense. With the attrition of launch vehicles the capability to economically orbit smaller satellites no longer exists. The company was formed with the initial intent of selling low cost market oriented space services that can launch a payload on a few weeks notice. The chairman of the board, David Hannah, commented:

> We've got ourselves in a position where we are pretty well stabilized for as long as it takes for the market to come. We are here to stay. We have our key elements positioned so if the market comes quickly we can respond quickly. If we have to wait for a couple of years we can still stay in

> position. We have a key staff of about eight people. There are 20 of us working in concert, but a lot of those have other sources of income. They are standing ready to work with us in a concerted effort when we get our first payload (Marsh, 1984).

Conestoga got its first payload in January 1985. The Celestis Group, a Melbourne, Florida, consortium of morticians contracted with Space Services to launch a payload consisting of the cremated remains of several thousand people into a 1900 mile high orbit. In February 1985 the Transportation Department approved the request for permission to launch from NASA's Wallops Island facility ("Expendable Launchers", Commercial Space, 1985). Since then the initial momentum has slowed because Celestis has been less than successful in marketing this unique service.

The initial vehicle launched from a cattle ranch on Matagorde Island off the Texas coast (Conestoga 1) consisted of the second stage of a Minuteman missile bought from NASA. This test proved the technical feasibility of launching a rocket. The Conestage 2 will be the first operational vehicle. It consists of three Morton Thiokol built Caster 4H motors for the first stage, one Castor 4H for the second stage, a Star 48 motor for the third stage and a Star 30 motor for the fourth stage (Marsh, 1984). This vehicle can put a 950 pound payload into low earth orbit. The Conestoga 3 is produced by adding a third Castor 4H motor to the first stage and adding a fifth will produce a Conestoga 4. The maximum payload attainable with the Conestaga 4 is 2000 pounds (Marsh, 1984). SSI intends to service the payload weight gap left between the Scout and Delta vehicles.

Space Services has contracted Morton Thiokol to provide the

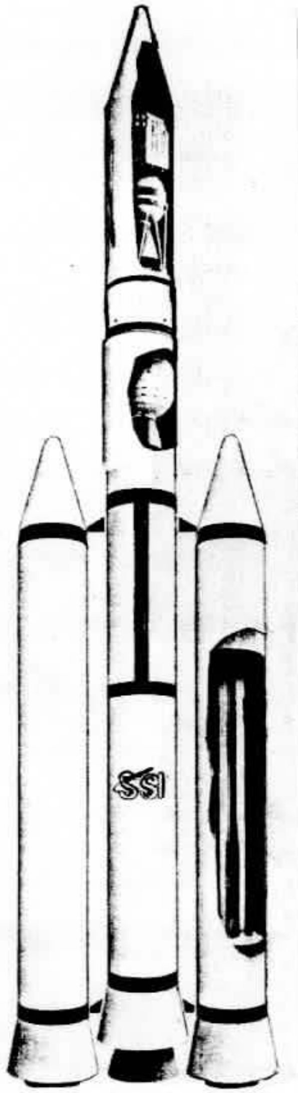


Figure 7. Space Services Inc. Connestoga 2 is made up of two Castor 4H solid rocket motors for the first stage, shown strapped on either side of the rocket. The second stage, center, is a single Castor 4H that fires after the two strap-on motors have dropped away. The Connestga 3 and 4 are made by adding one or two more strap-on motors respectively.

rocket motor components for the Connestoga vehicles (delivery time 18 months). Eagle Engineering in Houston, Texas has been contracted for the technical design and construction of the launch vehicle and engineering oversight. Space Data Corporation in Tempe Arizona has been contracted for integration, operation of the launch sites and conduct of launch operations (D. Slayton, personal communication, 15 March 1986). The normal lead time for a customer launch is 20 months. Space Services can launch its vehicle from a national range (Wallops Island, Virginia) or a customer site.

The standard orbit for the Conestoga is a low earth orbit of approximately 500 nautical miles (925 kilometers or 555 statue miles). (M. Daniels, personal communication, 5 May 1986). Ideal payloads for this vehicle are small remote sensing satellites and material processing satellites which could be recovered by the Shuttle. Space Services can launch a customer payload between 950 and 1900 pounds (430 and 860 kilograms). SSI's price to launch a payload are dependent on its weight and range from $12.5 million to $16.0 million. SSI requires that funds be paid on a progress schedule basis with the entire price fully paid by launch. The Castor 4H, the basic building block of the vehicle, is a highly reliable motor with one failure in 882 firings (M. Daniels personal communication, 5 May 1986).

Starstruck, another small firm in the space transportation industry, intended to build an inexpensive booster for customers who wanted to launch communications satellites but could not afford the European Ariane or the US space shuttle. They raised

$10 million and were only able to develop a single experimental vehicle. Starstruck's first President, Michael Scott (former President of Apple Computers), provided $7 million. The firm operated out of a 24,000 foot facility with fifty full time employees. Ground testing of the experimental rockets was conducted at a test site near Carson City, Nevada. The experimental rocket named the Dolphin (20,000 pounds and 50 feet long) was unique in two ways. First it used a revolutionary technique called hybird propulsion whereby liquid oxygen was sprayed on solid rubber fuel to ignite it. ("Company Plans Orbital Booster System Launch", Aviation Week and Space Technology, 1985). The primary attraction of this propulsion system was exceptional safety, which was important to a company with limited facilities. Secondly, the rocket was water launched (100 miles off the California coast) which eliminated in theory the need for expensive launch pad facilities and provided needed privacy from the public (O'Lone, 1984). After several false starts the Dolphin was launched in August 1984 and failed in-flight due to a stuck steering valve (O'Lone 1985). A short time later, the company declared the program a success, laid off nearly the entire staff, replaced the president, and began to reorganize. Putting the "dumb Dolphin" behind them and wisened by the experience, the company again put together a team , arranged "bridge financing" (intended to carry the firm for up to a year), and optimized the design of the Constellation, the firm's proposed communications satellite launcher

(O'Lone, 1985). The Constellation was to become an operational vehicle capable of placing a 1300-1500 pound payload into a geosynchronous orbit. It was to have been a 60 to 90 foot, two stage hybrid vehicle. Water launch was abandoned since it entailed long trips over land and sea and because at sea even simple support was lacking. Several times after a 30 hour ocean trip a minor problem such as a short circuit resulted in a launch cancellation and a 30 hour trip back to land. A short delay would have been the only problem encountered if the vehicle had been launched on land with the requisite support.

Douglas Ordahl, head of the propulsion system, felt that after the Dolphin launch an additional $5-10 million was required to complete the proof of concept (O'Lone 1985). Although a good initial response was received from Boeing, Raytheon and Hughes to sponsor and help finance Starstruck's continuing development efforts, funds were never forthcoming. (Ordahl, personal communication, May 14, 1986). Those companies very likely felt that while Starstruck had launched an experimental rocket too much development work remained to invest a substantial amount of capital. Barney Adelman former president of United Technology, a manufacturer of solid rocket motors similar to those used on the Shuttle, said that Starstruck needed between $100-200 million to "pay it's own way" ("Expendable Launcher", Commercial Space, 1985). Eventually, Starstruck, without the necessary funding had to close its doors. Several of the engineers and managers went to a new launch firm, the American Rocket Company of Palo Alto, California headed by former Starstruck employee, James Bennett. They hope to try and develop a viable launch vehicle. Bennett, reviewing his previous experience said "What has not happened yet is a team with the combination of expertise, experience and engineering talent with a commercial orientation and entreprenurial approach, that can go out and completely put it together"(O'Lone, 1985).

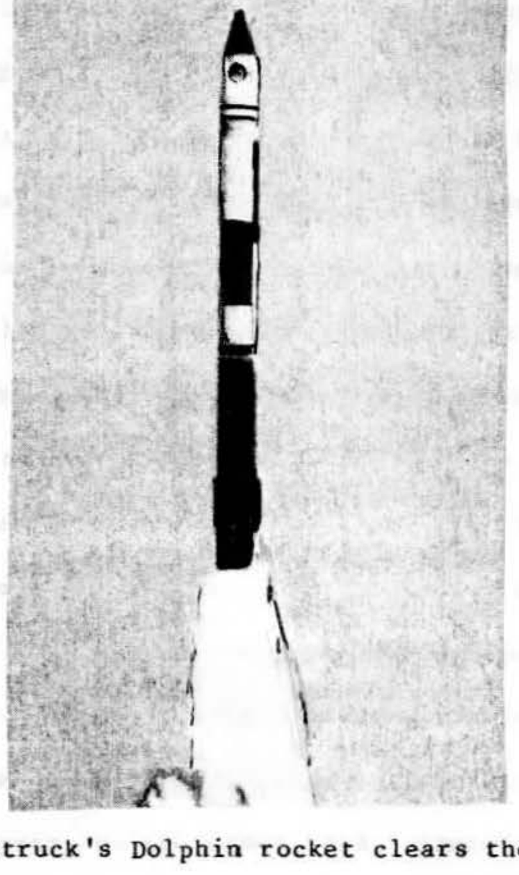


Figure 8. Starstruck's Dolphin rocket clears the surface of the Pacific on August 3, 1984. A stuck valve terminated the flight early.

Note. From "Starstruck Launches Prototype Dolphin Rocket", Aviation Week and Space Technology, August 13, 1984.

Transpace Carriers Inc. seemed to have as good a chance as any in the launch vehicle industry for a number of reasons. The government initially encouraged and supported its efforts to commercialize the Delta. Some of NASA's most experienced management and engineers founded the firm. Additionally, TCI instead of developing a new launch vehicle used a proven and reliable workhorse with 97% success rate over twenty years, McDonnell Douglas's Delta rocket.

During the 1970's with the reduction in expendable vehicle orders, personnel associated with expendable vehicles operations began leaving NASA and the manufacturers. David W. Grimes, the NASA Delta program manager, felt that after the Shuttle began operation there would still be a need for expendable vehicles. To him the key to continuing expendable launch vehicle operations was to commercialize them when NASA withdrew its support after the Shuttle became operational. The Reagan Administration early-on wanted to turn expendable vehicles over to private firms. In September 1983, NASA issued requests for proposals to industry for commercialization of the Delta and on January 5, 1984 it selected Transpace for the task. Transpace's operations significantly differed from Space Services and Starstruck's. Both of those companies decided to develop and construct new vehicles. Transpace, on the other hand, planned to market and launch an operational vehicle.

TCI is a venture capitalized booster company with 50 stockholders, a $15 million line of credit from the Bank of America and $8 million in venture capital from CIGNA, the merged INA and Connecticut Organizations ("TCI Embarks as Venture Capitalized Booster Company", Commercial Space 1984). TCI in order to minimize expenses will remain dormant until it receives its first contract to launch a satellite. Then it will employ a little over 100 people; 78 at its main Headquarters in Greenbelt, Maryland, 26 at Kennedy Spacecraft Center to conduct launch operations, 10 at Vandenburg Air Force Base to conduct West Coast launch operations, and 4 to conduct marketing efforts. At full operation TCI would pay NASA or the Air Force a user fee for access to their pads and support facilities. These facilities would include dual launch pads, common blockhouse, dual bay booster service buildings, spin test facility, and mission control room at the Kennedy Launch Range and a single launch pad with blockhouse, mission director center and gantry with white room at Vandenberg Air Force Base ("Transpace Embarks as Venture Capitalized Booster Company," Commercial Space, 1984).

TCI's dream of commercializing the Delta has eluded the corporation. With no additional orders for Deltas from either NASA or TCI, McDonnell Douglas closed its production line in 1982. TCI got its baptism in contract chasing when it went against the Shuttle and Ariane for Satellite Business System's SBS-5 satellite in 1984 and lost even though it lowered its price to equal NASA's offer. TCI's normal launch price in 1984 of $45 million could not compete with Arianespace's price of $21 million and NASA's price of $25 million ("Competition", Fortune 1985).

TCI in an attempt to combat what it considered unfair trade practices by Arianespace filed a complaint with the US Trade Office under Section 301 of the US Trade Act of 1974 stating that Arianespace charged prices to US firms that were 25 to 33% lower than those charged countries of the European Space Agency and as a result TCI had lost sales to Arianespace (OTA, 1985). A final decision has not been made but Arianespace continues to market its service in this country. TCI has yet to sign up a customer.

The Challenger accident, Shuttle grounding and growing satellite backlog should have brought customers to TCI. For a period of two years TCI has been unable to reach a final agreement with NASA on the commercialization of the Delta and has been working on the basis of 60 day extensions. NASA has taken an inflexible stance and has put the firm in a Catch 22 situation. A NASA official stated "The agreement they have now was based on conditions they haven't met .... demonstrated technical ability; signing up customers and so forth." (Mordoff, 1986). NASA has also taken the few remaining spare Deltas to launch geosynchrounous weather satellites and SDI payloads. Originally the Deltas were to have been turned over to TCI. David Grimes in testimony to Congress, indicated that such actions would have a "very severe reprecussions in the marketplace for TCI" (Mordoff, 1986). NASA since the Challenger accident, has launched a Delta which failed in flight rather than allow TCI handle the operation. "David Grimes in his testimony to Congress said that if the government operates Delta launchers concurrently with TCI or during a transition period to commercial operations, TCI's opportunity to commercialize the Delta will be 'effectively ended'" (Mordoff, 1986).

Pacific American Launch Systems Incorporated (PALS) is a firm with a futuristic flair. It hopes to be the first to promise regular passenger flights to low Earth orbit by 1992 according to PALS President Gary Hudson. The Phoenix E will require three and a half years of development work, followed by one and a half years of testing before operational flights are possible. It will offer twenty passengers an 8 to 12 hour space flight. The project is a joint venture between Pacific American and Society Expectations Incorporated of Seattle, Washington which is marketing these as tourist flights. A passenger would be required to place a $5000 deposit to confirm space on a specific flight. The total cost of the flight $50,000 would be paid prior to launch.

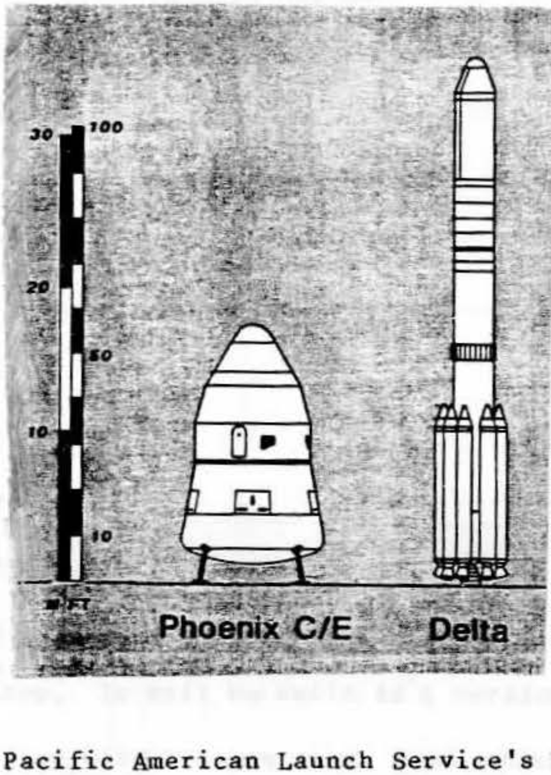


Figure 9. Pacific American Launch Service's Phoenix is a single stage reuseable vehicle scheduled to be operational in the 1990s. Transpace Carriers Inc. would like to commercialize the Delta.

Gary Hudson, the founder of Pacific American, earlier had developed a vehicle called the Percheron, which Space Services was interested in prior to the rocket's launch failure in 1981. Problems encountered in the Percheron's development included bad project management and a lack of capital ("O'Lone, 1985). Hudson learned from the experience and in developing the Phoenix has hired very well seasoned program managers, contracted most of the component manufacuring, and has made Pacific American responsible only for airframe work and final assembly. Subcontracting was not considered extremely expensive as long as major companies were not involved (O'Lone, 1985). The Phoenix will be a reuseable vehicle which will take off and land vertically. Usually several test flights are required to validate a vehicle's design. Though a more complicated vehicle, a reuseable launcher has the advantage especially during test flights, of being able to be reflown, the alternative being the loss of a vehicle every time one is launched. The Phoenix is a squat single stage rocket with 48 small combustion chambers lining the periphery of the vehicle bottom. It will be built in 4 versions: a cargo carrier, a cargo carrier with 2-4 man crew, a passenger carrier and a fuel tanker, all of which are supposed to be operational in the early 1990s (Hoeser, 1986). Development costs are planned in the neighborhood of $20 million.

The American Rocket Company (AMROC) is a very new firm that started operations after Starstruck Inc failed. Many of AMROC's employees came from Starstruck. The Industrial Launch Vehicle (ILV) is AMROC's launcher. Its first operational flights are planned for 1988. The ILV like Starstruck's Dolphin, uses hybrid rocket technology to power it. Nineteen nearly identical hybrid rocket engines would boost 3,000 pounds into polar orbit or 4,000 lb into equatoral orbit. AMROC has been trying to raise investment funds of about $40 million through a private offering

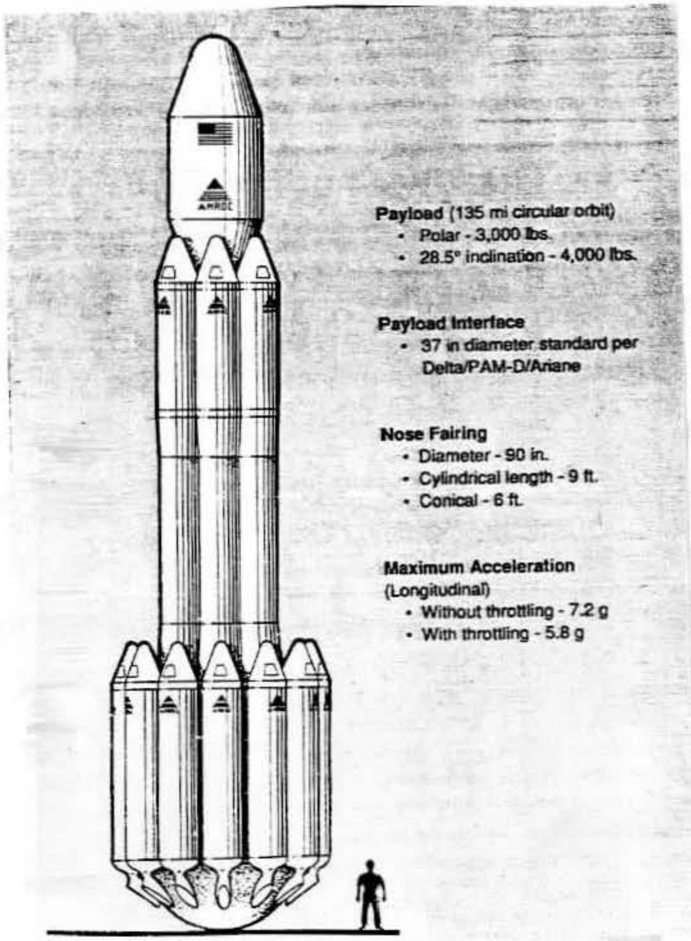


Figure 10. AMROC's launcher, or the Industrial Launch Vehicle is expected to start operational launches in 1988.

Note. From American Rocket Company.

for its commercial launch program. George Koopman, AMROC President, said the firm will charge $5-8 million per mission ("ELV Company Schedules Tests of Industrial Launcher for 1988", *Aviation Week and Space Technology*, 1986).

The small launch firms with the most promise are Space

Services Incorporated, Transpace Carrier Incorporated, Pacific American Launch Systems and the American Rocket Company. Other firms with similar plans remain dormant until the right conditions arise. Third Millenium is a Washington D.C. firm trying to develop an unusual launch system; a winged orbiter which will be launched from the top of an airborne Boeing 747 (Hoeser, 86). A one man company in California is developing a single person launch vehicle for sub-orbital flight. More exist, but for the most part they will remain obscure until the technical problems are overcome and the right market conditions exist.

OTHER COMPETITIVE SYSTEMS

CHAPTER 6

A payload system which has flown on several shuttles and will continue to do so when Shuttle flights resume is NASA's Getaway Services. On the majority of flights because of the configuration of the Shuttle's large payloads, small areas of the cargo bay would normally remain unused. NASA has used these areas to carry small payloads called Getaway Special Canisters or GAS Canisters. These small canisters which vary in size from 2.5 to 5 cubic feet are available for use by commercial business, educational institutions and individuals. Currently over five hundred reservations have been made for these containers on the Shuttles. Though NASA offers this service for $3000-$10,000 (Cassanto, 1985), this price is deceptive. Unless the business, school or individual is exceptionally familiar with the hardware involved and its integration with the Shuttle, a company such as Instrumentation Technology Associates (ITA) must be contacted to assist in this area. ITA will help in the design of the payload, offer the necessary equipment and integrate the payload with the Shuttle. The price for this service costs between $50,000 to $300,000 (Cassanto, 1985) dependent for the most part on the operational complexity of the payload. Fifty-eight GAS canisters have been flown on Shuttles over a four year period.

GAS CANISTER DATA

VOLUME		WEIGHT		
CUBIC-METERS	/ FEET	KILOGRAMS	POUNDS	PRICE ($)
.07	2.5	27.2	60	$ 3000
.07	2.5	45.4	100	$ 5000
.14	5	90.7	200	$10000

Table 5. Getaway Special Canister (GAS) data.

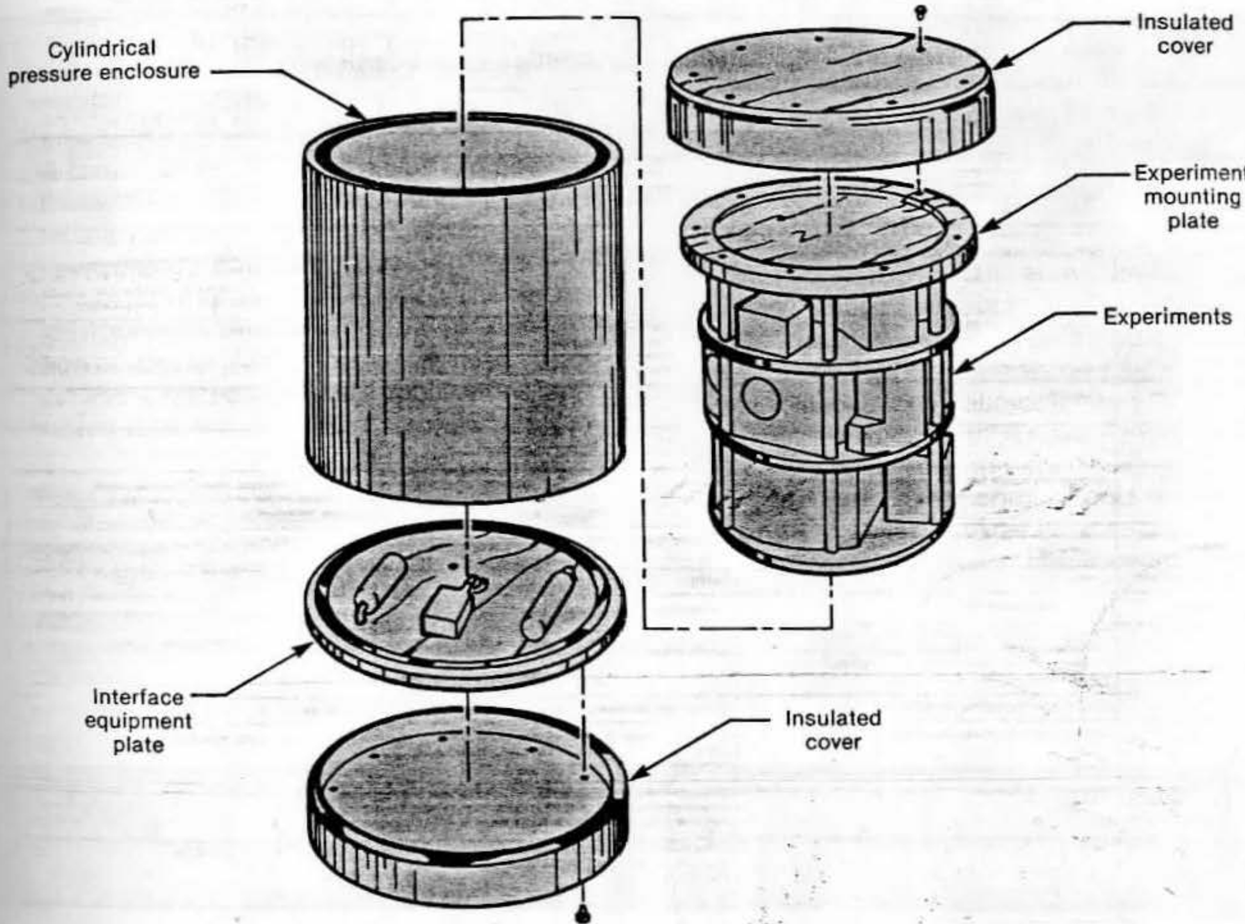


Figure 11. NASA's Getaway Special Canister is carried aboard the Shuttle. Companies, schools and individuals have used these small containers for special projects and experiments.

Though the GAS canisters limit the amount of space and the weight carried, their employment provide the users with several advantages: they permit access to space to those who would not normally have it, they are very economical (as low as $300/lb), small satellites can be ejected from them, the payload returns from space with the Shuttle and they allow a company to do the initial experimentation and research on a proof of concept basis without investing or committing itself heavily on a project. Numerous schools such as the University of Utah have taken advantage of NASA's Getaway Special program. West German firms have reserved 75 Getaway canisters. A follow-on to Getaway services is NASA's Hitchhiker program which will further maximize Shuttle cargo bay, reduce flight lead times to six months and increase the payload weight to 1000 pounds.

A factor which will have an influence on the space transportation industry is the possible entry of Japan and China into this market. The Japanese have developed several boosters using US technology. Restrictions associated with this transfer of technology has limited the use of their vehicles to only Japanese or US customers. Not surprisingly, the Japanese are developing two rockets from strictly Japanese resources; the H-1 and H-2. The operational H-1 can place 2,200 kilograms (4850 pounds) into low earth orbit or 550 kilograms (1210 pounds) into geosynchronous orbit. The H-2 which will begin flights later this decade, will orbit heavier payloads than the Titan 34D (7500 kilogram in low earth orbit and 2000 Kilogram in geosynchronous orbit). (OTA, 1985). The Japanese have not actively communicated a desire to enter the space transportation market but the presence of the H-1 and H-2 indicates that they are very likely will.

The Chinese are also noncommittal on the issue of whether they will commercialize their launch vehicle activities. A US Communications firm Teresat purchased the Shuttle recovered Palapa and Westar communications satellites from the insurance company they were turned over to. The Chinese have formally offered to launch these satellites for Teresat on their Long March 4 booster. ("PRC Evaluating Possible Participation in Space Station", Commercial Space 1986). If the Chinese enter commercial service, they could maintain a launch rate of six to seven flights a year at a price of $18 million dollars. To put satellites into geosynchronous orbit, an additional seven to ten million dollars would be required for an upper stage. ("PRC Evaluating Possible Participation in Space Station", 1986).

Even though Japanese and Chinese vehicles seem to offer an inexpensive alternative to Western launchers problems still exist. The stringent standards under which satellites are launched by Western countries are not always attainable by other nations. China, for example does not mate satellites to their boosters under clean room conditions and GTE stated they would not launch their satellites on Chinese or Japanese launch vehicles "because of vibration and stress qualification requirements" the Chinese and Japanese have not been able to meet (Lowndes, 1986).

THE PROBLEM AND ITS SETTING

THE STATEMENT OF THE PROBLEM

The purpose of this study is to determine through a market analysis incorporating trend analysis, forecast and opportunity analysis, whether a entity defined as a typical small launch firm similar primarily to Starstruck Incorporated or Space Services Incorporated or the American Rocket Company can establish itself and grow in the satellite launch market.

The Subproblems

The first subproblem is to determine through a trend analysis whether a trend exists which shows continued or sustained growth in the weight and category of satellites that will support a small launch firm.

The second subproblem is to compile and analyze a forecast of satellites.

The third subproblem is to evaluate critical issues which will affect the space transportation industry particularily small launch firms.

The Hypothesis

The first hypothesis is that a trend analysis will indicate that sufficient satellites of the appropriate weight and category will require launch services to support a small launch firm.

The second hypothesis is that a small launch firm will have enough satellite customers in the future to survive even when other launch agencies have entered the market.

The third hypothesis is that the critical issues when collectively analyzed will not significantly hinder the existence and growth of small launch firms.

The Decliminations

The study will not attempt to predict which launch firms will have the best chance for success.

Definitions:

Geosynchronous Orbit - See Appendix E

Expendable Launch Vehicle (ELV) - Conventional rocket made up of discardable stages, normally used to orbit most payloads. All nations with the exception of the US use only ELVs in their space transportation programs.

Small Launch Firm - ELV firms which have as their service or product a rocket capable of placing 2000 pounds into low earth orbit (2000 miles or lower).

Assumptions:

The first assumption is that the Department of Defense will not use a small launch firm to launch any of their payloads.

The second assumption is the Department of Defense will not bump commercial payloads off expendable launch vehicles.

The third assumption is that the only physical characteristic of a satellite to be considered is the weight of the satellite. The dimensions of the satellite will not be considered and a few satellites within the weight constraints of a launcher may be physically too large to launch on a particuliar launcher without major modification.

The fourth assumption is that spacecraft going beyond geosynchronous orbit (e.g. to the moon or planets) are beyond the capabilities of a small launcher and are therefore not considered in this study.

The fifth assumption is that all satellites can be practically reconfigured to interface with any launcher.

The sixth assumption is that the Chinese and Japanese will not actively compete against US ELV firms or the Ariane.

METHODS

THE RESEARCH METHODOLOGY

Several studies have been conducted during the relatively short period of the space program to determine what the predicted number and types of satellites would be for certain years. Since small launch firms have had a short history no study has been specifically conducted in their behalf. This study will provide a three part market analysis of small launch firm demand consisting of a trend analysis, forecast and an analysis of critical issues influencing the space transportation industry.

A trend analysis will examine historical data on the categories, weight/mass and pertinent characteristics of satellites orbited between 1974 and 1986. The trend of the weight/mass of satellites (or the specific energy required to put them in a specific orbit) is a determining factor in the success or failure of a small launch firm. If the trend is toward smaller numbers of heavier satellites rather than greater numbers of lighter satellites then small launch firms stand to lose. In the trend and forecast analysis the elaborate equations associated with orbital flight have been set aside, to investigate the satellite population from a market standpoint. This will not have an adverse impact on the results of this study since the general trend is being examined rather than characteristics of specific satellites.

The forecast of satellite demand will examine the satellites that are planned for orbital deployment between 1987 through 1994 and the liklihood of that deployment with the projected launch assets during that time period.

Finally an opportunity analysis of the six most critical issues affecting the space transportation industry will be analyzed.

Specific Treatment of the Data for Each Subproblem.

Subproblem One. To determine through a trend analysis whether a trend exists showing continued growth in the weight and category of satellites that will support a small launch firm.

The Data Needed

The data needed for solving this subproblem are technical data specifying the physical characteristics of all satellites and their orbits between 1974 and 1985. This data can be gotten from NASA's history, trade publications and publications dealing with the space programs of other nations. Several reference books provide performance data on the launch vehicles used by different nations today.

The Treatment of Data

The primary factors that determine which spacecraft can be orbited by a particular launch vehicle is the weight/mass of the spacecraft and the category of spacecraft. A geosynchronous communications satellite is normally more difficult to orbit than a weather (remote sensing) satellite. Material processing payloads are not well suited for ELV launch.

Two trend analysis are done based on this 12 year time period. One will measure the frequency of launches according to satellite categories while the other will examine the mean weight of the spacecraft launched in a particular year. The results of these analysis will be projected against a hypothetical firm representative of such small launch firms Space Services Inc., the American Rocket Company and Starstruck Inc.

Subproblem two. To compile and analyze a forecast of satellites from 1987 through 1994.

The Data Needed

The appropriate data for the forecast comes from NASA publications, trade journals, launch manifests, and reference books.

The Treatment of Data

Data on future satellites will be compiled and analyzed to determine whether a market exists (satellites of the appropriate weight class without launchers) for small launch firms. A histogram of satellite weights/masses of forcast satellites will indicate the most profitable satellite categories and weight classes. This information will be compared to the similar information derived from the trend analysis in subproblem one. This will verify or disprove the validity of the initial trend analysis.

Subproblem three. To evaluate critical issues which will affect the space transportation industry to include small launch firms.

The Data Needed

The data needed for this subproblem is historical data available primarily in trade publications and reference books.

The Treatment of Data

Six external issues will have the most significant impact on the space industry and small launch firms. These issues are:

1. Will a Shuttle be built to replace the Challenger?
2. What will be the policy on the type of cargo carried on future Shuttle flights? (What types of commercial cargo will be allowed aboard the Shuttle and how much will the deployment of the Stretegic Defense Initivates (SDI) and the space station tax this limited resource?)
3. Will the US Governments do anything to foster expendable launch vehicle production? (e.g. Shuttle pricing, insurance aid, DOT support?)
4. What effect will the reentry of large corporations in space transportation industry have.
5. What will the effect be of increased foreign launcher competition.
6. Will advances in fiber optic technology decrease the demand for communications satellites.

Each of the issues will be addressed in an opportunity analysis. Wherever possible past experience will be used to determine the liklihood of a particular outcome. The probable outcome of each issue will have an effect on the trend and forcast anaylsis. Based on the most current information as of September, 1986 a conclusion on the most likely outcome of each issue will be made and their effect on the space transportation industry and small launch firms will be assessed.

TREND ANALYSIS

An unusual string of failures in early 1986 has left the space transportation industry devastated. The Shuttle is grounded as it its strongest competitor the French Ariane. The Ariane at the earliest will be operational in February 1987 and the Shuttle willnot fly till 1988. Opportunities exist for foreign companies and the original US manufacturers of ELVs. There is a question as to whether a market exists for the small launch firm.

A twelve year period from 1974 to 1985 is covered which examines the launch rates of various ELVs. Specific ELVs are designed to serve a particular satellite weight category as shown in Table 5.

VEHICLE	MAXIMUM PAYLOAD (kg)	
	LOW EARTH ORBIT[1] (lb)	GEOSYNCHRONOUS TRANSFER ORBIT (lbs)
SCOUT	50 - 255	NONE
ARIANE 2/3	1000 - 3870	1000 - 2050
DELTA	2000 - 3045	1000 - 2135
ATLAS CENTAUR	3000 - 6100	1000 - 2360
TITAN 34D	7000 - 14920	2000 - 4540
SPACE SHUTTLE	29700[2]	

Table 5. Each ELV services specific payload weights.
1.Low Earth Orbit is a 185 kilometer circular orbit.

2. Orbit - 280 x 420 km

NOTE: From Aeronatics and Space Report of the President: Activities 1984.

The yearly flight rate for the twelve year period is shown for each launcher in Figure 12. Data that formed the basis of this study is in Appendix D. When the yearly flight rate for an ELV over the period was two or less the launcher was not included individually. (Japanese launches and one Titan III ELV.). However, they were incorporated in Figure 12's total flight rate. Only those Shuttle flights which deployed separate satellites into orbit were considered. The government ELV/Shuttle policy is clearly displayed. As the Shuttle was phased into operation in the early 1980s, ELVs were phased out. The Shuttle was to have entered service in the late 1970s but the delay in operational missions till 1982 caused the dip in the launch rate around 1980. Production lines for ELVs were kept open longer due to the Shuttles delay and a resurgent use of ELVs occurred until production was again closed down in 1982 and their use tapered off. The Shuttle and the Ariane started to accelerate the deployment of satellites in 1984. The Shuttle was starting a gradual upward swing in its flight rate while the Ariane's slowed slightly in the wake of a launch failure in September 1985. Other than the Ariane, only one ELV was successfully launched in 1985; an Atlas Centaur.

A complete analysis cannot address launch vehicle use alone, since the vehicles are dissimilar in their performance and capabilities. Though the Delta and Ariane can orbit satellites of approximately the same mass, the Ariane has the advantage of

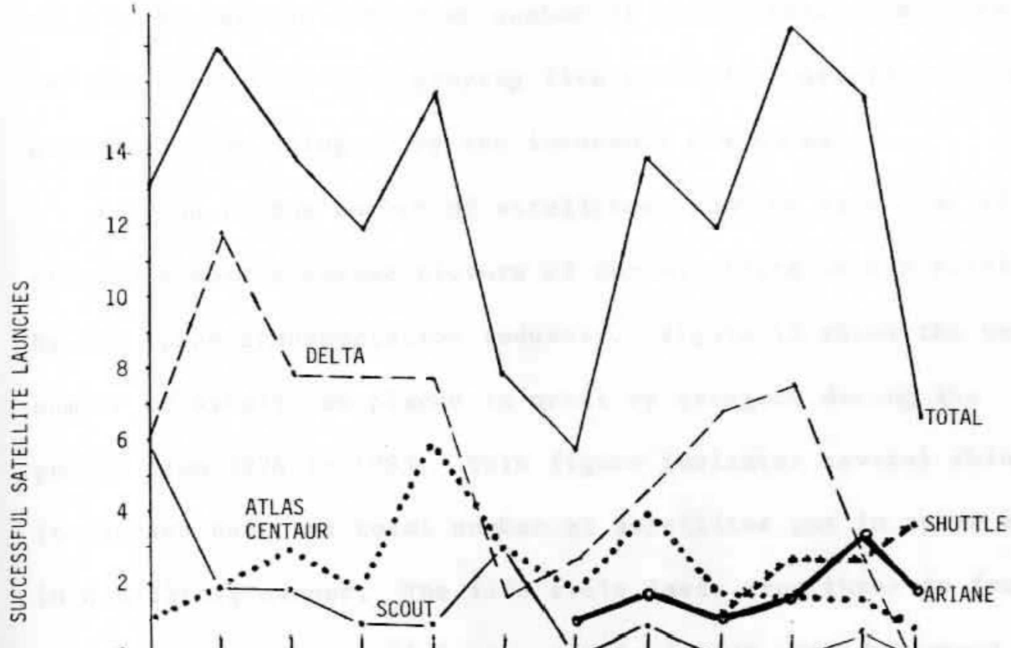


Figure 12. Successful Satellite Launches by Each Major ELV.

being able to orbit two smaller satellites, while the Delta can orbit only one. This gives the Ariane added flexibility in its ability to service a greater number of satellites. The Shuttle has the capability of deploying five individual satellites but is prevented from doing so by the insurance companies.

A graph of the number of satellites launched each year will provide a more accurate picture of the satellite market serviced by the space transportation industry. Figure 13 shows the yearly number of satellites placed in orbit by category during the period from 1974 to 1985. This figure indicates several things. It appears that the total number of satellites put in space vary in a cyclical manner. The life cycle lasts from three to four years and closely parellels the yearly launch rate discussed earlier. For any given year the largest number of satellites were launched in 1984 and the fewest in 1980. The fastest growing category are communications satellites. This is attributable to growth in the telecommunications and data processing industry, the founding of several companies which will compete with AT&T and the growth of the cable television industry which require Direct Broadcast Satellites. The remote sensing satellite market displayed no real growth during the period. A relatively constant number of weather and earth resources satellites is maintained in orbit. No additional remote sensing satellites are launched other than those to replace old or malfunctioning satellites. Any expansion in the remote sensing satellite market occurred on a gualitative rather than a

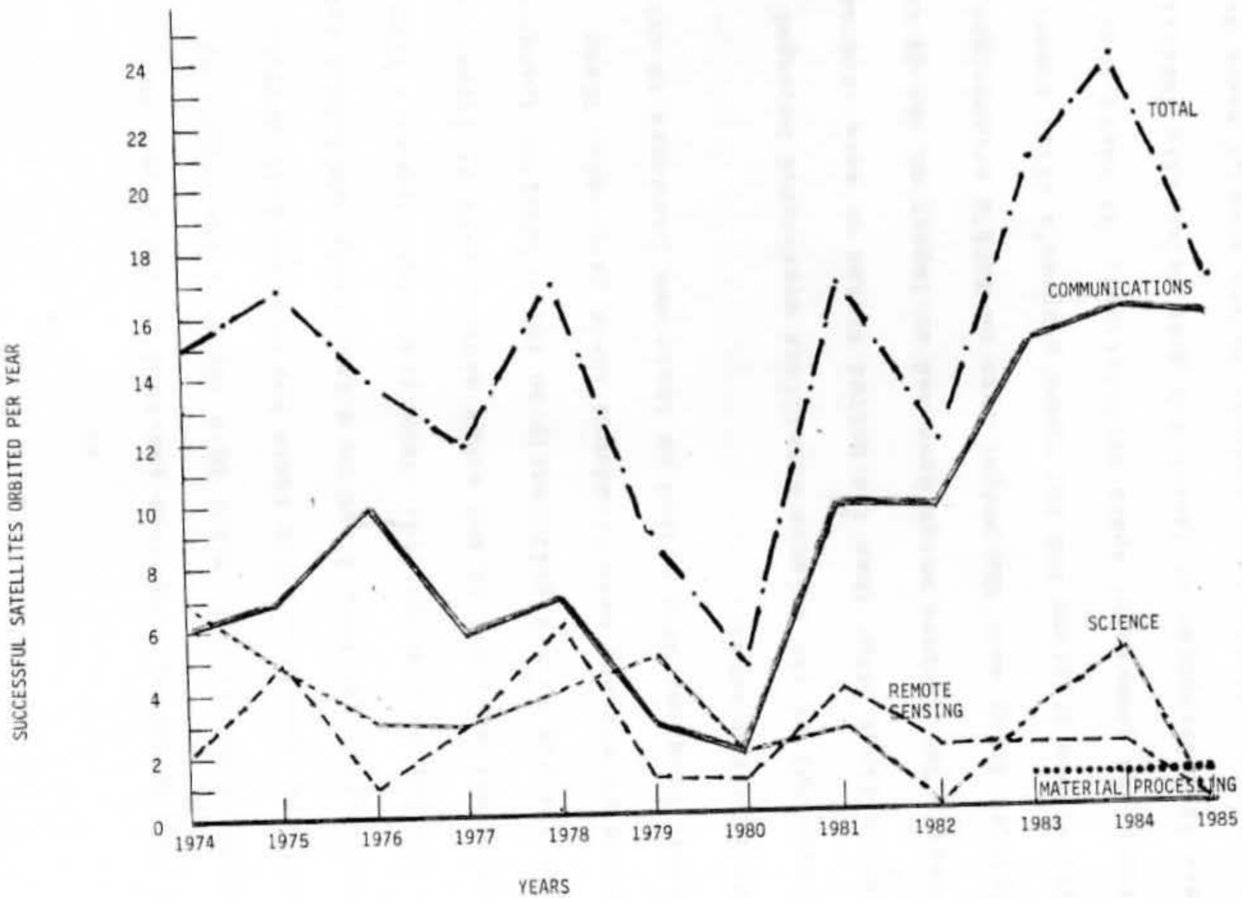


Figure 13. Satellites Successfully Deployed by Type (1974-1985).

quantitative basis. Improved instrumentation is put on replacement satellites rather than increase the number of satellites. Quantitatively there has been no real growth. Science satellites have flown on a relatively continuous basis over the twelve year period. They draw their sponsors from most European nations, the US and other nations such as Japan. While the US has cut back significantly on its scientific spacecraft these other nations have broadened their programs. These national programs have relied on their own launchers to orbit scientific spacecraft.

Over 50% of the science satellites considered belonged to either nations other than the United States or were international efforts. Two factors which have had an impact on the US science satellite trend were the budget cuts on NASA's science and applications programs and the space program's shift toward defense and commercial space applications. It takes four to five years from inception to launch for most scientific satellites (OTA, 1985). NASA's lower budgets in the area of space science and applications from 1977 to 1979 had its effects in 1982 since new science satellite programs had not been started and those already in progress were delayed (OTA, 1985). While several programs exist no scientific satellites were launched by the US during 1985.

Material processing is ideally suited for flights on manned spacecraft such as the Shuttle. The representation of this payload category in Figures 13 does not accurately reflect the fact that the Shuttle has on several flights been a platform for material processing experiments. Figure 13 reflects only those material processing payloads that were deployed in orbit by the Shuttle and later retrieved. A similar concept could incorporate ELVs. A material processing payload similar to those deployed by the Shuttle could be placed in orbit by an ELV and after a period to allow for processing of the material could be retrieved by a Shuttle. Shuttle material processing payloads that are carried and incorporated into the Shuttle do not lend themselves to ELV flights because they require man's intervention, a great deal of electrical power and other external support unavailable on an ELV. ELVs have never been used to launch a material processing payload. Since 1983 one material processing payload has been deployed from the Shuttle each year and two of the three have been recovered by the Shuttle. Material processing payloads will again be deployed and retrieved when the Shuttle flys again.

The total number of satellites orbited exhibits what appears to be a somewhat cyclical nature, especially when considered in the context of a longer period of time. A three year period exists between peaks or troughs and when a three term moving average is computed (smoothing effect) a graph emerges (Figure 14) which indicates a longer overall cycle. Accordingly, the peak satellite activity should occur in 1987, 1990 and 1993. Lower activity should occur in 1988 and 1991.

The mass of satellite is directly related to the amount of energy a rocket must expend to place that satellite into orbit.

The general tendency has been to increase the mass of the satellites as the performance of launchers improved.

Communications satellites have followed this trend. Initially expensive earth stations with large receiving antenna were used to pick up the weak signals of small communications satellites. Today inexpensive earth stations offer an alternative. The communications satellites have increased in size, with more power transmission and larger antenna. A slight reversal occurred since the introduction of Direct Broadcast Satellites, (DBS) which use a frequency band (C-Band) that allow for the smaller earth stations.

Overall, the trend indicates that the weight or mass of satellites will continue to increase as the capability of launch vehicles to lift heavy payloads improves. Both the French Ariane and the Japanese H series are vehicles that will continue to evolve and rival the US launchers.

An ELVs performance dictates what types of orbit it can provide service to. The low earth orbit (LEO) is relatively easy to achieve compared to a geosyhchronous orbit which requires significantly more energy. The ability of a vehicle to place a satellite into geosynchronous orbit may be essential to the success of a small firm. An increasing number of satellites are placed in geosynchronous orbit (Figure 16). Communications satellites, largest segment of the satellite market, are primarily geosynchronous satellites. The experimental satellites, navigation satellites or amateur radio satellites are

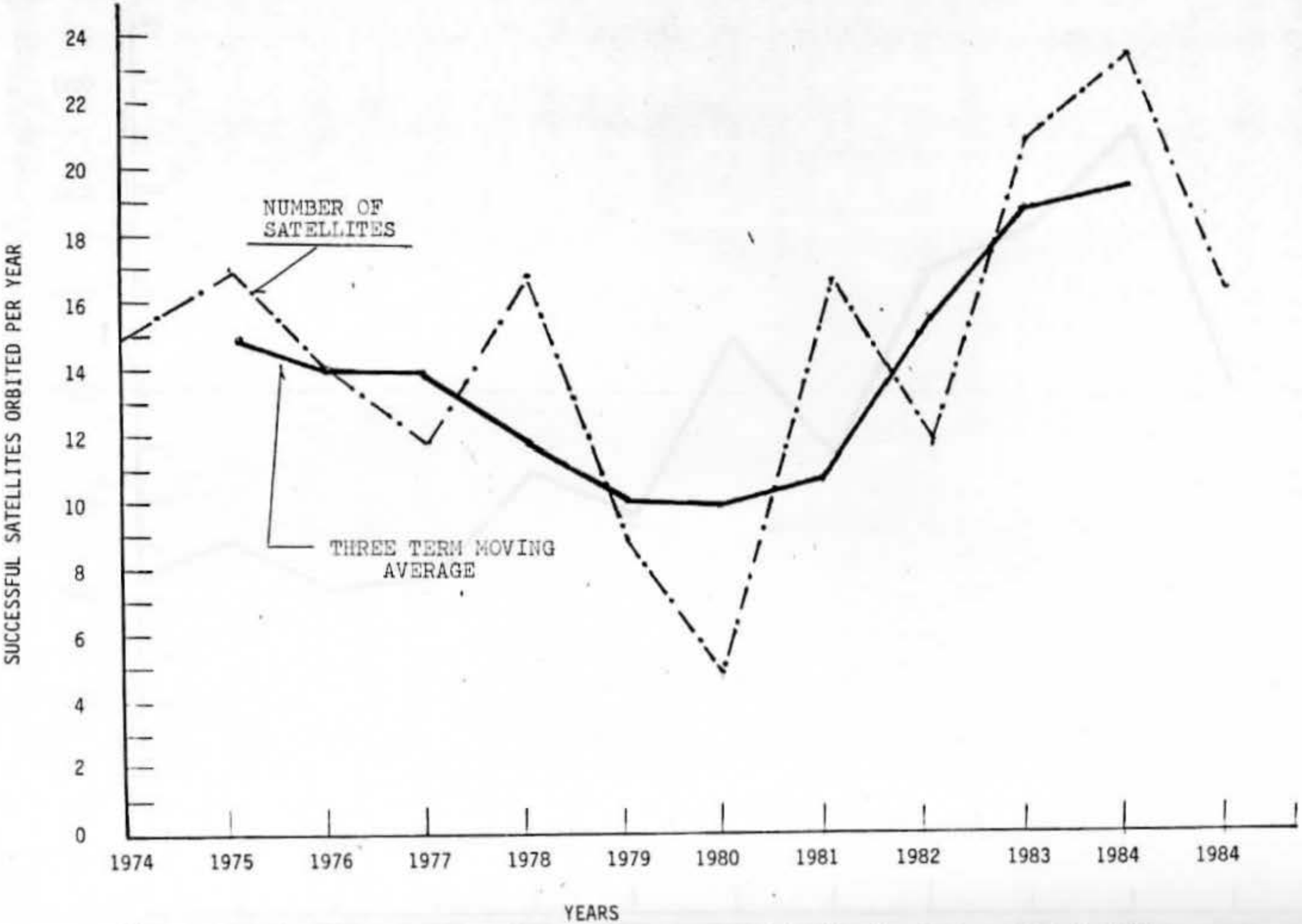


Figure 14. The Three Term Moving Average Compared to Yearly Number of Satellites

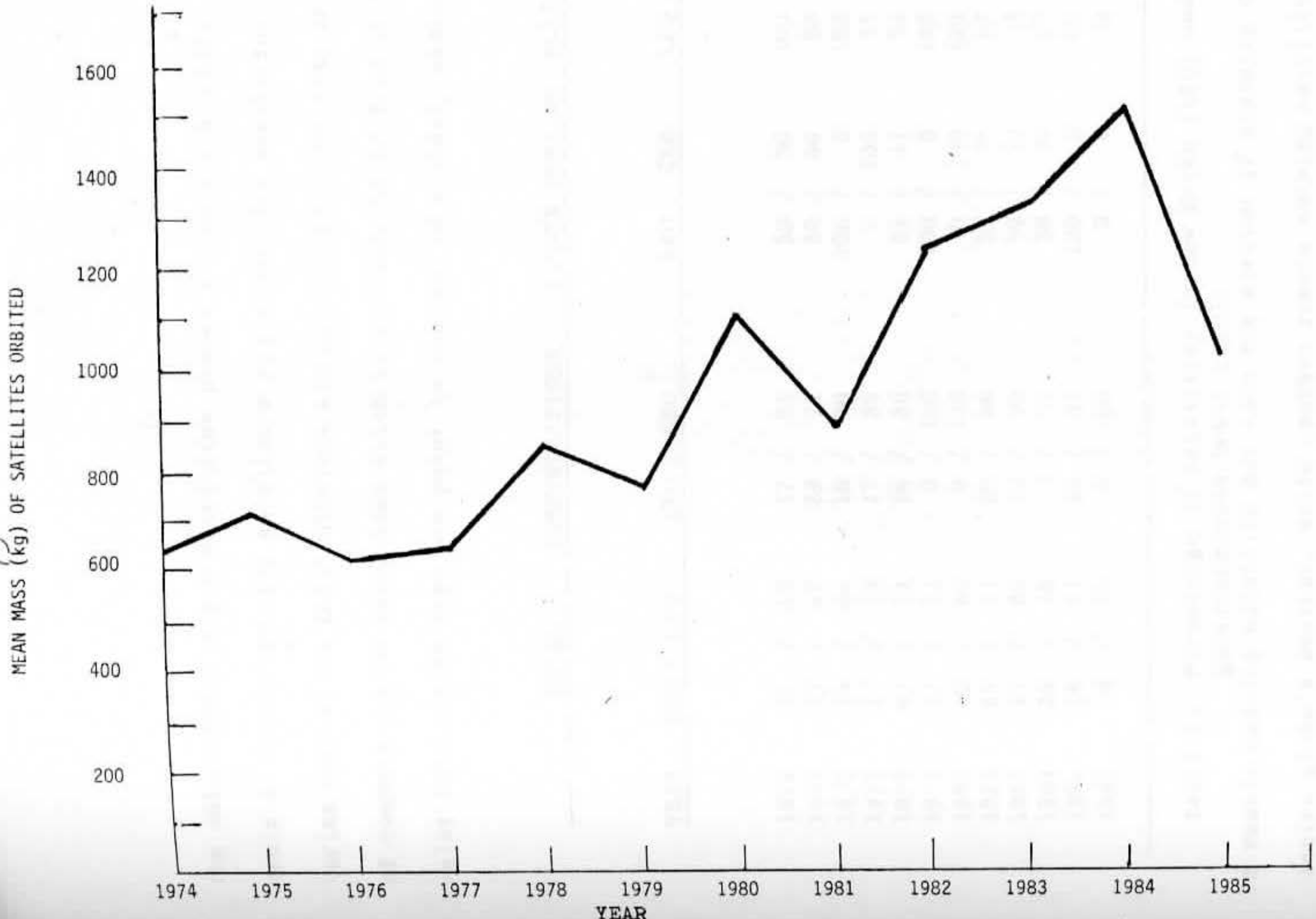


Figure 15. The Weight/Mass of Satellites Increased

the only communication satellites placed in low earth orbit. The orbit of remote sensing satellites and scientific satellites varies more since their missions are more diversified than those of communications satellites which in its most basic form is to relay information from one point to another in a timely manner.

	TOTAL	COMMUNICATIONS	REMOTE SENSING	SCIENCE
YEAR	LEO / GEO	LEO / GEO	LEO / GEO	LEO / GEO
1974	60 / 40	17 / 83	50 / 50	100 / 0
1975	53 / 47	29 / 71	60 / 40	80 / 10
1976	36 / 64	10 / 90	100 / 0	100 / 0
1977	17 / 83	17 / 83	0 / 100	33 / 97
1978	47 / 53	14 / 86	83 / 17	50 / 50
1979	67 / 33	0 / 100	100 / 0	100 / 0
1980	40 / 60	0 / 100	0 / 100	100 / 0
1981	29 / 71	20 / 80	25 / 75	67 / 33
1982	17 / 83	10 / 90	50 / 50	0 / 0
1983	24 / 76	7 / 93	50 / 50	67 / 33
1984	29 / 71	13 / 87	100 / 0	40 / 60
1985	6 / 94	0 / 100	0 / 0	0 / 0

Table 6. Percentage of Satellites in Low Earth (LEO) and geosynchronous Orbit (GEO):

A remote sensing satellite may have the mission of scanning the entire globe's weather, while another remote sensing satellite may be required to monitor the weather only over the United States, while yet another may have the mission of trying to detect acid rain damage in the forests of the United States, and Western Europe. The mission of scientific satellites will also dictate the type of orbit required. All material processing satellites to date have been placed in low earth orbit for easy

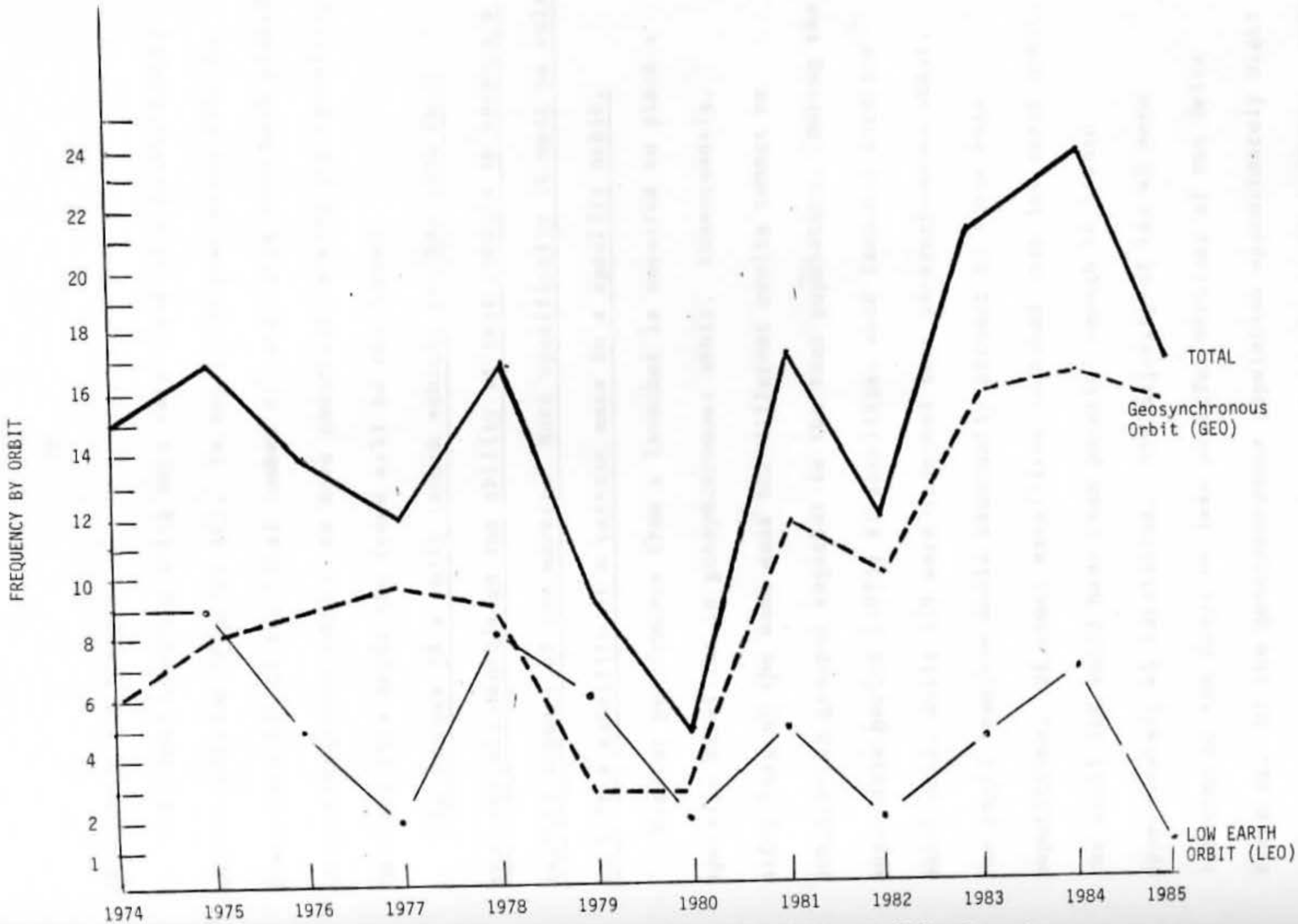


Figure 16. Low Earth Orbit and Geosynchronous Orbit Satellite Launches.

deployment and retrieval.

The trend toward placing more satellites into geostationary should continue (Figures 16). In any given year since 1980 no fewer than 60% of the total number of satellites have been placed in geostationary orbit. As more countries develop the capability to reach this orbit the trend will be reinforced.

The success of a small launch vehicle and the firm that produces it, depends on the ability of that vehicle to service a healthy segment of the market. More specifically it must be able to lift a satellite of a certain mass to a specific orbit.

Greater performance from a launcher is required to place a specific satellite in geosynchronous orbit. Consequently, satellites of the same mass but different orbits cannot be arbitrarily grouped together in the same population. During the applicable period (1975) 61 satellites were launched into low earth orbit while 119 were launched into geosynchronous orbit. The small launcher would eventually attempt to serve both populations. Of those satellites launched into low earth orbit, the small ELV would have been powerful enough to launch approximately 45 satellites. The majority of the 45 were launched by the Scout or less powerful versions of the Delta vehicles. Of the geosynchronous population approximately eight satellites could have been launched by the small launcher. Most of these satellites belong to Japan, which used US Deltas or their own ELVs based on US technology. The remainder were scientific satellites belonging to various nations. A small launcher had the capability of launching fourteen low earth and three geosynchronous orbit satellites during the most recent six year period (1980-1985). This group consisted of national and foreign remote sensing amateur radio and scientific satellites. A comparison of these two groups indicates an overall downward trend in the number of satellites in the lower weight classes.

Satellites, since their inception, have generally increased in weight over the years, so much in fact that they already outrun the capabilities of a small launch firm. The numbers of satellites launched in the weight classes serviced by a small launch firm are not enough to sustain one such firm much less the several firms in existence today. Even Space Services which vigorously marketed its services to foreign nations, universities and private companies was only partically successful and its primary customer was the Celestis Group. Its price was not to far below the shuttle price of $25 million.

To survive a small launch firm must rapidly expand out of the limited arena of small payloads to one where it can service a larger satellite population. A review of Figures 17 and 20 indicates that if a launcher could increase its capability by a factor of three (1200 to 3600 kg in low earth orbit) then the possibility of establishing a variable presence in the market exists. It could place a 780 kilogram satellite into geosynchronous orbit. From 1980 to 1986 twenty-one satellites were launched in this weight class and below. Seven were Japanese and were launched on their own vehicles. The remainder were Mexican, Australian, Indian, Arab, ESA, and US satellites launched on either the Delta, Ariane or Shuttle.

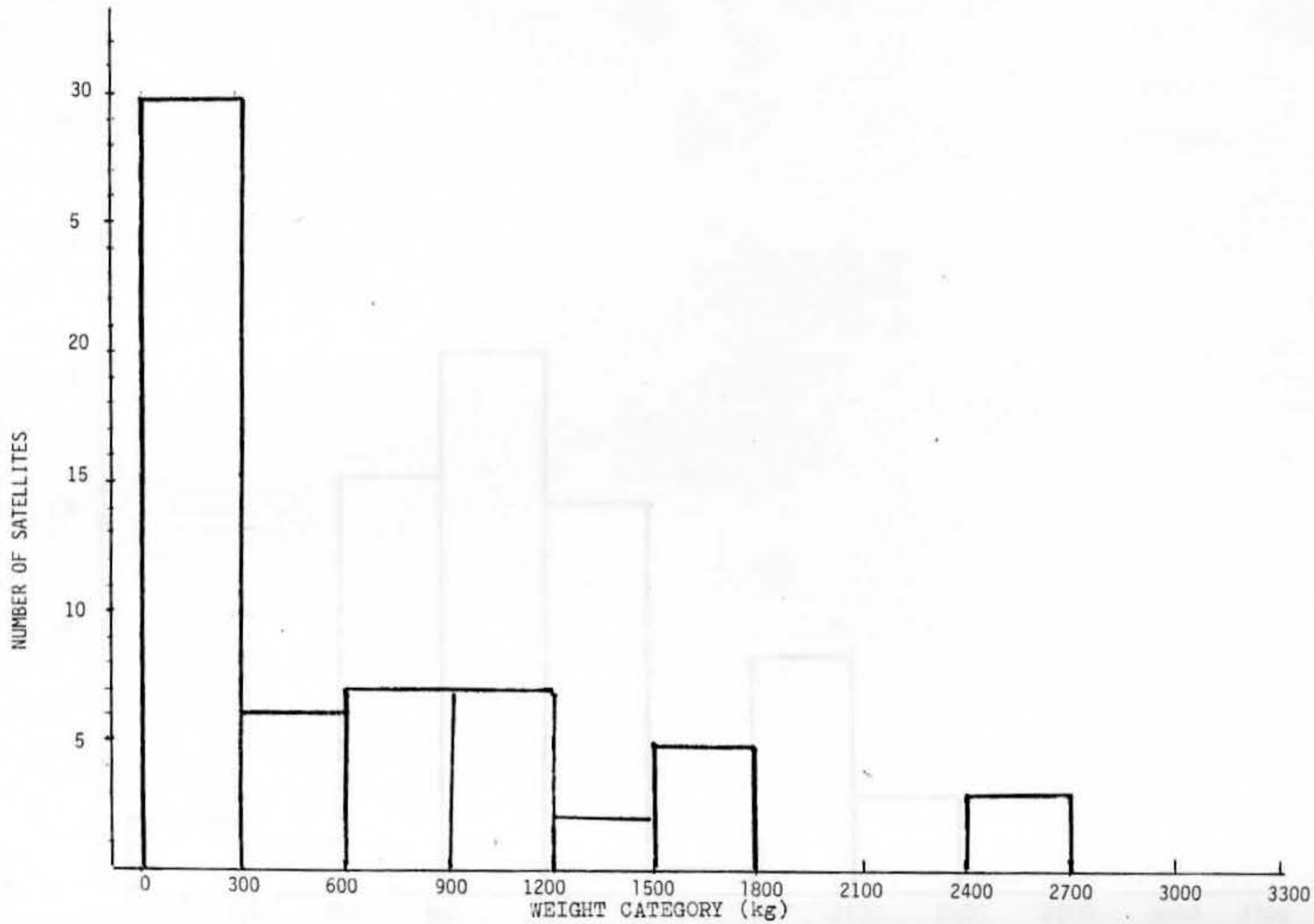


Figure 17. The Number of Satellites by Weight Category Placed into Low Earth Orbit (1974-1979).

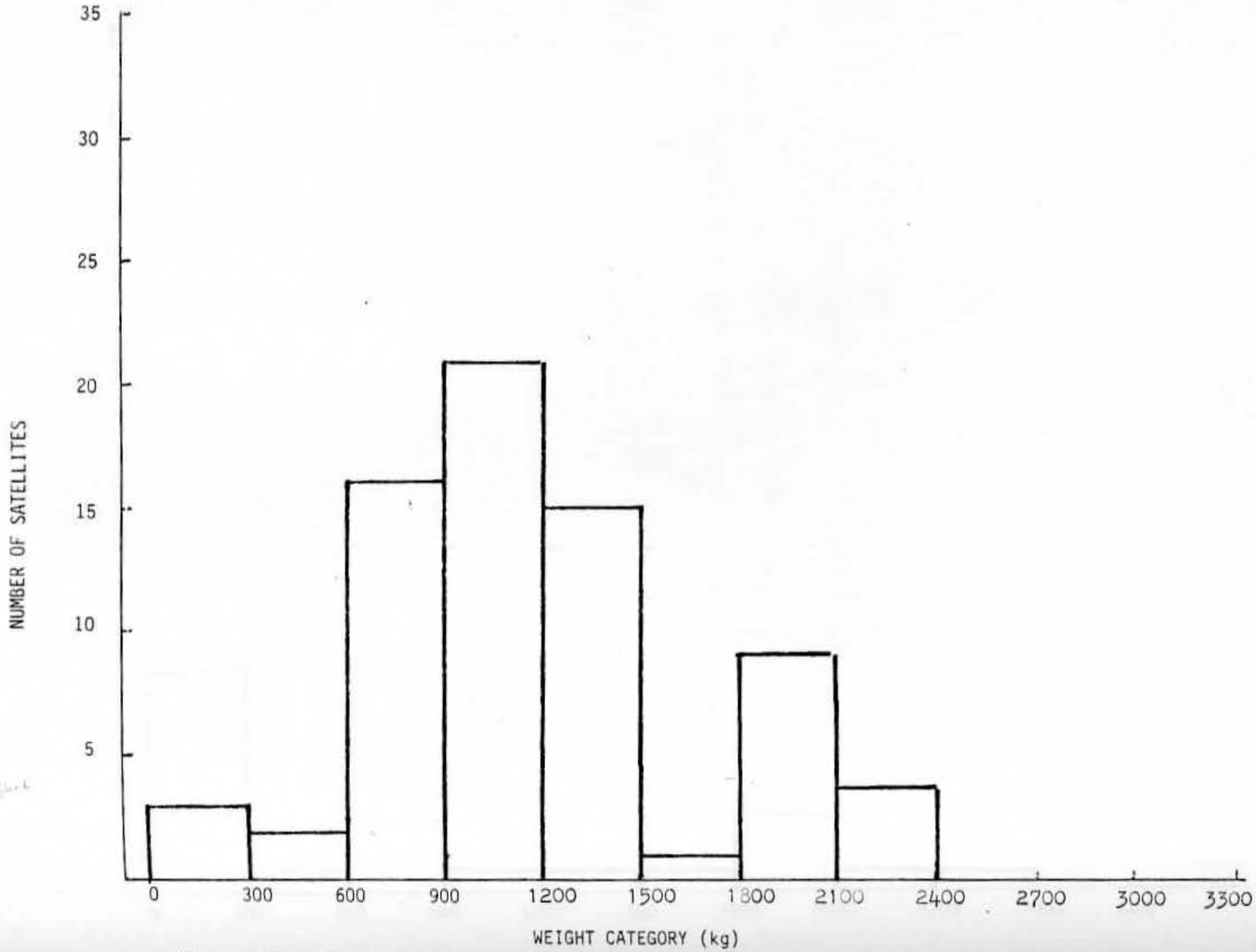


Figure 18. The Number of Satellites by Weight Category Placed into Geosynchronous Orbit (1974-1979).

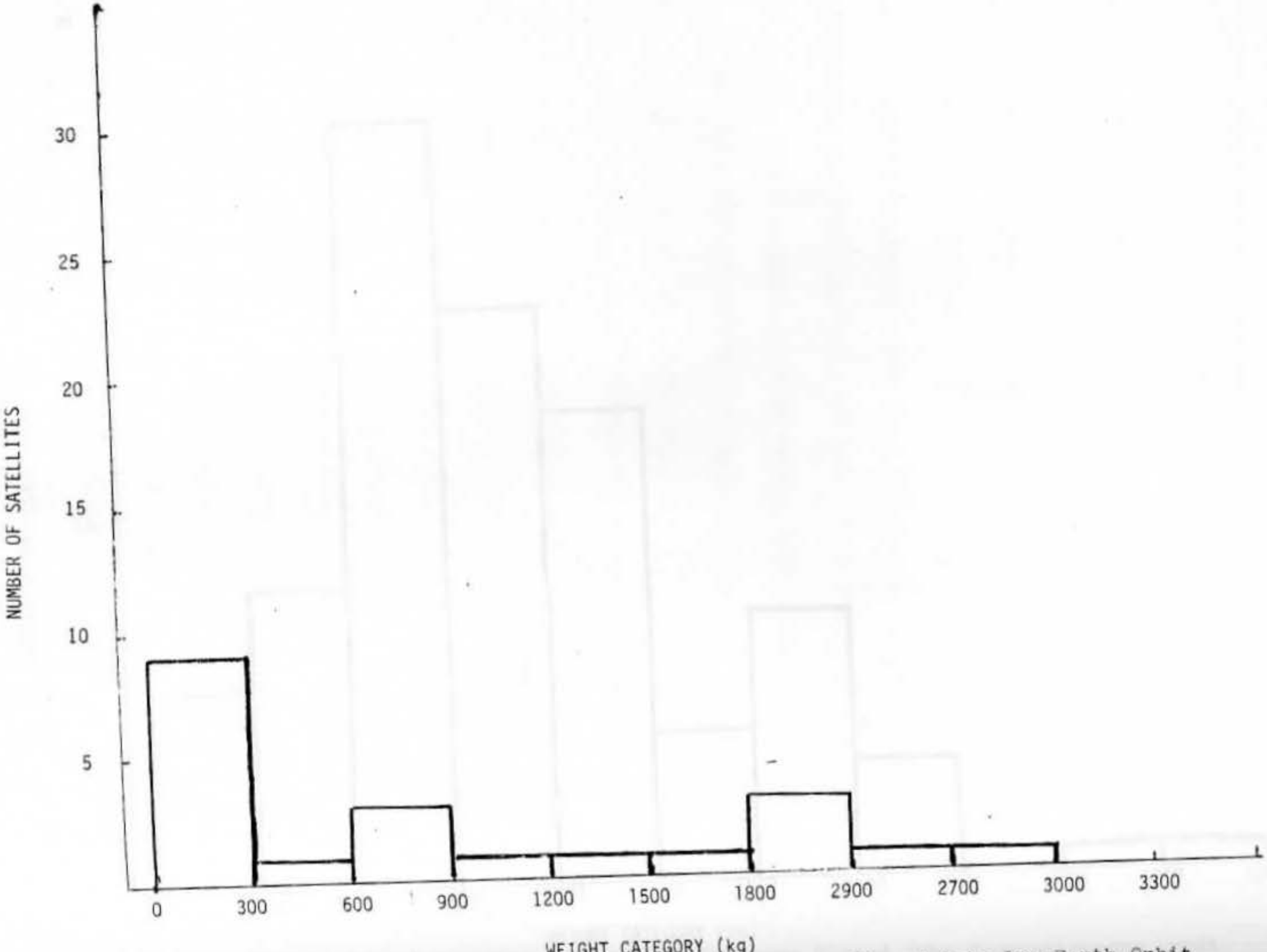


Figure 19. The Number of Satellites by Weight Category Placed into Low Earth Orbit (1980-1985)

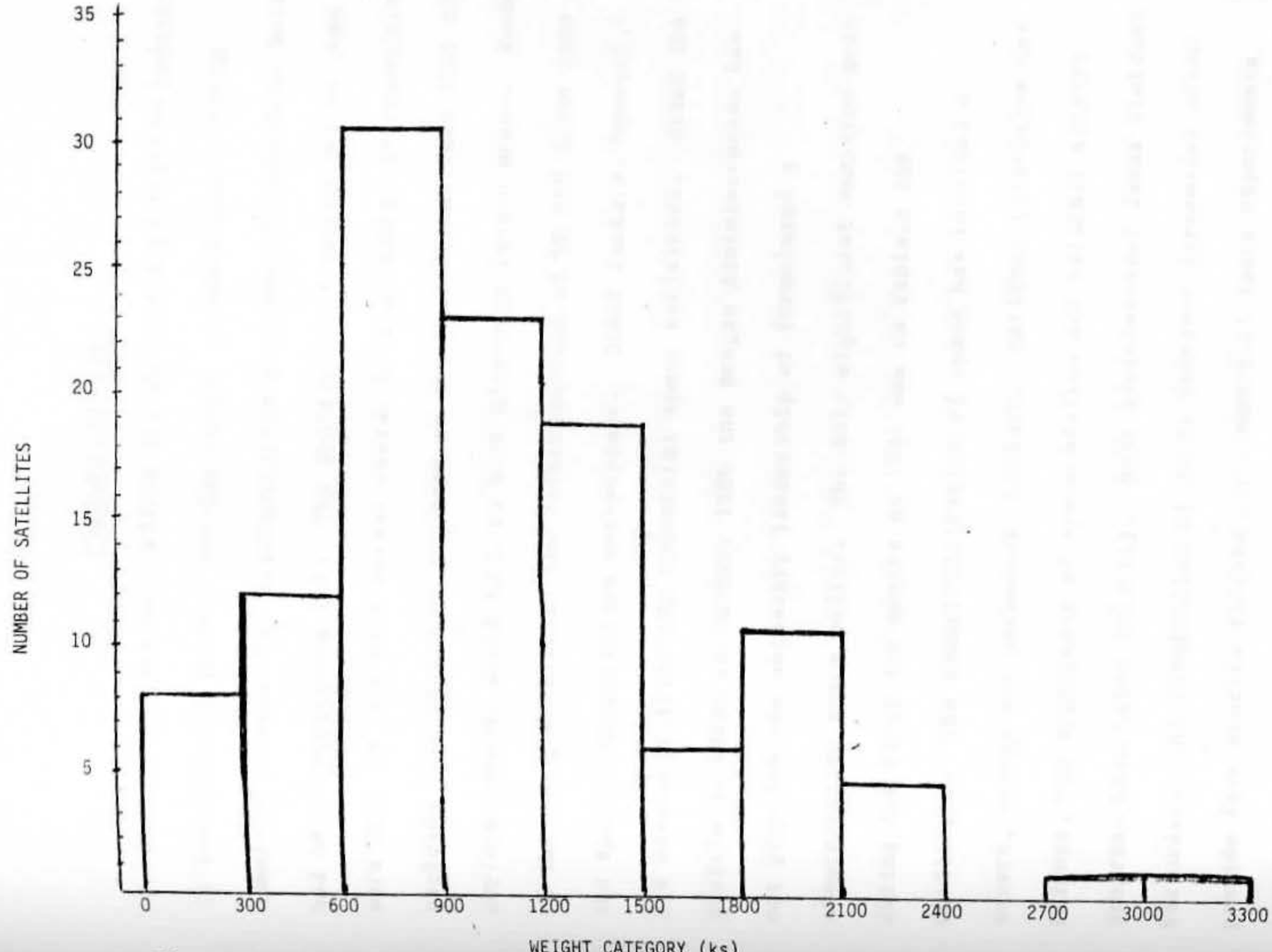


Figure 20. Number of Satellites by Weight Category Placed into Geosynchronous Orbit (1980–1985)

FORCAST ANALYSIS

Several factors will affect the space transportation industry in the upcoming years. The Challenger accident precipitated numerous changes that Transportation Secretary Elizabeth H. Dole had been campaigning for. The Shuttle would charge prices that were more in line with actual costs. A large number of commercial payloads were pushed so far back on the Shuttle manifest that the payload sponsor would have to seek alternate launch means. Both of the changes fostered the reintroduction of US ELV firms into the space transportation marketplace. Other factors, however, are adversely affecting commercial space activities. Since the Shuttle accident in January 1986 the Reagan Administration has not provided the necessary leadership or formulated a comprehensive space policy. The only significant decision made during the first six months of 1986 was to replace the Challenger. The commercialization of space has received a severe, though not permanent, setback. National priorities for Defense, the deployment of space station and national science programs have taken priority. NASA Administrator James Fletcher has ordered the termination of Joint Endeavor Agreements which provide free shuttle flights for commercial space experiments ("NASA Halts New Agreements for Free Shuttle Flights", Aviator Week and Space Technology, 1986). David W. Thompson, Orbital Sciences Corporation President said, "We are on the verge of a major policy failure. Our visions of sugar plums have stayed just that." ("Shuttle Manifest," Aviation Week and Space

Technology, 1986). The Administration's frequent vacillations have spelled financial disaster for dozens of industries that support the space program or commercial space ventures.

When the Shuttle manifest was released in early October, 1986, there were no commercial satellites listed for the first three years after Shuttle operations resume. The total number of Shuttle launch contracts at the time of the accident was 44. When a 31 of 44 or a 20 of 44 option was presented to the Administration, President Reagan elected the 20-payload option, which included only payloads that were shuttle-unique or had foreign policy or national security implications.

For an analysis of forcast ELV use a projection was made for the period 1987-1994. A list of all spacecraft was compiled with the associated launch vehicle when applicable. Shuttle manifests were accurate to 1991 after which projections were used to portray the most likely payload listing for a specific year. As an example, seven space station assembly flights are set for 1994 with the majority of the remainder being dedicated to DOD missions. This would leave the number of DOD missions equaling the total number of flights minus the seven dedicated station missions. NASA would like to achieve 16 flights a year by 1994. A realistic appraisal would indicate a lower number of flights especially in light of NASA's more conservative operations likely after the accident. A National Research Council report to the House Appropriations subcommittee overseeing NASA said that with a fourth orbiter the annual flight rate will be 11-13 missions a

Table 7. Forcast Analysis: This Study Projected That the Following Launchers Would Carry the Satellites Listed.

1987

ARIANE
- ECS 4/SPACENET F3
- TVSAT 1/TELECOM 1C
- APEX 401/METEOSAT/AMSAT
- AUSSAT K3/TDF 1
- SBS 5/ECS5
- INTELSAT F-14

FOREIGN LAUNCHER:
- MOS 1 (N-2, Japan)

U.S. LAUNCHER
- GOES H (D)

- WESTAR 6S (Long March-China)

BACKLOG
- Hughes ku Band
- AEROS (Connestoga)

1988

SHUTTLE
- TDRS C
- DOD Flight
- DOD Flight
- TDRS D

ARIANE
- INTELSAT F13
- SES/HIPPARCOS
- TEL-X/UOSAT
- OLYMPUS
- INTELSAT F15
- DFS 1/MOP 1
- INTELSAT F3

FOREIGN LAUNCHER
- MOS 2 (N-2, Japan)
- CS 3a (H-1, Japan)

US LAUNCHER
- LANDSAT 6
- RCA ku Band
- ACS 2
- FEDEX
- GSTAR
- ITALSAT
- Hughes COMSAT
- Hughes COMSAT
- Hughes COMSAT
- CYGNUS 1
- NOAA-A

BACKLOG
- KOPERNIKUS
- LAGEOS

Table 7. Continued

1989

SHUTTLE
- ASTRO-1 SHUTTLE SCIENCE PAYLOAD
- DOD
- Magellan (Venus Mapper)
- DOD Spacelab
- Global Positioning Satellites (GPS) 1 & 3, Material Science Lab (MSL)-3
- DOD
- DOD
- GPS 3 & 4, MSL-4
- GALLIEO (Jupiter Flight)
- Spacelab (SLS-1)

ARIANE
- Spot 2
- DFS 1/UOSAT/POSTSAT
- ERS 1/TDF 2
- MOP 1/GSTAR
- INTELSAT F 2/SKYNET 4c

FOREIGN LAUNCHER
- GMS-3 (N-2)
- CS 3b (H-1)
- MAILSAT (Long March)

US LAUNCHERS
- CBE
- GOES I
- HUGHES ku BAND
- PALAPA B3
- HUGHES COMSAT 3
- HUGHES COMSAT 4
- PAKSAT 1
- ORION A
- EQUASTAR 1

1990

SHUTTLE
- Gamme Ray Observatory (GRO)
- Spacelab (IML)
- DOD
- DOD
- GPS-5/FOS-1
- GPS-6/SKYNET 4 MSL-5
- DOD
- ULYSESS
- GPS-7/INSAT-1D/TT5
- (LDEF Retrieval)/SYNCOM-5

ARIANE
- METEOSAT P2
- TDF 3/MOP 3
- KOPERNIKUS 1
- INTELSAT 6/UOSAT
- KOPERNIKUS 2
- STC/ANIK E

FOREIGN LAUNCHER
- BS 3a (H-1)

US LAUNCHERS
- INSAT 1C/
- IAI
- SIRIO
- HUGHES COMSAT 5
- HUGHES COMSAT 6
- RCA COMSAT 1
- RAINBOW

Table 7. Continued

1991

SHUTTLE

- SPACELAB PALLET MSN
- GPS 8/MATERIALS PALLET MSN
- DOD FLIGHT
- EURECA
- JAPANESE SPACELAB
- W. GERMAN SPACELAB
- EURECA RETRIEVAL/SPACE TELESCOPE REFURBISHMENT
- ROSAT/RADARSAT
- ITELSAT 6
- DOD FLIGHT

ARIANE

- METEOSAT OM-1/ITALIAN RS Satellite
- sbs 6/AURORA
- OLYMPUS 2
- ATHOS/TOPEX
- RCA COMSAT/TELECOM 2
- UNISAT/

FOREIGN LAUNCHERS

- ERA 1 (H-1)
- BS 3b (H-1)
- ASTRO D (Mu 3s, Japanese)

US LAUNCHERS

- GOES J
- UARS
- INTERNATIONAL SOLAR EXPLORER
- HUGHES COMSAT
- USASAT 7D
- DIGISAT
- INMARSAT

1992

SHUTTLE

- INDUSTIAL PROCESS FACILITY
- TOPEX
- INMARSAT/INTELLSAT 6
- DOD FLIGHT
- DOD FLIGHT
- INMARSAT
- INMARSAT
- GPS 9, 10
- GPS 11, 12
- MSL 6, GPS 13
- CASSININ MISSION
- MARS OBSERVER

ARIANE

- METEOSAT OM-2/ERS 1
- TELE-X/MOP
- RCA ku BAND
- SES/DBSC
- ARABSAT
- BRASILSAT SPOT 3
- LUXSAT/MAILSAT

FOREIGN LAUNCHERS

- EOSAT 1 (Mu 3s)
- EOSAT 2 (Mu 3s)

US LAUNCHERS

- FORDSAT
- CBE
- RCA COMSAT 3

Table 7. Continued

1993	1994
SPACE STATION ASSEMBLY FLIGHT	**SHUTTLE**
SPACE STATION ASSEMBLY FLIGHT	DOD FLIGHT
INDUSTRIAL PROCESS FACILITY	DOD FLIGHT
SPACE STATION ASSEMBLY FLIGHT	DOD FLIGHT
SPACE STATION ASSEMBLY FLIGHT	DOD FLIGHT
SPACE STATION ASSEMBLY FLIGHT	SPACE STATION ASSEMBLY FLIGHT
INDUSTRIAL PROCESS FACILITY	SPACE STATION ASSEMBLY FLIGHT
DOD FLIGHT	SPACE STATION ASSEMBLY FLIGHT
DOD FLIGHT	SPACE STATION ASSEMBLY FLIGHT
DOD FLIGHT	SPACE STATION ASSEMBLY FLIGHT
INDUSTRIAL PROCESS FACILITY	SPACE STATION ASSEMBLY FLIGHT
	SPACE STATION ASSEMBLY FLIGHT
ARIANE	
GOES K	**ARIANE**
AUSSAT/TVSAT	EQUASTAR 2
INMARSAT	SES/INTELSAT UNISAT
ACTS/HUGHES COMSAT	LUXSAT/OLYMPUS
SBS A3	HUGHES COMSAT 9
CYGNUS 2/SBS A3	SBS A4/TELECOM 3
INMARSAT	STC 2/DFS 3
	ORION B
US LAUNCHERS	USASAT/AMERSAT
ANIKE	
RCA COMSAT 4	**US LAUNCHERS**
RCA COMSAT 5	HUGHES COMSAT 10
HUGHES COMSAT 8	FORDSAT 2
GALAXY KA2	PAKSAT 2
DIGISAT 2	AMERSAT
GEOTAIL	MMC 1
	GALAXY K A 1
	HR SOLAR OBS
	AXAF
	ITSO 2
	CRAFT

year. Assuming the lower rate in 1994 there should be about seven space station assembly missions and four DOD missions. The Ariane yearly flight schedule was derived in a similar manner. Firm manifests were available through 1991. The Ariane flight rate of 6 to 8 flights a year will continue to 1995.

Each year there will be a backlog of satellites that will be picked up by US ELV firms. General Dynamics by 1988 can produce 5 Atlas Centaurs a year and with additional tooling could produce up to seventeen. McDonnell Douglas can produce up to twelve Deltas a year. Table 7 represents a forcast of the satellites between 1987 and 1994 based on an analysis by this study of the vehicle launch manifests and the satellite backlog.

A backlog will exist during the first two years as the ELV firms continue to tool up for production. While a significant demand will exist initially, by 1992 there will be a very low number of flights by US launchers. By 1994 with the Shuttle dedicated to other missions and unable to launch NASA's science satellites the US missions again will see an increase in demand. The Ariane throughout the period will undercut the US ELV firms' prices and consequently its manifests will always be full. Should they expand their operations beyond their 6 to 8 flights per year capacity, the US firms could face financial hardship as launch customers are drawn away to the Ariane by their lower prices. The US launch industry has tried to have their operations subsidized by the US Government in order to remain competitive with the Ariane. To date these requests have failed to illicit any financial assistance. With the efforts to reduce the federal budget deficit it is less likely that any aid will appear in the future.

The number of satellites to be orbited by US launchers varied from 3 to 11. The mean for the period was seven launches a year and for three of the eight years studied seven launches by US ELV firms projected. This makes it difficult for two ELV firms to have profitable operations every year. One firm can almost handle the entire market. If two firms share the market competition will eventually drive one out. Since General Dynamic's Centaur is a far more flexible veichle capable of launching a single or two smaller satellites it could drive McDonnell Douglas's Delta out of the market.

This all makes it very difficult for a small launch firm to break into the market. Very few of the forcast payloads can be launched by the small launch vehicle. During the period considered the satellites that could be launched by a small launcher are:

1. AEROS
2. UOSAT (2)
3. LAGEOS
4. SIRIO
5. MAILSAT (2)

Seven launches in an eight year period is far from profitable. If the small launcher can be upgraded to launch the smallest geosynchronous satellites then the launcher would be eligible to launch 21 of the satellites. This is still too few for a profitable operation when several competing firms exist.

A market for small payloads does exist. The Shuttle had been carrying with it into orbit and back to earth Getaway Specials and middeck payloads, carried in the lower crew cabin. Competing for shuttle assignments will be 60-70 Getaway Special canisters, several small Hitchhiker payload bay experiments and 200 lockers full of middeck experiments. NASA will be able to fly 500 pounds of secondary payload cargo on each of the tracking and data relay satellite (TDRS) missions. This equates to 10 lockers for each flight.

However, most of the early scheduled missions are dedicated payloads and are not likely to be able to carry any secondary payload because they are already weight constrained. Mixed cargo flights, which combine several smaller primary satellites, offer the best opportunity for secondary payloads, but most of the mixed flights use Columbia, the heaviest orbiter. Columbia is 7000 pounds heavier than the other two orbiters. Shuttle secondary payloads represent 10,000 pounds of weight. A study in March 1986 conducted by the Center of Space Policy indicated that the Shuttle was servicing only 20% of the total number of payload sponsors seeking access to orbit. NASA has, in the past, always offered very economical prices for secondary payload space, although NASA has not issued any pricing policy in this area. This more than likely will continue to remain a bargain since regardless of the secondary payloads' presence or lack of it, a dedicated flight will be flown to orbit the primary payloads.

A small launch vehicle as they exist can only partially service these secondary payloads. The vast majority of them require a means of returning them to earth. While the technology exists, to return them to earth after launch onboard a small launcher, the costs entailed would be substantial and would require further study.

ISSUE ANALYSIS

ISSUE 1: Will a new shuttle be built and what effect will this have on space related industries?

The Reagan Administration gave the go-ahead to start construction on a replacement orbiter. However the construction of a new Shuttle cannot be assumed. While the President has approved an additional $272 million in budget authority for NASA in Fiscal 1987 for orbiter construction, the actual startup is threatened by the Gramm-Rudman-Hollings deficit reduction law cutbacks. NASA budget officials are trying to determine the effect of deficit projections on NASA's Fiscal 1988 budget. Should the Agency be forced to reduce this budget by $100-700 million a new orbiter would be out of the question. This would leave NASA with the authority to build the Shuttle, but without the actual appropriations to do so.

The White House decision received criticism because some of the funds for the vehicle would be taken from NASA's existing budget. Reagan authorized NASA to spend $272 million above its existing budget request of $7.7 billion for the next fiscal year. Not all of that would appear as new outlays. Only $139 million would be made available to pay for the obligation, with the rest being paid from another fiscal year budget. The $272 million was part of $500 million in Fiscal 1987 authority to start Shuttle construction as well as to replace the payload lost with the Challenger and to implement the Roger's commission recommendations. The other $228 million primarily was a result of the savings in not flying the Shuttle, and came from reprogramming in the agency's budget ("Industry Observer", Aviation Week and Space Technology, 1986). Senators Slade Gorton (R-Wash), Jake Garn (R-Utah), and John Danforth (R-Mo), key legislators who chair committees or subcommittees related to NASA, felt that the money saved from not flying the Shuttle will be absorbed by accident related costs and had severe doubts about the funding mechanisms involved. The senators said "This decision to replace the Shuttle has a funding mechanism that at this time is entirely too vague. We cannot cannibalize NASA for funds, weakening an already distressed agency in an attempt to sweep the funding question under the rug." ("Deficit Cuts Threaten Funds for Orbiter Construction", Commercial Space 1986). Shuttle funding requirements are $665 million in Fiscal 1988, $715 million in Fiscal 1989, $515 million in Fiscal 1990, and $180 million in Fiscal 1991. Another $600 million is required to replace the payload carried on the Challenger. The crucial question remains is the amount that would be designated as new budget authority and the amount NASA would be forced to pay from existing budget levels.

The new Shuttle is scheduled to be completed in 1991 and enter operation in 1992, taking seven years for the nation to replace a single Shuttle. The new vehicle will have no impact on the difficult process of relieving a backlog of satellites that a fully operational four orbiter fleet would still find impossible to handle. It will enter service shortly after the decision on whether to deploy the Strategic Defense Iniative has been made and at the same time that constructions starts on the Space Station. Under those and conditions the necessity for a fourth orbiter seems obvious. As it stands now all launch systems in the US have been grounded for the major portion of 1986. A large backlog of commercial, national and Defense satellites exist. A strong market entry by ELVs will occur no sooner than 1988 based on the time required to startup that industry.

As many payloads as possible will be moved to expendable vehicles. But, as mentioned earlier, a large number of payloads such as a Spacelab can only be handled by the Shuttle. Defense payloads consist of non-SDI related payloads such as military communications or reconnaissance satellite and SDI research payloads. Even if the SDI is not deployed in orbit payloads supporting research in this area will at a minimum continue to be orbited until the decision year, 1990. Until then money will continue to be authorized for SDI research. Already $6 billion dollars have been invested in this effort with contracts awarded in thirty states (Foley, 1986). The current Administration is completely committed to this effort and though serious arms control talks could derail the program, in light of the absence of substantial and significant advances in this area it seems very likely that it would not. Even if a sudden turn-about occurs the phase-out of the Strategic Defense Initiative will involve a long transition as contracts expire over time. The

Defense space budget exceeded NASA's in 1982 and the gap will continue to grow in upcoming years. (Covault, 1985). In effect what will be lost in the cancellation of SDI could be channeled into other Defense Department space programs. Under these circumstances continued support for a new Shuttle will continue to come from the Administration, Department of Defense (though it doesn't wish to allocate Defense funds for one) and indirectly from corporations involved in SDI.

Some public and governmental critics have argued that to build another Shuttle would be step backward to early 1970s technology and that funds currently allocated for the new Shuttle could more wisely be spent on a vehicle such as the Transatmospheric Vehicle (TAV) which is designed to take off from a runway, fly into orbit, and return to land on a runway. While achieveable such a vehicle could not realistically serve NASA or DOD as quickly as a new Shuttle could nor could it be built from the meager funds earmarked for Shuttle construction. The TAV represents the development of a challenging technology of hypersonic atmosphere flight coupled with the complexities involved in designing an engine incorporating two sets of fuel, capable of functioning efficiently as jet and later a rocket while still remaining within weight constraints required for orbital flight. Tag on the requirement to carry a substantial cargo into space and what evolves is a vehicle for the future which in no way can influence the current problem for the next ten years.

The new Shuttle would provide a part of the near term solution to the space transportation emergency. Much of the technology in the orbiter will be updated to more closely represent the technology of the day. The Soviet Union, Europe and Japan are developing smaller versions of the Shuttle. It will be a year and in most cases five years before any of them will be test flown. The Shuttle remains a significant national asset which the Administration and NASA will fight to retain. Unfortunately and to the severe detriment of NASA's other programs a budget price may well have to paid.

The construction of the Shuttle will have little impact during the near term because the operational date is 1992 rather than the earliest possible operational date of 1989. Consequently five of the next six years of this study will occur as if a Shuttle had not been built.

A new Shuttle entering service in 1992 will have no immediate impact on the satellite backlog. The remaining Shuttles offer not competition because they are overbooked and will not be able to serve all their contract customers.

For the small launch firm moving up the lower end of the weight spectrum this is a slightly positive sign. A market that poses possibilities and warrants further study is the use of small launcher to orbit a small material processing payloads such as the SPARTAN (1000 kg) for later Shuttle retrieval in 1988 or 1989.

ISSUE 2: What is the Administration's and NASA's policy on the type of cargo carried on future Shuttle flights?

Along with the decision to build another Shuttle, President Reagan barred the Shuttle from competing for any additional commercial payload contracts as a part of the Administration's plan to transition the commercial launch business to private unmanned rockets. The policy does not cancel the commercial contracts for the 44 holders. Several can still fly aboard the Shuttle before the contracts expire in 1995. The Administration policy leaves many questions unanswered and while it does intend to do so, it will discourage the development of new commercial space business that require the Shuttle for access to space. Projects focusing on material processing on Shuttle flights face uncertainty on whether regular access to space is still possible in the future. Until 1980 in any case this access will be virtually nonexistant.

Even among the larger communications satellite market, planners remain confused about the implication of President Reagan's decision to curtail use of the Shuttle for commercial payloads. This has forced companies to review plans and may cause several spacecraft builders to leave the business. The lack of short term launch availability has caused the following in the telecommunications market:

1. Curtailment of negotiations with prospective satellite customers.
2. Lost revenue for companies needing replacement satellites.

3. Mounting debt-service and storage costs for companies that have grounded satellites.

4. Drop in orders for new spacecraft. (Lowndes, 1986).

Proof of situation's severity lies in the fact that Ford Aerospace's review of options give strong consideration to the possibility that company's satellite assets could be sold (Lownders, 1986). The hardest hit by the consequences of the Challengers loss is Western Union. Its WESTAR 6 launched by the Shuttle in 1984 failed to achieve the proper orbit, was later recovered and sold to the insurance firm that covered its loss. A replacement, WESTAR 6S, was to have been orbited in June 1986 by the Shuttle Columbia. Revenue from the satellite is seen as critical to a financial turnaround at Western Union. Company officials are looking at alternate launch means to orbit the satellite. The longer a delay occurs in the establishment of a viable space transportation industry the greater the number of companies out of business due to a drop in telecommunications revenues.

Not only did the Challengers loss mark the destruction of a Shuttle and its crew but it also in that moment marked the end of numerous profitable space business ventures. The satellite builders and operators, Shuttle upper stage manufacturers, Astrotech Incorporated and material processing firms will see a significant thinning of their ranks. To the small launch firm it is critical to expand his operation upward. Fewer satellites will force stiffer competition between launch systems for the remaining satellites.

ISSUE 3: What will the national policy toward ELVs be and what affect will other external factors have?

As stated in the introduction, the Office of Commercial Space Transportation in the Department of Transportation was the government proponent agency for the development of commercial launch vehicles. Changes resulted from the Challenger accident that the Department of Transportation had endorsed all along, but had received stiff opposition to from NASA and the Commerce Department. In order to remain competitive with the Ariane the Shuttle charged prices so low that commercial ELVs could not hope to remain competitive with other vehicles. While the Administration endorsed commercial launch vehicle development it never actually provided an significant support to allow ELV companies to overcome these obstacles. The Department of Transportation actively became involved in clearing the way and unsuccessfully attempted to get the Administration to eventually charge prices that reflected some of the actual costs to launch the Shuttle. In 1984 a Shuttle payload cost $20 million while the Ariane charged US payloads approximately $25 million and TCI charged $45 million. The Shuttle now is barred from pursuing future Satellite launch contracts allowing US commercial ELVs to enter the market. The Atiane's price has risen to $35 million at the beginning of 1986 ("Fixing NASA", 1986.) The current price of the Delta is $40 million while the larger Titan III costs in the neighborhood of $59 million. The government is throwing support behind the idea of allowing ELVs to off load some of the Shuttle's scheduled payloads.

Legislation by Republican Bill Nelson, Chairman of the House Space Science and Applications Committee would authorize NASA to purchase 25 ELVs to launch grounded government payloads (Foley, 1986). An additional amendment to the legislation would require the Shuttle to charge comparitively higher prices than commercial ELVs should the Shuttle be allowed to contract for commercial payloads in the future. This legislation in part may face difficulty in light of the current deficit reduction climate. With the costs associated with the construction of a new orbiter and the costs to modify the other three it seems unlikely that NASA would purchase an additional fifteen launch vehicles. ELV firms have indicated that to remain competitive with foreign governments, their operations will have to be subsidized. However, James Fletcher has indicated that only those vehicles which are being newly developed will be subsidized. In the last few months Hughes Aircraft has proposed to build a large vehicle called the Jarvis, which would be very competitive with the Ariane and future foreign competition.

An issue which will have a significant effect on the satellites is the status of the space insurance industry. This form of insurance provides several types of coverages:

1. Preignition coverage is designed to pay the client for damages during manufacture, storage, transit and launch assembly phases and is not normally used

since the risk is assumed by the spacecraft manufacturer.

2. Launch coverage includes everything from ignition to 180 days after launch. The indemnity includes the cost of a replacement spacecraft and relaunch service.
3. Satellite life insurance coverage starts on the 181st day to the third year of operation and includes the lost of individual subsystems.
4. Spacecraft liability, which NASA requires in the amount of $5 million, involves third party claims (Coleman, 1985).

The satellite insurance industry started with its use to cover the Early Bird communications satellite in 1965. The premium base was first depleted between 1977 and 1979 with a loss ratio of 200% (2 dollar claim/1 dollar premium). Since then 13 commercial satellites have failed. For the 1984 failure of the WESTAR and PALAPA to reach the appropriate orbit after being deployed by the Shuttle $180 million had to paid; more than the premiums collected over the history of launch insurance. The premiums have rasen from 25% to 30% of the cost of a launch, and several firms have left the insurance industry altogether. During the 1983-1985 period the loss ratio was 330%. Premiums are close to the ceiling above which demand for space insurance would disappear. The most recent loss of Ariane May 30, 1986 caused space insurance underwriters to stop issuing policies and to stop giving premium quotations out until the status of the cause of Ariane's failure could be found. Several payloads on the Ariane manifest are without insurance.

The question arises whether the lack of insurance could close down satellite production and curtail the production of ELVs. Fairchild's Leascraft, a $100 million material processing retrievable satellite, was a victim of its inability to get insurance for itself in the event of a Shuttle loss. Fairchild, after it failed to find an insurer for its spacecraft could not get NASA itself to provide insurance against its loss or non-use of the spacecraft by NASA. So satellite operators today are faced with a similar dilema. Since the historical launch loss rate has been about 12 to15%, premiums should be high enough for underwriters to make a profit on launch insurance. Interruption of revenue from launch insurance has led to a complete halt in launch insurance revenue. Some experts have tied the recent ELV failures to personnel problems and poor quality control practices that have resulted from closing the ELV production lines (Covault, 1986). Insurance firms are concerned that the technical solutions worked out during the groundings will restore a degree of confidence in the vehicles concerned. "Until successful launch frequency begins to build and creates the potential for increased premium volume, space insurance capacity cannot increase" ("Insurers Stop Issuing Policies Following Loss of Ariane", 1986). This indicates a vicious circle were none can enter unless someone takes the risk of launching several satellites without insurance. RCA did that during several shuttle flights.

To a small launch firm the current situation is indeed bleak. The few space insurance firms in existence today will not issue insurance to a firm without an established reputation. In order to establish a reputation more than likely some expensive developmental flights will have to be flown probably in the neighborhood of three, without a commercial payload to demonstrate the favorable flight characteristics of the vehicle. Should the vehicle suffer a significant failure during any flight, it would be extremely difficult to recover from the setback. Externally if commercial ELVs fly without failure the small launch firm would likely feel less insurance pressure.

ISSUE 4: What affect will continued US governmental involvement with INTELSAT and the growth of fiber optics have on the communications satellite population.

The International Telecommunications Satellite Organization (INTELSAT) is a consortium with more than 100 member countries and is the monopoly provider of intercontinental satellite facilities. This organization was established under US leadership pursuant to the Communications Satellite Act of 1962 which also authorized the charter of the Communications Satellite Corporation (COMSAT) as a private company which in essence acts a a go between US carries and INTELSAT when these carriers are sending international satellite communications.

In the US increasing numbers of communications satellite companies have applied for permission to launch competitive satellites. In November 1984, the Administration endorsed US private transatlantic satellite systems that circumscribed their ability to compete with INTELSAT directly. These private satellite systems are systems unique to an individual entity such as a business firm or organization. A significant stumbling block should competition expand, is the fact that foreign government PTTs (government owned post, telegraph and telephone entity) as the sole communications establishment in a country, do not allow foreign competition and limit their access to one external source: INTELSAT. Direct competition still seems several years away and could eventually increase the numbers of communications satellites required.

Another significant communications issue deals with a promising technology. Fiber optics is evolving rapidly and becoming more efficient in the sense that improved digital multiplication techniques are increasing the number of telephone circuits that can be carried on a given cable. Because communication satellites constitute the largest segment of dedicated launches in the space transportation industry large scale fiber optics expansion would have a detrimental impact on them. However at a very long distance, satellites are expected to retain the cost advantage because transmission cost by satellite is nearly invariant with distance while transmission cost by cable is not.

The US Government is considering four options in dealing with the satellite versus fiber optics issue. The first is to control the amount of transatlantic cable and satellite capacity available so that some form of balanced use of cables and satellites occur. The second option would be the same as the first except that control would be less stringent and would rely on the market, carriers, and foreign regulations as the primary determinant on the relative use of satellites and cables. The third option would leave telecommunications firms free to invest in international cable or satellite facilities as they see fit. In the final option the US would seek the same things as in option 3 but would also seek access to foreign communication markets. To date the US has favored the first option which will have a detrimental impact on the communication satellite market. In 1990 a trans-Atlantic fiber optic cable should be completed opening a high capacity channel to Europe. This will have a larger impact on INTELSAT's fortunes than those of the domestic satellite corporations serving US and European nations.

Should fiber optic cables be installed, satellites will continue to share a significant portion of the telecommunication market since they offier some advantages especially in the area of business data transmission such as videoconferencing.

ISSUE 5: What effect will the large ELV firms have on the Satellite market?

Three firms and their vehicles are expected to attempt to carve their niche in the space transportation market. They are General Dynamics with their Atlas Centaur, McDonnell Douglas with their Delta and Martin Marietta with their Titan IIIC. A totally new vehicle, the Jarvis, is being designed at Hughes Aircraft.

General Dynamics Atlas Centaur -	First production vehicle mid 1988. Production rate 3-4 vehicles per year. (3 - 1988, 5 - 1989 through 1992). Price $50 million for launch.
McDonnell Douglas Delta -	First production vehicle 1988. Production rate, 11-12 vehicles per year. Price $40 million for launch.
Martin Marietta Titan 3 -	1989 Production rate, 5-6 vehicles per year.

The French Ariane will manage between ten and twelve flights a year. It raised its price at the beginning of the year from $25 million to $35 million and by so doing still maintains a significant price advantage over its nearest active US competition. So far it has beat US ELVs to the punch and is solidly booked through 1990. US ELV manufacturers were reluctant to commit themselves to carrying payloads until the Administration came out with its space policy in August, 1986. The Japanese and Chinese will offer commercial launch services in the upcoming years. The Japanese are constrained by being limited to rockets which do not incorporate American technology when launching the payloads of nations other than itself and the US. At this time they have enough payloads to keep themselves busy without looking at the US satellite backlog. The Japanese H-2 rocket which will be operational in 1990 will be more powerful than the US Titan. It incorporates no US technology and could launch any nations payload.

The Chinese have already contracted to launch two satellites of the TERESAT Corporation. These satellites were purchased from the insurance firm that received the WESTAR 6 and PALAPA. These refurbished satellites were acquired by TERESAT. Launch is expected within the next few years. It is doubtful that this trend will be repeated too often while the Chinese possess a reliable rocket powerful enough to place the heavier satellites in the appropriate orbit, and inexpensive insurances is available from the Peoples' Insurance Company. In China clean room conditions are not always available and in-flight vibrations are more severe than normal limiting the number of customers willing to take a chance on launching their satellites on Chinese boosters.

CONCLUSION AND RECOMMENDATIONS

This study addressed the problem of whether a small launch firm can successfully service a portion of the satellite population. The trend, forcast, and issue analysis indicated that the firm would not survive. The trend analysis covered the ten year period between 1974 and 1985. This period saw the gradual increase in the mean satellite weight to the point where the small launch vehicle would not have been able to orbit very many spacecraft. In essence the small launcher is years behind its time. It is generally only capable of lifting payloads into low earth orbit but could be upgraded to lift a very small payload (500 pounds) into geosynchronous orbit. However, the weight of satellites designed for geosynchronous orbit has increased to the point where the small launcher can no longer service them. Overall, the trend analysis presented a continuously decreasing population of satellites that the small launcher is capable of deploying in orbit.

The forcast analysis supported the findings of the trend analysis. The small launch vehicle despite the satellite backlog could not launch a significant number of them. It could launch only 21 satellites over the period 1985 to 1994. Even with the absence of competition this represents an insufficient number of launches for profitable operations. An area which offers the potential for success is the backlog of secondary payloads for the Shuttle. The major obstacle that needs to be overcome in this area is a means for returning the payloads from orbit. A recovery system for the payload similar to the type developed by General Electric for Air Force reconnaissance satellites could be developed for a small launch vehicle. This would increase the cost of the vehicle considerably. Further study in this area would be valuable. With the Shuttle limited in the amount of secondary payload it can carry, payload customers may be willing to pay the extra cost for access into space.

An analysis of the issues indicates that:

1. A replacement Shuttle will be constructed to late to relieve the initial backlog of satellites. The small launcher will prove too small to launch a significant number of satellites.
2. The insurance industry will pose problems for expendable launch vehicles. For small firms they will prove especially difficult. Insurers may require test flights of a new vehicle before a cargo is flown. Should no test flights occur then the premium charged the satellite owner may drive him away.
3. The US Government will encourage ELV production, but no significant support or subsidies will occur.
4. The space station and the deployment of SDI commit a large portion of the Shuttle and ELV assets. This may provide some opportunities for the small launch firm as other launch assets are stretched thin.

5. The competition with INTELSAT will not have a significant impact on the small launch firm. The many firms of the telecommunications may switch to fiber optics in light of the inability to orbit and use communications satellites.

A small firm today may wish to reevaluate its position. It will orbit very few satellites in its present configuration. Should the vehicle's performance be upgraded it is likely to compete directly against the proven ELVs of the aerospace industries. A market may exist if it remains a relatively small launcher, able to orbit the backlogged secondary payload of the Shuttle and return it to earth through a newly developed recovery system. A recent market opportunity is the demand of news organizations for remote sensing satellites to enable them to monitor directly news worthy events on the earth's surface. The Chernobyl accident sparked the demand. Both of these market opportunities would require additional studies.

REFERENCES

AAS Science and Technology Assn., (1966). "The Management of Aerospace Programs, Los Angeles: Author.

Aeronautics and Astronautics Association. (1986). The 1986 Aerospace Directory, New York: McGraw Hill.

Aerospace Industries Association of American Inc. (1985). Aerospace Facts and Figures 85/86, Washington, DC: Author.

AMSAT Seeking Low Cost Launch for Relay Satellites (1983, September 26). Aviation Week and Space Technology, pp. 14-18.

Announcement of US Government Support for Commerical Operations By the Private Sector. (1983, May 16). Weekly Compilation of Presidential Documents, (Volume 19). Washington, DC: U. S. Government Printing Office.

Budget Constraints. (1986, Spring). Commercial Space, p. 49.

Broad, W. Military Missioins to Dominate Role of Space Shuttle (1986, March 24) New York Times, p. 11.

Brady, B., & Kindel, S. (1983, January 31). We Mean Business. Forbes, pp. 76-78.

Caney, T. (1983, September). Satellites That Serve Us. National Geographis, jpp. 286-308.

Capsules. (1986, April). Space World, p.5.

Clifton, D.S., & Fyffe, D.E. (1977). Project Feasibility Analysis, London: John Wiley & Sons.

Coleman. H., (1985, Fall). Insurance, Commercial Space, p. 65.

Company Plans Orbital Booster System Launch. (1983, October 17). Aviation Week and Space Technology, pp. 81-82.

Competition. (1985, May 27). Fortune, pp. 140-141.

Covault, C. (1986, May 5). Space Agency Hopes to Resume Shuttle Flights in July 1987. Aviation Week and Space Technology, pp. 21-22.

ELV Firm Schedules Tests of Industrial Launchers for 1988 (1986, September 19), Aviation Week and Space Technology, p. 44.

Egan, J., (1985, Fall). Shuttle Pricing Plan. Commercial Space, p. 33.

Expendable Launcher. (1985, Fall). Commercial Space, pp. 29-30.

Farchild Leasecraft Project at a Standstill. (1985, Fall). Commercial Space, pp. 38-40.

Fill the Gap. (1986, Spring). Commercial Space, p. 30-31.

Finch, E.R. & Moore, A.L., (1984). Astrobusiness., New York: Praeger.

Foley, T., (1986, May 5). White House to Weigh Options for Funding New Orbiter, ELVs. Aviation Week and Space Technology, p. 18.

Frances Athos Satellite to Test Space Communication Payload. (1983, October 17). Aviation Week and Space Technology, p. 20.

General Dynamics Studies New Expendable Boosters (1986, May 5). Aviation Week and Space Technology, p. 25.

G. E. Display Model of Space Recovery Vehicle. (1986, June 30) Aviation Week and Space Technology, p. 52.

Getaway Specials Create New Market for Hardware. (1984, June 24). Aviation Week and Space Technology, p. 140-141.

Gwynne, P. (1986) Rethinking Space Business. High Technology, pp. 38-45.

Grimes, D. (1984, October) Transpace Carries Incorporated Press Packet.

Hoeser, S., (1986, May). Filling the Launch Gap. Space World, pp. 27-32.

Industry Observer. (1986, June 25). Aviation Week and Space Technology, p. 23.

Instrumentation Technology Associates. (1985) ITA Press Packet, Exton, PA: Author

Klass, P., (1985, Spring). Reagan Competitive Policy Placces INTELSAT Future at Crossroads. Commercial Space, p. 70.

Kolcum, (1986, March 10). Challenger Loss Prompts Questions on Use of Expendable Launcher. Aviation Week and Space Technology, p. 142.

Lowndes, J., (1985, Spring). Satellite Owners Move to Offset Telephone Losses to Optical Fiber. Commercial Space. pp. 66-69.

Lenowitz, J., (1986, February 17). European Ariane's Launch Manifest Contains Nine Open Payload Slots. Aviation Week and Space Technology, p. 103.

Lenowitz, J. (1985, Spring). Progress of Europe's Ariane Launchr Challenges US SHuttle on Cost Issue. Commercial Space, p.p. 44-47.

Magnuson, E. (1986, June 9). Fixing NASA. Time, pp. 21-34.

Marsh, A. (1984, June 24) Space Services Pushing Conestoga Launch Vehicle. Aviation Week and Space Technology, pp. 165-168.

Mordoff, K. (1986, Spring). Production Restart. Commercial Space, pp. 46-50.

NASA Launch Schedule Pared to Five. (May 86). Space World, p. 7

National Aeronautics and Space Administration (1984) Aeronautics and Space Report of the President - Activities 1974-1984. Washington, DC: Author.

New Manifest for Space Shuttle Generates Payload Sponsor Debate (1986, October 13). Aviation Week and Space Technology, pp. 22-23.

Office of Technology Assessment. (1985). International Cooperation and Competition in Civilian Space Activities. Washington DC: U.S. Government Printing Office.

O'Lone, R. (1984, June 25). Bay Area Firms Pursue Booster Designs. Aviation Week and Space Technology, pp. 166-167.

O'Lone, R. (1985, Fall). Entrepreneurial Spirit. Commercial Space, pp. 37-40.

O'Lone, R. (1985, Spring). Starstruck's Problems Spotlight Rises, Opportunities in Space. Commercial Space, pp. 60-65.

Rhea, J. (1985, December). Through a Glass Quickly. Space World, pp. 27-28.

Roland, A. (1985, November). The Shuttle. Discovery, pp. 48-62.

Shifrin, C. A. (1986, March 10), NASA Nears Final Decision on Station Configuration. Aviation Week and Space Technology, p. 108.

Sarsfield, L.P., (1985). Information Exchange. New York: Macmillan

Shuttle Marketing Approach Spurs Hughes Launch buy. (1985, November 4). Aviation Week and Space Technology, p. 18

Shuttle Launch Pricing Issue Produces Diverging Opinions. (1985, March 18). Aviation Week and Space Technology, p. 140.

Space Launching: France Will Give NASA a Run For Its Money. (1984, March 19). Business Week p. 50.

Terrestial Facility Advances May Curb Telephone SATCOM Use (1985, March 18), Aviation Week and Space Technology, pp. 127-128.

Transpace Embarks as Venture Capitalized Booster Company. (1984, June 24). Aviation Week and Space Technology, pp. 141-142.

Washington Overview. (1985, Fall). Commercial Space, p. 15.

Wilford, J. N. (1985, May 14). Gap Between Early Hope and Present Accomplishments Grows Large. New York Times, pp. C1, C6.

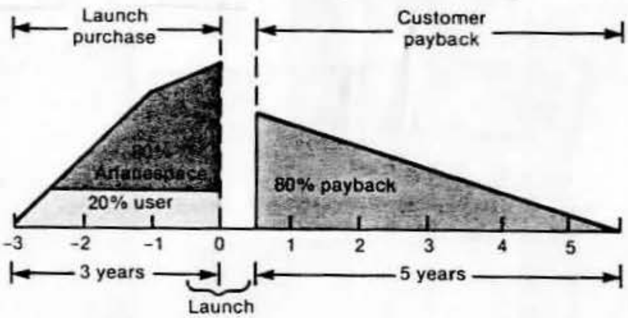
APPENDIX A.

Arianespace charges customers for payloads on a linear pricing scale based on weight rather than on the model of Ariane used for the launch. As an example, $27 million is the price for a 1140 kg satellite and, along a straight line pricing scale, $49 million is the price for a 2500 kg satellite. Actual price could

NASA vs. Arianespace Financing (1982 $M)
(FY 1982-85 pricing)

NASA's STS		Ariane
Total launch price:		
SBS	$12.65	$22.0
INTELSAT	$28.34	$39.6
Prelaunch payments required (SBS example):		
36 months	$ 0.1	
33 months	1.25 (10%)	
27 months	1.25 (10%)	$4.4 (20%) due 30 months prior to launch
21 months	2.13 (17%)	
15 months	2.13 (17%)	
9 months	2.9 (23%)	
3 months	2.9 (23%)	
	$12.65 (100%)	
Postlaunch payments—none		80% balance—payments begin 6 months after launch, spread over 5 years at 5-10% interest

Arianespace Financing



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

Figure A.1. NASA Financing and Arianespace Financing.

NOTE: From the Office of Technology Assessment.

vary 10% to take into account currency exchange rate risks, satellite specific launch requirements, and other factors. Ariane's price for the average payload is $24 million compared to the Shuttle's $25 million.

Arianespace provides favorable financing. Its payment schedule requires that 20% of the cost is paid prior to launch and the balance is spread over five years at low interest rates while the satellites are in space earning revenue. Normally, Arianespace will finance 80% of the cost of which 80% of this debt will be at a subsidized rate. The remaining 20% of the 80% financing would be at market rates. This is especially favorable to the US domestic firms since subsidized financing is illegal in the EEC. NASA requires that the entire cost be paid prior to launch. NASA can with the help of the US Export-Import Bank arrange financing similar to Arianespace to non-EEC (European Economic Community) countries.

PRESIDENTIAL DOCUMENTS

Title 3—Executive Order 12465 of February 24, 1984

Commercial Expendable Launch Vehicle Activities

By the authority vested in me as President by the Constitution and laws of the United States of America, and in order to encourage, facilitate and coordinate the development of commercial expendable launch vehicle (ELV) operations by private United States enterprises, it is hereby ordered as follows:

Section 1. The Department of Transportation is designated as the lead agency within the Federal government for encouraging and facilitating commercial ELV activities by the United States private sector.

Sec. 2. *Responsibilities of Lead Agency.* The Secretary of Transportation shall, to the extent permitted by law and subject to the availability of appropriations, perform the following functions:

(a) act as a focal point within the Federal government for private sector space launch contacts related to commercial ELV operations;

(b) promote and encourage commercial ELV operations in the same manner that other private United States commercial enterprises are promoted by United States agencies;

(c) provide leadership in the establishment, within affected departments and agencies, of procedures that expedite the processing of private sector requests to obtain licenses necessary for commercial ELV launches and the establishment and operation of commercial launch ranges;

(d) consult with other affected agencies to promote consistent application of ELV licensing requirements for the private sector and assure fair and equitable treatment for all private sector applicants;

(e) serve as a single point of contact for collection and dissemination of documentation related to commercial ELV licensing applications;

(f) make recommendations to affected agencies and, as appropriate, to the President, concerning administrative measures to streamline Federal government procedures for licensing of commercial ELV activities;

(g) identify Federal statutes, treaties, regulations and policies which may have an adverse impact on ELV commercialization efforts and recommend appropriate changes to affected agencies and, as appropriate, to the President; and

(h) conduct appropriate planning regarding long-term effects of Federal activities related to ELV commercialization.

Sec. 3. An interagency group, chaired by the Secretary of Transportation and composed of representatives from the Department of State, the Department of Defense, the Department of Commerce, the Federal Communications Commission, and the National Aeronautics and Space Administration, is hereby established. This group shall meet at the call of the Chair and shall advise and assist the Department of Transportation in performing its responsibilities under this Order.

Sec. 4. *Responsibilities of Other Agencies.* All executive departments and agencies shall assist the Secretary of Transportation in carrying out this Order. To the extent permitted by law and in consultation with the Secretary of Transportation, they shall:

(a) provide the Secretary of Transportation with information concerning agency regulatory actions which may affect development of commercial ELV operations;

(b) review and revise their regulations and procedures to eliminate unnecessary regulatory obstacles to the development of commercial ELV operations and to ensure that those regulations and procedures found essential are administered as efficiently as possible; and

(c) establish timetables for the expeditious handling of and response to applications for licenses and approvals for commercial ELV activities.

Sec. 5. The powers granted to the Secretary of Transportation to encourage, facilitate and coordinate the overall ELV commercialization process shall not diminish or abrogate any statutory or operational authority exercised by any other Federal agency.

Sec. 6. Nothing contained in this Order or in any procedures promulgated hereunder shall confer any substantive or procedural right or privilege on any person or organization, enforceable against the United States, its agencies, its officers or any person.

Sec. 7. This Order shall be effective immediately.

Ronald Reagan

THE WHITE HOUSE
February 24, 1984.

APPENDIX C

COMMERCIAL LAUNCH VEHICLE POLICY AND PROCEDURES

Both NASA and the Administration under the Commercial Space Policy indorsed the development and use of commercial launch vehicles to supplement the Shuttle Transportation System. On May 16, 1983, the President announced his Directive on Commercialization of Expendable Launch Vehicles. It was felt by proponents of the directives that the nation had a great deal to gain by maintaining a separate stable of launchers. Launch vehicle Commercialization would provide jobs for thousands of workers and add to the Federal tax base, provide a healthier US launch capability and offer a domestic backup to the Shuttle at essentially no cost to the US Government. There would still be a market for US Government launch facilities or equipment that would otherwise be underutilized or no longer required.

The Presidential Directive made the following points:

1. The government favored and would encourage the commercialization of ELVs.
2. The government would set minimal licensing, supervisory and regulatory requirements. These would be necessary primarily to meet national and international obligations and to ensure public safety.
3. The government to encourage the use of national launch ranges and associated equipment would make them available to commercial "launch

vehicle operators at reasonable rates consistent with the goal of encouraging viable commercial ELV launch activity."(Directive on Commercialization of Expendable Launch Vehicles, Weekly Compilation of Presidential Documents, 1983,)

4. The government will review and approve any commercial launch facility on a case-by-case basis.

Executive Order 12465 of February 24, 1984, followed the Directive on Commercialization of Expendable Launch Vehicles and provided the necessary guidance to receive national authorization to launch a commercial space vehicle. Previously Space Services Incorporated was the only company to gain the necessary approval from the appropriate federal agencies to launch a commercial rocket in 1982. At that time no single point of contact in the government existed. Executive Order 12465 simplified the authorization process by designating the Department of Transportation (DOT) as "the lead agency within the Federal Government for encouraging and facilitating commercial ELV activities by the United States private sector(Presidential Documents Title 3 - Executive Order 12465, 1984.). More specifically the Department of Transportation integrates and coordinates the efforts of all other federal agencies, thereby reducing any redundant requirements and conflicting guidelines that apply to firms seeking authorization to launch their vehicles.

The Office of Commercial Space Transportation (OCST) was established within the Department of Transportation to handle commercial launch vehicle affairs. Jennifer Dorn is its head. OCST works primarily with the Federal Communications Commission (FCC), the Federal Aviation Administration (FAA), the Coast Guard, the Commerce Department, the State department, the Department of Defense (DOD) and NASA.

The Federal Communications Commission's responsibility to OCST involves assigning the appropriate radio frequencies for the support functions (telemetry, radar tracking, and abort/destruct capability) associated with a firm's launch activities. This is applicable when a private launch site is used rather than a national range. The Federal Aviation Administration has responsibility for airspace control. Federal Aviation Regulations (FARs) do not specifically cover the activities associated with a small commercial launch vehicle firm. Part 101, subpart C of the FARs regulates the activities of small rockets launched by hobbyists and scientists. Nonetheless, until new legislation is passed these regulations will require waivers for commercial launches. Restricted airspace must be requested from the FAA whenever a private launch site is used. The Coast Guard is responsible to insure that launchings do not adversely affect the safety of national and international shipping lanes, while the Materials Transportation Bureau oversees the transportation of fuels and any hazardous materials to the launch site.

The Department of State is the agency responsible for negotiating and executing international agreements and for dealing with foreign governments in the administration of and compliance with international treaties. Article VI of the 1967 Outer Space Treaty set forth that "states bear international responsibility for national activities in space whether by governmental or nongovernmental bodies and they bear responsibility resulting from any launch activities from their territories by private or public concern."(Finch & Moore, 1984). International responsibilities for launches were dictated by the 1972 Convention on International Liability for Damage Caused by Space Objects. The term "launching state" in reference to liability was expanded to include the state that procures the launching, the state from whose territory the launching occurred and the state from whose facility the spacecraft is launched. To increase the effectiveness of the Liability Convention in regard to unidentified satellites and launch vehicles the 1976 Registration Treaty obligates all states to register all space objects from their territory on an international registry (Finch & Moore, 1984).

Consequently, a corporation that launches a satellite that causes damage to a foreign interest would make the Department of

State responsible for responding at a governmental level to foreign claims. Space Services Incorporated serves as an example to illustrate the requirements imposed by the State Department. The Department required Space Services to obtain an export license for its launch, to comply with the requirements imposed by NASA and the FAA and finally to obtain insurance in the amount of $100 million for damages that might be incurred by the launch to include any payments for which the US might become responsible for under any treaty. Since then the first requirement has been removed since Congress passed legislation that would no longer treat space vehicles as exports and would specifically exempt launch vehicles from any laws controlling exports.

The Department of Defense provides necessary support to private space ventures by operating the launch pads, tracking facilities associated with the government rocket ranges. Commercial launch firms have the option of either investing a great deal of time, money and labor in seeking approval to establish a private launch site or they can use the national launch facilities on a reimbursable basis. Firms that use these facilities are subject to DOD rules and regulations. In support of the Office of Commercial Space Transportation, DOD comments on the national security and safety aspects of proposed private space activities through an interagency review process. DOD through NORAD/Space Command which tracks all space vehicles and debris will also assist the launch firm in timing its launch and defining the trajectory to minimize the risk of collision with orbiting satellites or debris.

NASA has no responsibility or authority to regulate private space activities. However, its technical expertise on the operation of launch vehicles and spacecraft is second to none and the Department of Transportation does not feel totally competent technically and relies heavily on NASA's recommendations. NASA sets the terms and conditions when its facilities, equipment and personnel, are made available for use by private space ventures. While theoretically, NASA will be a lessor of launch facilities rather than regulator of commercial ELV firm activities, as owner of the Kennedy Space Center, NASA will have to nonetheless regulate many important commercial space efforts. Consequently a firm using a national range is subject to both DOD and NASA regulations dependent upon which launch facility it uses.

It is evident that the Office of Commercial Space Transportation has undertaken a monumental task in its efforts to draw together and coordinate the functions of various government agencies under one roof. It has not been extremely successful and severe interagency in-fighting has made the task more difficult. To date the Department of Transportation has not issued a single license or authorization for a commercial rocket launch and its continued responsibility for commercial launch activities is coming under severe scrutiny by Congress.

SATELLITES LAUNCHED 1974 - 1985

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
1974						
SAN MARCO 4	18 Feb	SCOUT	LEO 200 x 200 km 120 x 120 mi	177kg 390 lbs		SCIENCE Italian payload and launch
UK X-4 (MIRANDA)	9 Mar	SCOUT	LEO 200 x 200 km 120 x 120 m	180 kg 397 lb		SCIENCE UK payload
WESTAR 1	13 Apr	DELTA	GEO	1065 kg 2347 lb	572 lbs 1261 lb	COMMUNICATIONS Western Union Satellite
SMS1 (SYNCHRONOUS) METEOROLOGICAL SATELLITE	17 May	DELTA	GEO	593 kg 1307 lb	243 kg 536 lb	REMOTE SENSING
ATS-6 (APPLICATION TECHNOLOGY SATELLITE)	30 May	TITAN IIIC	GEO	3670 kg 8090 lb	1503 kg 3315 lb	COMMUNICATIONS

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	 GEO	REMARKS
HAWKEYE (EXPLORER 52)	3 Jun	SCOUT	LEO 518 x 509 km 310 x 305 mi	197 km 434 lb		SCIENCE
AEROS 2	16 Jul	SCOUT	LEO 483 x 483 km 300 x 300 mi	177 km 390 lb		SCIENCE West German Satellite
ANS (ASTRONOMICAL NETHERLANDS SATELLITE)	30 Aug	SCOUT	LEO 483 x 483 km 300 x 300 mi	190 kg 418 lbs		SCIENCE Dutch Satellite
WESTAR 2	10 Oct	DELTA	GEO	1065 kg 2347 lb	572 kg 1261 lb	COMMUNICATIONS
ARIEL 5	15 Oct	SCOUT	LEO	60 kg 132 lbs		SCIENCE UK Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
INTASAT	15 Nov	DELTA	LEO 1468 x 1468 km	29 kg 64 lbs		SCIENCE Spanish Satellite
AMSAT (OSCAR 7)	15 NOV	SAME DELTA	LEO 1478 x 1444 km 886 x 866 mi	15 kg 33 lb		COMMUNICATIONS
NOAA-4 (ITOSG) 15 Nov	 DELTA	SAME 877 x 872	1462 x 1454 km mi	345 kg 760 lb		REMOTE SENSING
INTELSAT IV (F-8)	21 Nov	ATLAS CENTAUR	GEO (PACIFIC)	1515 kg 3340 lb	826 kg 1820 lb	COMMUNICATION
SYMPHONIE 1	19 Dec	DELTA	GEO	402 kg 886 lb		COMMUNICATIONS French/German Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
1975						
SASC (EXPLORER 53) (Small Astronomy Satellite)	7 May	SCOUT	LEO 518 x 509 km 310 x 305 mi	197 kg 434 lb		SCIENCE Italian Launched (San Marco)
INTELSAT IVA (F-1)	22 May	ATLAS CENTAUR	GEO (Pacific)	1387 kg 3060 lb	700 kg 1543 lb	COMMUNICATIONS Last (8th) in series
NIM BUS 6	12 Jun	DELTA	LEO-Polar 1104 x 1097 km 662 x 658 mi	827 kg 1823 lb		Remote Sensing

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	GEO	REMARKS
OSO-8 (ORBITAL SOLAR OBSERVATORY)	21 Jun	DELTA	560 x 543 jn 336 x 326 mi	1088 kg 2398 lb		Science
COS-B (COSMIC RAY SATELLITE)	9 Aug	DELTA	POLAR-Elliptical 99002 x 442 km 59400 x 265 mi	277 kg 612 lb		SCIENCE ESA Equivalent to Geosynchronous Orbit
SYMPHONIE 2	27 Aug	DELTA	GEO	402 kg 886 lb		COMMUNICATIONS French/West German Satellite
ETS-1	9 Sep	N-I	LEO 1000 x 1000 km 600 x 600 mi	825 kg 182 lb		COMMUNICATIONS Japanese Sattelite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
INTELSAT IVA (F-1)	26 Sep	ATLAS CENTAUR	GEO (Atlantic)	1515 kg 3340 lb	826 kg 1820 lb	COMMUNICATIONS First New Series
EXPLORER 54 AE (Atmoshperic Explorer)	6 Oct	DELTA	LEO-POLAR 3816 x 154 km 2290 x 92 mi	675 kg 1488 lb		SCIENCE
TIPS-2 (TRANSIT IMPROVEMENT PROGRAM)	12 OCT	SCOUT	LEO-POLAR 699 x 357 km 419 x 214 mi	165 kg 364 lb		COMMUNICATIONS
GOES 1 (A) (GEOSTATIONARY OPERATIONAL ENVIRONMENTAL SATELLITE)	16 Oct	DELTA	GEO	628 kg 1384 lb	272 kg 600 lb	REMOTE SENSING

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
EXPLORER 55 AF	20 Nov	DELTA	LEO 3025 x 157 km 1815 x 94 mi	720 kg 1587 lb		SCIENCE
RCA-SATCOM-1	13 Dec	DELTA	GEO (PACIFIC)	868 kg 1914 lb	463 kg 1021 lb	COMMUNICATIONS
LANDSAT 2	22 Jan	DELTA	LEO-POLAR 917 x 907 km 550 x 544 mi	953 kg 2100 lb		REMOTE SENSING
SMS-2	6 Feb	DELTA	GEO	628 kg 1384 lb	272 kg 600 lb	REMOTE SENSING
GEOS 3 (C)	9 Apr	DELTA	LEO-POLAR 848 x 839 km 508 x 544 mi	340 kg 750 lb		REMOTE SENSING Ocean Observation

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
ANIK 3 (Telsat 3)	7 May	DELTA	GEO	544 kg 1200 lb	272 kg 600 lb	COMMUNICATIONS Canadian Satellite Last in a Series of 3
			1976			
CTS-1	17 Jan	DELTA	GEO	850 kg 1870 lb	355 kg 782 lb	COMMUNICATIONS Canadian/U. S. Satellite
INTELSAT IVA (F-2)	29 Jan	ATLAS CENTAUR	GEO (ATLANTIC)	1515 kg 3340 lb	826 kg 1820 lb	COMMUNICATIONS

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
MARISAT 1 (A)	19 Feb	DELTA	GEO (ATLANTIC)	317 kg 699 lb		COMMUNICATIONS Maritime Satellite (COMSAT)
ISS (IONOSPHERE SOUNDING SATELLITE)	29 Feb	N-I	LEO 1000 x 1000 kg 600 x 600 mi	141 kg 311 lb		SCIENCE Japanese Satellite
LES 8 and 9 (SOLRAD HiA, HiB)	15 Mar	TITAN III C	CIRCULAR 120,000 x 120,000 km 72,000 x 72,000 mi			COMMUNICATIONS Advanced Techniques Orbit beyond Geosynchronous Satellite not Considered

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
RCA SATCOM-2	26 Mar	DELTA	GEO	868 kg 1914 lb	463 kg 1021 lb	COMMUNICATIONS Second out of three Satellites
LAGEOS	4 May	DELTA	LEO-POLAR 5941 x 5844 km 3565 x 3506 mi	411 kg 906 lb		SCIENCE
			1976			
COMSTAR 1	13 May	ATLAS CENTAUR	GEO (PACIFIC)	1410 kg 3109 lb		COMMUNICATION Leased by ATT from COMSAT

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
P-76-5	22 May	SCOUT	LEO	130 kg 286		SCIENCE
MARISAT 2	10 Jun	DELTA	GEO (Pacific)	317 kg 699 lb		COMMUNICATIONS Maritime COMSAT
PALAPA 1	8 Jul	DELTA	GEO	572 lg 1268 lb		COMMUNICATIONS Indonesian Satellite
SESP 74-2	8 Jul	TITAN III C	GEO (not attained) 800 x 4800 km			SCIENCE ESA, Geosynchronous orbit not attained; Failure

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
COMSTAR 2	22 Jul	ATLAS CENTAUR	GEO	1410 kg 3109 lb		COMMUNICATIONS
NOAA 5 (ITOS H)	29 Jul	DELTA	LEO	340 kg 750 lb		REMOTE SENSING
TIP 3	1 Sep	SCOUT	LEO-POLAR 699 x 357 km 419 x 214 mi	165 kg 364 lb		COMMUNICATIONS
MARISAT 3	14 Oct	DELTA	GEO	317 kg 699 lb	317 kg 699 lb	COMMUNICATIONS Indian Ocean COMSAT

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
			1977			
ETS-2 (ENGINEER TEST SATELLITE)	23 Feb	N-I	GEO (103°E)	130 kg 287 lb		COMMUNICATIONS
PALAPA 2	10 Mar	DELTA	GEO	574 kg 1265 lb	281 kg 620 lb	COMMUNICATIONS Indonesian Satellite
INTELSAT IVA (F-4)	26 May	ATLAS CENTAUR	GEO (ATLANTIC)	1515 kg 3340 lb	826 kg 1830 lb	COMMUNICATIONS
GOES 2	16 Jun	DELTA	GEO	635 kg 1400 lb	235 kg 518 lb	REMOTE SENSING Weather Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
GMS 1 GEOSYNCHRONOUS METEROLOGICAL SATELLITE)	14 Jul	DELTA	GEO (160°E)	670 kg 1477 lb	280 kg 617 lb	REMOTE SENSING Japanese Satellite
HEAO 1 (HIGH ENERGY ASTRONOMICAL OBSERVATORY)	12 Aug	ATLAS CENTAUR	LEO-POLAR 455 x 435 km 273 x 261 mi	2560 kg 5643 lb		SCIENCE
SIRIO	25 AUG	DELTA	GEO	398 kg 877 lb	198 kg 437 lb	COMMUNICATIONS Italian Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
ISEE 1 (INTERNATIONAL SUN EARTH EXPLORER)	22 Oct	DELTA	ELLIPTICAL 138, 124 x 280 km 82874 x 168 mi	330 kg 728 lb		SCIENCE Orbit equivalent to geosynchronous orbit.
ISEE 2	22 Oct	DELTA	ELLIPTICAL 138, 330 x 279 km 82999 x 167 mi	158 KG 348 lb		SCIENCE
TRANSIT	28 Oct	SCOUT	LEO-POLAR 1106 x 1067 km 667 x 640 mi	94 kg 207 lb		COMMUNICATION
METEOSAT	23 Nov	DELTA	GEO	697 kg 1537 lbs	345 kg 760 lbs	REMOTE SENSING ESA

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
CS (SAKURA) (COMMUNICATIONS SATELITE)	15 Dec	DELTA	GEO	677 kg 1493 lbs	340 kg	COMMUNICATIONS
			1978			
INTELSAT IV A (F-3)	7 Jan	ATLAS CENTAUR	GEO (INDIAN OCEAN)	1515 kg 3340 lb	826 kg 1820 lb	COMMUNICATIONs
IUE (INTERNATIONAL ULTRAVIOLET EXPLORER)	26 Jan	DELTA	ELLIPTICAL 46081 x 174 km 27650 x 105 mi	700 kg 1543 lb 1543 lb		SCIENCE Equivalent to geosynehronus orbit
ISS-b	16 Feb	N-I	1000 x 1000 km 600 x 600 mi	141 kg 311 lb		SCIENCE Japanese Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
LANDSAT 3	5 Mar	DELTA	LEO 917 x 916 km 500 x 550 mi	900 kg 1984 lb		REMOTE SENSING
OSCAR 8	5 Mar	Same DELTA	LEO 941 x 906 km 565 x 544 mi	26.7 kg 59 lb		COMMUNICATIONS Amateur Radio Satellite
INTELSAT IVA (F-6)	31 Mar	ATLAS CENTAUR	GEO (INDIAN OCEAN)	1515 KG 3340 lb	826 kg 1820 lb	COMMUNICATIONS
BSE (BROADCAST SATELLITE EXPERIMENTAL)	7 Apr	DELTA	GEO (110°E)	635 kg 1900 lb	350 kg 772 lb	COMMUNICATIONS Japanese DBS Domestic Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
HCMM (HEAT CAPACITY MAPPING MISSION AEM-1)	26 Apr	SCOUT	LEO	65 kg 143 lb		REMOTE SENSING
OTS 2 (ORBITAL TEST SATELLITE)	11 May	DELTA	GEO	865 kg 1906 lb		COMMUNICATIONS ESA Domestic Satellite
GOES 3	16 Jun	DELTA	GEO	635 kg 1400 lb	235 kg 518 lb	REMOTE SENSING
SEASAT	27 Jun	ATLAS F	LEO	865 kg 1906 lb		REMOTE SENSING Ocean Observation Satellite
COMSTAR D-3	29 Jun	ATLAS CENTAUR	GEO	1484 kg 3722 lb		COMMUNICATIONS

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
GEOS 2	14 Jul	DELTA	GEO	575 kg 1268 lb		SCIENCE ESA
ISEE 3 (INTERNATIONAL SUN, EARTH EXPLORER)	12 Aug	DELTA	ELLIPTICAL 1,088,031 x 181 km 652,818 x 400 mi	479 kg 1056 lbs		SCIENCE Beyond the normal capabilities of small launcher
TIROS-N (NOAA)	13 Oct	ATLAS F	LEO-POLAR	734 kg 1618 lbs	90 kg 198 lb	REMOTE SENSING
NIMBUS 7	24 Oct	DELTA		954 x 954 km 572 x 572 mi	987 kg 2176 lb	REMOTE SENSING Last in Nimbus Series
HEAO 2	13 Nov	ATLAS CENTAUR	LEO-POLAR 455 x 435 km 273 x 261 mi	2560 kg 5640 lb		SCIENCE

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
ANIK 4 (TELESAT D)	16 Dec	DELTA	GEO	442 kg 974 lb		COMMUNICATIONS Canadian Satellite
			1979			
ECS 1 (EXPERIMENTAL COMMUNICATIONS SATELLITE)	6 Feb	N-I	GEO	131 kg 286 lb		COMMUNICATIONS Failure
SAGE	18 Feb	SCOUT	LEO	180 kg 397 lb		SCIENCE Aerosols/Ozone STUDY

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
SOLWIND P-78-1	24 Feb	ATLAS F	LEO	980 kg 2160 lb		SCIENCE Solar Wind Study
ARIEL 6	6 Jun	SCOUT	LEO	60 kg 130 lb		SCIENCE UK
NOAA 6	27 Jun	ATLAS F	LEO	838 kg 1948 ;b		REMOTE SENSING Similar to DOD Weather Satellite 2nd in Series
WESTAR 3	9 Aug	DELTA	GEO	1065 kg 2347 lb	572 kg 1261 lb	COMMUNICATIONS

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
HEAD 3	20 Sep	ATLAS CEMTAIR	LEO-POLAR 455 x 435 km 273 x 261 mi	2560 kg 5640 lb		SCIENCE
MAGSAT	30 Oct	SCOUT	LEO	113 kg 285 lb		SCIENCE
RCA SATCOM-3	2 Dec	DELTA	GEO	1082 2325 lb	576 kg 1269 lb	COMMUNICATIONS Failure, Contract lost
			1980			
SMM (SOLAR IMUM MISSION)	14 Feb	DELTA	LEO-POLAR 562 x 558 km 337 x 335 mi	2315 kg 5104 lbs		SCIENCE

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
ECS-b (EXPERIMENTAL COMMUNICATIONS SATELLITE)	22 Feb	N-I	GEO (1450°E)	310 kg 685 lbs	130 kg 287 lb	COMMUNICATIONS Failure (Japanese Satellite)
AMSAT-FIREWHEEL	23 May	ARIANE (L02)				COMMUNICATIONS Failure
NOAA-B	29 May	ATLAS F	LEO-POLAR 1028 x 250 km 617 x 150 mi	723 kg 1593 lb		Remote Sensing 3d in Series of 8 Placed in wrong orbit by launch vehicle. Replacement Required

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
ROHINI RS-1	18 Jul	SLV-3	LEO	34 kg 76 lb		SCIENCE Indian Satellite
GOES 4	9 Sep	DELTA	GEO (90^{0}W)	835 kg 1841 lb	495 kg 1091 lb	REMOTE SENSING First of three to replace initial three
SBS 1 (SATELLITE BUSINESS SYSTEMS)	15 Nov	DELTA	GEO (106°W)	1094 kg 2412 lb	555 kg 1224 lb	COMMUNICATIONS First to Use PAM D Upper Stage
INTELSAT V F2	6 Dec	ATLAS CENTAUR	GEO (ATLANTIC)	1928 kg 4250 lb		COMMUNICATIONS First of a series of nine

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
			1981			
ETS 4 (EXPERIMENTAL TECHNOLOGY SATELLITE)	11 Feb	N-II	GEO	640 kg 1411 lb		COMMUNICATIONS Japanese
COMSTAR D-4	21 Feb	ATLAS CENTAUR	GEO (127°W)	1484 kg 3272 lb		COMMUNICATIONS Last in series of 4. Leased to ATT by COMSAT
NOVA 1	15 May	SCOUT	LEO-POLAR 931 x 351 km 559 x 210 mi	167 kg 368 lb		COMMUNICATIONS Improved Transit

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
GOES 5	22 May	DELTA	GEO (75°W)	837 kg 1845 lb	444 kg 979 lb	REMOTE SENSE 2d of 3 to replace original 3. Failed in orbit July 29, 1984. GOES 6 moved to cover both coasts
INTELSAT V (F-1)	23 May	ATLAS CENTAUR	GEO (24.5°W)	1928 kg 4250 lb		COMMUNICATIONS
APPLE	19 Jun	ARIANE (L03)	GEO	670 kg 1477 lb		COMMUNICATIONS Indian Satellite
METEOSAT 2	19 Jun	(L03)	GEO (0°)	697 kg 1537 lb	295 kg 650 lb	REMOTE SENSING ESA

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
NOAA 7	23 Jun	ATLAS	LEO-POLAR 858 x 838 km 515 x 503 mi	723 kg 1594 lb		REMOTE SENSING Joined NOAA 6 2 Satellite System
DE1 (DYNAMICS EXPLORER 1)	3 Aug	DELTA	ELLIPTICAL/LEO- POLAR 24,770 x 671 km 14862 x 403 mi	424 kg 935 lbs		SCIENCE Similar to Geosynchronous orbit
DE2	3 Aug	Same DELTA	1002 x 304 km 601 x 182 mi	1876 kg 4136 lbs	1005 kg 2216 lb	SCIENCE Similar to Geosynchronous orbit.
GMS-2 (GEOSTATIONARY METEOROLOGICAL SATELLITE)	11 Aug	N-II	GEO (120°W)	296 kg 652 lb		REMOTE SENSING Japanese Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
SBS 2	3 Sep	DELTA	GEO (97°W)	1094 kg 2410 lb	555 kg 1224 lb	COMMUNICATIONS Second of Four
SME (SOLAR MESOSPHERIC EXPLORER)	6 Oct	DELTA	LEO-POLAR 534 x 530 km 320 x 318 mi	145 kg 320 lb	437 kg 963 lb	SCIENCE
UOSAT (OSCAR 9)	6 OCt	Same DELTA	LEO-POLAR 533 x 531 kg 320 x 319 mi	50 kg 111 lb		COMMUNICATIONS Swedish Satellite
RCA SATCOM 3-R	20 Nov	DELTA	GEO (131°W)	1082 kg 2385 lb		COMMUNICATIONS Replacement for SATCOM 3
INTELSAT V (F-3)	15 Dec	ATLAS CENTAUR	GEO (25°W)	1928 kg		COMMUNICATIONS Third of Series of Nine

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
MARCES A	20 Dec	ARIANE (L04)	1000 kg 2400 lb	590 kg 1300 lb	ESA	COMMUNICATIONS
			1982			
LANDSAT 4	16 Jul	DELTA	LEO 638 x 700 km 410 x 420 mi	1938 kg 4272 lb		REMOTE SENSING Solar panel problem. Not enough power for thematic mapper.
ANIK D-1	26 Aug	DELTA	GEO	1238 kg 2730 lb	660 lbs 1455 lb	COMMUNICATIONS In orbit spare. Canadian Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
ETS III	3 Sep	N-I	LEO 1000 x 1000 km 600 x 600 mi	358 kg 789 lb		COMMUNICATIONS
MARCES B	10 Sep	ARIANE 1 (L5)				COMMUNICATIONS Launch Vehicle failure
SIRIO	10 Sep	ARIANE 1 (L5)				SCIENCE Italian Satellite
INTELSAT V (F-5)	28 Sep	ATLAS CENTAUR	GEO (INDIAN OCEAN)	1928 kg 4250 lb		COMMUNICATIONS Fifth of Nine Satellites
RCA-SATCOM 5 (AURORA)	27 Oct	DELTA	GEO	1082 kg 2385 lb	589 kg 1298 lb	COMMUNICATIONS Joined four Operational Satellites

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
RCA SATCOM 4	16 Jan	DELTA	GEO	1082 kg 2385 lb		COMMUNICATIONS
WESTAR 4	26 Feb	DELTA	GEO	1094 kg 2410 lb	555 kg 1224 lb	COMMUNICATIONS First Second Generation Satellite
INTELSAT V (F-4)	5 Mar	ATLAS CENTAUR	GEO (PACIFIC)	1928 kg 4250 lb		COMMUNICATIONS
INSAT 1A	10 Apr	DELTA	GEO	1152 kg 2539 lb		REMOTE SENSING Indian Satellite
WESTAR 5	9 Jun	DELTA	GEO	1094 kg 2385 lb		COMMUNICATIONS Replaced Webster 2

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
SBS 3	11 Nov	SHUTTLE (PAM D)	GEO	4541/1094 kg 10010 lb	555 kg 1224 lb	COMMUNICATIONS Third of a Series of Four Satellites
ANIK C-3	12 Nov	SHUTTLE (PAM D)	GEO	4443/996 kg 9790 lb	1238 kg 2728 lb	COMMUNICATIONS Second in Series
			1983			
IRAS (INFRARED RADIATION ASTRONOMICAL SATELLITE)	26 Jan	DELTA	LEO-POLAR 911 x 894 km 547 x 536 mi	1076 kg 2372 lb		SCIENCE Dutch, U.S., and U.K. Satellits

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
CS 2a (COMMUNICATIONS SATELLITE)	4 Feb	N-II	GEO (132^{o}E)	840 kg 1850	350 kg 772 kb	COMMUNICATIONS
ASTRO B	20 Feb	MU-3S	LEO	216 kg 476 lb		SCIENCE
NOAA 8	28 Mar	ATLAS E	LEO-POLAR 829 x 806 km 497 x 484 mi	1712 kg 2774 lb	1030 kg 2271 lb	REMOTE SENSING Advance TIROS-N turned off after battery explosion Dec 30, 85.
TDRS 1 (TRACKING AND DATA RELAY SATELLITE)	4 Apr	SHUTTLE (IUS)	GEO (67^{o}W)	20,308/5652 44,771		COMMUNICATIONS

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
RCA-SATCOM 6	11 Apr	DELTA	GEO (128°W)	2802 kg 2385 lb	598 kg 1320 lb	COMMUNICATIONS Second in new series.
GOES 6	28 Apr	DELTA	GEO (135°W)	838 kg 1847 lb	444 kg 979 lb	REMOTE SENSING
INTELSAT-V (F-6)	19 May	ATLAS CENTAUR	GEO (ATLANTIC)	1996 kg 4400 lb		COMMUNICATIONS
EXOSAT	26 May	DELTA	ELLIPTICAL 189,834 x 2178 km 113,900 x 1307 mi	500 kg 1102 lb		SCIENCE ESA Similar to Geosynchronous Orbit
ECS-1 (EUROPEAN COMMUNICATIONS SATELLITE)	16 Jun	ARIANE (L6)	GEO	1345 kg 2965 lb		COMMUNICATIONS

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
OSCAR	16 Jun	Same ARIANE (L6)	LEO	130 kg 286 lb		COMMUNICATIONS
ANIK C-2	18 Jun	SHUTTLE (PAM D)	GEO	4443 kg 9795 lbs		COMMUNICATIONS Canadian Satellite
PALAPA B-1	18 Jun	SHUTTLE (PAM D)	GEO	4443/1996 kg 9795 lbs		Communications Identical to ANIK C-2 Indonesian Satellite
SPAS 01 (SHUTTLE PALLET SATELLITE)	18 Jun	SHUTTLE	LEO 296 x 296 km 178 x 178 mi	1448 kg		MATERIAL PROCESSING Deployed and retrieved by German Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
GALAXY 1	28 Jun	DELTA	GEO (135°W)	1222 kg 2690 lb	519 kg 1144 lb	COMMUNICATIONS Hughes Communications INC.
TELSTAR 3A	28 Jul	DELTA	GEO (87°W)	1250 kg 2750 lb	653 kg 1440 lb	COMMUNICATIONS ATT
CS 2b	6 Aug	N-II	GEO (136°E)	770 kg 1695 lb	350 kg 772 lb	COMMUNICATIONS Japanese Satellite
INSAT 1B	30 Aug	SHUTTLE (PAM D)	GEO (74°E)	4596/1150 kg 10132 lb		COMMUNICATIONS Indian Satellite
RCA SATCOM 7	8 Sep	DELTA	GEO (72°W)	1082 kg 2305 lb	598 kg 1320 lb	COMMUNICATIONS Replaces SATCOM 2

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
GALAXY 2	22 Sep	DELTA	GEO (74°W)	1222 kg 2690 lb	519 kg 1144 lb	COMMUNICATIONS Hughes Communications Inc 2nd in Series of 3
INTELSAT V-F7	19 Oct	ARIANE (L7)	GEO	1996 kg 4440 lb		COMMUNICATIONS
			1984			
BS-2a (BROADCAST SATELLITE)	23 Jan	N-II	GEO (110°E)	770 kg 1697 lb	350 kg 772 lb	COMMUNICATIONS Japanese Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
WESTAR-6	3 Feb	SHUTTLE (PAM)	(GEO)-LEO 1220 x 307 km 732 x 184 mi	4443 kg 9795 lb	630 kg 1389 lb	COMMUNICATIONS PAM failure. Placed satellite in wrong orbit. Later retrieved.
PALAPA-B2	3 Feb	SHUTTLE (PAM)	(GEO)-LEO 1190 x 280 km	4443 9795	630 lb 1389 lb	COMMUNICATIONS PAM Failure. Later retrieved.
EXOS C	14 Feb	MU 3S	LEO	265 kg 584 lb		SCIENCE Japanese satellite.

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
LANDSAT 5	1 Mar	DELTA	LEO-POLAR 700 x 699 km 420 x 419 mi	1947 kg 4292 mi		REMOTE SENSING
UOSAT-2	1 Mar	Same DELTA	694 x 673 km 416 x 403 mi	60 kg 133 lb		COMMUNICATIONS University of Surrey, U.K.
INTELSAT V (F8)	5 Mar	ARIANE (V8)	GEO	1996 kg 4400 lb		COMMUNICATIONS
LDEF 1 (LONG DURATION EXPOSURE FACILITY)	6 Apr	SHUTTLE	483 x 473 km 293 x 284 mi	9670 kg 21318 lb		MATERIAL PROCESSING Released by Shuttle to be picked up by a later shuttle flight.

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
SPACENET F-1	23 May	ARIANE (V 9)	GEO	1190 2623		COMMUNICATIONS
INTELSAT V (F-9)	9 Jun	ATLAS CENTAUR	LEO (GEO) 1220 x 223 km 732 x 134 mi	2016 kg 4444 lb		COMMUNICATIONS Launched into wrong orbit. Decayed October 19 '83 Failure.
GMS 3	3 Aug	N-II	GEO (140^{o})1	296 kg 652 lb		COMMUNICATIONS
ECS 2	4 Aug	ARIANE (V10)	GEO	1345 kg 2965 lb		COMMUNICATIONS
TELECOM 1A	4 Aug	Same ARIANE	GEO	1210 kg 2667 lb		COMMUNICATIONS French Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
CCE (CHARGE COMPOSITON EXPLORER)	16 Aug	DELTA	ELLIPTICAL 49663 x 1130 km 29798 x 778 mi	650 kg 1432	242 kg 534 lb	SCIENCE Equivelent to Geosynchronous orbit
IRM (ION RELEASE MODULE)	16 Aug	SAME DELTA	ELLIPTICAL 113741 x 553 km 68245 x 332 mi	705 kg 1554 lb		SCIENCE West German Satellite Equivalent to GEO
UKS (UNITED KINGDOM SATELLITE)	16 Aug	SAME DELTA	13741 x 553 km 68245 x 332 mi	77 kg 170 lb		SCIENCE U.K. Satellite Equivelent to GEO
SBS 4	30 AUG	SHUTTLE (PAM)	GEO	4541/1094 kg 10010 lb		COMMUNICATIONS

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
SYNCOM IV-2 (LEASAT-2)	30 Aug	SHUTTLE	GEO	6889/2000 kg 15187 lb		COMMUNICATIONS Hughes Communications Inc. Lease to U.S. Navy
TELSTAR 3-C	30 Aug	SHUTTLE	GEO	4697 kg 10300 lb		COMMUNICATIONS ATT
GALAXY 3	21 Sep	DELTA	GEO (93.5°W)	1222 kg 2690 lb	519 kg 1144 lb	COMMUNICATIONS Hughes
ERBS (EARTH RADIATION BUDGET SATELLITE)	5 Oct	SHUTTLE	LEO 608 x 598 km 365 x 359 mi	2250 kg 4960 lb		SCIENCE One of 3 satellite system with NOAA-9 and NOAA-G

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
NOVA 3	12 Oct	SCOUT	LEO 1198 x 1152 km 719 x 691	167 kg 268 lb		COMMUNICATION Navigation Satellite
ANTK D-2	8 Nov	SHUTTLE PAM	GEO (111.5°W)	4676/1229 kg 1030 lb	730 kg 1609 lb	COMMUNICATIONS
SYNCOM IV-1	8 Nov	SHUTTLE	GEO	6889/2200 kg 15187 lb		COMMUNICATION Hughes Communications Company. Leased by Navy.
SPACENET F2	10 Nov	ARIANE (V 11)	GEO	1190 kg 2623 lb		COMMUNICATION
MARCES B2	10 Nov	ameE ARIANE	GEO	1000 kg 2205 lb		COMMUNICATION

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
NOAA 9	12 Nov	ATLAS E	LEO-POLAR 862 x 841 km 517 x 504 mi	1712 kg 3774 lb		REMOTE SENSING Replaced NOAA-7
			1985			
ARABSAT F-1	8 Feb	ARIANE (V12)	GEO	675 kg 1490 lb		COMMUNICATIONS Arab League Satellite
SBTS-1 (BRASILSAT)	8 Feb	Same ARIANE	GEO	675 kg 1490 lb		COMMUNICATIONS Brazilian Satellite
INTELSAT V (F9)	22 Mar	ATLAS CENTAUR	GEO	2014 kg 4441 lb		COMMUNICATIONS
ANIK C-1	12 Apr	SHUTTLE (PAM)	GEO	4443/996 kg 9795 lb	1000 kg 2205 lb	COMMUNICATIONS

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
SYNCOM IV (LEASAT F3)	12 Apr	SHUTTLE	(GEO) LEO	7500/2200 kg 16534 lb	1300 kg 2866 lb	COMMUNICATIONS Failure - LEO achieved. Repaired on a latter Shuttle mission.
GSTAR 1	7 May	ARIANE (V13)	GEO	1230 kg 2712 lb	700 kg 1543 lb	COMMUNICATIONS
TELECOM 1B	7 May	Same ARIANE	GEO	1210 kg 2667 lb	690 kg 1521 lb	COMMUNICATIONS
MORELOS A	17 Jun	SHUTTLE (PAM)	GEO	4112/665 kg 9066 lb	512 kg 1128 lb	COMMUNICATIONS Mexican Satellite
ARABSAT A	17 Jun	SHUTTLE (PAM)	GEO	4122/675 kg 9085 lb	592 kg 1305 lB	COMMUNICATIONS Arab League Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
TELSTAR 3D	17 Jun	SHUTTLE	GEO	4697/1250kg 10300 lb	630 kg 13889	COMMUNICATIONS
SPARTAN	17 Jun	SHUTTLE	LEO	1008 kg 2222 lb		MATERIAL PROCESSING
GIOTTO	2 Jul	ARIANE 1 (V 14)	ELLIPTICAL	960 kg 2116 lb	512 kg 1128 lb	SCIENCE Halley's Comet probe. Not considered.
AUSSAT 1	27 Aug	SHUTTLE (PAM)	GEO	4180/733 kg 9215 lb		COMMUNICATIONS Australian Satellite
ASC-1 (AMERICAN SATELLITE COMPANY)	27 Aug	SHUTTLE (PAM)	GEO	4180/673 kg 9080 lb		COMMUNICATIONS

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	GEO	REMARKS
SYNCOM V (LEASAT F-4)	27 Aug	SHUTTLE	GEO	4443/2200 kg 9795 lb		COMMUNICATIONS
SPACENET F3	12 Sep	ARIANE (V15)	GEO			COMMUNICATIONS Launch failure
ECS-3 (EUTELSAT)		Same ARIANE	GEO			COMMUNICATIONS Launch failure
MORELOS B	26 Nov	SHUTTLE PAM	GEO	4112/1665 kg 9066 lb	COMMUNICATIONS 1128 lb	HS-376 (Mexican Satellite)
AUSSAT 2	26 Nov	SHUTTLE PAM	GEO	4180/733 kg 9215 lb		COMMUNICATIONS Australian Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
SATCOM KU-2	26 Nov	SHUTTLE PAM DS	GEO	6855/1200 kg 9797 lb		COMMUNICATIONS
			1986			
SATCOM KU-1	12 Jan	SHUTTLE	GEO	6855/1200 kg 979 lb		COMMUNICATIONS
SPOT	21 Feb	ARIANE (V16)	LEO	1540 kg 3395 lb		REMOTE SENSING French Satellite
VIKING	21 Feb	Same ARIANE	GEO	1179 kg 2600 lb		COMMUNICATIONS Swedish Satellite
BRASILSAT 2	29 Mar	ARIANE	GEO	675 kg 1490 lbs		COMMUNICATIONS Brazilian Satellite

SPACECRAFT	DATE	LAUNCH VEHICLE	ORBIT	WEIGHT LAUNCH	WEIGHT GEO	REMARKS
INTELSAT 5 (F14)	30 May	ARIANE 2 (V18)	GEO	2014 kg 4440 lb		COMMUNICATIONS Launch failure

APPENDIX E Description of Satellite Operations

The mathematics involved with the celestial mechanics governing the path of satellites in the orbits is very complex. Accordingly the quantitative approach to space flight will be avoided in favor of providing a general understanding of the terminology and operations involved in placing payloads in their appropriate orbit.

In this study the terms weight and mass will be used interchangeably. Technically, they are not the same. Weight is the force exerted by gravity on an object. The same object would have a different weight on the moon than it would have on earth. Mass is used to specify how much matter is contained in an object. This is a hard term to visualize but a Shuttle astronaut in space repairing a 700 kilogram (1540 pound) satellite can appreciate the difference in terms. While the satellite is weightless it still has mass. When at rest in a weightless environment it takes a considerable force to move it and when it is moving, even slowly, it cannot be easily stopped.

Low earh orbit (150 to 4000 kilometers above the earth) is relatively easy to achieve by all launch vehicles. The trajectory to low earth orbit carries the vehicle above the atmosphere where it gradually flattens until a velocity of approximately 18,000 miles per hour achieved and the satellites fall matches the slope of earth.

Numerous factors must be considered and will influence the type of orbit achieved by a satellite. A polar orbit or one crossing both poles causes the object to eventually overfly the entire globe since the earth rotates as the satellite flys over it. This orbit has the added advantage for an earth observation satellite if timed right of always allowing it and the ground underneath it to remain in sunlight (sun synchronous orbit). To achieve polar orbit a price must be paid. A polar launch is only 70-80% as efficient as a launch on or near the equator.

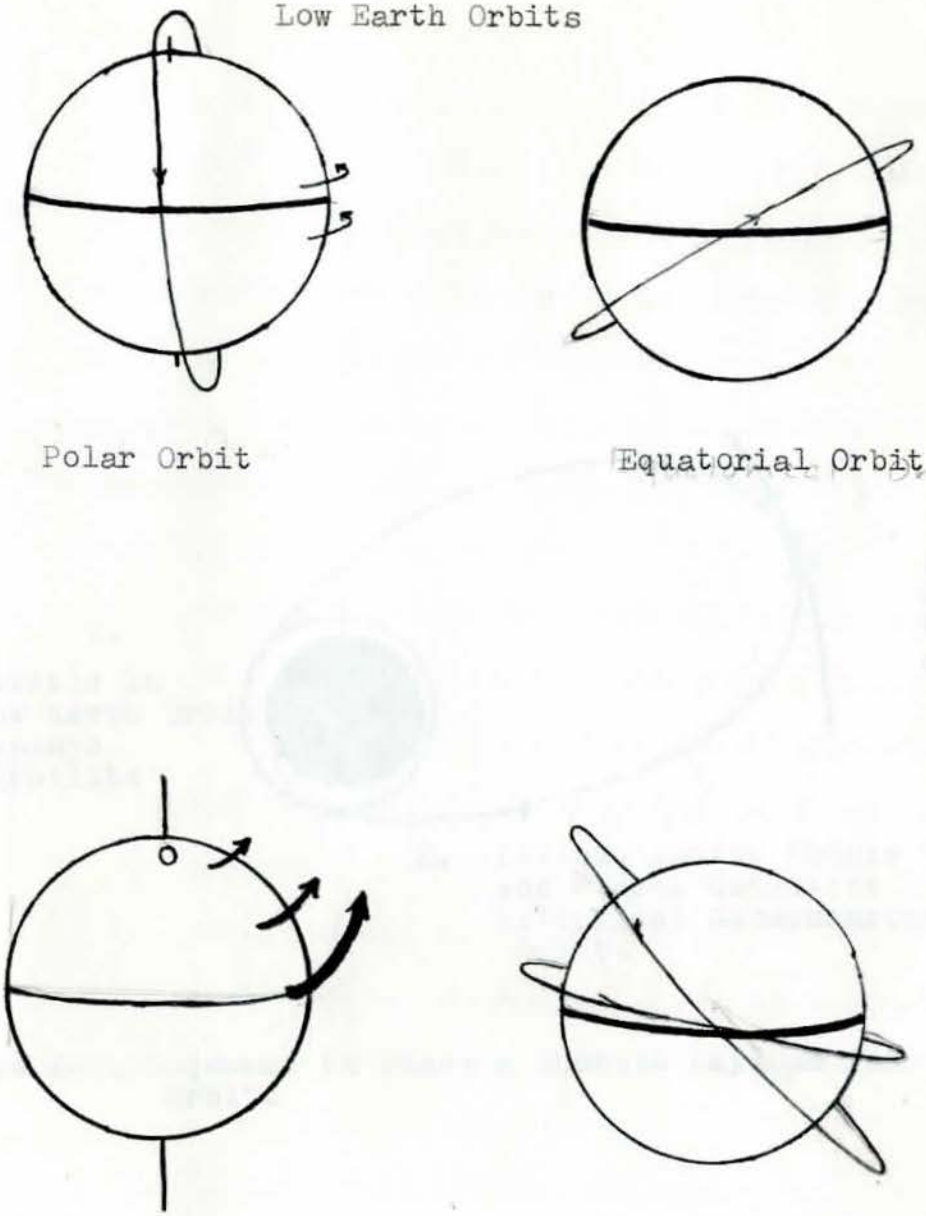
Another important point is that the closer a launch site is to the equator the greater the efficiency and flexibility of unches. There are two major reasons for this. First, the angular velocity of the earth's rotation is greatest at the equator. The French Ariane which is launched at French Guiena 5 degrees north of the equator receives a considerable boost from the earth's rotation. Secondly, the latitude determines the minimum inclination the equator normally achievable by a satellite without having to orbit a large rocket to change this inclination. As an example the launch site at French Guinea (5^{o} latitude) can orbit satellites from 5^{o} to 90^{o} inclination, Kennedy Space Center (27^{o} latitude) 27^{o} to 90^{o} inclination, and the Soviet Zyurentam (55^{o} latitude) 55^{o} latitude) 55^{o} to 90^{o} inclination (this made it far more difficult for the Soviets to reach the moon which is inclined near 20^{o} to the equator).

Most of today's satellites are launched into geosynchronous orbit. The satellite travels at the same speed as the Earth's rotation, keeping the satellite over the same area of Earth's surface. This type of orbit benefits communications satellites which earlier had moved away from the earth station using them as it traveled along its orbit. Weather satellites serving a specific area also use this orbit. To attain a 36,000 kilometer (21,600 mile) circular geosynchronous orbit several space maneuvers are required.

Most ELVs place the satellite in an elliptical (200 x 36,000 kilometer) rather than low earth orbit. This is called a geosynchronous transfer orbit (GEO1). The satellite revolves around the Earth one or more times before a rocket motor contained within the satellite (apogee motor) is ignited at the high point of its orbit (A). This boost will place it in the final geosynchronous orbit. The Shuttle uses a slightly different method in placing satellites into geosynchronous orbit. It first achieves low earth orbit and then deploys the satellites with a rocket motor called a payload assist module (PAM) attached to the exterior of the satellite. At the appropriate point in low earth orbit this motor is fixed placing the satellite in a geosynchronous transfer orbit. The PAM is detached and like earlier the apogee motor within the satellite is used at the far point of the transfer orbit to place the satellite in geosynchronous orbit.

The mass of the satellite decreases significantly during the transition from its launch on Earth to its final orbit. As much as 3/4 of its mass may be taken up by the apogee motor and the fuel to make the fine adjustments to place it in its final orbits.

Low Earth Orbits



Polar Orbit

Equatorial Orbit

Eqatorial Launches Receive a Significant Boost From the Earth's Rotation

Launch Sites Far From the Equator are Limited to High Inclination Orbits

Figure E-1. Types of Orbits.

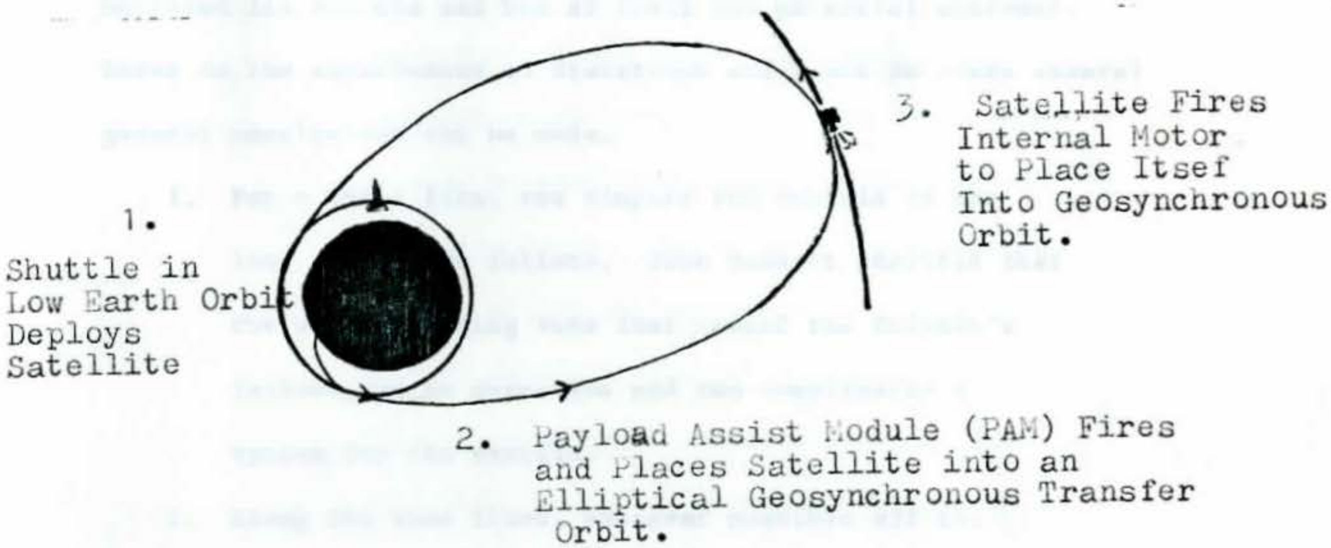


Figure E-2. Sequence to Place a Shuttle Payload into Geosychronous Orbit.

APPENDIX F The Model Firm

Space Services stands the best chance for surviving as a small launch firm for while it has not launched a single customer's payload it was the first and is still the only firm to have gotten permission from the US Government to launch a private launch vehicle and succeeded in launching it. It has also marketed its vehicle and has at least one potential customer. Based on the experiences of Starstruck and Space Services several general conclusions can be made.

1. For a small firm, the simpler the vehicle is the less chance for failure. John Bennett admitted that the stuck steering vane that caused the Dolphin's failure was an expensive and too complicated a system for the vehicle.
2. Along the same lines, whenever possible off the shelf components which have proven themselves should be used. Major components can be subcontracted for to cut costs of development.
3. Launch operations should be simple. Water launch caused problems for Starstruck.
4. If a private launch site which meets all the requirements set forth by the government along with the necessary support cannot be established then the national ranges should be used.
5. Analysis of the market and its dynamic nature may reveal opportunities with potential.

The hypothetical firm has the following characteristics which reflect some of the features of Starstruck Incorporate. Space Services Incorporated and the American Rocket Company.

Product: The launch vehicle would incorporate characteristics of both AMROC's ILV and SSI's Conestoga. Like the Conestoga it would use off the shelf components. The launcher would have three stages which would be able to place 2600 pounds (1180 kg) into low earth orbit. The vehicle would have the ability to improve performance through the use of additional rocket components much like the Conestoga. Eventually it might have the capability of placing 500 pounds into geosynchronous orbit.

Market: All low orbit satellites light enough to be launched by this vehicle. Geosynchronous satellites may be orbited with an upgrading and addition of rocket components. This vehicle could also be used to orbit material processing payloads significantly larger than NASA's Getaway Special. If General Electric can commercially market the same technology and process it used to recover military satellite film then this would prove a viable means of recovering processed material in small quantities until the Shuttle becomes operational ("GE Displays model of Space Recovery Vehicle", Aviation Week and Space Technology, 1986).

Operations: The average launch rate would be six flights a year from a national launch range. Three launches would occur the first year.

Venture and Other Forms of Capital Raised = $53 million - based on American Rocket Company, ("American Rocket Company tests 6000 lb Thrust Engine", Aviation Week and Space Technology, 1986).

According to maintain a viable operation a minimum of four flights a year must occur to meet variable and fixed costs. (AMROC-8, SSI-4, PAL-2).

For a firm similar to Space Services Incorporated the costs would be as follows:

Vehicle Cost:

1. Component Cost (Rocket Motors)

Morton Thiokal Castor 4h	- $1.7 million
Morton Thiokal Star 48	- $3.0 million
Morton Thiokal Star 30	- $1.6 million
Guidance System,	- $ .3 million
Airframe and	
Miscellaneous Components	

2. Cost by configuration

	Vehicle Derivative (Conestoga)		
Components	II	III	IV
Caster 4H	3	4	5
Star 48	1	1	1
Star 30	1	1	1
Other Components	1	1	1
Total Cost ($ Million)	10	11.7	13.4

Anticipated Flight Rates (From SSI)

		Vehicle Derivative		
Year	Launch Rate	II	III	IV
1	3	2	1	
2	6	2	4	
3	8	2		4

Price

Vehicle	Price	Payload
Conestoga II	$12.5 Million	945 lb
Conestoga III	$13.1 Million	1100 lb
Conestoga IV	$16.0 Million	2000 lb

Gross Profit

	Sales Revenue		Costs		Gross Profit
Year 1 -	$ 38.1 Million	-	$31.7 Million	=	$ 6.4 Million
Year 2 -	$ 77.4 Million	-	$66.8 Million	=	$10.6 Million
Year 3 -	$115.2 Million	-	$97.0 Million	=	$18.2 Million