Industrial Assessment for Space Launch Vehicles

January 1995

PREFACE AND ACKNOWLEDGMENTS

Victory in the Cold War era has brought significant changes to the defense industry. Since the peak year in 1985, the defense procurement and research, development, test, and evaluation budgets have declined by more than 50 percent in real terms. Defense suppliers have responded to these cuts in predictable ways. Factories have been restructured, reduced, or closed. Skilled personnel have been laid off. Some firms have merged or restructured; others have abandoned defense production entirely, and still others threaten to follow that course. These changes are vitally important to the Department. DoD risks losing some essential design and production capabilities as suppliers adjust to lower defense budgets. The Department must be able to identify and, if necessary, preserve these capabilities. However, the Department neither can nor should attempt to preserve all capabilities. To do so would draw funds away from readiness and modernization.

The Department has begun a series of industry studies to identify and analyze industrial concerns and to form the basis for budget and program decisions. This report describes the results of one of those studies--the Department's assessment of the space launch vehicle industry.

This study was directed by Mr. John Goodman, Deputy Assistant Secretary of Defense for Industrial Affairs. The Department would especially like to acknowledge the contributions of James Carlson, Charles Cook, Seth Sulkin and others of the Institute for Defense Analyses whose initial work formed the foundation for the report and who were repeatedly called upon to research specific issues. Gary Powell and Dennis Granato of the Office of the Secretary of Defense were instrumental in organizing and refining both early drafts and the final presentation of the report. Blaise Durante, Col. Charles Banta, and Col. Terry Talbott of the Department of the Air Force provided invaluable expertise and guidance. The Department of Defense's Martin Meth, David Hickman, John Turek, Arv Nadkarni, and Tim Maza also provided essential technical guidance and support. Other individuals within U.S. Air Force systems program organizations and the space launch industry--too numerous to list here--made invaluable contributions to the assessment process.

We welcome comments on this report. Please address them to Mr. John Goodman, Deputy Assistant Secretary of Defense (Industrial Affairs), 3300 Defense Pentagon, Washington, DC 20301-3300.

Joshua Gotbaum
Assistant Secretary of Defense (Economic Security)

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EXECUTIVE SUMMARY

The Department of Defense (DoD) uses a wide variety of satellites to carry out its responsibilities. These range from weather and navigation to communications and surveillance. To place satellites into orbit, the Department relies upon a range of different expendable launch vehicles, currently supplied by three prime contractors (Martin Marietta, McDonnell Douglas, and Orbital Sciences Corporation). All three firms are profitable. In addition, other manufacturers have begun investing in new vehicles to be used for commercial launches beginning in 1995. For the foreseeable future, the Department expects industrial space launch capabilities will be adequate to meet its needs. Additionally, DoD is supporting the development of a new evolved family of launch vehicles to reduce costs and ensure adequate space launch capability in the next century.

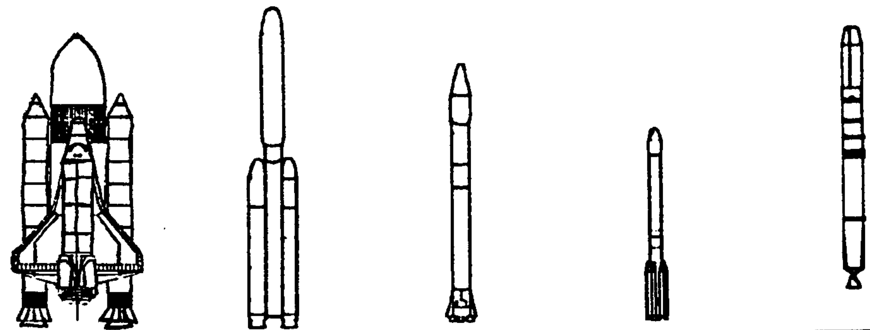
This report summarizes our analysis of this industry. It relies upon the many previous studies undertaken by DoD and others (which are listed at the end of this section).

A. SPACE LAUNCH VEHICLES

Space launch vehicles are usually classified as "large", "medium", or "small," depending on the weight of the payload they can put into orbit. The DoD uses expendable launch vehicles (ELVs) for all three vehicle classifications. The reusable Space Shuttle, managed by NASA, provides an additional capability. Table ES-1 provides information on the nine U.S. launch vehicles that are currently, or will soon be, in service. Not all are used by DoD.

The large class consists of the Titan IV ELV for heavy DoD payloads and the Space Shuttle for NASA's scientific payloads. The Space Shuttle could be used as an alternative for some heavy DoD payloads, but modifying payloads to use the Shuttle is technically difficult, time consuming, and costly. Additionally, some payloads are too large for the Shuttle or require orbital insertions not available from the Shuttle. ELVs are the primary vehicles used by DoD to place payloads into orbit. This assessment therefore focuses on ELVs and the prime contractors that produce them.

Table ES-1. U.S. Launch Vehicles



Launch Vehicle	Space Shuttle	Titan IV	Atlas I,II,IIA,IIAS	Delta II	Titan II
Class	Large	Large	Medium	Medium	Medium
Overall Length	184 ft	204 ft	156 ft	125 ft	141 ft
Lift-Off Mass	4,493,392 lb	1,900,000 lb	361,872-535,242 lb	510,726 lb	341,410 lb
Performance (LEO[i])	53,500 lb	39,000 lb	13,000-19,050 lb	11,110 lb	4,500 lb
Performance (GTO[ii])	12,995 lb	14,000	5,240-8,450 lb	4,057 lb	N/A
Maximum Flight Rate[iii]	8/year[a,b]	6-8/year[a]	14/year[d]	12/year[a,b,d,f]	3/year[a,b,e,f]
Mission Success Rate	98.4%[c]	90%[c]	50-100%[iv, c]	100%[c,e]	100%[c,e]
Launch Cost	$375M[b]	$200-350M[c]	$65-120M[c,e]	$50-60M[c]	$45M[c]
Primes	Rockwell International	Martin Marietta	Martin Marietta	McDonnell Douglas Aerospace	Martin Marietta

i LEO - low earth orbit

ii GTO - geosynchronous transfer orbit

iii Limited by launch site infrastructure and processing.

iv The range of mission success rates reflects differences among specific vehicle models.

Sources:

a 1993 Space Launch Activities, Space Technology Division Note IADN 94-4, ANSER.

b *Space Launch Modernization Plan* (Draft), U.S. Department of Defense, Technical Panel, Annex C, May 1994.

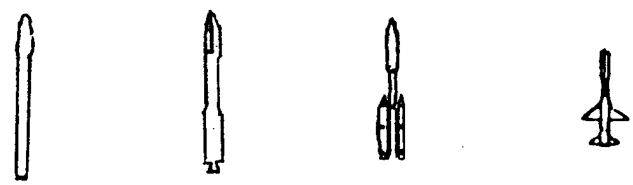
c Launch Vehicle Systems Design & Engineering Course Notes, Applied Technology Institute, September 1994.

d *Report of the Commercial Expendable Launch Vehicle Industry Technology Panel,* IDA Paper P-2981, May 1994.

e *International Reference Guide to Space Launch Systems,* S.J. Isakowitz, AIAA.

f 1992 Space Launch Activities, Space Technology Division Note STDN 93-2, ANSER.

Table ES-1. (continued)



Launch Vehicle	LLV[v]	Taurus	Conestoga[v]	Pegasus Std, XL
Class	Medium/Small	Small	Small	Small
Overall Length	100 ft	90.25 ft	51.5 ft	51-56 ft
Lift-Off Mass	N/A	180,000 lb	191,528 lb	42,000-51,000 lb
Performance (LEO)	2,000 - 8,000 lb	3,200 lb	3,300 lb	731-1021 lb
Performance (GTO)	N/A	987 lb	N/A	80-105 lb
Maximum Flight Rate	N/A	3/year[d,e]	12/year[h]	12/year[d,e]
Mission Success Rate	N/A	100%[c]	N/A	86%[g]
Launch Cost	$16-27M Advertised	$15-20M[c]	$20-25M[c]	$12-15M[c]
Primes	Lockheed	OSC	EER Systems	OSC

v First launch scheduled for 1995.

Sources:

c Launch Vehicle Systems Design & Engineering Course Notes, Applied Technology Institute, September 1994.

d *Report of the Commercial Expendable Launch Vehicle Industry Technology Panel*, IDA Paper P-2981, May 1994.

e *International Reference Guide to Space Launch Systems*, S.J. Isakowitz, AIAA.

g *Space News*, July 4-10, 1994.

h Contractor data.

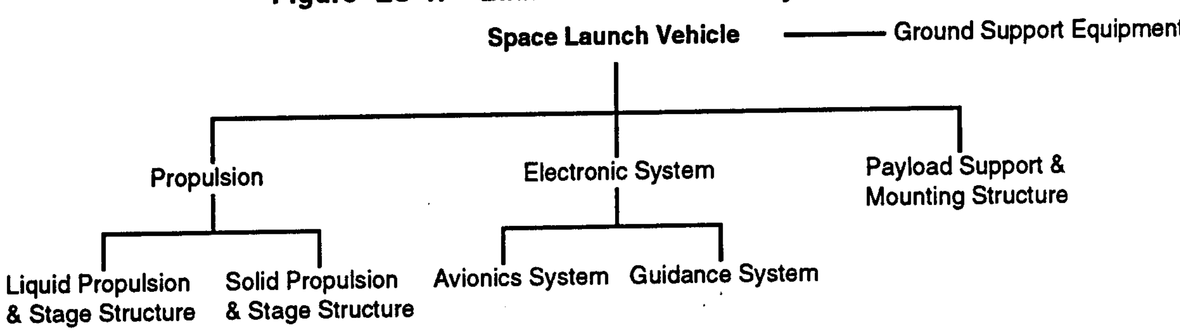
The medium class includes two primary launchers: Atlas in the upper weight end and Delta in the lower end. These systems are used in the majority of DoD and commercial launches, as well as a significant set of civil--i.e., non-DoD U.S. Government agency (NASA or NOAA)--missions. Decommissioned Titan II intercontinental ballistic missiles (ICBMs) also have been used for selected medium-weight DoD and civil missions.

The small class includes vehicles that DoD developed for flexible launch of light payloads (Pegasus and Taurus) and vehicles that companies are developing on their own initiative to take advantage of potentially significant increases in the demand for small civil and commercial satellites (Conestoga and Lockheed Launch Vehicle).

Launch systems are composed of six basic subsystems: liquid propulsion and stage structure, solid propulsion and stage structure, avionics, guidance, payload support and mounting structure, and ground support equipment. (See Figure ES-1). Normally, these subsystems are used on all launch vehicles. Most launch vehicles utilize similar technologies, processes, and suppliers. They do, however, vary in propulsion systems. Large and medium ELVs generally use a combination of liquid and solid propulsion systems. The solid propulsion systems provide thrust augmentation as strap-on boosters. Small ELVs use only solid propulsion systems.

ELVs were originally developed from early ballistic missile designs. Consequently, ELVs and ballistic missiles use many of the same technologies to transport payloads into space. Many ELV component producers also produce subsystems or components for ballistic missiles.

Figure ES-1. Launch Vehicle Subsystems



The space launch industry is predominantly "dual-use." That is, similar or identical technologies are used in both defense and commercial systems. Most ELVs were originally designed and produced to meet DoD requirements. The first ELV carrying a commercial payload was launched in 1967. Since then, launch technology has been advanced through both government and corporate research and development. The same launch vehicles are used for both government and commercial customers. Since the DoD is responsible for almost all demand for heavy payloads and much of the demand for medium payloads, however, medium and large ELV manufacturers probably would not be viable without U.S. government purchases.

B. THE SPACE LAUNCH VEHICLE MARKET

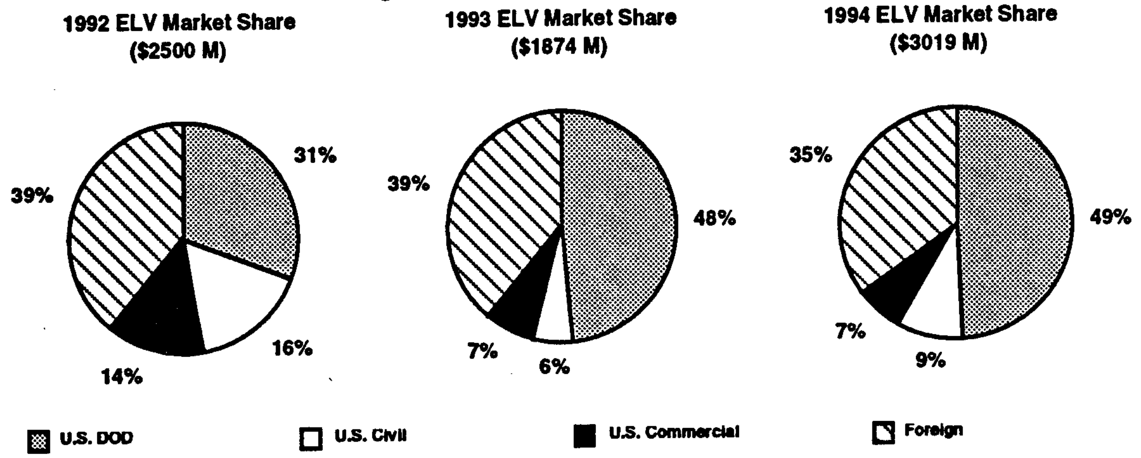
The space launch industry provides vehicles to three sets of customers: DoD (military and intelligence), U.S. Government civilian agencies (such as NASA and NOAA), and commercial (U.S. and foreign). The U.S. ELV industry depends on DoD and civil agency launches for the vast majority of its business. Figure ES-2 summarizes world market data by value for 1992 through 1994. (It excludes former Soviet Union non-commercial launches.) Between 1992 and 1994, U.S. launches represented more than 60 percent of the total. DoD launches varied from slightly less than one third to almost one half of the total, U.S. civil agency launches declined from 16 percent to 9 percent, and U.S. commercial launches declined from 14 percent to only 7 percent of the total. The percentage of the market held by foreign launches has remained stable at slightly more than one third of the total market.

Because of the high costs associated with a limited number of large vehicle DoD launches (see "Launch Cost," Table ES-1) these numbers reflect relatively small shifts in total launches. DoD launched two large vehicles in 1992, one in 1993, and four in 1994. (Russia launched one large ELV with a commercial payload in 1994.)

Table ES-2 summarizes the Department's current estimate of the average annual world commercial (U.S. and foreign), DoD, and U.S. civil space launch vehicle market from 1995 through 2010. It also estimates that portion of the market which will be captured by U.S. ELV producers.

Worldwide, estimates for annual launches of small and medium systems are subject to significant uncertainty. The demand for these systems will be influenced by potential reductions in their costs, as well as a number of competing plans for new low earth orbit (LEO) communications constellations. Table ES-2 distinguishes between the average yearly demand for commercial ELVs and potential increases due to the emerging LEO market.

Figure ES-2. ELV World Market



Source: IDA analysis of historical contractor data.

U.S. ELV producers are expected to capture seventy-five percent of the world commercial market for small vehicles and thirty percent of the world commercial market for medium and large vehicles. U.S. Government payloads are restricted by policy[1] to U.S. space launch vehicles. Therefore, U.S. launchers are projected to capture all DoD and U.S. civilian agency launch requirements.

DoD's Titan IV launches dominate the total world requirements for large ELVs. Because of the high launch costs of the Titan IV, however, DoD's annual launch requirements for these vehicles are expected to average only about three per year into the foreseeable future. In the small and medium ELV market, DoD demand is projected to be relatively stable at approximately two and eight launches per year, respectively. DoD launches will comprise about 29 percent of the U.S. market for small launch vehicles and 42 percent of the U.S. market for medium vehicles. If potential LEO communications constellation increases materialize, these percentages would drop to 15 percent for small ELVs and 38 percent for medium ELVs.

In the past decade, European competitors have been successful players in the world market. Recently, the former Soviet Union and China have entered the commercial launch market.[2] As a result, U.S. space launch firms no longer dominate the world's commercial market (see Figure ES-3).

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[1] National Space Transportation Policy, August 1994.

[2] International competition discussed in Chapter III.

Table ES-2. U.S. Space Launches vs World Demand per Year (Estimated Average, 1995-2010)[a]

Launch Vehicle Class	World[b] Commercial	U.S. Share[d] of World Commercial	U.S.[e] DoD	U.S.[e] Civil	Estimated U.S. Total
Small	3 + 8[c]	2 + 6[c]	2	3	7 + 6[c]
Medium	12 + 6[c]	4 + 2[c]	8	7	19 + 2[c]
Large	0+1[c]	0 + 0[c]	3	0	3 + 0[c]
Shuttle	0	0	0	8	8
Total	15+15[c]	6 + 8[c]	13	18	37 + 8[c]

a Launch projections are annual averages. Launches in an individual year may vary. Includes firm (funding/contract in place), probable (funding/contract not yet complete), potential (funding/contract anticipated in future), and launch-on-need (firm/probable, but launch date unspecified) launches.

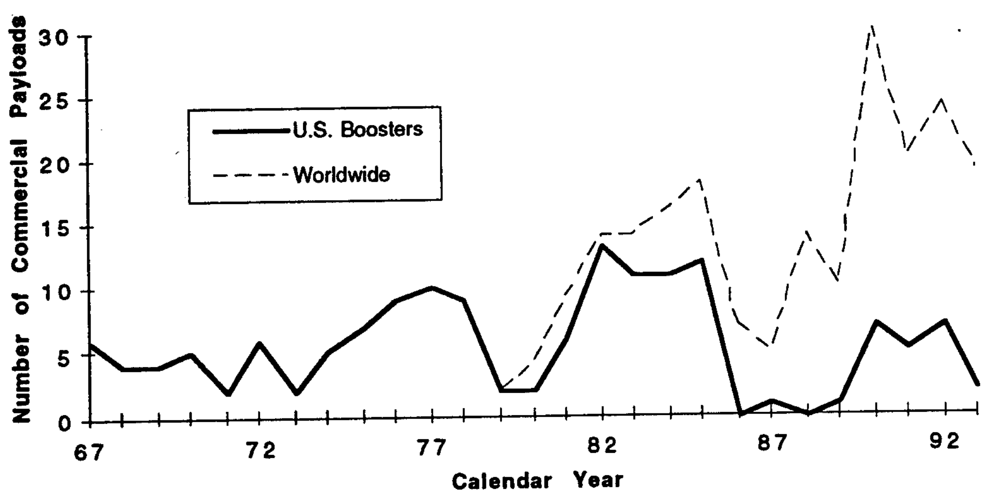
b Source: IDA analysis of various launch projections.

c Estimated number of launches per year for proposed LEO satellites based on IDA analysis of March 1994 DOT projections.

d Expected U.S. total assumes an average 30 percent capture of the world commercial market for large and medium vehicles; and 75 percent for small launch vehicles where the United States still dominates.

e Source: AFSPACECOM National Mission Model of 5 Oct 1994 and recent NASA program thrusts.

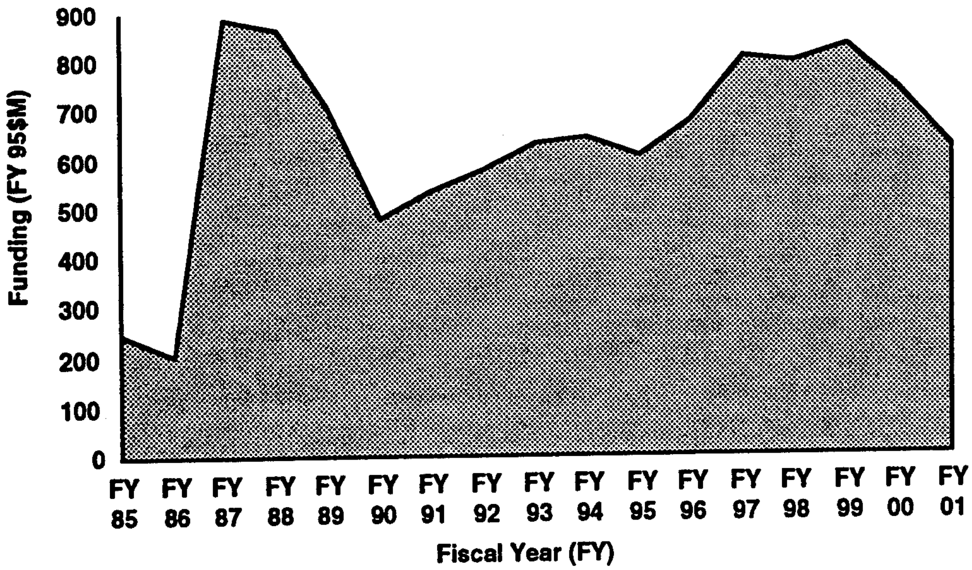
Figure ES-3. Number of U.S. ELV-Launched Commercial Payloads and Number Launched Worldwide



Source: IDA analysis of historical launch data.

DoD's space launch procurement budget (Figure ES-4) is expected to increase from $601M in FY 1995 to $805M in FY 1997, and peak at $830M in FY 1999.

Figure ES-4. DoD Space Launch Procurement Funding



Source: OSD/API, FY 96 Budget Estimate Submission

Nevertheless, DoD's influence--especially on small and medium ELVs--has been reduced as the market has become increasingly large, commercial, and competitive. DoD wants to take greater advantage of the competitive commercial market in order to reduce its costs while assuring continued access to space. DoD is applying advanced technology to reduce the size of its payloads, thereby reducing its need to use costly large ELVs--currently Titan IVs. DoD is also examining ways to reduce the costs associated with launching heavy payloads that cannot be reduced to fit on small or medium ELVs.

C. CURRENT CAPABILITIES MEET DOD'S SPACE LAUNCH REQUIREMENTS

The U.S. space launch industry will continue to meet DoD requirements into the foreseeable future. Existing manufacturers of DoD's space launch vehicles are profitable (see Table ES-3) despite declining sales, increased competition, and significant excess capacity in the large and small vehicle segments.

Table ES-4 compares U.S. launch and production capacities with projected demand. DoD's demand for large ELVs has fallen, and there is considerable production overcapacity in that industry segment. U.S medium class ELV producers do not appear to

Table ES-3. Profitability of U.S. ELV Prime Contractors[1]

	1991			1992			1993			1994 (First 3 Qtrs.)		
	Sales ($ M)	Operating Profit ($ M)	Operating Margin (%)	Sales ($ M)	Operating Profit ($ M)	Operating Margin (%)	Sales ($ M)	Operating Profit ($ M)	Operating Margin (%)	Sales ($ M)	Operating Profit ($ M)	Operating Margin (%)
McDonnell Douglas Missiles, Space and Electronics Group	2979	163	5.5	3169	191	6.0	2575	338	13.1	1312	196	14.9
Martin Marietta Space Group	3104	286	9.2	3054	304	10.0	3442	249	7.2	2373[2]	266	11.2
Lockheed Missiles and Space	4859	360	7.4	4587	401	8.7	4238	348	8.2	2698	227	8.4
Orbital Sciences Corp.	135	2	1.5	175	4.7	2.7	190	8.7	4.5	130	5.5	4.3

[1] Data was not obtained from privately-held ELV prime contractors (for example, EER Systems).

[2] Includes contributions from recently acquired Space Systems Division from General Dynamics.

Source: Company Reports

have excess production capacity. Demand is stable for small ELVs, although there is a potential for significant increases. In expectation of these increases, a number of U.S. and foreign launch service providers have entered, or are poised to enter, the small vehicle market. As a result, there also is significant production overcapacity in the small vehicle industry segment.

Table ES-4. Current Production and Launch Capacities for U.S. Space Launch Vehicles Compared with Future U.S. Launch Rates

Launch Vehicle	Launch Vehicle Class	Annual[1] Launch Capacity (CCAFS+VAFB)	Annual[2] Production Capacity	Annual[3] U.S. Launches	Production[4] Over Capacity	Excess[5] Capacity Factor
Pegasus	Small	12	12-50	6	6+	2X
Taurus	Small	3	24	3	21	8X
Delta	Medium	12+ 6	12	11	1	Small
Atlas	Medium	10+ 4	8	8	0	None
Titan IV	Large	3-4 + 3-4	10	3	7	3X

1 The maximum number of launches possible, given current facilities and personnel at both Cape Canaveral Air Force Station and Vandenberg Air Force Base, based on IDA analysis.
2 Based on IDA analysis of contractor data. Does not include surge capability.
3 Typical annual U.S. launches, 1995-2010. Apportionment of launches to specific vehicles within a launch vehicle class may vary. Includes firm, probable, potential, and launch-on-need launches. Launches in an individual year may vary.
4 "Annual Production Capacity" minus "Annual U.S. Launches."
5 "Annual Production Capacity" divided by "Annual U.S. Launches."

Production overcapacity in the small and large space launch industry segments, and the increasingly competitive ELV market, mean that substantial industry consolidation is both inevitable and necessary. The Department expects to benefit from this restructuring, since consolidation will lead to reduced overhead costs and reduced prices. The Department prefers to maintain competition. However, our acquisition process gives us greater information about supplier costs and therefore greater leverage than normally exists for commercial buyers.

Major contractors in the U.S. space launch industry generally support multiple launch vehicle systems or subsystems (see Table ES-5). Although the industry will consolidate, sufficient capable suppliers will remain. Additionally, the major prime and first tier contractors have demonstrated an ability to manage the risks associated with a changing vendor base.

Table ES-5. Major Contractors in the Space Launch Industrial Base[1]

Specific Items	Shuttle	Titan	Atlas	Delta	Lockheed LLV	Taurus	Pegasus	Minuteman III	Trident D5
Prime	Rockwell	Martin Marietta	MM	McDonnell Douglas	Lockheed	Orbital Sciences Corp. (OSC)	OSC	Ogden Air Logistics Center	Lockheed
Liquid Propulsion	Rocketdyne Aerojet	Aerojet	Rocketdyne UTC-P&W	Rocketdyne Aerojet	Rocket Research	—	—	—	—
Solid Propulsion	Thiokol	UTC-CSD Hercules Boeing	Thiokol	Thiokol Hercules	Thiokol UTC-CSD	Thiokol Hercules	Hercules	Thiokol UTC-CSD Aerojet	Hercules Thiokol UTC-CSD
Payload Fairing	—	MDC	MM	MDC	Lockheed	Courtaids Structural Composites, Inc. OSC	Hercules	—	—
Guidance	Honeywell IBM	Delco Honeywell	Honeywell	Delco Allied Signal	Litton	Litton Trimble	Litton	Autonetics Honeywell	Honeywell Kearfott MM
Avionics	Bendix Kearfott Eaton Collins	Honeywell	Honeywell Teledyne	Microcom Ball Aerospace	Loral Herley-Vega M/A-COM	Aydin OR/Dynatem OSC	OSC		

1 Includes strategic missiles, which are produced by many of the same contractors.

Source: IDA analysis of contractor data.

D. POLICIES TO ENSURE FUTURE SPACE LAUNCH CAPABILITIES

DoD small launch vehicle requirements are limited (approximately two per year) and there is considerable private investment in new small ELVs for commercial purposes. U.S. small ELV prime contractors will be able to meet DoD's needs into the foreseeable future. U.S. medium ELV prime contractors do not have excess capacity.

Changes in payload requirements necessitate a restructuring of current contracts to maintain heavy-lift capabilities (Titan IV) during a period of low demand. Current requirements for Titan IV launch vehicles are lower than were expected when the current production buy of 41 vehicles was initiated. The most recent change in payload requirements has resulted in a 2-year slip in plans for a Titan IV follow-on buy. The Department has realigned Titan IV deliveries on the current contract to match the anticipated flight rate. This will sustain essential industrial and technological capabilities until a follow-on contract is executed.

Because of its reliance on large and medium launch vehicles, DoD also is taking action to reduce the recurring cost of space launches. The DoD intends to begin immediately a program to develop a cost-effective alternative to the current medium and large launch vehicles. The program will evolve one of the current ELVs, or its subsystems and components, into a family of vehicles to perform the missions now accomplished by the Delta, Atlas, and Titan systems. The acquisition strategy for the evolved expendable launch vehicle (EELV) program is to conduct a full and open competition to select a single provider for the EELV family. The single provider could be one major prime contractor or a consortium of contractors. A family of vehicles with common subsystems and components will increase production efficiency and reduce production and operations costs. The procurement rate for the EELV producer will be greater than the current rates for any of the individual medium or large ELV prime contractors. Business levels will be sufficient to maintain those essential capabilities necessary to meet the Department's medium- and heavy-lift space launch requirements into the foreseeable future. Initial launch capability is scheduled for 2001 (medium launch vehicle) and 2005 (large launchvehicle). These actions are among those the Department is taking to implement the President's National Space Transportation Policy.

The Department believes the small launch vehicle industry segment will mature through commercial activity and market pressures. Therefore, the Department does not intend to invest heavily in new small launch vehicle development.

DoD's policies and implementing actions will have positive collateral affects. In particular, they will: (1) ensure adequate capacity and essential industrial and technological capabilities will be retained during the downsizing of the U.S. space launch industry, and (2) improve U.S. ELV industry international competitiveness.

Other government policies and agreements also have a considerable impact on the space launch industry. The President's National Space Transportation Policy requires that U.S. Government payloads be launched on space vehicles manufactured in the United States. This ensures U.S. ELV manufacturers have a strong domestic business base from which to compete internationally. Additionally, the U.S. has entered into foreign space launch agreements with Russia and China in an attempt to eliminate disparities between the non-market economy countries and western (particularly U.S.) launch nations. The agreements limit the number of Russian and Chinese contracts for geosynchronous launches for western customers. They require consultations if Russian or Chinese launch bid prices fall significantly below the lowest comparable western price. The agreement with the Chinese expired at the end of 1994. Negotiations are underway for a new agreement covering the period 1995-2001.

E. CONCLUSIONS

The U.S. space launch industry remains viable and capable of meeting DoD launch requirements. All three prime contractors currently supplying ELVs for DoD use are profitable, despite considerable production overcapacity in the large and small launch vehicle industry segments. Considerable industry consolidation is both inevitable and necessary. Overhead costs will be reduced and the Department, and ultimately the U.S. taxpayer, will benefit.

DoD has executed a bridge contract to sustain essential Titan IV industrial and technological capabilities until a follow-on contract is executed. Additionally, DoD is pursuing the EELV program to reduce its recurring space launch costs. Together, these actions will sustain required production and design capabilities, and improve industry competitiveness.

PREVIOUS STUDIES CONTRIBUTING TO THIS ASSESSMENT

Space and Missile Industrial Base Assessment, Air Force Systems Command, Dec 90

Missile Industry Sector Study, Department of the Army, Apr 92

Expendable Space Launch Vehicle Industrial Base Survey, OUSD(A) S&SS, Dec 92

Integrating Defense into the Civilian Technology and Industrial Base, IDA, Feb 93

SLBM and ICBM Industrial Base Study, USSTRATCOM Strategic Advisory Group, Apr 93

Solid Rocket Motor Industrial Base Study For Strategic Ballistic Missiles, Institute on Global Conflict and Cooperation, May 93

Assessment of the Expendable Launch Vehicle Industrial Base, OUSD(A) P&L, May 93

Bottom-Up Review For Space Launch Systems, OUSD(A) S&SS, May 93

Space Working Group, Defense Policy Advisory Committee on Trade, Jul 93

Air Force Industrial Base Assessment of the Space and Strategic Missile Sector, Dec 93

Rocket Motors: An Assessment of the Domestic Industrial Base, U.S. Army Missile Command, Jan 94

Commercial Space Transportation Advisory Group, DOT, Apr 93 and Feb 94

LEO Commercial Payload Projections, DOT, Mar 94

DoD Space Launch Modernization Study, LG Thomas S. Moorman, Jr., Chairman, Apr 94

Commercial Space Transportation Study, CSTS Alliance in coordination with NASA, Apr 94

Commercial ELV Industry Technology Panel, NASA, May 94

Laboratory Infrastructure Capabilities Study, IDA, Jun 94

Space Systems Technology Working Group, IDA, Jun 94

Sustaining the U.S. Expendable Launch Vehicle Industrial Base, Rand, Jul 94

Space Facilities, National Research Council, Oct 94

I. SPACE LAUNCH VEHICLES

DoD[1] uses a wide variety of satellites to carry out its responsibilities. These range from weather and navigation to communications and surveillance. To place satellites into orbit, the Department relies upon a range of different expendable launch vehicles, currently supplied by three prime contractors. This assessment focuses on the major U.S. prime contractors which provide expendable vehicles for DoD launches. Launch subsystems and subcontractors are addressed to the extent necessary to understand the vehicles and the network of suppliers which build them.

A. INDUSTRY SEGMENTS

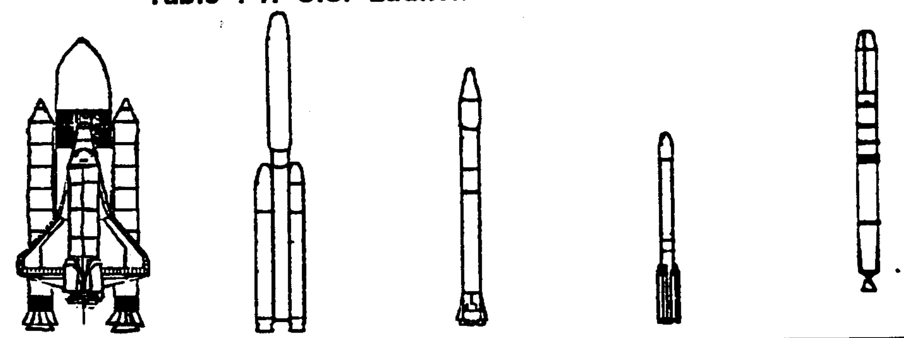
Space launch vehicle systems include both space launch vehicles and the necessary ground support equipment. Space launch vehicles are categorized as large, medium, or small based on the payloads they are intended to carry. The Space Shuttle is the only manned U.S. launch vehicle and the only one with largely reusable components. All other U.S. space launch vehicles are expendable launch vehicles (ELVs).

B. LAUNCH VEHICLE SYSTEMS

Table I-1 contains a short summary of the major characteristics of the nine U.S. launch vehicles that currently are, or will soon be, in service.

[1] In this report, "DoD" includes both military and intelligence requirements.

Table I-1. U.S. Launch Vehicles



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Maximum Flight Rate[iii]	8/year[a,b]	6-8/year[a]	14/year[d]	12/year[a,b,d,f]	3/year[a,b,e,f]
Mission Success Rate	98.4%[c]	90%[c]	50-100%[c, iv]	100%[c,e]	100%[c,e]
Launch Cost	$375M[b]	$200-350M[c]	$65-120M[c,e]	$50-60M[c]	$45M[c]
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i LEO - low earth orbit

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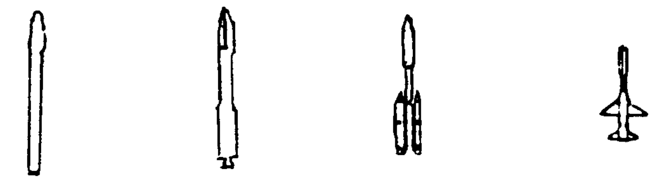
f 1992 Space Launch Activities, Space Technology Division Note STDN 93-2, ANSER.

Table I-1. (continued)



Launch Vehicle	LLV[v]	Taurus	Conestoga[v]	Pegasus Std, XL
Class	Medium/Small	Small	Small	Small
Overall Length	100 ft	90.25 ft	51.5 ft	51-56 ft
Lift-Off Mass	N/A	180,000 lb	191,528 lb	42,000-51,000 lb
Performance (LEO)	2,000 - 8,000 lb	3,200 lb	3,300 lb	731-1021 lb
Performance (GTO)	N/A	987 lb	N/A	80-105 lb
Maximum Flight Rate	N/A	3/year[d,e]	12/year[h]	12/year[d,e]
Mission Success Rate	N/A	100%[c]	N/A	86%[g]
Launch Cost	$16-27M Advertised	$15-20M[c]	$20-25M[c]	$12-15M[c]
Primes	Lockheed	OSC	EER Systems	OSC

v First launches scheduled for 1995.

Sources:

c Launch Vehicle Systems Design & Engineering Course Notes, Applied Technology Institute, September 1994.

d *Report of the Commercial Expendable Launch Vehicle Industry Technology Panel,* IDA Paper P-2981, May 1994.

e *International Reference Guide to Space Launch Systems,* S.J. Isakowitz, AIAA.

g *Space News,* July 4-10, 1994.

h IDA analysis of contractor data.

1. Large Launch Vehicles

a. Titan IV

The Titan family was established in 1955, when the Air Force awarded the Martin Company, now Martin Marietta, a contract to build a heavy duty missile. It became known as Titan I, the nation's first two-stage intercontinental ballistic missile (ICBM) and first underground silo-based ICBM. It proved many structural and propulsion techniques that were later incorporated in the Titan II. In 1984, DoD called for a launch system that would complement the Space Shuttle and better ensure access to space for certain national security payloads. In 1985, the U.S. Air Force contracted with Martin Marietta Corporation for 10 Complementary Expendable Launch Vehicles, which over time have evolved to the Titan IV. The Titan IV launch cost is in the range of $200-350 million. With its ability to launch a 39,000-pound payload to low earth orbit (LEO)[2], the Titan IV has become DoD's main access to orbit for heavy payloads.

b. Space Shuttle

In 1968, NASA examined its future programs, goals, and requirements for the post-Apollo era and conducted studies of a reusable space transportation system. In 1969, NASA established a Space Shuttle Task Group, and on April 12, 1981, the first Space Shuttle was launched. However, on January 28, 1986, the 25th Shuttle mission, and the 10th for the orbiter Challenger, ended in disaster when a solid rocket booster O-ring failed and caused an explosion that destroyed the space vehicle. Numerous design changes and safety modifications were made as a result. This disaster also resulted in operational changes that limited the flight rate to eight per year with four orbiters. Many commercial, NASA, and DoD customers, effectively denied access to the Shuttle because of delays after Challenger and subsequent limited capacity, chose to launch future payloads on expendable launch vehicles.

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[2] LEO - An orbit near the earth's surface for mission purposes, but high enough to avoid orbital decay from atmosphere drag. One typical orbit used for standardized performance calculation is a circular orbit 100 nautical miles above the earth, inclined at an angle of 28 degrees with the equator.

The Space Shuttle consists of a reusable delta-winged spaceplane called an orbiter; two solid propellant rocket boosters which are recovered and reused; and an expendable external tank containing liquid propellants for the orbiter's three main engines. The Space Shuttle is the only manned U.S. launch vehicle, the only one with largely reusable components, and the only one primarily managed by NASA.

2. Medium Launch Vehicles

a. Atlas

The Atlas family of vehicles was begun in 1952 when the Air Force contracted with General Dynamics to develop the Atlas-E ICBM. In 1987, General Dynamics Commercial Launch Services, now Martin Marietta Space Systems, decided to build 18 Atlas/Centaurs (a design based on the Atlas E, a decommissioned ICBM) for commercial sale. The company later increased production to 62 vehicles. General Dynamics then also developed the improved Atlas II vehicle, primarily to launch 10 Defense Satellite Communications System payloads. Currently four commercial vehicles are available: Atlas I, Atlas II and two enhanced versions, Atlas IIA, and Atlas IIAS. The two final configurations of the Atlas/Centaur family, Atlas IIA and Atlas IIAS, are improved versions of the Atlas II. An upgraded RL10 engine is used for the Centaur in both versions, but the Atlas IIAS also adds four Thiokol Castor IVA solid rocket motors to the booster stage. (A stage is a propulsion component consisting of solid and/or liquid rocket motors which provide thrust during a portion of trajectory.) These newer versions of the Atlas provide improved performance to lift heavier payloads into higher orbits.

b. Delta

The Delta family of launch vehicles evolved from the Thor ballistic missile, begun in 1959 when NASA-Goddard Space Flight Center awarded a contract to Douglas Aircraft Company, now the McDonnell Douglas Corporation, to produce and integrate 12 launch vehicles. The original Delta launch vehicle had a payload capacity of only 120 pounds to geosynchronous transfer orbit (GTO)[3]. In the years since the first vehicles were produced, the Delta has evolved to meet the demands for larger payloads. The current generation of Delta launch vehicles can lift a 4,000 pound payload to the same orbit. The Delta II was

[3] GTO - a parking orbit from which a payload can be transferred.

developed following the Challenger accident as a means to move DoD Global Positioning System payloads from the Shuttle manifest in order to accelerate operational availability.

c. Titan II

Titan II launch vehicles are ICBMs that have been refurbished and equipped with hardware required for space launch.[4] DoD uses Titan II vehicles to launch smaller payloads into polar orbit.

3. Small Launch Vehicles

a. Lockheed Launch Vehicle (LLV)

Borrowing on experience gleaned from the Polaris, Poseidon, and Trident solid-propellant, sea-launched ballistic missile programs, Lockheed Missiles and Space Corporation unveiled plans for a new family of launch vehicles in May 1993. The LLV will have three primary configurations designed to carry payloads of 2,000 pounds (LLV1), 4,000 pounds (LLV2), and 8,000 pounds (LLV3) to LEO. A demonstration flight is scheduled for spring of 1995 with full service expected to begin several months later. Like many of its competitors, the LLV series is a mix-and-match system in which motors, the Thiokol Castor 120, Castor IV, and the Chemical Systems Orbus 21D solid rocket motor, can be added to meet a customer's launch requirement. Lockheed will offer the LLV series for payloads to geosynchronous earth orbit (GEO)[5], but the primary marketing emphasis will be on deployment of LEO communication satellites.

b. Taurus

In July 1989, the Advanced Research Projects Agency (ARPA) awarded a contract to Orbital Sciences Corporation (OSC) to build and demonstrate a four-stage, inertially-guided, three-axis stabilized, solid-propellant, standard small launch vehicle. The Taurus vehicle configuration is derived from Pegasus and Peacekeeper (ballistic missile) stages. Stage one is from the Peacekeeper; stages two through four are from Pegasus. Taurus can be launched from a simple, dry concrete pad and is fully transportable. This allows for rapid launch-site establishment with a set-up time of 5 days or less after arrival on site.

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4 Titan ICBMs were decommissioned prior to the START agreements. Their use as ELVs is not subject to the restrictions on decommissioned ICBMs established in the National Space Transportation Policy.

5 GEO - circular orbit approximately 19,000 nautical miles above the equator in which the payload maintains a constant position with respect to the earth's surface.

c. Conestoga

EER Systems is the first U.S. firm to develop a completely new launch vehicle with commercial funding for commercial customers. The Conestoga is still under development. Its original launch date, the first quarter of fiscal year 1993, has been postponed until mid-1995 because of a funding shortfall. EER has designed a family of launch vehicles with the ability to launch payloads ranging from 800 to 3,300 pounds into low earth orbit (LEO). The Conestoga launch vehicle was designed in a modular configuration to meet the cost, payload, and technical needs of individual missions and to support the launch of single or multiple spacecraft. The Conestoga has the largest fairing (72 inches in diameter) among small launch vehicles, increasing flexibility to carry different light payloads. It will be available in three standard sizes, plus custom lengths. Its transportable service tower gives Conestoga the ability to launch from almost any range and have convenient late (up to 4 hours before launch) access to payloads. In 1991, a NASA consortium awarded EER a contract to supply launch vehicles and services for the COMET (COMmercial Experiment Transporter) program.

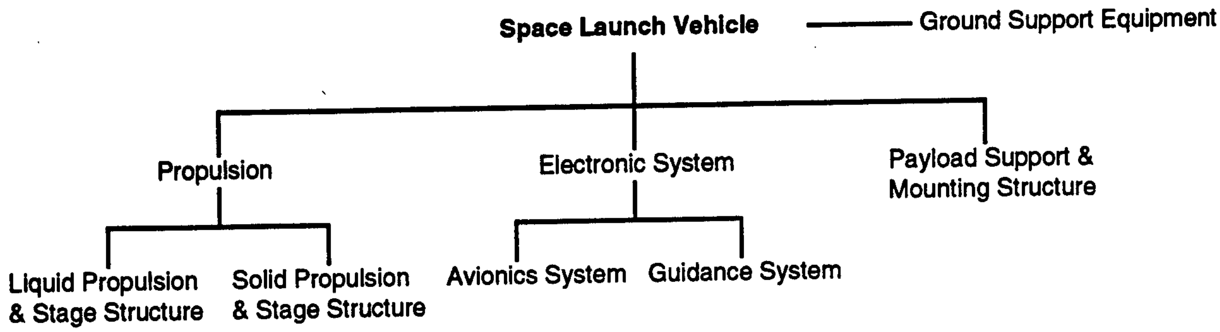
d. Pegasus

Pegasus is a three-stage, solid-propellant, inertially-guided, graphite composite, winged launch vehicle developed as a privately-funded joint venture of OSC and Hercules Aerospace Company. Pegasus is carried aloft by conventional transport/bomber-class aircraft to level flight conditions at 40,000 feet altitude and Mach 0.8. After release from the carrier aircraft and first-stage motor ignition, the vehicle follows an optimal-lifting, direct ascent trajectory to orbit. OSC and Hercules have recently developed a Pegasus XL version which provides added payload-to-orbit performance due to the extra length of the first two stages. An optional Hydrazine Auxiliary Propulsion System can be attached to the payload for additional performance.

C. LAUNCH VEHICLE SUBSYSTEMS

A launch vehicle system generally is comprised of six basic subsystems (Figure I-1). Normally, these subsystems are used on all launch vehicles. The same technologies and processes are used in large, medium, and small vehicles. They do, however, vary in propulsion systems. Large and medium ELVs generally use a combination of liquid and solid propulsion systems. The solid propulsion systems provide thrust augmentation as strap-on boosters. Small ELVs use only solid propulsion systems. In most cases, the contractors involved in a particular subsystem are quite distinct from those involved in other subsystems. However, contractors for a particular type of subsystem often furnish such subsystems for a number of different launch vehicles. Each subsystem is discussed in further detail below.

Figure I-1. Launch Vehicle Subsystems



1. Liquid Propulsion and Stage Structure

Liquid propulsion engines, tanks, and associated structures are used for most large and medium launch vehicle cores and upper stages. The liquid propellant stages are made up of large tanks, which store the propellants and form the core of the structure itself. The propellant flow is governed by a complex combination of tubing, valves, sensors, and regulators. The rocket is steered by a thrust vectoring system, sometimes employing a gimbal-mounted engine, which can direct the thrust.

2. Solid Propulsion and Stage Structure

Solid propulsion engines and stage structures often are used as strap-on thrust augmentation for early stages of flight in larger vehicles. The lift capacity of the overall vehicle can be augmented to meet various payload demands by adding strap-on boosters as necessary to accommodate different payload weights. Solid propulsion engines and stage structures usually make up the core and upper stages in small launch vehicles. As solid rocket motor technology advances, some all-solid space launchers are entering the commercial market.

Solid rocket motors consist of a shell or casing which provides a gas-tight seal and can withstand the pressures generated by the burning propellant. The solid fuel is inside the casing. It is usually composed of some combination of ammonium perchlorate, plastisizers, metals such as aluminum or magnesium, other organic resins, and various chemicals which enhance chemical stability or affect the rate at which the material burns. Some casings are filled directly by pouring the propellant in while a liquid and letting it harden. This is impractical for very large motors, such as the Shuttle and Titan IV solid rocket boosters. In these cases the motors are poured in sections which are then stacked and joined to form a complete rocket motor. Solid rocket motors also must have thrust vector control mechanisms for steering.

3. Payload Support and Mounting Structures

Specialized structures are required to support, protect, and interface the payload to the stages that lift it into orbit. Payload support includes structural support for the payload and the fairing, and the mechanism to cleanly separate the payload from the booster at the appropriate time. In addition, some payloads may require power or data links while still attached to the rocket. Finally, the payload fairing protects the payload as it exits the atmosphere.

4. Guidance Systems

The guidance system provides signals and information that allow delivery of the payload to the proper orbit. The guidance system consists of inertia measurement devices (gyroscopes and accelerometers) that measure rates of rotation, attitude, and acceleration. These data then are fed into a computer that calculates the needed corrections which must be sent to the steering mechanisms.

5. Avionics Systems

Avionics systems provide for telemetry tracking and control, range safety, and other essential functions like thrust vector control or timing for stage separation. Avionics systems include radio transmitters to report diagnostic information about the performance of the rocket, radio receivers to allow in-flight instruction from ground-based controllers, and transponders to aid in tracking. The avionics systems also contain power supplies, data busses, antennas, and other electronic components.

6. Ground Support Equipment

Although not part of the launch vehicle, ground support equipment is an important element in launching payloads into space. Maintenance and general infrastructure for most of the ground support equipment is provided by the government. U.S. commercial launch services providers pay for those support services (recurring costs and facility upgrades) that are directly attributable to a commercial launch. The ground support infrastructure includes, but is not limited to, launch pad physical towers, stage integration facilities, electronic test equipment, and ground tracking stations.

D. ASSOCIATED MISSILE PRODUCTS

Ballistic and tactical missiles are unique ordnance devices with sophisticated electronics, guidance, weapons, and command and control. However, they utilize many of the same technologies as ELVs to transport payloads into orbit or trajectory. Thus, demand for, and production of, ballistic and tactical missiles indirectly affects the U.S. space launch industry, because many of the same contractors are common to both.

ELVs originally drew on early ballistic missile designs and have many similar components. For example, the Taurus first stage is derived from the Peacekeeper missile, and the Delta is derived from the Thor intermediate range ballistic missile. The Atlas II is based on the Atlas intercontinental ballistic missile (ICBM), and the Titan family of ELVs is a direct descendant of the early ICBMs built for the Air Force more than 30 years ago. The Titan II ELV is a refurbished conversion of decommissioned Titan ICBMs.

U.S. excess ballistic missile assets, slated for elimination under the START agreements, can be used for launching payloads into orbit by requests from DoD or any other U.S. Government agency, with the approval of the Secretary of Defense, and only when more cost-effective than using commercially-provided ELVs [1]. Excess missiles are sometimes converted for space launch roles (for example, the regular practice of converting decommissioned Titan II missiles for DoD space launch and the current conversion of two excess Minuteman missiles for suborbital launch). But the payload weight is small, and the ride is harsh.

Tactical and ballistic missile propulsion systems, stage structures, and manufacturer base are also similar to, and sometimes overlap, those of smaller space launch vehicle systems. Many strap-on boosters and other stages used in current space launch vehicles are derived from tactical missile designs.

E. ELV TECHNOLOGY IS PREDOMINANTLY DUAL-USE

In the expendable launch vehicle sector, it is difficult, if not impossible, to distinguish between "commercial" and "defense" technology, launch services, or vehicles. As described earlier, ELVs in their present form are based on ICBMs designed in the 1950s for strictly military use. The first ELV carrying a commercial payload was launched in 1967, and since then, launch technology has been updated and modernized, partially with government funding, and partially through corporate research and development investment. However, the U.S. launch vehicle industry, particularly those segments supplying medium and large ELVs, heavily depends on U.S. Government launch requirements.

For the purposes of DoD, "dual-use" is a product or process that has both military and commercial applications. As more dual-use technology is used, the Department will realize cost savings and performance improvements through economies of scale and access to a broader technology base. In the case of space launch, other civilian government customers, most notably NASA and NOAA, have similar interests. Dual-use in the context of space launch, therefore, refers to vehicles, subsystems, and components capable of serving both DoD and other missions.

In the United States, launch services are dual-use although the government owns most of the ground support equipment and launch facilities. Both government and commercial customers rely on the ELV manufacturer to provide the launch vehicle, payload/vehicle integration, and the launch services themselves.

Different launch vehicles are subject to different commercial and military demands. For some of the newly developed small systems just making their first launches, commercial demand is expected to predominate. For the mid-class Delta and Atlas, the mix is relatively balanced between DoD and other users, depending on international competition for commercial payloads, government requirements, and, especially, the government's ability to downgrade payload size, thus reducing the need for heavy lifters. Commercial customers generally size their payloads to fly on medium or small launch vehicles. Therefore, Titan IV is expected to be used primarily for government missions requiring heavy lift capability.

U.S. government payloads are restricted, by policy[6], to U.S. space launch vehicles. Commercial customers, by contrast, may use foreign launchers to meet their

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[6] National Space Transportation Policy, August 1994.

needs and cost constraints. Additionally, DoD has special needs driven by national security requirements for particular launch vehicle capabilities:

1. Heavy Payloads

DoD is striving to minimize dependence on large launch vehicles by reducing all payload sizes to fit within the medium-weight class. By the year 2000, the application of advanced technology is expected to reduce payload mass on the order of 30 percent for most satellites [2]. However, some DoD payloads are necessarily large in order to satisfy mission requirements, and no current technology is available to allow downsizing to a medium-class vehicle. Therefore, DoD must be able to continue to send heavy payloads into orbit in a predictable and dependable manner.

2. Quick Reaction Payloads

DoD is evaluating the need for new defense satellites for tactical support that can be launched quickly upon request for any of a variety of special purposes. Consequently, space launch vehicles that can accommodate rapid changes in payloads to support specific DoD needs are a growing area of emphasis, unique to the Department. As a result of system design choices made years ago and the primacy of performance requirements, none of the current launch systems was built to quickly and dependably respond to payload or launch complex changes. Small launch vehicles fare best in this regard by the very nature of their size and flexibility. As system size and complexity increase, system responsiveness decreases. One indicator of system responsiveness is the flight rate for each system. On the Eastern Range, Delta II can launch up to 12 missions per year. On the low end, Titan IV can launch only 3 to 4 missions per year from each coast. The Shuttle can launch up to eight missions per year, but at a high cost involving labor-intensive operations.

3. Ability to Select Different Orbits

There is a potential for rapidly changing circumstances during a modern military crisis. Therefore, DoD would benefit from the capability to send military reconnaissance and communication satellites to a range of orbits. The Western launch facility at Vandenberg Air Force Base (VAFB) provides range capability for polar and high inclination orbits which are used mostly for DoD missions.

REFERENCES

1. *National Space Transportation Policy,* Office of Science and Technology Policy, The White House, August 1994.

2. *Bottom-Up Review for Space Launch Systems, Industrial Base Considerations for DoD's Space Launch Review*, IDA Paper P-2860. I May 1993.

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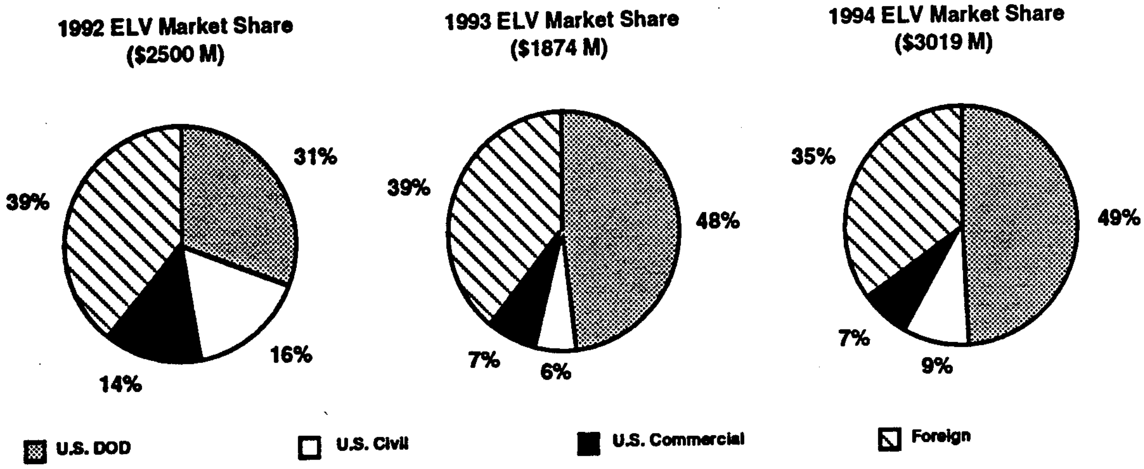
II. THE SPACE LAUNCH VEHICLE MARKET

A. DEMAND

Launch vehicles are purchased by three sets of customers: DoD, U.S. Government civilian agencies such as NASA and NOAA, and commercial. The U. S. ELV industry depends on DoD and civil agency launches for the vast majority of its business. Figure II-1 summarizes world market data by value for 1992 through 1994. (It excludes non-commercial launches in the former Soviet Union.) Between 1992 and 1994, U.S. launches represented more than 60 percent of the total. DoD launches varied from slightly less than one third to almost one half of the total, U.S. civil agency launches declined from 16 percent to 9 percent, and U.S. commercial launches declined from 14 percent to only 7 percent of the total. The percentage of the market held by foreign launches has remained stable at slightly more than one third of the total market.

Because of the high costs (see "Launch Cost", Table I-1) associated with a limited number of large vehicle DoD launches, these numbers reflect relatively small shifts in total launches. DoD launched two large vehicles in 1992, one in 1993, and four in 1994. Russia launched one large ELV with a commercial payload in 1994. (A Titan IV normally is more than twice as expensive as a medium ELV and more than ten times as expensive as a small ELV.)

Figure II-1. ELV World Market



Source: IDA analysis of historical contractor data.

Table II-1 summarizes projections for the three categories of space launch vehicles (large, medium, and small) by the three sets of space launch vehicle users. These numbers represent an annual average from 1995 to 2010. Specific levels are likely to vary from year to year.

Table II-I. U.S. Space Launches vs World Demand per Year (Estimated Average, 1995-2010)[a]

Launch Vehicle Class	World[b] Commercial	U.S. Share[d] of World Commercial	U.S.[e] DoD	U.S.[e] Civil	Estimated U.S. Total
Small	3 + 8[c]	2 + 6[c]	2	3	7 + 6[c]
Medium	12 + 6[c]	4 + 2[c]	8	7	19 + 2[c]
Large	0+1[c]	0 + 0[c]	3	0	3 + 0[c]
Shuttle	0	0	0	8	8
Total	15+15[c]	6 + 8[c]	13	18	37 + 8[c]

a Launch projections are annual averages. Launches in an individual year may vary. Includes firm (funding/contract in place), probable (funding/contract not yet complete), potential (funding/contract anticipated in future), and launch-on-need (firm/probable, but launch date unspecified) launches.

b Source: IDA analysis of various launch projections.

c Estimated number of launches per year for proposed LEO satellites based on IDA analysis of March 1994 DOT projections.

d Expected U.S. total assumes an average 30 percent capture of the world commercial market for large and medium vehicles; and 75 percent for small launch vehicles where the United States still dominates.

e Source: AFSPACECOM National Mission Model of 5 Oct 1994 and recent NASA program thrusts.

DoD has been, and will continue to be, an important figure in space launch activities. DoD vehicle launches will comprise virtually all of the large vehicle market, about 42 percent of the U.S. market for medium launch vehicles, and about 29 percent of the U.S. small launch vehicle market. If potential LEO communications constellation increases materialize, these percentages would drop to 38 percent for medium ELVs and 15 percent for small ELVs. U.S. ELV producers are projected to capture 75 percent of the small vehicle emerging low earth orbit (LEO) communications satellite market. (Table II-1 distinguishes between the average yearly demand for ELVs and potential increases due to the emerging LEO market.) U.S. ELV producers are not expected to do as well in the medium vehicle market. These producers will have a strong medium vehicle business base because of DoD and U.S. civilian agency launches, but are projected to capture only 30 percent of the world commercial market. The Ariane series of ELVs, developed by the European Space Agency, dominate the medium vehicle market.

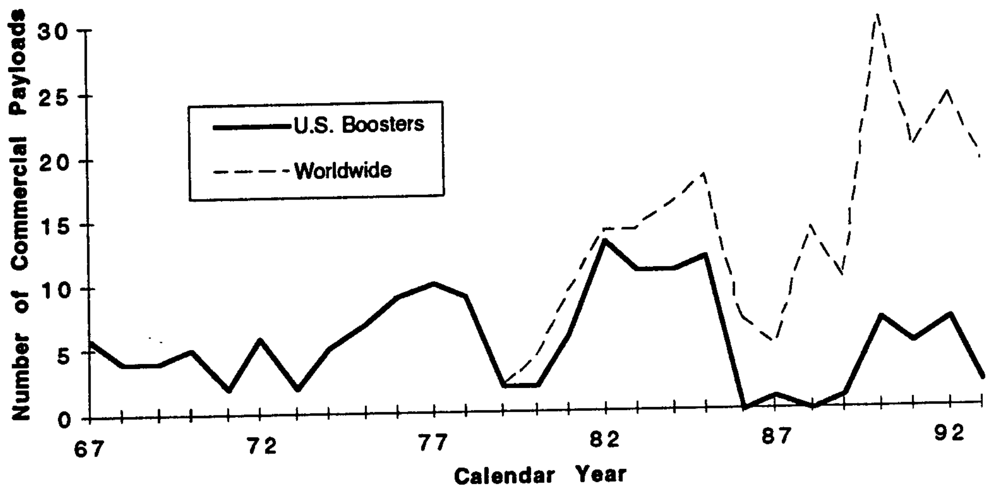
Demand for space launch vehicles is thought to be elastic. One recent study [1] concluded that a substantial reduction of launch vehicle prices could greatly influence the number of launches per year, perhaps by an order of magnitude or more. Thus, the development of less expensive launch systems could significantly expand the space launch market.

B. TRENDS

Demand for commercial U.S. launch vehicles has fluctuated greatly in recent years. Figure II-2 summarizes the number of commercial payloads launched on U.S. boosters and the total number of commercial payloads launched worldwide. During the period from 1967 through 1979, when the U.S. launched all commercial payloads on ELVs, the number of payloads launched per year varied between 2 and 10 (average of about 5.5) annually. From 1980 through 1993, the number of commercial payloads launched annually on U.S. boosters varied between 0 and 13. If payloads launched by the Shuttle are subtracted, the average annual number of commercial payloads launched by U.S. ELVs between 1980 and 1993 dropped to 3.8.

Part of the decline in the use of ELVs for payload launches can be attributed to U.S. government policies that shifted most launches to the Space Shuttle in the early 1980s--temporarily reducing the production of ELVs. The Shuttle failure in 1986 renewed the use of ELVs for payloads that do not require human presence in space. Foreign launch providers, especially Arianespace, took advantage of the lull in U.S. ELV production and have captured a significant percentage of the commercial market.

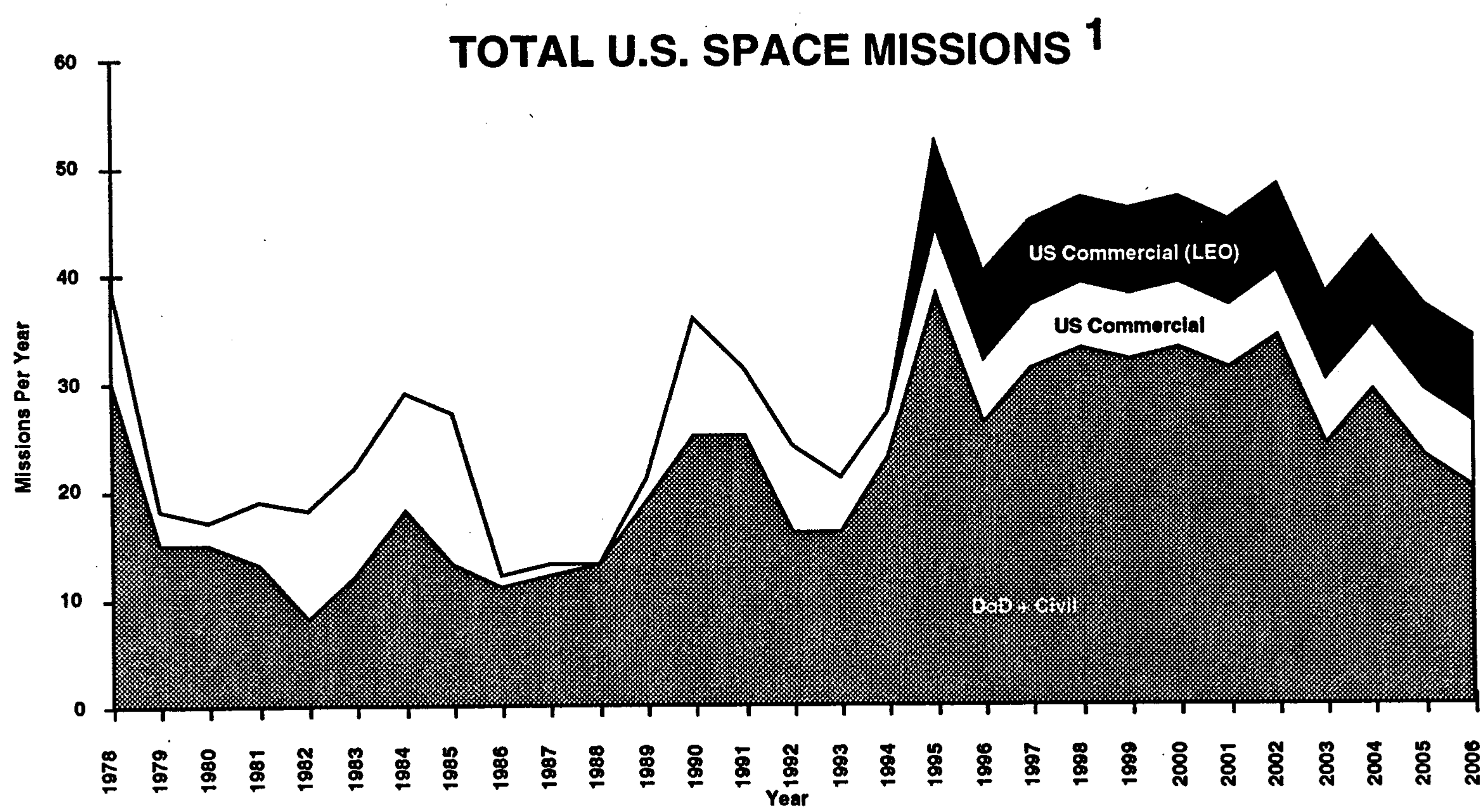
Figure II-2. Number of U.S. ELV-Launched Commercial Payloads and Number Launched Worldwide



Source: IDA analysis of historical launch data.

Figure II-3 summarizes past and projected total U.S. government missions (DoD plus civil) and U.S. commercial missions. U.S. Government demand is projected to decline beginning in 1995, for the near term. This is a result of a decline in NASA's budget and the consolidation of DoD and civil weather satellite programs. U.S. commercial launches are expected to increase moderately, with a potential for significant increases if the LEO communications satellite business solidifies. Figure II-4 separates projected DoD and civil missions within the total U.S. Government demand. Both DoD and civil agency demand are expected to decline in 1995. But civilian agency launches are expected to grow moderately in 1996, while DoD's are expected to continue to decline.

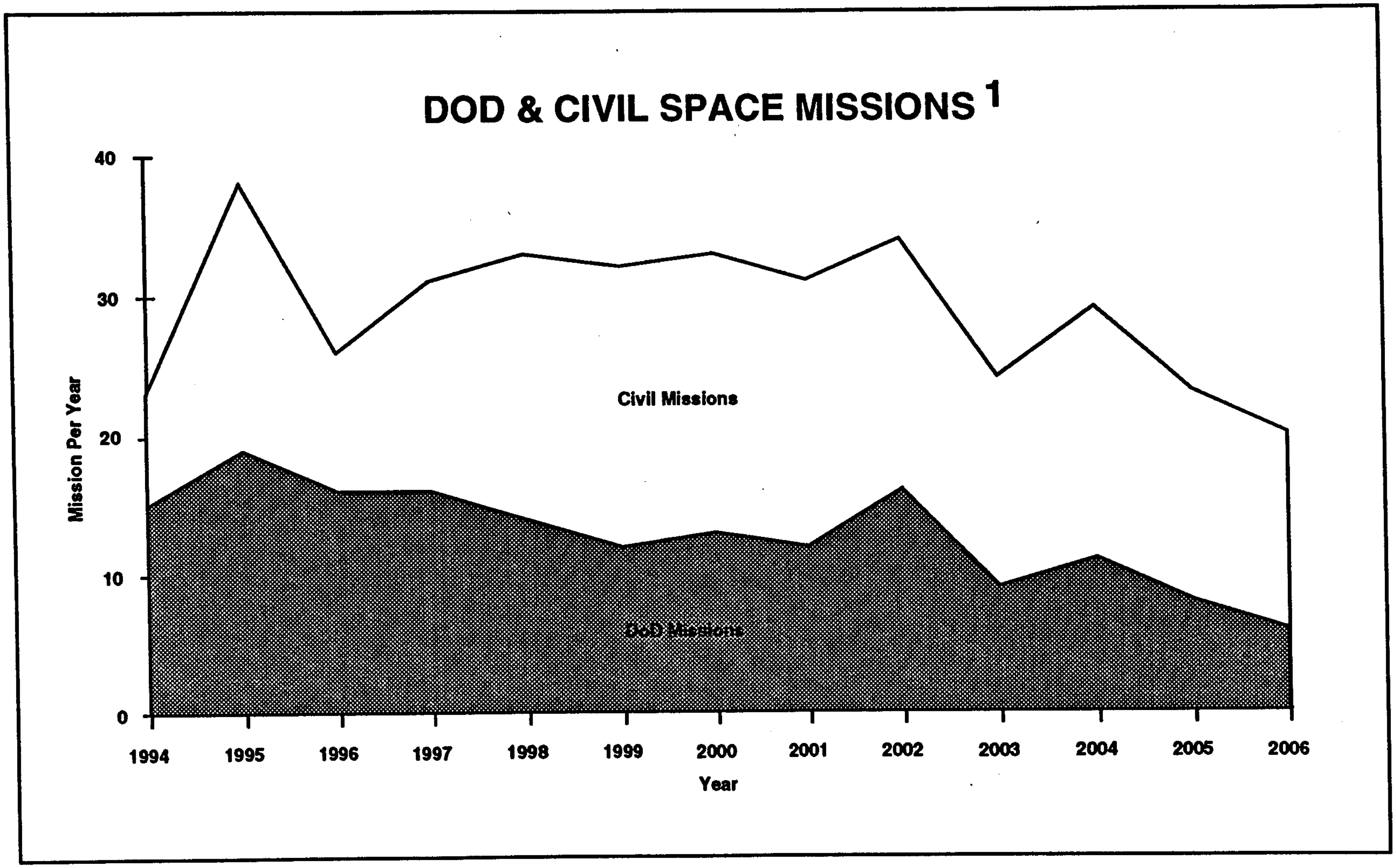
Figure II-3. Historical and Projected U.S. Space Missions



[1]Includes firm, probable, potential, and launch-on-need requirements.

Sources:
- Historical data for years 1978-1994 from GAO Report, "National Space Issues," August 1994.
- DoD and Civil projections for years 1995-2006 from AFSPACECOM National Mission Model, 5 October 1994.
- U.S. Commercial and Commercial (LEO) projections for years 1995-2006 from Table II-1.

Figure II-4. Projected U.S. DoD and Civil Missions

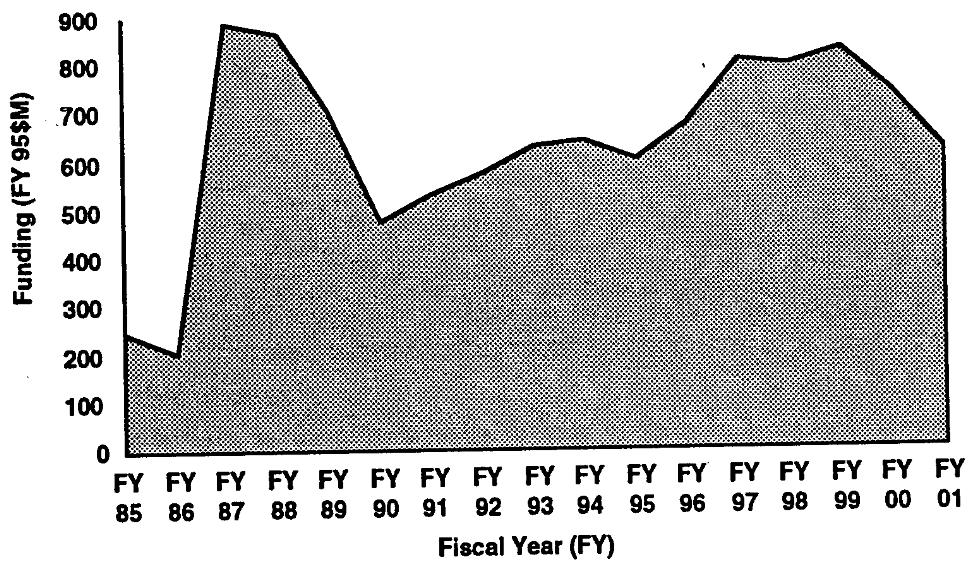


[1]Includes firm, probable, potential, and launch-on-need requirements.

Source: AFSPACECOM National Mission Model, 5 Oct 1994.

Figure II-5 summarizes the DoD ELV procurement budget from FY 1985 to FY 2001. Funding jumped from $200.7M in FY 1986 to $887M in FY 1987 to buy additional ELVs in the wake of the Challenger Space Shuttle failure. Funding is expected to increase from $601M in FY 1995 to $805M in FY 1997, decline to $796M in FY 1998, and rebound to $830M in FY 1999. Projected DoD ELV launches (Figures II-3 and II-4) cannot be compared directly with this funding profile. Titan IV ELVs are normally funded for construction starting 4 to 10 years in advance of launch date. Additionally, Titan IV deliveries are being extended due to reduced demand. (See discussion of the Titan IV bridge contract in Chapter IV.) At the low Titan IV production rates (three per year now; being reduced to two per year) stretchouts result in increased unit and total program costs.

Figure II-5. DoD Space Launch Procurement Funding



Source: OSD/API, FY 96 Budget Estimate Submission

Specific DoD launch vehicle requirements are shown in Table II-2. Although demand for large ELVs is declining, demand for small and medium ELVs appears stable. This can be attributed to the high cost of Titan IV launches, as well as the Department's efforts to reduce the size of its payloads to avoid those high costs. Therefore, despite the overall decline in DoD launches, demand for small and medium ELVs remains stable.

Table II-2. DoD Mission (Payloads) Requirements by Vehicle (FY 1995-FY 2004)

Launch Vehicle	FY 95	FY 96	FY 97	FY 98	FY 99	FY 00	FY 01	FY 02	FY 03	FY 04
Large										
Titan IV Class	8	7	2	4	3	2	3	4	1	3
Total Heavy	8	7	2	4	3	2	3	4	1	3
Medium										
Delta Class	2	4	4	5	4	5	5	6	2	3
Titan II	0	1	3	1	1	1	1	1	1	1
Atlas E	2	0	0	0	0	0	0	0	0	0
Atlas I/II Cl.	3	1	5	3	2	3	1	4	3	3
Total Medium	7	6	12	9	7	9	7	11	6	7
Small										
Small Class	4	3	2	1	2	2	2	1	2	1
Total Small	4	3	2	1	2	2	2	1	2	1
Total DoD	19	16	16	14	12	13	12	16	9	11

Reference: AFSPACECOM National Mission Model (As of 5 October 1994)

1. All firm, probable, potential, and launch-on-need missions are included.

C. COMPETITION IN THE COMMERCIAL MARKET

The U.S. space launch industry, for decades without competition in the Western world, has in the last 15 years lost market share to foreign launch providers. Most notable are the European Ariane expendable launchers which have captured almost 60 percent of the commercial market. Arianespace, assisted by European government willingness to sponsor considerable nonrecurring development costs, has produced highly competitive launch systems. The new Ariane 5, expected to be operational in 1995, will be able to lift 15,000 pounds into geosynchronous transfer orbit (GTO). This will give Arianespace a range of vehicles able to lift from 4,000 to 15,000 pounds and allow the company to compete for 85 percent of the world's commercial business, including those few large commercial payloads which have been carried on the U.S. Titan IV. The estimated $7 billion spent developing the Arianespace vehicles as a commercial enterprise to meet commercial and European civil agency needs was funded by the European Space Agency. No repayment from launch vehicle operations was required. Separately, a British firm, Rolls-Royce's Bristol Aerospace, has a small launch vehicle called Black Brant, which it is considering for the light payload market. The Black Brant would carry 1,200 pounds into LEO [2].

In recent years, Russia and China have begun to market launch services (facilities, vehicles, and support systems) commercially. The U.S. negotiated agreements with Russia and China allowing a limited number of launches of western commercial satellites to geosynchronous earth orbit (GEO). Russia has also joined Western marketing groups (including Lockheed Corp. and McDonnell Douglas) to sell its products worldwide. In addition, Russian submarine-launched and air-launched vehicles may play a key role in the future. The Russians are offering modified SS-N-23 missiles for small payload launch (730-950 kilograms) from the sea. Russia also offers An-124 or An-225 Mriya transports to carry vehicles to an altitude of 12 kilometers for launching payloads into space much in the style of Pegasus [2]. Ukraine is planning to enter the market with Zenit and Cyclone launchers, as well as SS-18 and SS-24 converted excess strategic ballistic missiles.

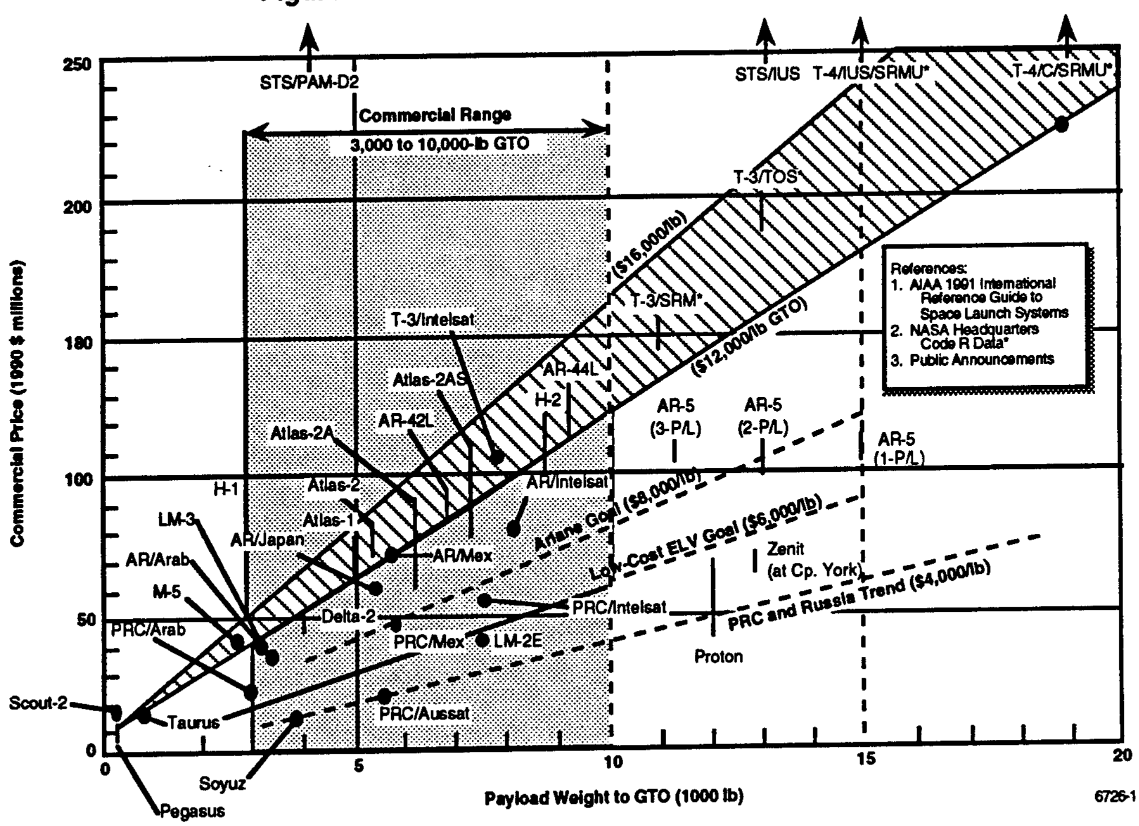
Japan is also moving to produce a commercial launch vehicle, but its new ELV is not fully proven, its price competitiveness is in doubt, and its two 45-day launch windows are very constraining. The Japanese government may use their system to launch domestic and possibly military satellites, but most forecasters do not see widespread sales in the near future.

Most U.S. vehicles have an inherent drawback in that they have long pre-launch assembly and test times. They can wait up to 120 days on the launch pad. These long lead times are costly. Commercial customers want faster setup times to contain expenses, to be able to respond quickly to new orders, or to recover quickly from accidents or mishaps that delay or scrub a planned launch.

The ELV launch price for commercial payloads is usually expressed as either a commercial price per launch or a price per pound of payload delivered to a specific orbit, usually geosynchronous transfer orbit (GTO). Figure II-6 displays the recurring launch service price in millions of 1990 dollars versus the GTO payload weight [3]. The shaded area in Figure II-6 covering the payload weight of 3,000-10,000 pounds to GTO represents the current range of commercial payloads. The cross-hatched area that gradually expands as both GTO weight and commercial prices increase, represents the $12,000-$16,000 per pound to GTO range, typical of U.S. launch vehicles and the Ariane-44. Figure II-6 also depicts the Ariane 5 goal to achieve a cost per pound of payload to GTO of $8,000, a distinct cost advantage. Because of its large size, the Ariane 5 will need to carry multiple payloads of the current commercial size or much larger payloads to meet its cost goal. Whether this will be achieved is yet to be seen.

The Commercial Space Transportation Advisory Committee (COMSTAC) has estimated that U.S. ELV producers could significantly increase their market share if they could design and build ELVs of greater reliability and short lead times and that place a payload into GTO for a cost of about $6,000 per pound of payload. The DoD Space Launch Modernization Study of 1994 estimated the total cost to develop and produce such a vehicle at $5B - $8B.

Figure II-6. Launch Service Price Versus GTO Payload Weight



U.S. firms have developed several new vehicles in the past few years despite the shrinking overall market. These vehicles are mostly small launch vehicles such as the Lockheed Launch Vehicle, Pegasus, and Taurus. Other U.S. firms, although not as far along, are also developing new products to take advantage of expected increases in small satellites due to miniaturization of components and new architectures. CTA, Inc., a manufacturer of small satellites has also entered the market for launch vehicles. In 1993, CTA acquired International MicroSpace, which was developing a booster called Orbital Express. CTA discontinued the Orbital Express for an all solid fueled model called Orbex 7E, which can boost small payloads less than 600 pounds into low earth equatorial or polar orbits. Hercules Aerospace has designed what it calls the Low Cost Launch System family of boosters. These vehicles would use solid rocket motor upgrades from the Titan IV to lift payloads from 5,000 pounds to almost 12,000 pounds to LEO.

Foreign equipment increasingly will be used to upgrade or improve U.S. ELVs. Martin Marietta is considering a two-stage launcher using a Russian liquid-propellant rocket motor. The former General Dynamics Space Systems Division, now part of Martin Marietta, has considered using a Russian NPO Energomash RD-180 liquid rocket engine to replace the MA-5 on the Atlas [2].

D. DOD INFLUENCE AND THE MARKET

DoD is a significant consumer of space launch services and its requirements must (by policy) continue to be met by U.S. suppliers. DoD requirements comprise virtually all of the large vehicle market, about 42 percent of the U.S. medium vehicle market, and about 29 percent of the U.S. small launch vehicle market. (If potential LEO communications constellation increases materialize, these percentages would drop to 38 percent for medium ELVs and 15 percent for small ELVs.) DoD wants to leverage the competitive commercial market in order to reduce its costs, and is applying advanced technology to reduce the size of its payloads and requirements for costly large ELVs. It is also examining ways to reduce the costs associated with launching heavy payloads which cannot be reduced to fit on small or medium ELVs. DoD plans to rely on commercial market forces in the small vehicle market and will not need to invest heavily. DoD small vehicle requirements are limited (approximately two per year) and there is considerable private investment in new small ELVs for commercial purposes. Finally, U.S. manufacturers of small ELVs are very competitive. They are projected to capture approximately 75 percent of the world small vehicle market. DoD's plans to improve its medium and large vehicle space launch capabilities and reduce its recurring costs to space will be discussed in more detail in Chapter IV.

REFERENCES

1. *The CSTS Alliance, Commercial Space Transportation Study, Executive Summary,* April 1994.

2. *The World Market for Expendable Launch Vehicles, 1994-2013,* Forecast International, July 1994.

3. *Commercial Spacecraft Mission Model Update,* COMSTAC, Office of Commercial Space Transportation, U.S. Department of Transportation, February 1994.

III. CURRENT CAPABILITIES MEET DOD'S SPACE LAUNCH REQUIREMENTS

Despite declining sales and significant excess capacity, existing prime contractors for DoD's space launch vehicles are profitable. Furthermore, there is significant private commercial investment developing commercial vehicles to carry small and medium payloads. For these reasons, the Department expects that existing capabilities will be ample to meet DoD requirements.

A. PROFITABILITY

Table III-1 summarizes recent profitability for publicly-owned U.S. companies that produce ELVs. All of these companies are profitable. In 1993, operating profit margins for the relevant divisions ranged from 4.5 percent of sales for Orbital Sciences to 13.1 percent for McDonnell Douglas. (This data includes products other than space launch vehicles.) Data from the first three quarters of 1994 point towards continued profitability on an operating basis this year.

Additionally, U.S. firms--including Lockheed and EER--are developing ELVs using private capital to compete with existing suppliers of small launch vehicles. Private investment in new space launch capacity suggests U.S. companies believe there is continued potential for profit within the industry.

B. CAPACITY

There are two types of capacity relevant to space launch vehicles--production and launch. Neither production nor launch capacity is constraining U.S. space launches. Table III-2 summarizes predicted annual launch vehicle demand and compares that demand with production and launch capacity for the major U.S. space launch vehicles. Titan IV demand, dependent primarily on DoD business, is down; production capacity exceeds predicted demand by a factor of more than three. In medium ELVs, where DoD has significant requirements, there is no excess capacity. Some U.S. commercial payloads will be launched on foreign medium launch vehicles. However, several companies are developing new launch vehicles which may increase U.S. production capacity for medium

Table III-1. Profitability of U.S. ELV Prime Contractors[1]

	1991			1992			1993			1994 (First 3 Qtrs.)		
	Sales ($ M)	Operating Profit ($ M)	Operating Margin (%)	Sales ($ M)	Operating Profit ($ M)	Operating Margin (%)	Sales ($ M)	Operating Profit ($ M)	Operating Margin (%)	Sales ($ M)	Operating Profit ($ M)	Operating Margin (%)
McDonnell Douglas Missiles, Space and Electronics Group	2979	163	5.5	3169	191	6.0	2575	338	13.1	1312	196	14.9
Martin Marietta Space Group	3104	286	9.2	3054	304	10.0	3442	249	7.2	2373[2]	266	11.2
Lockheed Missiles and Space	4859	360	7.4	4587	401	8.7	4238	348	8.2	2698	227	8.4
Orbital Sciences Corp.	135	2	1.5	175	4.7	2.7	190	8.7	4.5	130	5.5	4.3

[1] Data was not obtained from privately-held ELV prime contractors (for example, EER Systems).

2 Includes contributions from recently acquired Space Systems Division from General Dynamics.

Source: Company Reports

ELVs. Small ELV manufacturers, where DoD has relatively fewer requirements, also have significant production overcapacity. Production capacity for small vehicles exceeds demand by a factor of at least two for Pegasus, and eight for Taurus. The prospective entry of other small launch vehicles could further increase production overcapacity among small vehicle manufacturers.

Table III-2. Current Production and Launch Capacities for U.S. Space Launch Vehicles Compared with Future U.S. Launch Rates

Launch Vehicle	Launch Vehicle Class	Annual[1] Launch Capacity (CCAFS+VAFB)	Annual[2] Production Capacity	Annual[3] U.S. Launches	Production[4] Over Capacity	Excess[5] Capacity Factor
Pegasus	Small	12	12-50	6	6+	2X
Taurus	Small	3	24	3	21	8X
Delta	Medium	12+ 6	12	11	1	Small
Atlas	Medium	10+ 4	8	8	0	None
Titan IV	Large	3-4 + 3-4	10	3	7	3X

1 The maximum number of launches possible, given current facilities and personnel at both Cape Canaveral Air Force Station and Vandenberg Air Force Base, based on IDA analysis.

2 Based on IDA analysis of contractor data. Does not include surge capability.

3 Typical annual U.S. launches, 1995-2010. Apportionment of launches to specific vehicles within a launch vehicle class may vary. Includes firm, probable, potential, and launch-on-need launches. Launches in an individual year may vary.

4 "Annual Production Capacity" minus "Annual U.S. Launches."

5 "Annual Production Capacity" divided by "Annual U.S. Launches."

Demand for DoD launches is relatively predictable and not likely to change substantially from the estimates. Predictions for future commercial space launches, however, could change significantly. Potential increases in the LEO communications market, and the introduction of new, more cost-effective launch vehicles (such as those discussed in Chapter II) could lead to a large increase in commercial demand for small and medium ELVs.

C. INDUSTRY CONSOLIDATION AND RELIANCE ON SINGLE SOURCES

Industry consolidation is occuring in response to declining sales, increased competition, and excess capacity. A number of consolidations have already taken place in companies with space-related business, including Martin Marietta's acquisition of GE Aerospace in 1993, its 1994 purchase of General Dynamics' space launch and launch services business, and its proposed merger with the Lockheed Corporation. More recently, Alliant has announced its intention to purchase Hercules Aerospace.

In May 1994, a Department technical panel concluded in its draft DoD Space Launch Modernization Plan: "With the defense drawdown, industry consolidation, or 'rightsizing', is needed. The overhead associated with maintaining similar facilities, equipment, and skills to produce just a few units a year is financially burdensome in this time of shrinking fiscal resources." [1].

Major contractors in the U.S. space launch industry generally support multiple launch vehicle systems and subsystems (Table III-3). Although the industry will consolidate, sufficient capable suppliers will remain. This process will eliminate excess capacity and reduce attendant overhead costs. Absent rationalization and the resulting efficiencies and savings, DoD will pay more than necessary for the ELVs it needs. The Department prefers to maintain competition. However, our acquisition process gives us greater information about supplier costs and therefore greater leverage than normally exists for commercial buyers.

Many space launch vehicle parts and components have only one supplier. In most cases, these are "single sources." A single source supplier is one which is the only source for a particular product now, but other sources are available if needed (given sufficient time and money to qualify similar, but not identical, manufacturing processes or products). In some cases, these suppliers are "sole sources." A sole source normally has some genuinely unique equipment, process, facility, or technology and is the only one capable of producing the product. For example, one manufacturer is the only domestic supplier with the large forges necessary to produce the bottom and top domes of all large U.S. solid rocket motors. Consequently, every large motor manufacturer depends on this same supplier.

The number of single and sole sources in an industry is often inversely related to demand quantities and, particularly, product differentiation. The space launch industry is characterized by production rates of dozens, as opposed to thousands, per year. The subsystems, parts, and components often are very specialized. Most firms prefer to reduce their vendor base to as small a number of reliable suppliers as possible, sometimes to one vendor per part. Consequently, it is not surprising that many launch vehicle prime and subcontractors have found it cost-effective to qualify and contract with a single source.

Table III-3. Major Contractors in the Space Launch Industrial Base[1]

Specific Items	Shuttle	Titan	Atlas	Delta	Lockheed LLV	Taurus	Pegasus	Minuteman III	Trident D5
Prime	Rockwell	Martin Marietta	MM	McDonnell Douglas	Lockheed	Orbital Sciences Corp. (OSC)	OSC	Ogden Air Logistics Center	Lockheed
Liquid Propulsion	Rocketdyne Aerojet	Aerojet	Rocketdyne UTC-P&W	Rocketdyne Aerojet	Rocket Research	—	—	—	—
Solid Propulsion	Thiokol	UTC-CSD Hercules Boeing	Thiokol	Thiokol Hercules	Thiokol UTC-CSD	Thiokol Hercules	Hercules	Thiokol UTC-CSD Aerojet	Hercules Thiokol UTC-CSD
Payload Fairing	—	MDC	MM	MDC	Lockheed	Courtaids Structural Composites, Inc. OSC	Hercules	—	—
Guidance	Honeywell IBM	Delco Honeywell	Honeywell	Delco Allied Signal	Litton	Litton Trimble	Litton	Autonetics Honeywell	Honeywell Kearfott MM
Avionics	Bendix Kearfott Eaton Collins	Honeywell	Honeywell Teledyne	Microcom Ball Aerospace	Loral Herley-Vega M/A-COM	Aydin OR/Dynatem OSC	OSC		

1 Includes strategic missiles, which are produced by many of the same contractors.

Industry surveys have revealed only mild concerns about the availability of parts and components. Prime contractors understand the peculiar nature of their business. They have demonstrated an ability to manage production risk by monitoring their suppliers, developing alternative suppliers, and moving capabilities in-house.

REFERENCE

Space Launch Modernization Plan , U.S. Department of Defense, April 1994.

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IV. POLICIES TO ENSURE FUTURE SPACE LAUNCH CAPABILITIES

In order to meet its responsibilities, DoD is taking actions to ensure continued access to space, both with greater reliability and lower long term costs.

The Administration's National Space Transportation Policy (Appendix B) sets a clear course for the nation's space program, providing a coherent strategy for supporting and strengthening U.S. space launch capability to meet the growing needs of the civilian, national security, and commercial sectors. The policy establishes roles and responsibilities for the chief agencies--NASA and DoD--by assigning each agency a lead role. DoD is the lead agency for the improvement and evolution of the expendable launch fleet. NASA is the lead agency for development and demonstration of next generation reusable launch systems, such as the single-stage-to-orbit concept.

Just as government investment was required to establish the original U.S. space launch capability, so too will it be required to maintain DoD's access to space. The Department intends to begin immediately a program, based on full and open competition, to develop cost-effective alternatives to the current medium and large launch vehicles. The small launch vehicle industry will mature through commercial activity and market pressures, and does not require significant government involvement.

A. THE EVOLVED EXPENDABLE LAUNCH VEHICLE

The Department is planning an Evolved Expendable Launch Vehicle (EELV) program that will evolve one of the current expendable launch vehicles, or its components, into a family of vehicles to perform the missions now accomplished by the McDonnell Douglas Delta and the Martin Marietta Titan and Atlas. Russian and other technologies will be considered. The capability of the new EELV will not extend below the current capability of the Titan II since the Air Force believes there is sufficient competition in the small launch vehicle range to meet DoD needs and to keep prices down. The objective of the EELV program is to reduce total cost for medium launch vehicle and heavy launch vehicle space launch.

The launcher development program was outlined in broad terms as Option 2 in the Department's May 1994 report to the Congress and will be presented in more detail in a following report. The program involves:

"...flying out current launch vehicles already on contract, evolving a family of launch vehicles from current systems by consolidating medium and heavy lift booster families, and fielding the evolved vehicles to meet payload transition windows.

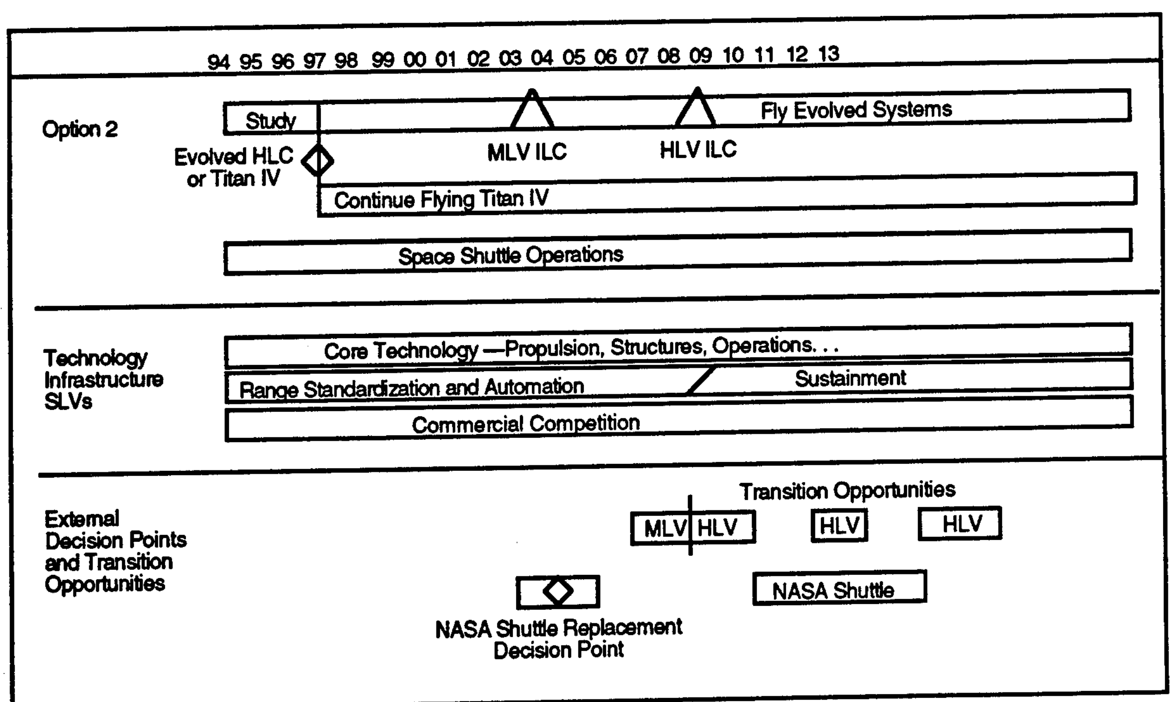
The option includes:

two suboptions: either continue to fly Titan IV for all heavy payloads while evolving a medium launch vehicle (MLV), [or] consolidate the heavy launch vehicle (HLV) requirements into one system family." [1]

This option assumes that the EELV is not required to replace the space shuttle nor to support NASA's space station. This option involves the evolution of the Delta and Atlas programs into a single system with the possibility that the heavy lift missions of the Titan IV would also be included (see Figure IV-1).

The selection of this option indicates that the U.S. is committed to sustainment of an ongoing upgrade and development program and to continuous production to support DoD, civilian, and commercial requirements for launch capability well into the next century. This program will offer improvements in reliability, reduction in launch time, reduction in costs, more efficient production quantities, and increased payload flexibility. The program is expected to cut the cost of heavy lift launches by more than half.

Figure IV-1. Roadmap for Evolved ELV



Source: DoD "Space Launch Modernization Plan," April 1994.

The EELV acquisition will be based on full and open competition that will result in a single U.S. "provider" (either a prime contractor or consortium) for the EELV family. There is a potential for multiple suppliers of essential components and subsystems if the capital investment and qualification costs are deemed worthwhile. However, the most likely result is a reduced number of suppliers, more in line with projected launch requirements. A family of vehicles with common components will increase production efficiency over current vehicles and lead to reduced costs for production and operations. The program also will include modifications to launch pads. Initial operation of the system is planned to begin with the launch of two medium-lift vehicles in 2001 and one heavy-lift vehicle in 2005.

The EELV planned procurement program would reduce DoD sponsorship to one prime contractor (or consortium) for its ELV needs. The launcher procurement rate under the single program would be greater, however, than the current rates for any of the individual ELV contractors. Business levels will be sufficient to maintain those essential capabilities necessary to meet the Department's medium- and heavy-lift space launch requirements into the foreseeable future. The Department's small payload requirements will continue to be met by a predominantly commercial space launch industry.

B. NEAR TERM ACTIONS

The Department has acted in specific instances to ensure its continued access to space. DoD initiated a "bridge" contract for the Titan IV program between the current 41-vehicle contract and the start of the follow-on contract. Additionally, the Air Force is currently funding a reliability enhancement program for the Atlas launch vehicle and has initiated programs to upgrade the Delta launch vehicle. DoD is also maintaining launch capabilities and upgrading launch infrastructure to ensure safe and affordable launches.

1. Titan IV Bridge

Current requirements for Titan IV launch vehicles are lower than were expected when the current production buy of 41 Titan IV vehicles was initiated. The most recent change in payload user requirements has resulted in a 2-year slip in the plans for a follow-on buy of the Titan IV. The Air Force has realigned Titan IV deliveries on the current contract to match the currently anticipated flight rate.

The Titan IV Production Bridge includes provisions to reduce, from three per year to approximately two per year, production rates for the Martin Marietta core vehicles and the McDonnell Douglas payload fairings. This will maintain a minimum assembly crew required to produce Titan IV payload fairings. Also included is an extension of the Continuous Products and Process Improvements (CPPI) efforts at Aerojet. In parallel, there is a slow-down in production of solid rocket motors upgrades at Hercules extending the period of performance from FY97 to FY99. This will maintain a capability for casting operations at Hercules throughout the period. All activities in the Production Bridge Contract have been structured so that the existing 41-vehicle Titan IV procurement remains intact.

Additionally, significant actions are being undertaken in the Bridge Contract to provide for improvements in vehicle components. The CPPI effort funds liquid rocket engine design improvements in performance, operability, and reliability.

Candidate CPPI efforts to be performed during the Production Bridge program:

- LRE Stage I-Nozzle Extension. This program will design, analyze, and development test an ablative nozzle extension with a larger area ratio. Such an improvement will increase specific impulse and thrust for the engine and will result in a payload increase for the Titan IV vehicle.
- LRE Stage I-Turbopump Improvements. This program will achieve the same reliability and performance of the current Titan IV Stage I Turbopump Assembly but at a slower turbine speed. The effort includes performance and design analysis, computational fluid dynamics analysis of the fluid flow through the pump impellers and volutes, design of the optimized impellers and volutes, and associated development tests.
- Stage I-Injector Performance Improvements. This program will conduct testing to evaluate mass and mixture maldistribution across the injector face and then redesign the injector to improve flow distribution. In addition, the injector redesign will increase orifice diameter to lower propellant system flow pressures.
- Stage I and II. This program will design and demonstrate Stage I and II composite engine frames, which will use filament-wound structural members as direct replacements for the existing steel frames. A decrease in frame weight correlates to an increase in payload capability. The structure will be improved as well.
- LRE Reliability Plan Update. This program will update the reliability plan and failure modes analyses for the Titan IV D Stage I and II engines and interfaces. These tasks will assure the continued overall effectiveness of the Titan reliability program and its failure analysis and reporting system.

2. Atlas Reliability Enhancement

The Air Force is currently funding an Atlas Reliability Enhancement Program (AREP) with Martin Marietta to improve the reliability of the Atlas launch vehicle. The program is expected to be completed in FY98.

The AREP consists of a number of distinct tasks, each contributing to the overall goal of improving launch vehicle reliability. The AREP contract includes:

- Centaur RL 10 Engine-Electronic Ignitor. The program will develop a redundant continuous torch ignitor with a solid-state modern electronic spark plug excitor assembly.
- Atlas Centaur RL 10 Engine-Electromechanical Thrust Control. The program replaces the pneumatic-actuated thrust control valve with an electromechanical-actuated (EMA) sleeve valve. The pressure-actuated oxidizer flow control will be replaced with an EMA ball valve. An EMA controller will control valve functions according to vehicle avionics command and provide diagnostic feedback.
- Atlas Centaur RL 10 Engine-Electromechanical Valves. The program will develop valves to be actuated by an electromechanical controller/actuator, which responds to vehicle signals.
- Atlas Centaur RL 10 Engine-Boost Phase Chilldown. The program eliminates ground engine chilldown and performs engine chilldown during boost phase.

3. Delta Flight Safety and Avionics Upgrades

The redundant Inertial Flight Control Assembly (RIFCA), and the Advanced Launch Control System (ALCS) are McDonnell Douglas initiatives to modernize the Delta II space launch vehicle. In addition, the Air Force sponsored a safety upgrade of the Delta II flight termination system. These improvements for Delta will be completed in FY96.

The RIFCA system offers a practical implementation of fault tolerant avionics through redundancy. Because redundancy potentially offers significant improvements in the probability for launch success it is currently one of the most desirable capabilities for launch vehicles. The new RIFCA system will replace the Delta Redundant Inertial Measurement System and the Guidance Computer. The RIFCA development program phase is almost completed.

RIFCA is a single package strapdown navigation and control unit using ring laser gyros. A triple modular redundant hardware architecture ensures no single point failures in the design and provides sufficiently improved reliability to permit progressive elimination of high-cost Class S devices.

The RIFCA consists of an inertial sensor assembly (ISA) and an inertial processing electronics (IPE). It implements the guidance, navigation, flight control, and mission sequencing function for the Delta vehicle. The ISA contains six Allied-Signal ring laser gyros, six Sundstrand accelerometers, and six high-voltage power supplies. The IPE contains three computers based on an Allied-Signal microprocessor, two communication ports to interface with redundant power and control subsystems, and a telemetry port for ground communications.

The Flight Termination System replaces the current termination system. It improves safety compliance by increasing the redundancy of internal system routing and preserves important elements of the industrial base through continuation of system engineering and supplier hardware efforts.

Efforts are also underway to add improvements to the ALCS. These efforts include ground system upgrades, integrated control, data acquisition, and data analysis systems. Specific enhancements to the current ALCS include: (1) automated launch procedures, which will reduce test execution time by more than 50 percent and reduce manpower required for launch operations by 40 percent; (2) digital archive system for data storage, which will reduce magnetic handling labor by up to 200 hours per launch; (3) vehicle simulator, which will decrease the checkout time for the central data processing system by 40 percent; and (4) transportable analysis station, which will decrease time required for troubleshooting and maintenance operations.

4. ELV Launch Capabilities

The DoD will maintain a launch capability for the Delta, Atlas and Titan IV space launch systems at Cape Canaveral, and will also maintain the necessary infrastructure and range resources that support these launch programs. Titan IV and Titan II launch capability will be sustained at Vandenberg Air Force Base. Construction of the new Atlas II Space Launch Complex at Vandenberg is continuing. Systems check-out and pathfinder activities will prepare this facility to support NASA and DoD missions beginning in FY98. NASA and DoD will continue to share support of the Delta launch complex at Vandenberg AFB.

5. ELV Range Infrastructure

The flight tracking, safety and other supporting infrastructure of the Eastern and Western Space Launch Ranges are being upgraded to support current ELV programs. This includes the completion of Range Standardization and Automation (RSA) investments in the space launch infrastructure. These projects are critical to reduction of operating costs at the ranges and to modernization of operations for the long term. The RSA includes computer and electronics upgrades to completely overhaul operations at both ranges. Other infrastructure investments include industrial utilities modernization and repair to facilities and roads.

REFERENCE

Space Launch Modernization Plan, U.S. Department of Defense, April 1994.

V. CONCLUSIONS

- The ability to place satellites in orbit is critical to the accomplishment of a range of national security missions.
- The same type of expendable launch vehicles, all initially based on DoD ballistic missile designs, are used for commercial, civil, military, and intelligence launches.
- All three prime contractors currently supplying ELVs for DoD use are profitable.
- Reduced U.S. Government requirements for space launch and ballistic missiles and strong foreign competition has led to production overcapacity in the large and small vehicle segments of the U.S. launch industry.
- Substantial U.S. space launch industry consolidation is inevitable and necessary.
- Consolidation will ultimately result in reduced costs for ELV production and operations--and lower prices.
- Although the industry will consolidate, sufficient capable U.S. suppliers will remain.
  - DoD will rely on the healthy commercial market to meet its limited small ELV requirements.
  - U.S. medium launch vehicle prime contractors do not have excess capacity and will maintain necessary capabilities to meet DoD's launch needs.
  - DoD has executed a bridge contract to maintain heavy-lifting capabilities during a period of low Titan IV demand. This contract stretches deliveries and sustains essential industrial and technological capabilities until a follow-on contract is executed.
- DoD also is taking action to improve launch vehicle capabilities and reduce the recurring cost of space launch. The Department is beginning a program to develop a single evolved expendable launch vehicle (EELV) family capable of handling medium and heavy payloads. A family of vehicles with common subsystems and components will increase production efficiency and reduce production and operations costs.
- These actions will have additional benefits. They also will (1) sustain essential capabilities during industry consolidation, and (2) improve the international competitiveness of U.S. space launch providers by developing more cost-effective vehicles.

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APPENDIX A

COMPANIES AND FACILITIES

APPENDIX A

COMPANIES AND FACILITIES

1. Martin Marietta

Martin Marietta Space Group, a corporate division of Martin Marietta Corporation, manufactures space launch vehicles and provides affiliated services. In May 1994, Martin Marietta acquired General Dynamics' Space Systems Division, which builds the Atlas Centaur family of launch vehicles and high-energy upper stage, and offers commercial launch services to both business and Government users. In August 1994, Martin Marietta and Lockheed announced their intention to merge. The two corporations proposed to continue operating all current business segments.

a. Titan Facilities

The Titan IV is the largest U.S. booster, with a capacity that far exceeds either Atlas or the European Ariane 4 [1]. The Titan IV is used for the largest U.S. military launch requirements. It provides 71 percent of the U.S. Government's heavy lift capability. The rest is provided by the Space Shuttle. Titan IV will continue to be built for the Air Force and perhaps certain commercial users requiring heavy lift well into the next decade. At present, there are no identified commercial Titan IV customers.

The main Martin Marietta Titan assembly plant is in Denver, CO. Titan sections are then moved to Cape Canaveral, where final assembly is done at launch complex 40/41. An integrate-transfer-launch assembly process is used in which the core vehicle and solid rocket boosters are integrated on a mobile platform before reaching the launch pad. Bay 1 at the vehicle assembly building was dedicated to commercial Titan work, but the facility is no longer used. Bay 2 handles USAF Titan preparation. Bay 3 is used for Centaur. Solid boosters for thrust augmentation are added at the Solid Motor Assembly Building. Launch control is conducted from the pad 40/41 location. The Vandenberg space launch complex uses a assemble-on-pad concept for Titan launches.

Titan production is nearing the end of the current 41 vehicle production program, with a 2-year slip in the time before beginning follow-on Titan production run. This time slip would have created serious problems not only at Martin Marietta, but also at several subcontractors: McDonnell Douglas, Hercules, and particularly Aerojet. To avoid the gap in production and the consequent loss of skills as these companies close production facilities, Martin Marietta and the U.S. Air Force agreed on a bridge contract. This agreement covers the period 30 September 1997 to 30 September 1999; it reduces the current production run from three vehicles per year to two per year. There is a similar slowing of production at Aerojet, McDonnell Douglas, and Hercules, but each subcontractor and each subcontractor supplier will be able to continue work through the end of this decade. The new production acquisition period for an as yet undetermined number of Titan vehicles beyond number 42 will begin when the bridge period is completed [2].

The Defense Authorization Act of 1994 extended the current Titan IV program from 41 vehicles to 47. This change was made in part to accommodate launches of Defense Support Program satellites shifted from the Space Shuttle [3].

b. Atlas Facilities

The former General Dynamics subsidiaries purchased by Martin Marietta built, assembled, and tested the Atlas and Centaur airframes at its Kearny Mesa facility near San Diego, CA. This operation is now moving to Denver. It will be integrated with Titan work to provide efficiencies of production. Also in San Diego, Martin Marietta uses Air Force Plant 19 to fabricate Atlas fuel tanks. The company builds Atlas/Centaur payload fairings, thrust structures, and adapters at a plant in Harlingen, TX, also acquired as part of the purchase from General Dynamics. The Atlas-E launch complex (SLC-3W) at Vandenberg will be deactivated in FY95, and the Atlas II launch complex (SLC-3E) will be operational in FY98. The company provides launch operations at Cape Canaveral, FL, or Vandenberg AFB, CA, depending on customer needs and the type of orbit sought. The Centaur upper stage, originally a GD product, is used on Martin Marietta's Titan as well as on the Atlas. The company also now owns the acoustic and thermal test facilities used for the Centaur program [1]. The Atlas family of vehicles provide 52 percent of the U.S. Government's medium launch vehicle business.

About a year before Martin Marietta bought the General Dynamics space launch operations, the company also purchased General Electric Aerospace, including the Astro

Space Division. The former GE Astro Space is currently working on a $200 million contract from the U.S. Air Force to build 10 DSCS 3B communications satellites. As an example of the Martin Marietta-General Dynamics fit, an Atlas Centaur will launch the DSCS 3B satellites. In addition, Martin Marietta received an Air Force contract to convert two Minuteman II ICBMs into suborbital launchers, with options for orbital versions as well [1].

c. Space Shuttle Facilities

Martin Marietta Manned Space Systems Company is located at NASA's Michoud Assembly Facility, New Orleans, LA. This company designs, assembles, and tests the external tanks for NASA's space shuttle. Once assembled, the tanks are moved to Florida by barge [1].

d. Launch Facilities

Martin Marietta Space Launch Systems Company is the prime contractor for the USAF's Titan II and Titan IV space launchers. ELVs are launched from both Cape Canaveral, FL, and Vandenberg, CA. At Cape Canaveral, pads 40 and 41 are used for Titan launches. Also at Cape Canaveral, Atlas uses complex 36. Pad 36A is primarily for USAF launches, but open time slots can be used for commercial work. Pad 36B is allocated for commercial launches. On the west coast, Martin Marietta launches the Atlas from Vandenberg AFB's pad SLC-3. Pads SLC-4E/W support Titan II and Titan IV launches at Vandenberg. [1].

e. Company Financial Position

Both Martin Marietta Corporation and its Space Group are profitable. In 1993, the company (which is also engaged in electronics, information and services, materials, and energy businesses) earned $859M on $9,436M sales. The Space Group earned $249M on sales of $3,442M sales, an operating profit margin of 7.2 percent.

2. McDonnell Douglas

McDonnell Douglas builds the successful Delta series of launch vehicles. Delta production began in 1959 as an interim space launcher based on the Air Force Thor missile. McDonnell Douglas has an Air Force contract to launch 20 GPS satellites with the Delta plus a GPS follow-on contract for at least 25 additional launches, beginning in 1996. Commercial launches have represented approximately 25 percent of McDonnell Douglas' Delta business over the past three years [1].

McDonnell Douglas is lead contractor in a single stage to orbit (SSTO) reusable launch vehicle development project. Sponsored initially by the Strategic Defense Initiative Office (now the Ballistic Missile Defense Office), the SSTO development version is known as the DC-X, or sometimes as the Delta Clipper. The current DC-X is a flight demonstration program of a one-third scale test article. It is intended to demonstrate the ability of a space vehicle to be operated with the same cost effectiveness and rapid turnaround efficiencies of an aircraft. The design uses vertical take off and landing. The DC-X has completed first static firing tests at NASA's White Sands, NM, facility. Final flight testing of the DC-X was recently funded by Congress. The DC-X subsonic flight demonstration program will be followed with a 3-year, DC-X2 hypersonic, space-capable flight demonstration that would also develop commercial design and manufacturing processes. The DC-X2 would be followed by a 4-year effort to develop and fly the full-scale orbital prototype, the DC-Y. The multi-engine DC-X uses advanced Pratt & Whitney RL-10 rocket engines for propulsion. These liquid hydrogen/liquid oxygen engines produce an exhaust product that is mostly heat and water, and is environmentally clean [3,4].

The DC-X has completed four test flights at altitudes up to 3,000 feet, lasting as long as 136 seconds. Four additional tests are scheduled at altitudes up to 5,000 feet to demonstrate engine performance, aerodynamic drag, and vehicle flight and control capabilities. The next flight series will be to an altitude of about 20,000 feet to validate the autonomous flight control system, GPS inertial navigation system, and low speed handling and rotation maneuver performance [4].

a. Delta Facilities

The main McDonnell Douglas Delta stage fabrication facility is in Huntington Beach, CA, with assembly done in Pueblo, CO. From Colorado, the vehicle is moved to Cape Canaveral, where launch assembly and vehicle/payload mating and checkout takes place. For equatorial orbits, Deltas use Cape Canaveral's Pad 17 complex. The launcher assembly work takes from 9 to 16 weeks at Air Force facilities on the station. Alternatively, Astrotech Space Operations company offers some assembly at its Titusville, FL, facility that can supplement and support the Delta assembly operation. Delta polar launches are from Vandenberg AFB's Pad SLC-2W, and the associated assembly and support facilities. Assembly and test times at Vandenberg are the same as at Cape Canaveral [1, 5].

The Defense Plant Representative at McDonnell Douglas recently estimated the Huntington Beach facility is now working at a capacity of less than 45 percent for launch vehicles (Delta II and Titan IV fairings). Manufacturing operations are currently supplemented by nonlaunch vehicle work. At Huntington Beach, McDonnell Douglas now has more than 50 percent of its work in nonlaunch vehicle fabrication.

b. DC-X Facilities

The DC-X is assembled and checked out at McDonnell Douglas Aerospace' Huntington Beach, CA, facility. A launch facility has been built at White Sands Missile Range, adjacent to the Space Shuttle runways. It consists of a concrete pad surrounded by operations and maintenance trailers and liquid oxygen and liquid hydrogen supply trailers [4].

c. Fairing Production

McDonnell Douglas Space Systems Company supplies the Titan 34D-style aluminum skin and stringer payload fairings to Martin Marietta. The company also supplies Martin Marietta with isogrid aluminum 6061 fairings for the Titan IV. The fairings are fitted for use with the no-upper-stage version, the Inertial Upper Stage, and the Centaur versions of Titan IV. Separation is done with a low explosive detonating fuse along the seams and 12 explosive bolts [1]. Under the terms of the Air Force-Martin Marietta bridge contract, McDonnell Douglas will slow its rate of payload fairing production and delivery from three ship sets per year to two. This agreement will extend the current production period of performance by 18 months

d. Foreign Agreements

The company has cooperative agreements with Russia for technology transfer and is pursuing international cooperative agreements with Russia, Japan, and other countries for various technologies.

e. Company Financial Position

Both McDonnell Douglas and its Missiles, Space, and Electronics Systems segment are profitable. In 1993, the company (which is also engaged in commercial and military aircraft and financial businesses) earned $492M on $14,474 sales. The Missiles, Space, and Electronics Systems segment earned $338M on $2,575M sales, an operating profit margin of 13.1 percent.

3. Orbital Sciences Corporation

Orbital Sciences was organized in 1982, primarily to design and market space shuttle upper stages. Their first main product was the Transfer-to-Orbit Stage. In 1992 the company was reorganized into three divisions: Space Systems (space launchers, orbit transfer vehicles, and spacecraft systems), Space Data (suborbital launchers, space payloads, satellite tracking systems), and Satellite Services (communications and remote sensing). OSC has two primary space launch vehicles. Pegasus is a three-stage, solid propellant, winged launch vehicle that can be air launched from a B-52, an L-1011, or a comparable aircraft. Taurus is a four-stage launch vehicle that is fully road mobile, and can be launched from any concrete surface. The Taurus first stage is derived from the Peacekeeper missile, the three other stages are from the Pegasus [1]. OSC also produces suborbital target launch vehicles and research launch vehicles.

a. Facilities

The Pegasus and an extended capability vehicle called Pegasus XL are assembled from components shipped from manufacturers to the vehicle assembly building, NASA Dryden Flight Research Facility, Edwards AFB, CA. Pegasus assembly normally requires 14 days. In June of 1994, OSC's first launch of its Pegasus XL model failed to orbit a payload because of faulty aerodynamic analysis. Taurus' launch preparations at the site require 8 days from arrival of the sections until launch. Most flights can be initiated from a variety of locations. The small size of the vehicles plus their relative simplicity (subcontractors make just in time deliveries for assembly) means that OSC need not develop an extensive manufacturing facility network. OSC manufactures a variety of electronic components such as cable assemblies, circuit cards, and electronic subassemblies (much of it for the Government) in Chandler, AZ, Chantilly, VA, and Boulder, CO [1].

The Taurus ELV can be deployed anywhere in the world for a short notice launch. Orbital Sciences states that, assuming assembled Taurus vehicles are available, launch can be accomplished within 72 hours for satellite replenishment. There are no U.S. Government nor commercial Taurus launches scheduled.

b. Production Status

By March 1993, OSC had 25 firm launch orders and 51 optional orders for small satellite launches with Pegasus. OSC is expanding by adding assembly facilities on the East coast at Wallops Island, VA. Other locations are being pursued. NASA will use Pegasus for its Small Explorer satellite, the Air Force for its small launch vehicle program. In addition, the Ballistic Missile Defense Office has contracted with OSC for launch of its Miniature Seeker Technology Integration satellite (MSTI 3) in support of the missile and space tracking system development project. ARPA contracted with OSC to use Taurus for demonstration/validation of a road transportable launch system for rapid deployment. The objective is to find a launch system that can put small vehicles into LEO using virtually any site [1].

c. Company Financial Position

Orbital Sciences Corporation is profitable. In 1993, the company earned $8.7M on $190M sales, an operating profit margin of 4.5 percent, up from 2.7 percent in 1992.

4. Lockheed

Lockheed is a leader in military programs for aircraft, missiles, space, electronics, and aerospace support services. The company sought to secure its future by purchasing (in February 1993) General Dynamics' aircraft operations, which is developing the U.S. Air Force's F-22 advanced fighter. In August 1994, Lockheed and Martin Marietta announced their intention to merge. The two corporations proposed to continue operating all current business segments.

Lockheed has extensive experience in the missile business. It produced the Polaris, Poseidon, and Trident series for the Navy, and is still producing the Trident II. Lockheed has also produced the Agena second stage for the Air Force. Missile production is done at the Sunnyvale, CA, and Austin, TX, facilities.

a. New Vehicle Development

Recently, Lockheed announced intentions to enter the commercial launcher market with a newly designed small space launch vehicle. The Lockheed Launch Vehicle (LLV) will be made up of existing launch vehicle components [1] and will be available in three primary configurations. These configurations (LLV1, LLV2, and LLV3) will carry payloads of 2,000, 4,000, and 8,000 pounds, respectively, to an orbit of 185 km. Lockheed also plans to be able to lift an 8,400-pound payload to GEO using added strap-on boosters and upper stages [6].

The price for the two-stage LLV1 is proposed to be about $14 million, while that for the LLV3 will be about $20 million. The first launch is scheduled for early 1995, and Lockheed has one customer so far. The Lockheed launch vehicle series will compete directly with the Pegasus and Taurus products offered by Orbital Sciences, the Martin Marietta Titan II, and the McDonnell Douglas Delta mid-range launch vehicle.

b. Foreign Agreements

Early in 1993, Lockheed helped form Lockheed-Krunichev-Energia International to market the Russian Proton launch vehicle. An agreement with the U.S. allows eight GEO/GTO launches through the year 2000, except for certain already concluded contracts. The restrictions were imposed because of fears that the Russians would sell launch services at drastically reduced prices in order to generate foreign hard currency revenues.

c. Subcontractors and Facilities

LLV contractors include Lockheed Missiles and Space Company, Sunnyvale, CA, for the launcher development, Thiokol Corp, Brigham City, UT, for the Castor 120 and Castor 4 solid rocket motors, United Technologies Chemical Systems Division, San Jose, CA, for the Orbus 21D solid rocket upper stage motor, and Olin Aerospace, Redmond, WA (Rocket Research) for velocity trim thrusters and attitude control system [6].

d. Company Financial Position

Both Lockheed Corporation and its Missiles and Space segment are profitable. In 1993, the company (which also is engaged in aircraft, technology services, and electronics businesses) earned $844M on $13,071M sales. The Missiles and Space segment earned $348M on $4,238M sales, an operating profit margin of 8.2 percent.

5. EER Systems

EER's space launch vehicles are built by its Space Services Division. EER designed the Conestoga family of solid fueled rockets that can be used to put 3,300 pounds into LEO. The first Conestoga used a Minuteman I second-stage motor for a suborbital flight. Current models are based on the Thiokol Castor 4B solid fuel rockets with additional Star stages, also built by Thiokol. EER's Starfire is a suborbital ELV used for microgravity research payload launch. The vehicle is based on the Thiokol Castor 4 solid rocket booster, and multiple boosters firing together can lift a 3,960 pound payload into a 20-minute microgravity flight [1].

EER has used launch facilities on Matagorda Island, TX, for most of its flights. The first commercial launch, for the Consortium for Materials Development in Space at the University of Alabama, was a suborbital sounding rocket launch done from White Sands, NM, Complex 36 [1].

EER is a privately-held company, for which public financial information is not available.

6. Boeing

Boeing's Missiles and Space Division produces the two stage Inertial Upper Stage (IUS), designed to move payloads of up to 5,000 pounds from LEO into geosynchronous orbit. Both segments of the IUS are powered by solid rocket motors, with stage 2 holding the avionics bay and the environmental measuring unit. The IUS can be used with the space shuttle, or after launch from another vehicle. The U.S. Air Force controls production and allocates IUS use for all customers, including civil. Most IUS manufacturing is done at Boeing's Kent, WA facility. Rocket engines are manufactured by United Technologies' Chemical Systems Division, San Jose, CA [1].

Annual IUS production capacity, constrained by limited test and acceptance facilities, is four units. There are IUS launches scheduled through 1997. Additionally, there are good prospects for continued, if limited, production since the vehicle has solid rocket motors and can be used with the Space Shuttle, whereas the liquid hydrogen/liquid oxygen Centaur stage cannot. Boeing has plans to develop an improved IUS version with lighter weight avionics and greater reliability [1].

No public financial information is available on this component of Boeing's Defense and Space Group.

7. Rockwell

Rockwell International is a leading producer of space systems. In addition, Rockwell makes electronics products for defense systems, telecommunications, avionics, factory automation systems, automotive parts, and graphics systems. Through its subsidiary Rocketdyne, Rockwell is a subcontractor to many primary space launch contractors.

Rockwell's Space Systems Division is one of four units of the company's aerospace interests (also included are Rocketdyne, North American Aircraft, and National AeroSpace Plane). Space Systems builds the space shuttle orbiter for NASA and assists NASA in the integration of shuttle components. It provides support services, payload integration, flight analysis, and orbiter turnaround, logistics and engineering support [1].

Rockwell's Autonetics Electronics Systems Division produces guidance units for the Minuteman III missile.

The shuttle orbiter's forward and aft fuselages, crew compartment, forward reaction control system, vertical stabilizer, and secondary structures are fabricated at Rockwell's Downey, CA, facility. The orbiters are assembled or modified at Palmdale, CA, near Edwards AFB [1].

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APPENDIX B

GOVERNMENT POLICIES

Appendix B

GOVERNMENT POLICIES

A. National Space Transportation Policy [1]

In August 1994 the President signed a National Space Transportation Policy directive which set forth specific space launch policies. This policy is the result of extensive discussion and agreement among all agencies of the Government with an interest in space systems. Government intentions in several areas that previously had produced uncertainty in the industrial community were clarified. Key elements are discussed below.

1. Use of U.S. Launch Services

- For the foreseeable future, United States Government payloads will be launched on space launch vehicles manufactured in the United States, unless exempted by the President or his designated representative.
- U.S. Government agencies shall purchase commercially available U.S. space transportation products and services to the fullest extent feasible that meet mission requirements and shall not conduct activities with commercial applications that preclude or deter commercial space activities, except for national security or public safety reasons.
- The Department of Defense will maintain the Titan IV launch system until a replacement is available.
- The U.S. Government will make all reasonable efforts to provide stable and predictable access to appropriate space transportation-related hardware, facilities, and services; these will be on a reimbursable basis. The U.S. Government reserves the right to use such facilities and services on a priority basis to meet national security and critical civil sector mission requirements.
- The Department of Defense and the National Aeronautics and Space Administration will combine their expendable launch service requirements into single procurements when such procurements would result in cost savings or are otherwise advantageous to the Government. A Memorandum of Agreement will be developed by the Agencies to carry out this policy.

2. Consideration of Commercial Aspects

- The U.S. Government will foster the international competitiveness of the U.S. commercial space transportation industry, actively considering commercial needs and factoring them into decisions on improvements in launch facilities and launch vehicles.
- U.S. Government agencies, in acquiring space launch-rated capabilities, will, to the

extent feasible and consistent with mission requirements:

- Provide for private sector retention of technical data rights, limited only to the extent necessary to meet government needs.

3. Use of Excess Ballistic Missiles

- U.S. excess ballistic missile assets that will be eliminated under the START agreements shall either be retained for government use or be destroyed. These assets may be used within the U.S. Government in accordance with established DoD procedures, for any purpose except to launch payloads into orbit. Requests from within the Department of Defense or from other U.S. Government agencies to use these assets for launching payloads into orbit will be considered by the DoD on a case-by-case basis and require approval by the Secretary of Defense.

  Mindful of the policy's guidance that U.S. Government agencies shall purchase commercially available U.S. space transportation products and services to the fullest extent feasible, use of excess ballistic missile assets may be permitted for launching payloads into orbit when the following conditions are met:

  The payload supports the sponsoring agency's mission.

  - The use of excess ballistic missile assets is consistent with international obligations, including the Missile Technology Control Regime (MTCR) guidelines and the START agreements.

  - The sponsoring agency must certify the use of excess ballistic missile assets results in a cost savings to the U.S. Government relative to the use of available commercial launch services that would also meet mission requirements, including performance, schedule, and risk.

4. DoD's Role

- The Department of Defense will be the launch agent for the national security sector and will maintain the capability to evolve and operate those space transportation systems, infrastructure, and support activities necessary to meet national security requirements.
- The Department of Defense will be the lead agency for improvement and evolution of the current expendable launch vehicle fleet, including appropriate technology development. All significant ELV technology-related development associated with medium and heavy-lift ELVs will be accomplished through the DoD. In coordination with the DoD, NASA will continue to be responsible for implementing changes necessary to meet its mission-unique requirements.

5. Technology Support

- The U.S. Government will maintain a strong space transportation capability and technology base, including launch systems, infrastructure, and support facilities, to meet the national needs for space transport of personnel and payloads.

- U.S. Government agencies shall work with the U.S. commercial space sector to promote the establishment of technical standards for commercial space products and services.
- The U.S. Government will seek to take advantage of foreign components or technologies in upgrading U.S. space transportation systems or developing next generation space transportation systems. Such activities will be consistent with U.S. nonproliferation, national security, and foreign policy goals and commitments as well as the commercial sector guidelines contained in this policy. They will also be conducted in a manner consistent with U.S. obligations under the MTCR and with due consideration given to dependence on foreign sources and national security.

B. Foreign Space Launch Agreements

There are significant disparities in the cost/price space launch sales structure between the nonmarket economy countries and the western launch countries, and also between some western nations.

The U.S. has entered into an agreement with Russia that limits the number of Russian contracts for geosynchronous launches for non-Russian customers to 8 total through the year 2000. The agreement also requires consultations if the Russians bid less than 7.5 percent below the lowest comparable Western price. A January 1989 6-year agreement limits Chinese launches of western geosynchronous orbiting satellites to 9 total through 1994. It also stipulates that prices for launches using China's Long March launcher be on par with comparable services offered by firms from market economies. These agreements are intended to be temporary, pending transformation of Russian and Chinese industry to a market economy. Negotiations are underway with China on a new agreement covering the period 1995-2001. Foreign ballistic missiles retired under arms limitation treaties could likewise pose a significant threat to the commercial space launch industry if allowed in the market place. Restrictions on the use of excess ballistic missiles are being negotiated with foreign nations, as well as accepted practices regarding the pricing of commercial launch vehicles.

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