Commercial Space Transportation

QUARTERLY LAUNCH REPORT

Featuring the launch results from the previous quarter and forecasts for the next two quarters

1st Quarter 1999

United States Department of Transportation • Federal Aviation Administration
Associate Administrator for Commercial Space Transportation

1ST QUARTER 1999 REPORT

Objectives

This report summarizes recent and scheduled worldwide commercial, civil, and military orbital space launch events. Scheduled launches listed in this report are vehicle/payload combinations that have been identified in open sources, including industry references, company manifests, periodicals, and government documents. Note that such dates are subject to change.

This report highlights commercial launch activities, classifying commercial launches as one or more of the following:

- ***Internationally competed launch events (i.e., launch opportunities considered available in principle to competitors in the international launch services market),***
- ***Any launches licensed by the Office of the Associate Administrator for Commercial Space Transportation of the Federal Aviation Administration under U.S. Code Title 49, Section 701, Subsection 9 (previously known as the Commercial Space Launch Act), and***
- ***Certain European launches of post, telegraph and telecommunications payloads on Ariane vehicles.***

Photo credit: Lockheed Martin (1998). Image is of the Atlas 2AS launch on October 9, 1998 from Cape Canaveral Air Station. This commercial launch successfully orbited the Hot Bird 5 satellite for Eutelsat.

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This document was released on January 30, 1999.

SUMMARY

Fourth Quarter 1998 Launch Events

- The United States conducted 11 launches in the fourth quarter of 1998. Five were commercial (two Atlas, two Delta 2, and one Pegasus) and six were non-commercial (two Delta, two Shuttle, one Taurus, and one Pegasus). All of these launches were successful.
- There were six Russian launches in this period of which one was a commercial Proton launch. The remaining five non-commercial launches consisted of two Cosmos, two Proton, and one Soyuz launch. All launches were successful.
- Europe conducted four successful commercial launches of Ariane 4 vehicles with no failures. Europe also made a final successful test launch of the Ariane 5.
- China used one Long March vehicle on a successful commercial launch.

First and Second Quarter 1999 Scheduled Launch Events

- The United States intends to make 25 launches in the next two quarters. Eleven of these launches will be commercial: one each Athena 1 and Athena 2, three Atlas 2 and one Atlas 3, two Delta 2 and one Delta 3, one Pegasus and one Sea Launch. Non-commercial launches will consist of one Atlas 2, six Delta 2, two Pegasus, two Shuttle launches, one Titan 2, and two Titan 4 launches.
- Russian launch vehicles are scheduled to make 17 launches, 12 of which are commercial. These commercial launches are on seven Proton, three Soyuz, one Dnepr, and one Cosmos. Non-commercial launches will include two Soyuz, one Proton, one Zenit, and one Cyclone.
- One Ukrainian non-commercial Zenit will be launched.
- Europe plans five commercial Ariane 4 launches and two commercial launches of the Ariane 5 for a total of seven commercial launches.
- China anticipates the launch of two non-commercial Long March vehicles.
- India will conduct a non-commercial launch of the PSLV.
- Brazil will make a second attempt to launch its VLS launch vehicle.

SUMMARY

Commercial Products and Services

First and Second Quarter 1999

Three New US Launch Systems to Fly

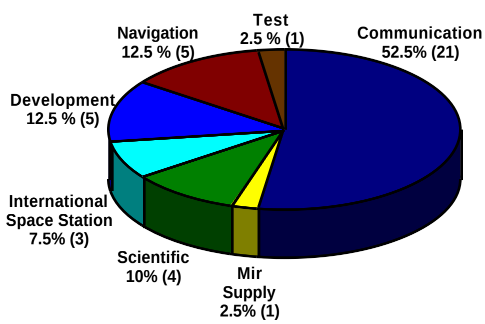
The first flight of the Sea Launch vehicle is scheduled for March. Sea Launch, a multi-national partnership led by Boeing, will launch the Ukrainian-manufactured Zenit vehicle with a Russian-built Block DM upper stage, from an ocean platform south of Hawaii. Sea Launch is capable of lofting 11,050 pounds into geosynchronous transfer orbit. The first flight is scheduled to deploy a dummy test payload in order to prove the vehicle on its inaugural launch.

The Delta 3 vehicle is also scheduled to make a commercial launch in March. If successful this will be the first successful flight of the Delta 3 after its initial failure in August 1998. It will carry the Orion F3 spacecraft for Orion Network Systems. The Delta 3 is capable of placing 8,360 pounds into geosynchronous transfer orbit.

The Lockheed Martin Atlas 3A will make its first flight in June 1999. The vehicle is capable of lifting 8,940 pounds to geosynchronous transfer orbit and has a first stage powered by the Russian-designed RD-180 engine. The RD-180 engine is co-produced by RD AMROSS, a joint venture formed by NPO Energomash and Pratt & Whitney. The first flight of the Atlas 3A will launch Loral Skynet's Telstar 7 satellite.

Payload Use Analysis

Fourth Quarter 1998



In the fourth quarter of 1998, there were 40 payloads launched worldwide. These payloads were divided between communications (52.5 percent), scientific (12.5 percent), navigation (12.5 percent), development (10.0 percent), International Space Station (7.5 percent), Mir supply (2.5 percent), and test (2.5 percent).

All of the 18 internationally competed payloads on commercial launches were communications payloads.

LAUNCH SCHEDULE

Scheduled Launch Events

Vehicle	Payload	Site
JANUARY 1999		
Athena 1	Rocsat 1	Spaceport Florida
Atlas 2AS	JCSat 6	CCAS
Delta 2 7425	Mars Polar Lander Deep Space 2	CCAS
Delta 2 7925	Argos Oersted Sunsat	VAFB
Long March 3B	ChinaSat 8	Xichang
Proton	Telstar 6	Baikonur
FEBRUARY 1999		
Ariane 44L	Arabsat 3A Skynet 4E	Kourou
Delta 2 7426	Stardust	CCAS
Proton	AsiaSat 3S	Baikonur
Proton	Sesat	Baikonur
Soyuz	Soyuz TM-29	Baikonur
Soyuz	Globalstars 21-24	Baikonur
Titan 4B/IUS	DSP 19	CCAS
Zenit 2	Okean O1	Baikonur
MARCH 1999		
Ariane 44P	Intelsat K-TV	Kourou
Atlas 2AS	Eutelsat W3	CCAS
Atlas 2A	GOES L	CCAS
Delta 2 7920	Iridiums 88-91, 94	VAFB
Delta 3	Orion F3	CCAS
Proton	Astra 1H	Baikonur
Proton	Raduga 34	Baikonur
Sea Launch	Galaxy 11 Mock-up	Sea Launch Platform
Soyuz	Progress M-41	Baikonur
Titan 4B	USA 1999-03	VAFB

LAUNCH SCHEDULE

Scheduled Launch Events

(Continued)

Vehicle	Payload	Site
APRIL 1999		
Ariane 44L	Galaxy 11	Kourou
Ariane 5	Eutelsat W4	Kourou
	Telkom 1	
Cosmos	Abrixas	Kapustin Yar
	MegSat 0	
Delta 2 7920	Landsat 7	VAFB
	Iowasat	
Delta 2 7925	Navstar GPS 2R- 3	CCAS
Dnepr	UoSat 12	Baikonur
Proton	ICO 1	Baikonur
Shuttle Columbia	Chandra	KSC
	STS 93	
Titan 2	QuikSCAT	VAFB
MAY 1999		
Ariane 44LP	Orion F2	Kourou
Ariane 5	AsiaStar 1	Kourou
	Insat 3B	
Atlas 2A	GBS 10	CCAS
Delta 2 7320	FUSE	CCAS
Delta 2 7420	Globalstars 45-48	CCAS
Proton	Nimiq 1	Baikonur
Shuttle Discovery	STS 96	KSC
JUNE 1999		
Athena 2	IKONOS 1	VAFB
Atlas 3	Telstar 7	CCAS
Proton	ICO 2	Baikonur
VLS	SACI 2	Alcantara

LAUNCH SCHEDULE

For the First and Second Quarter 1999

Additional Launch Events to be Announced*

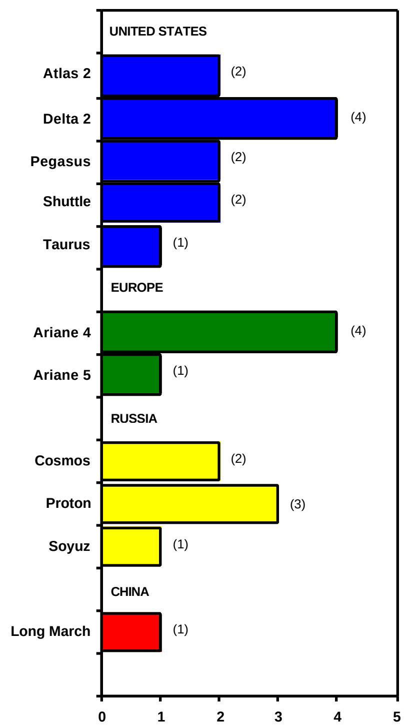
Vehicle	Payload	Site
FIRST QUARTER OF 1999		
Pegasus XL	WIRE	VAFB
PSLV	IRS P4 Kitsat 3 Tubsat C-DLR	Shriharikota
Soyuz	Globalstars 25-28	Baikonur
Soyuz	Globalstars 29-32	Baikonur
SECOND QUARTER OF 1999		
Ariane 4-TBA	Astra 2B	Kourou
Cyclone 3	Coronas F	Plesetsk
Pegasus XL	TERRIERS MUBLCOM Celestis 3	VAFB
Pegasus XL	TSX 5	VAFB
Proton	Coupon/Bankir 1R	Baikonur
Zenit 2	Meteor 3M- 1 Badr 2	Baikonur

* This section summarizes launches and payloads that are expected to occur during the next two quarters. Exact launch dates were not available prior to publication of this report

LAUNCH REPORT

Launch Events

Fourth Quarter 1998



Number of Launches
October - December 1998

In the fourth quarter, United States launch vehicles conducted 11 of the 23 total launches worldwide. Five of these launches were commercial; two Atlas vehicles with GEO communications satellites, and two Delta vehicles, one with a set of five Iridium LEO communications satellites and the other with a GEO communications satellite. A commercial Pegasus vehicle carried a LEO communications satellite to orbit. Non-commercial launches consisted of two Delta 2 vehicles with a science and a development payload, two Shuttle missions (one of these was the first International Space Station assembly flight), a Pegasus with a science payload, and a Taurus with a development payload.

Russia carried out six launches of which one was a commercial Proton launch of a GEO communications satellite. Two of the remaining non-commercial launches consisted of Cosmos vehicles, one with a navigation satellite and one with a navigation and a science satellite. Two Proton vehicles were launched with an International Space Station component on one flight and three navigation satellites for the Glonass system on the other. The remaining non-commercial launch carried a Progress supply craft Soyuz launch to Mir.

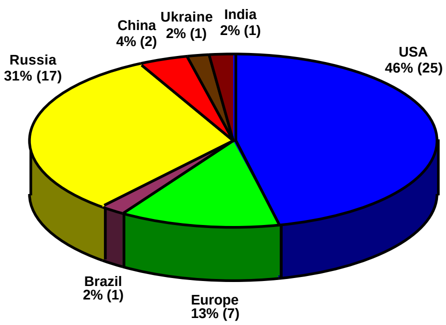
Europe launched four commercial Ariane 4 vehicles carrying six GEO communications satellites to orbit. Europe's one non-commercial launch was the successful launch of the final Ariane 5 test vehicle with a dummy GEO satellite and a re-entry test vehicle.

China successfully launched a single Long March vehicle with pair of Iridium LEO communications satellites on board.

LAUNCH REPORT

Scheduled Launch Events

First and Second Quarter 1999



Scheduled Launch Events, by Region
January - June 1999

(includes small launch vehicles, excludes sub-orbital launch events)

Fifty-four orbital launch events are scheduled in the first two quarters of 1999. The United States will conduct 25 of these launches, the first four of which will be on variants of Atlas 2 (three carrying GEO communications satellites and the fourth a meteorological satellite). The first launch of an Atlas 3 will deploy a GEO communications payload. Eight Delta 2 vehicles will loft 10 communications satellites, five scientific spacecraft, two developmental satellites, one remote sensing satellite, and one navigation satellite. One Delta 3 flight is planned to launch a GEO communications satellite. In its first launch, Sea Launch is expected to deploy a dummy GEO communications satellite. An Athena 2 vehicle will carry a remote sensing satellite and an Athena 1 will orbit a developmental satellite. Two Pegasus launches will each orbit a scientific satellite with one of them also launching a funerary payload and a communications satellite. A third Pegasus will lift a developmental satellite into space. Two Shuttle missions are also planned, one of which will launch the Chandra X-ray Telescope. There will also be one Titan 2 launch with a science satellite and two Titan 4 launches will orbit a classified and an intelligence payload.

Russia plans to launch 17 vehicles. Eight will be Proton rockets with communications satellites (two MEO and six GEO). Five Soyuz vehicles will loft one crew capsule and one robotic supply flight to Mir, as well as three sets of four Globalstar LEO communications satellites. The four remaining launches will be of a Cosmos with a communications and a scientific satellite, a Dnepr (on its first launch) lifting a scientific satellite, a Zenit 2 caring a remote sensing and a meteorological satellite, and a Cyclone 3 with a science payload.

Ukraine plans to launch one remote sensing satellite from Russia’s Baikonur site on a Zenit 2 vehicle.

Europe's Arianespace is scheduled to orbit six GEO communications satellites on five Ariane 4 vehicles. The first two Ariane 5 commercial launches will carry four GEO communications satellites.

China intends to launch two Long March vehicles, one with a communications payload and one with a meteorological and a science payload.

India is scheduled to launch an IRS remote sensing satellite and two small foreign satellites on a PSLV.

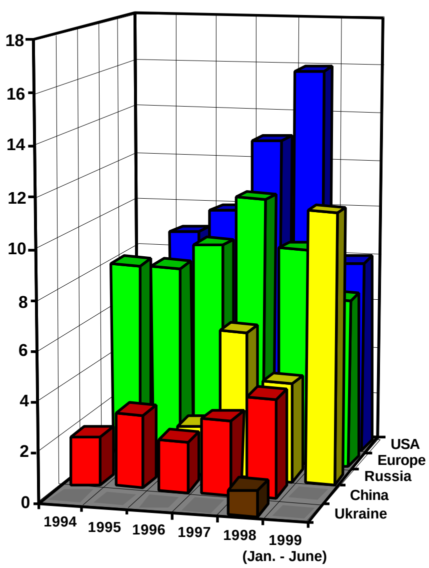
Brazil will make a second attempt to launch its VLS small launch vehicle.

LAUNCH REPORT

Scheduled Commercial Launch Events

First and Second Quarter 1999

Excluding small launch vehicles, 46 launches are planned for the next two quarters. Of these, 26 will be commercial launches. When small launch vehicles are included, this total increases to 54, of which 30 are commercial. The United States plans to conduct 8 commercial launches (excluding small vehicles). These will consist of three flights of the Atlas 2 family of vehicles launching GEO communications satellites and the first launch of an Atlas 3 also with a GEO communications satellite. The Delta 2 will launch commercially twice, once with a set of five Iridium and once with a set of four Globalstar LEO communications satellites. The Delta 3 is expected to deploy one commercial GEO communications satellite. The first flight of the Sea Launch Zenit 3 from its ocean platform with a simulated GEO communications satellite is also expected. Commercial small vehicle launches will include two launches of Athena vehicles, an Athena 1 which is to carry a developmental payload and an Athena 2 which is to loft a remote sensing satellite. One Pegasus vehicle will launch a single communications satellite, and another will carry a scientific satellite along with a small communications satellite and a funerary payload.



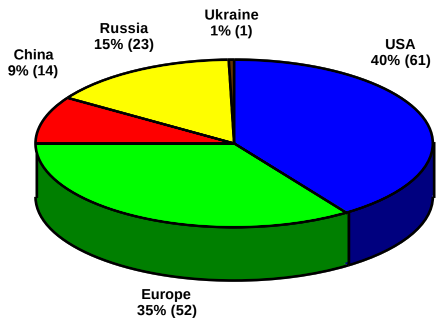
Commercial Launch Events
January 1994 - June 1999
(small vehicles excluded)

All of Europe’s seven scheduled launches are commercial. Five commercial launches will be on Ariane 4 vehicles carrying a total of six GEO communications satellites with two commercial flights of the Ariane 5 deploying four GEO communications satellites.

Russia plans a total of 12 commercial launches, seven of which are commercial Proton launches of GEO communications satellites. Three Soyuz vehicles will carry three sets of four Globalstar LEO communications satellites, a Dnepr vehicle will launch a scientific satellite, and one commercial small vehicle launch will deploy a scientific satellite on a Cosmos vehicle.

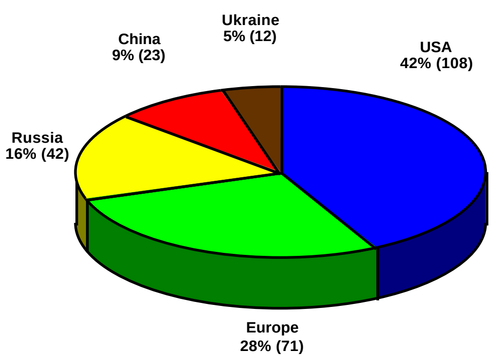
LAUNCH REPORT

Commercial Launch Trends



Commercial Launch Market Trend
January 1994 - June 1999

(small vehicles excluded)



Internationally Competed Payloads Market Trend
January 1994 - June 1999

(small vehicles excluded)

One hundred fifty-one commercial launch events (excluding small launch vehicles) are projected for the period between January 1994 and June 1999. The United States has a 40-percent share, or 61, of these launches. In terms of internationally competed payloads on commercial launches (excluding small launch vehicles), the United States will have launched 108 of 260 payloads, for a 41-percent share of payloads.

Europe's portion of the total is 52 launches, for a 34-percent share of launches, and 71 payloads or 28 percent of total payloads.

China will have 14 launches for nine percent of launches, and 19 payloads for nine percent of the total.

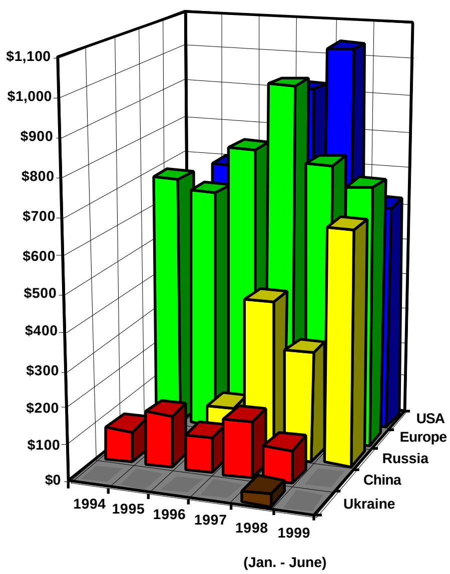
Russia will have conducted 23 commercial launches for a 15-percent share and deployed 42 internationally competed payloads or 16 percent of the total.

Ukraine will have made one commercial launch from Russia's launch site at Baikonur representing just under one percent of launches, to deploy 12 payloads or five percent of total payloads.

In the period covered by this report, October 1998 through June 1999, 36 commercial launches (excluding small launch vehicles) are planned worldwide. It is expected that there will be 58 internationally competed payloads (excluding small launch vehicles) launched on commercial flights in this period. The United States plans 12 launches for 33 percent of these launches and will loft 19 internationally competed payloads on commercial launches for 35 percent of such payloads. Europe plans 11 launches (31 percent) and 16 payloads (26 percent). China's share is one launch (three percent) and two payloads (three percent), while Russia's plans include 21 payloads on 12 vehicles for 36 percent of payloads and 33 percent of launches.

LAUNCH REPORT

Commercial Launch Revenues



Commercial Launch Revenues by Region (in US $ Millions)*

January 1994 - June 1999

* Graph reflects approximate revenues based on actual price quotes and historical price averages. Launch vehicle pricing data is currently being verified for historical accuracy, which may affect figures, shown in future quarterly launch reports. Figures here are shown in constant 1994 dollars. Includes small vehicles.

Revenues for the period between January 1994 and June 1999 are expected to be approximately $11.0 billion. United States launch providers will achieve a 39-percent share of these revenues with about $4.3 billion, and European launch providers will capture 42 percent with about $4.6 billion. Russian launch providers hold an estimated 14-percent share with about $1.5 billion, and launch service revenues from China will consist of about $567 million for a five-percent share. Ukraine's single launch will account for less than one percent of revenues at roughly $33 million.

For the first half of 1999, revenues from commercial launch events are projected to approach $2.0 billion. In this period United States launch service providers will have about $621 million (30 percent) of the total. Europe plans to use both Ariane 4 and Ariane 5 vehicles for commercial launches in the new year. European revenues are expected to reach $713 million (37 percent) in the first half of 1999. An increase in Russian launch service revenues is expected in 1999 with $640 million for the first half alone compared to $300.1 million for all of 1998. This growth is due to the first Soyuz launches of Globalstar LEO satellites, in addition to a large number of projected GEO Proton launches. China and the Ukraine have no publicly announced plans for commercial launches in the first half of 1999.

Special Report

Trends in Satellite Manufacturing: Changing How the Commercial Space Transportation Industry Does Business

INTRODUCTION

In recent years, the commercial sector of the satellite industry has seen unprecedented growth. An expanding base of satellite applications and satellite services has increased the demand for satellites and has brought about changes in almost every aspect of the commercial space industry. In particular, the increasing demands placed on current and future communications satellites have had major effects on satellite design and production.

Manufacturers are building larger satellites to provide the greater capacity required by geosynchronous (GEO) communication satellite operators. Competitive pressures are also pushing manufacturers to reduce cycle times on GEO satellite orders. As a result, larger satellites are being built in a shorter period of time than ever before. At the same time, an entirely new market for smaller, low-earth orbit (LEO) satellites has arisen. New mobile satellite services require large fleets of smaller satellites to LEO which in turn require manufacturers to build dozens of identical spacecraft in a short period of time. To accomplish this, manufacturers have moved away from extensive customization and craft production methods and towards an assembly line style of production. Part of this change involves the use of standardized satellite designs and more commercial off-the-shelf parts from outside suppliers. Another aspect of this change is the emergence of new production facilities designed, from their inception, for mass production.

These differing satellite production requirements have given rise to a two-tiered manufacturing industry. One tier builds large GEO satellites and large numbers of smaller satellites for LEO constellations, while a smaller segment of the industry uses the availability of off-the-shelf components to construct customized, individual satellites. Although there is some overlap between these groups, they are largely distinct: one serves large commercial customers, and the other serves smaller science, education, and technology development customers.

The launch industry has also been affected by the growing demand for satellite services. The need to launch larger GEO payloads and to launch multiple LEO satellites on a single launch vehicle has increased the demand for space transportation services worldwide. Launch service providers have moved to develop vehicles capable of carrying heavier payloads to GEO, as well as new hardware capable of deploying multiple satellites to LEO. Moreover, the need to launch and replenish LEO constellations has increased the demand for medium and intermediate vehicles. Reusable launch vehicle (RLV) operators have also targeted the LEO constellation replenishment market.

This report examines the effects that the growth in LEO and GEO satellite services has had on satellite manufacturers, service providers, and on the launch industry. It will also examine some of the implications that these changes hold for the future of the commercial space industry.

LEO SATELLITE MANUFACTURING

The unique characteristics of LEO constellations have, in part, driven new manufacturing practices. Because of their lower orbits, LEO satellites have smaller signal footprints and are in view for only short periods of time from a particular spot on the ground. Consequently, LEO constellations require the construction of dozens of satellites for complete global coverage (Table 1). In order to meet the demand for the satellites required by LEO constellations, manufacturers have adopted mass-production assembly line techniques to speed and streamline the manufacturing process. Although small details may differ between manufacturers, there is a basic underlying similarity. Satellites are mounted on wheeled dollies and moved from production station to production station. Work teams at each station are assigned to specific tasks.[1]

The efficiency of the assembly line method relies, in part, on the standardization of the manufacturing process. Instead of using custom-built satellite buses and components, manufacturers are now able to use a standard bus structure and integrate off-the-shelf payload hardware. Motorola, discussed below, uses this practice to build the Iridium satellites. In the manufacture of the Globalstar satellites, for example, Alenia uses pre-assembled subsystem kits.[2] By using proven technology and relying on the suppliers' quality control processes, satellite manufacturers are able to eliminate a significant amount of time previously spent testing and inspecting individual parts. Additionally, manufacturers have reduced the number of completed satellites being tested. At Alenia, only every other Globalstar is tested, which can be expected to drop to every fourth satellite as production progresses and quality remains high.[3] Consequently, manufacturers have been able to reduce completion time to a

Table 1: Selected Current and Proposed LEO Systems

System	# Satellites in System (# On-Orbit Spares)	# Currently in Orbit	Manufacturer	Launch Vehicle	Beginning of Service
Iridium	66 (6)	79 (+5 inactive)	Motorola, Lockheed Martin	Long March, Delta, Proton	November 1998
Globalstar	48 (8)	8	Space Systems/ Loral, Alcatel, Alenia	Delta, Soyuz, Zenit	1999
Orbcomm	28 (8)	28	Orbital Sciences Corp.	Pegasus, Taurus	November 1998
Skybridge	60 (4)	0	Skybridge LLC	Not selected	2002
Teledesic	288*	0	Motorola, Matra Marconi	Not selected	2003

*The most recent plans call for a 288-satellite constellation (original plans called for a 980-satellite constellation) but this number may change as details of the new constellation plans are worked out.

[1] "Faster and Cheaper Ways to Build Satellites," *Interavia Business and Technology*, March 1997.

[2] Ibid.

[3] Ibid.

matter of days. Teledesic, for example, recently reported that their planned mass-production methods will allow the completion of a satellite every two days.[4]

Faster production and the purchase of standardized components allows manufacturers – and their customers – to save money in the manufacturing process. As a result, LEO constellation designers have been able to trade off the possibility of launch failure or on-orbit failure against the ease of replacement brought by a faster and cheaper manufacturing process. If a satellite fails once on orbit, it can be quickly and cheaply replaced by an on-orbit spare or another low-cost ground spare from the same factory. Teledesic, for example, has announced that rather than paying insurance premiums on their constellation, they will simply construct more back-up satellites.

Iridium provides one of the most publicized examples of the new manufacturing processes. The Iridium bus is first built by Lockheed Martin's Sanders subsidiary in Nashua, New Hampshire. According to officials at the plant, their assembly line procedures allowed them to produce a record of fourteen buses in one month. The communications payload is then built and integrated into the bus at the Motorola Satellite Communications facility in Chandler, Arizona.

Motorola's Chandler facility is also a classic assembly-line operation, operational 24 hours a day, seven days a week, and is organized into three phases. In the first two, workers wire circuit boards and components and integrate the boards onto the satellite bus. The final process couples assembly line procedures with a work-station environment: satellites are wheeled from station to station, rather than forcing workers to move their operations from satellite to satellite. The payload is also designed so that a defective module can be replaced within 60 seconds, rather than the three weeks it may take for a conventional satellite.[5] Once the satellite bus is received at the Chandler facility, Motorola can integrate the components and complete the satellite within 28 days.[6] The facility is able to produce a new satellite every four days.

The new mass production methods have allowed the construction of dozens of satellites for LEO constellations. As a result the number of LEO satellites built per year has risen in the last few years and will likely continue to do so for the next five years. This has implications for the launch industry, as will be discussed below.

EFFECT ON THE LAUNCH INDUSTRY

The growing number of LEO payloads awaiting launch opportunities signal increased opportunities for launch service providers (Figure 1). The current demand for medium and intermediate launch vehicle services has been driven, in part, by the growth in the LEO market.[7] In order to capitalize on this market, launch providers have also developed dispenser systems for deploying multiple satellites to LEO. These systems have been successfully used aboard Delta, Proton, and Long March vehicles, and are planed for use on Soyuz, Ariane, and Zenit. These dispensers allow the deployment of multiple payloads within a single launch.

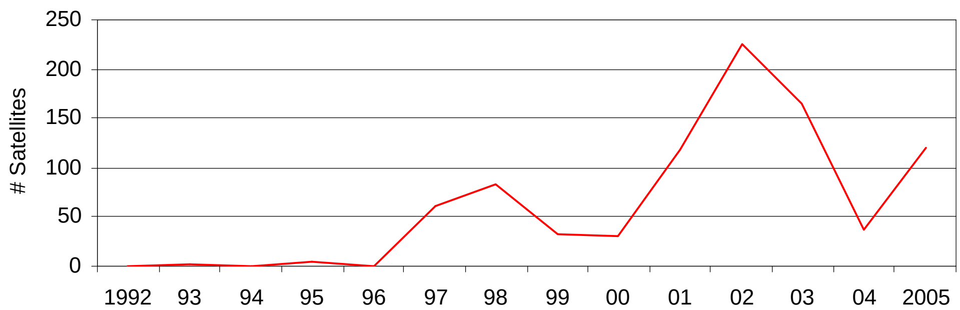
[4] "Motorola Plans Speedy Teledesic Assembly Line," *Space News* 12/14/98, p. 2.

[5] "Faster and Cheaper Ways to Build Satellites," *Interavia Business and Technology*, March 1997.

[6] "Motorola Plans Speedy Teledesic Assembly Line," *Space News* 12/14/98, p. 2.

[7] "New Satellite Uses Spur Space Boom," *Aviation Week & Space Technology*, 6/3/96.

Figure 1: Commercial LEO Satellites Launched/ Scheduled for Launch 1992-2005



Source: STAR Database, 1998 LEO Commercial Market Baseline Projections (FAA/AST May 1998)

Standardized satellite designs also allow greater flexibility in choosing a launch vehicle. Because these small satellites fit inside a number of fairing types, manufacturers and operators are able to choose from among several launch vehicle sizes in order to meet tight schedules or overcome unforeseen problems. This is precisely what has happened to Loral's Globalstar constellation. The September 9, 1998 failure of a Zenit vehicle (which carried twelve Globalstar satellites onboard) threatened the plans to begin service in 1999. Within two months, however, the company was able to arrange additional launches on board Soyuz and Delta vehicles, thus reducing the delay to Globalstar's schedule.[8]

Additionally, the emerging LEO launch market has encouraged a host of entrepreneurial firms to develop reusable launch vehicles (RLVs) in order to capitalize on the demand for LEO constellation maintenance and replenishment. RLVs such as the Kistler K-1, Rotary Rocket's Roton-C, Kelly Space and Technology's Astroliner, Pioneer Rocketplane's Pathfinder, and Space Access' SA-1 plan to begin service within the next few years. These RLV start-up companies, and others, intend to enter the launch market by offering inexpensive frequent flights to LEO, including replenishment flights to replace aging or inactive constellation satellites.[9]

GEO Satellite Manufacturing

The increase in demand for C-band, Ku-band, and Ka-band GEO satellite services has affected the hardware being integrated into satellites, as well as their manufacturing methods. In response to the market, satellite manufacturers and their suppliers are developing new technologies to achieve higher performance while attempting to keep launch mass as low as possible.

As GEO satellites have become more powerful, a number of specific applications have been developed, including VSAT networks, direct-to-home broadcasting, internet backbone, and regional mobile telecommunications services. In turn, this brings a particular set of technical requirements to the manufacturing process. These new satellites use smaller ground terminals than their previous counterparts, requiring greater signal strength and higher on-board power. In order to maximize the

[8] "Globalstar Shifts Launchers After Failure of Zenit," *Space News*, 9/14/98 p. 1.

[9] *Reusable Launch Vehicle Programs and Concepts*, FAA/AST, January 1998.

use of orbital slots while at the same time maximize revenue, new GEO satellites must also carry additional transponders and antennas in order to meet the increasing traffic requirements, as well as more on-board fuel for station-keeping to extend mission life. Despite the entry of a number of new technologies that decrease satellite structural mass -- such as more efficient transponders, gallium arsenide solar cells, better thermal radiators to dissipate the extra heat caused by higher power, and ion propulsion instead of standard fuel -- the mass of new GEO satellites is steadily increasing (see Figures 2 and 3). As discussed below, this trend also has further implications for the launch industry.

The time required for construction has also changed in response to market demands. Originally, GEO satellite manufacturing was highly specialized: each satellite was largely one-of-a-kind with customized systems, painstakingly assembled and tested, taking three years to build. In order to meet the growing demand for GEO satellites, manufacturers have had to decrease construction time. Like LEO manufacturing, this has been accomplished through several methods. Both Hughes and Lockheed Martin have introduced assembly-line procedures at their new satellite factories in El Segundo and Sunnyvale, respectively. GEO satellite manufacturers further reduce construction times by relying on standard components from suppliers, rather than relying on customized systems. Based on the assumption that proven designs and suppliers' quality control processes ensure component reliability, this eliminates the need for time-consuming testing of subsystems. While not as short as LEO times, GEO satellite manufacturing has been reduced from three years to around 18 months, with some firms targeting one year or less. The recent launch of Russian broadcast company Media Most's Bonum-1 provides a timely example of the increased demand for both satellite services and quick cycle time. On October 22, 1997, Media Most signed a contract with Hughes Space and Communications to provide Bonum-1, a HS-376 satellite for direct-to-home services over western Russia. The contract marked the first time that a satellite for a private Russian company would be built by a U.S. manufacturer. According to the Bonum-1 subsidiary of Media Most, Hughes won the contract because it promised to manufacture and deliver the satellite on-orbit within sixteen months.[10] Russian manufacturer NPO Prikladnoi Mekhaniki, on the other hand, might have taken 36 months. The now-operational satellite was successfully launched on a Delta 2 on November 22, 1998, only thirteen months after the contract was signed, and three months earlier than expected.

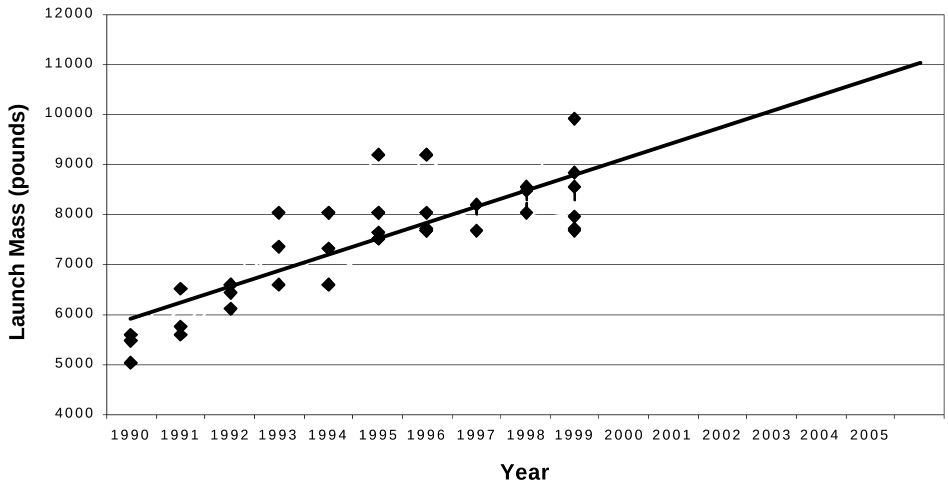
Effects on the Launch Industry

In order to meet the increased launch demand for large GEO satellites (Figure 4), several companies have developed vehicles capable of taking heavier satellites to geosynchronous transfer orbit (GTO) (Table 2). Many of these new vehicles have also required the construction of new construction and launch facilities.[11]

These new vehicles include the new Atlas 3B which will offer a GTO capacity of 9,920 pounds, compared to the 8,196 pounds offered by the largest Atlas variant in service, the Atlas 2AS. The future Delta 4 and Atlas EELV launch vehicles will

[10] "U.S. Firms Hope Bonum-1 Opens Russia's Doors," *Space News*, Dec. 6, 1998, p. 7.
[11] *Commercial Space Transportation Quarterly Launch Report* FAA/AST, 4th Quarter 1998.

Figure 2: GEO Satellite Mass Trends 1990-2005



Note: Heaviest 25 percent of commercial GEO satellites launched 1990-1998, with projected payloads for 1999. Trend line represents linear fit of average payload mass in sample for each year, extended through 2005. The COMSTAC mission model for 1998 projects that one third to one half of 2002-2005 payloads will be heavy (>9,000 lb.). Source: STAR database, COMSTAC Report (May 1998).

Figure 3: Launch Mass of Satellite Models Currently In Production

Note: Date following mass range indicates year of first launch. Source: STAR database.

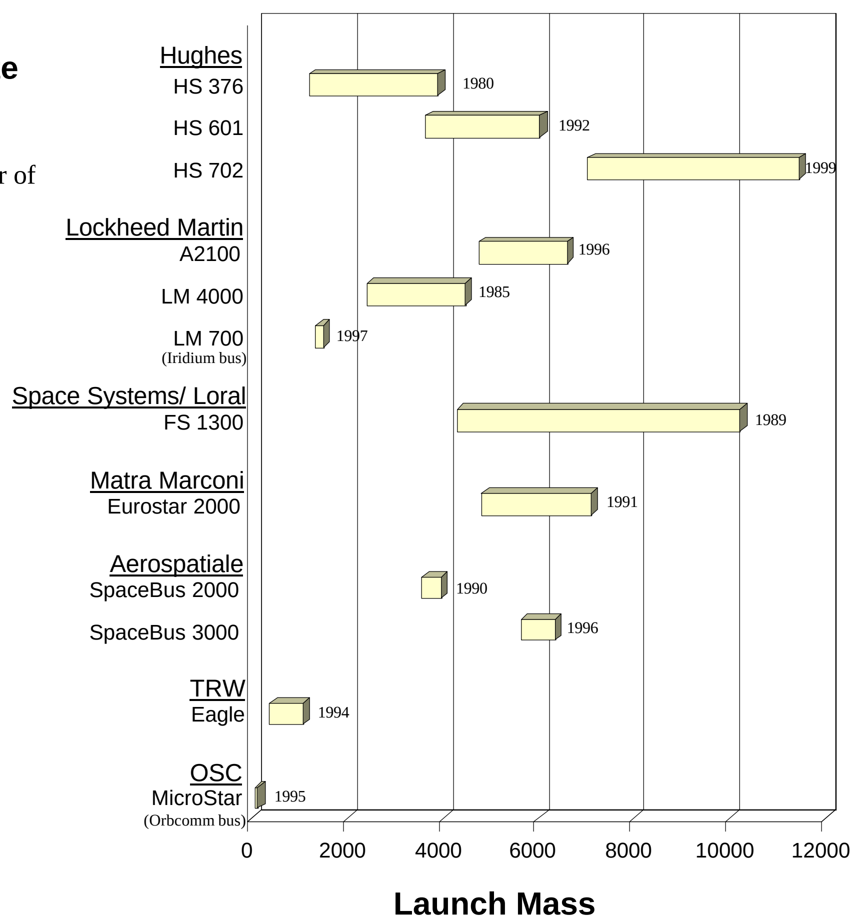
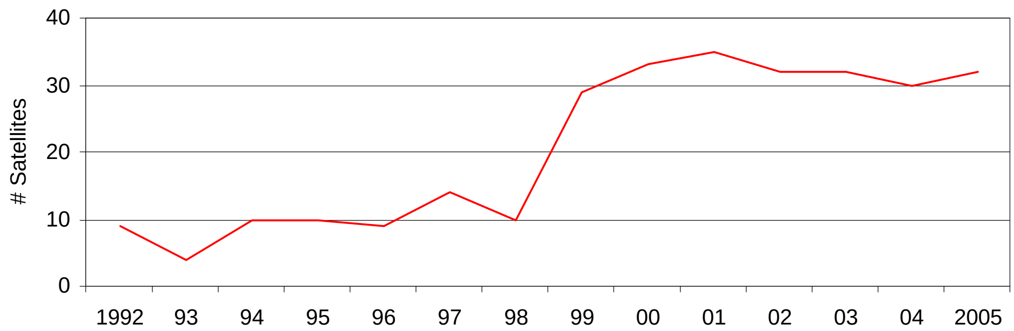


Figure 4: Commercial GEO Satellites Launched/Scheduled to be Launched Per Year (1992-2005)



Source: STAR Database, COMSTAC Report (May 1998)

include commercial variants with GTO capacities greater than 10,000 pounds. Ariane, Proton, and Sea Launch are also offering heavier lift capacities to GTO.

Table 2: Current and Future Commercial GEO Launch Vehicles

Vehicle	Capacity to GTO (lbs.)	Launch Provider	Introduction Year
Atlas 3A	8,940	Lockheed Martin	1999
Atlas (EELV)	11,600	Lockheed Martin	2003
Delta 3	8,360	Boeing	1998
Delta 4 (EELV)	9,100	Boeing	2002
Ariane 5	14,990	Arianespace	1998
Sea Launch	11,050	Boeing Sea Launch	1999
Proton	10,175	ILS, Krunichev	1996*
H-2A	8,800	RSC	2000

*Although the Proton has been in use since 1967, the first commercial launch did not occur until 1996.
SOURCE: STAR Database

The proliferation of launch service providers offering service to GTO is another result of the increased demand for GEO launches. With an increase in the number of payloads awaiting launch, the market could support additional launch providers. As a result, the Sea Launch consortium and International Launch Services have emerged to join Boeing, Lockheed Martin and Arianespace as GEO launch service providers. Additionally, the Proton and Delta 3 have arisen as additional entries to the launch market currently served largely by Atlas and Ariane.

PanAmSat's Galaxy XI satellite, a Hughes-built HS-702, demonstrates both the trend towards increasing mass and the need for larger launch vehicles. Weighing approximately 9,900 pounds at launch, Galaxy XI is the heaviest commercial communications satellite built to date.[12] Original plans called for the satellite to launch onboard the inaugural flight of Sea Launch, which is capable of carrying over 11,000 pounds to GTO.[13] After the loss of Galaxy X onboard the failed inaugural flight of the Delta 3, however, PanAmSat searched for an established vehicle. PanAmSat was faced with one hurdle: the launch mass of Galaxy XI comes close to

[12] *ISIR* 11/23/98, p. 27
[13] STAR Database.

the lift capacity of most vehicles in service – the Atlas 2AS, for instance, can carry only 8,196 pounds to GTO.[14] Currently, Galaxy XI is scheduled for a 1999 launch on board an Ariane 44L, which has a GTO capacity of 10,903 pounds.

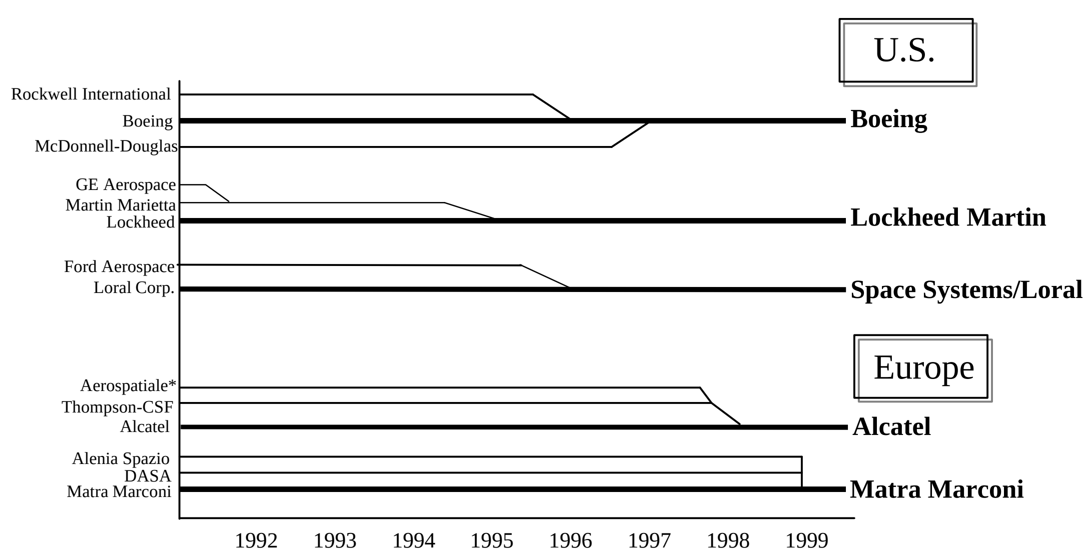
CHANGES IN MANUFACTURING FACILITIES

During the 1990's, the world's aerospace industries have undergone a major consolidation. In particular, economic forces following the end of the Cold War have caused the rearrangement and consolidation of the United States' aerospace industry, as various companies attempted to retain profitability in a period of reduced defense spending. As a result of the general reorganization of the aerospace industry, multiple corporate mergers led to a reorganization of the satellite manufacturing aspects of the aerospace industry in particular (Figure 5).

The increasing use of mass-production techniques in the satellite industry has made it desirable to consolidate not only production techniques, but production facilities as well. This trend has been reinforced by the desire to combine duplicative facilities inherited from previous owners. Three of the industry's largest manufacturers – Lockheed Martin, Hughes Space and Communications, and Space Systems/Loral – have all moved towards consolidation of facilities and practices within the last few years.

Lockheed Martin's satellite production plants provide one such example. Lockheed Martin inherited plants in East Windsor, NJ, and Valley Forge, PA, from General Electric via Martin Marietta. In October 1996, Lockheed Martin consolidated satellite production into the newly-built Astro Communications Production Facility at the Lockheed Martin Missiles and Space complex in Sunnyvale, CA, replacing the other factories.

Figure 5: Major Satellite Manufacturer Reorganization



*Satellite division only

[14] STAR Database.

The Astro Communications Production Facility is intended to triple Lockheed Martin's satellite production capacity while reducing manpower demands for an individual satellite by 35 to 40 percent. At times, Lockheed Martin's New Jersey plant experienced production bottlenecks that resulted in the shipment of satellites to Lockheed Martin's Pennsylvania plant. Many of these delays resulted from the uneven growth of the older production facility and will be solved by the design of the new Sunnyvale plant. Computer-aided designs used in the planning phase of the new facility are intended to facilitate work flow and avoid the sorts of blockages that affected the previous facilities. For example, the major test facilities have been built within the manufacturing clean room for easier access.

Hughes Space and Communication Co., the industry's largest manufacturer of commercial satellites, has also consolidated its production facilities. Its Integrated Satellite Factory (ISF) in El Segundo, CA, combines operations from ten different Hughes facilities. The ISF, which was originally purchased in 1955, underwent major modifications in 1992; an additional 41,000 square feet of testing facilities were added in 1998.[15] The ISF has reduced the number of buildings occupied by Hughes satellite manufacturing operations from 44 buildings in four California cities to 22 buildings all located in El Segundo, California. Hughes reports a ten-percent annual increase in production efficiency in the 1992 through 1996 period of operations, with production cycle times reduced by 30 percent. Average output is 14 commercial spacecraft a year, but the ISF is designed to produce up to 20 annually.[16]

Space Systems/Loral built its state-of-the-art Palo Alto satellite production facility in 1992. This facility was designed to help Space Systems/Loral expand into the commercial marketplace and did not replace a comparable facility, as did Lockheed Martin and Hughes. Nonetheless, this facility also demonstrates the current trend towards integrated, efficient, satellite manufacturing facilities. The Palo Alto plant uses a computer-based manufacturing system that would have allowed overflow production to be picked up by Space Systems/Loral's European partners (before Loral's buyout of these partners). The Palo Alto facility is capable of producing nine to twelve satellites per year.

CHANGES IN CONTRACTING

The effects of the growing use of off-the-shelf components by satellite manufacturers is evident in the organization of several recent satellite construction contracts. Contrary to previous practice, companies that are not constructing the bus can become the prime contractor for a satellite program. One such contract, between Iridium and Motorola, has already been mentioned – Motorola is the prime contractor, but Lockheed Martin is the bus manufacturer. This is also found in the contract for Australia's Optus C1 GEO communications satellite. Although Space Systems/Loral will provide the bus for this satellite, Japan's Mitsubishi will serve as "prime negotiator."

CHANGES DIVIDING COMMUNICATIONS FROM SCIENCE

As a result of the changes in manufacturing procedures and facilities, a two-tiered manufacturing industry has emerged. The first tier includes manufacturers rising to meet the market demand for LEO and GEO

[15] *AeroWorldNet* March 1998.
[16] *Industry Uplink* Spring 1995.

communications satellites. In order for the manufacturers to meet this demand, very large capital expenditures were required to build the "factories of the future" capable of producing higher numbers of satellites in a short period of time. Companies in this first tier include larger manufacturers, like Hughes, Lockheed Martin, and Space Systems/Loral, who have changed their practices in order to meet the market demand. The second tier involves small-satellite manufacturers meeting another market demand: the need for one-of-a-kind scientific, remote sensing, and interplanetary missions. Companies like AeroAstro, Spectrum Astro, Ball Aerospace, and Surrey Satellite Ltd., as well as microsatellite manufacturers, still maintain smaller, more customized procedures, and have not turned towards the assembly line process.[17]

IMPLICATIONS AND CONCLUSIONS

Just as satellite manufacturers have changed the way they do business in response to the needs of their customers, the launch providers are responding to the needs of the satellite manufacturers. The growing number of GEO satellites to be launched has attracted new entrants to the launch service market, including Proton, Delta 3, Long March, and Sea Launch, greatly expanding industry capacity. The growth in satellite size and mass has also driven the incorporation of increased lift capacities into the Ariane 5 and Atlas 3, as well as the Lockheed Martin and Boeing's EELVs. The arrival of commercial LEO constellations has stimulated demand for medium and intermediate vehicles for constellation deployment, and has inspired entrepreneurs to pursue RLV technology to meet the projected demand for LEO launches.

The launch services industry will face several challenges in the coming years: to accommodate a greater number of payloads, to accommodate heavier payloads, and to launch them within a shorter time period than in the past. As more service providers enter the marketplace, each will face vigorous competition to offer the best in terms of price, reliability, and availability.

[17] Interview with AeroAstro engineers, 12/18/98.

GLOSSARY

For proper interpretation of the data in this report, the following definitions should be understood:

Commercial Launch Events: A commercial launch event is an internationally competed launch event, as defined below, and/or any launch licensed by the Department of Transportation/Office of Commercial Space Transportation (DoT/OCST), under the Commercial Space Launch Act (CSLA), or certain Post, Telegraph and Telecommunications launches.

Commercial Launch Revenue: Commercial launch revenues are generated from launch services provided by private and government licensed entities. It is understood that commercial launch providers of different countries operate within different economic, policy, and procedural contexts which affect the respective prices for a launch contract, however, this report does not attempt to adjust its data for these factors.

Geosynchronous Orbit (GEO): An orbit approximately 22,300 miles above the equator in which a payload completes one orbit around the Earth every 24 hours.

Geosynchronous Transfer Orbit (GTO): A temporary orbit used to later place payloads in a geosynchronous orbit.

Internationally-Competed Launch Events: An internationally competed launch event results from a launch opportunity which is available in principle to competitors in the international launch services market.

Low Earth Orbit (LEO): An orbit range on the order of 100-1000 nautical miles.

Market Share: That segment of a commercial market which is captured by a specified entity.

Microgravity: An environment in which gravitational forces are essentially nonexistent. Microgravity is used for materials processing, life-sciences, and other experiments. Suborbital flights generally are conducted to expose experimental payloads to a brief microgravity environment. Microgravity is also utilized for orbiting payloads.

Orbital Insertion: The point of a launch event at which a payload has attained planned orbital velocity and finally separates from its launch vehicle.

Payload: Cargo to be jettisoned or released which may include attached kick motors.

Payload Mass Class: Payloads are categorized in the following mass classes:

Microsat	0 - 200 lbs	Small	201 - 2,000 lbs
Medium	2,001 - 5,000 lbs	Intermediate	5,001 - 10,000 lbs
Large	10,001 - 20,000 lbs	Heavy	over 20,000 lbs

Scheduled Launch Events: Future launch events associated with specific dates as reported in open sources.

Secondary Payload: A payload of lesser dimensions and weight than the primary payload(s). These payloads are launched along with primary payload(s) due to excess launch capacity.

Suborbital: A term used to describe a launch event or payload that does not achieve a full earth orbit.

ACRONYMS

AMSAT Amateur Radio Satellite
ARD Atmospheric Re-entry Demonstrator
CCAS Cape Canaveral Air Station
DARA German Space Agency
DASA Deutsche Aerospace
DoD Department of Defense
DoT Department of Transportation
DSP Defense Support Program
ELI Elliptical
ELINTS Electronic intelligence satellites
ELV Expendable Launch Vehicle
ESA European Space Agency
ETS Engineering Test Satellite
EXT Extra-Orbital
FAA Federal Aviation Administration
FUSE Far Ultraviolet Spectrometer Explorer
FY Fen Yung
GBS Global Broadcast System
GEO Geosynchronous Orbit
GOES Geostationary Operational Environmental Satellite
GTO Geosynchronous Transfer Orbit
INMARSAT - International Maritime Satellite Organization
INPE National Institute for Space Research
INTA Instituto Nacional de Tecnica Aeroespacial
INTELSAT–International Telecommunications Satellite Organization
IRS Indian Resource Satellite
ISAS Institute of Space and Astronautical Science
ISRO Indian Space Research Organization
JCSAT Japan Communications Satellite Co. Satellite
JPL Jet Propulsion Laboratory
JSAT Japan Satellite Systems, Inc.
KB Design Bureau
KSC Kennedy Space Center
LEO Low Earth Orbit
MEO Medium Earth Orbit
MoD Ministry of Defense
MUBLCOM - Multiple Beam Beyond Line-of-Sight Communications
NASA National Aeronautics and Space Administration
NASDA National Space Development Agency of Japan
NEC Nippon Electric Corp.
nMI Nautical Mile
NOAA National Oceanic and Atmospheric Administration
NPO Scientific Production Organization
NRO National Reconnaissance Office
NSAB Nordiska Satellit AB
NSAU National Space Agency of Ukraine
OSC Orbital Sciences Corporation
PAS Pan American Satellite
PSLV Polar Satellite Launch Vehicle
PTT Post Telegraph and Telecommunications
QuickSCAT - Quick Scatterometer
RKK Energia - Rocket and Space Company Energia
SAC Satellite de Aplicaciones Cientificas
SACI Satellite Cientifico
SCD Satellite de Coleta de Dados
SES Societe Europeene des Satellites
SJ Shi Jian
SLV Satellite Launch vehicle
STEX Sensor Test Experiement
STS Space Transportation System
SWAS Submillimeter Wave Astronomy Satellite
TERRIERS - Tomographic Experiment using Radiative Recombinative Ionospheric EUV and Radio Sources
TRACE Transition Region and Coronal Explorer
TSX Tri-Service Experiment
VAFB Vandenberg Air Force Base
WIRE Wide-Field Infrared Explorer
XL Extra Long

Characteristics of Cited Vehicles

Vehicle	(Success + Partials) / Attempts	LEO 28 Degrees	GTO	GEO	SUB	Price per Launch (Approx.)	Launch Sites
Heavy							
Ariane 5	2/3|66.7%	39600 lb 18000 kg	15000 lb 6800 kg	N/A*	N/A	$115-143 M	Kourou
Long March 3B	4/5|80%	29900 lb 13600 kg	9900 lb 4500 kg	4950 lb 2250 kg	N/A	$60-70 M	Xichang
Proton (SL-12)	202/225|89.8%	46297 lb 21000 kg	12100 lb 5500 kg	4850 lb 2200 kg	N/A	$75-75 M	Baikonur
Proton (SL-13)	25/28|89.3%	46000 lb 20900 kg	16535 lb 7500 kg	N/A	N/A	$50-70 M	Baikonur
Sea Launch	N/A	35000 lb 15876 kg	11050 lb 5000 kg	N/A	N/A	$90-100 M	Sea Launch Platform
Shuttle Columbia	25/25|100%	47300 lb 21455 kg	13007 lb 5900 kg	5203 lb 2360 kg	N/A	$161-215 M	KSC
Shuttle Discovery	27/27|100%	47300 lb 21455 kg	13007 lb 5900 kg	5203 lb 2360 kg	N/A	$161-215 M	KSC
Shuttle Endeavour	13/13|100%	47300 lb 21455 kg	13007 lb 5900 kg	5203 lb 2360 kg	N/A	$161-215 M	KSC
Titan 4B	N/A	47800 lb 21682 kg	19000 lb 8618 kg	N/A	N/A	$250-350 M	VAFB
Titan 4B/IUS	1/1|100%	47800 lb 21727 kg	N/A	12700 lb 5773 kg	N/A	$250-350 M	CCAS, VAFB
Zenit 2	25/31|80.6%	30300 lb 13740 kg	N/A	N/A	N/A	$25-40 M	Baikonur
Intermediate							
Ariane 42L	7/7|100%	16300 lb 7400 kg	7450 lb 3380 kg	N/A	N/A	$75-85 M	Kourou
Ariane 44L	26/27|96.3%	21100 lb 9600 kg	9965 lb 4520 kg	N/A	N/A	$90-110 M	Kourou
Ariane 44LP	18/19|94.7%	18300 lb 8300 kg	8950 lb 4060 kg	N/A	N/A	$80-95 M	Kourou
Ariane 44P	14/14|100%	15200 lb 6900 kg	7320 lb 3320 kg	N/A	N/A	$75-90 M	Kourou
Atlas 2A	14/14|100%	16050 lb 7280 kg	6700 lb 3039 kg	3307 lb 1500 kg	N/A	$65-80 M	CCAS, VAFB
Atlas 2AS	15/15|100%	19050 lb 8640 kg	8150 lb 3688 kg	4604 lb 2090 kg	N/A	$90-100 M	CCAS, VAFB
Atlas 3A	N/A	19097 lb 8641 kg	8940 lb 4055 kg	N/A	N/A	$45-80 M	CCAS
Delta 3	0/1|0%	18408 lb 8350 kg	8360 lb 3800 kg	N/A	N/A	$55-60 M	CCAS
Soyuz	952/959|99.3%	15400 lb 7000 kg	N/A	N/A	N/A	$12-25 M	Baikonur, Plesetsk

*GEO capable with kick motor

Characteristics of Cited Vehicles

Vehicle	(Success + Partials) / Attempts	LEO 28 Degrees	GTO	GEO	SUB	Price per Launch (Approx.)	Launch Sites
Medium							
Cyclone 3	112/114|98.2%	8818 lb 4000 kg	N/A	N/A	N/A	$10-15 M	Baikonur, Plesetsk
Delta 2 7320	N/A	4370 lb 1982 kg	2100 lb 952 kg	N/A	N/A	$45-50 M	CCAS, VAFB
Delta 2 7326	1/1|100%	4370 lb 1982 kg	2100 lb 952 kg	N/A	N/A	$45-50 M	CCAS, VAFB
Delta 2 7420	2/2|100%	N/A	N/A	N/A	N/A	$45-50 M	CCAS, VAFB
Delta 2 7425	2/2|100%	5160 lb 2340 kg	2430 lb 1102 kg	N/A	N/A	$45-50 M	CCAS, VAFB
Delta 2 7426	N/A	N/A	N/A	N/A	N/A	$45-50 M	CCAS, VAFB
Delta 2 7920	15/15|100%	11330 lb 5139 kg	2800 lb 1270 kg	N/A	N/A	$45-50 M	CCAS, VAFB
Delta 2 7925	40/41|97.6%	11330 lb 5139 kg	3965 lb 1799 kg	2000 lb 907 kg	N/A	$45-50 M	CCAS, VAFB
Dnepr	N/A	9700 lb 4400 kg	N/A	N/A	N/A	$20-40 M	Baikonur
Long March 2C	20/20|100%	7040 lb 3200 kg	2200 lb 1000 kg	860 lb 390 kg	N/A	$20-25 M	Taiyuan, Jiuquan
Long March 4	2/2|100%	8818 lb 4000 kg	2430 lb 1100 kg	1220 lb 550 kg	N/A	$20-30 M	Taiyuan
PSLV	3/4|75%	6400 lb 2900 kg	990 lb 450 kg	N/A	N/A	$15-15 M	Sriharikota Range
Titan 2	19/19|100%	7900 lb 3583 kg	N/A	N/A	N/A	$41-47 M	CCAS
Small							
Athena 1	1/2|50%	1755 lb 800 kg	N/A	N/A	N/A	$14-16 M	Spaceport Florida, VAFB, Wallops (proposed)
Athena 2	1/1|100%	4390 lb 1990 kg	N/A	N/A	N/A	$19-21 M	Spaceport Florida, VAFB, Wallops (proposed)
Cosmos	410/414|99%	3100 lb 1400 kg	N/A	N/A	N/A	$10-10 M	Baikonur, Plesetsk, Kapustin Yar
Pegasus 1	7/7|100%	754 lb 342 kg	274 lb 124 kg	152 lb 69 kg	N/A	$10-14 M	VAFB, Wallops
Pegasus XL	10/13|76.9%	1015 lb 460 kg	322 lb 146 kg	181 lb 82 kg	N/A	$12-14 M	VAFB, Wallops
Taurus 1	3/3|100%	3100 lb 1400 kg	990 lb 450 kg	N/A	N/A	$18-20 M	VAFB
VLS	0/1|0%	440 lb 200 kg	N/A	N/A	N/A	N/A	Alcantara
Suborbital							
Maxus	4/5|80%	N/A	N/A	N/A	926 lb 420 kg	N/A	Esrange
TR 1A	6/6|100%	N/A	N/A	N/A	1653 lb 750 kg	N/A	Tanegashima

Characterisitcs of Cited Payloads

Payload	Use	Price	Orbit	Apogee	Perigee	Launch Mass	Mass in Orbit	Freq. Bands & Trans.	Stab.	Power
Classified										
USA 1999-03	Classified	Unknown	Unknown	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Communications										
AfriStar 1	Communications	Unknown	GEO 21E	19305 nMi	19305 nMi	6155 lb/ 2785 kg	2093 lb/ 947 kg	3 L, 3 X	N/A	N/A
Arabsat 3A	Communications	Unknown	GEO	19400 nMi	19400 nMi	5967 lb/ 2700 kg	N/A	20 Ku	N/A	N/A
AsiaSat 3S	Communications	Unknown	GEO 105.5E	19400 nMi	19400 nMi	7656 lb/ 3480 kg	N/A	16 Ku, 28 C	N/A	N/A
AsiaStar 1	Communications	Unknown	GEO 105E	19305 nMi	19305 nMi	6155 lb/ 2785 kg	2093 lb/ 947 kg	3 L, 3 X	N/A	N/A
Astra 1H	Communications	Unknown	GEO 19.2E	19400 nMi	19400 nMi	7260 lb/ 3300 kg	N/A	32 Ku, 2 Ka	3-axis	N/A
Astra 2B	Communications	Unknown	GEO 28.2E	19400 nMi	19400 nMi	7040 lb/ 3200 kg	N/A	30 Ku	N/A	N/A
Bonum 1	Communications	Unknown	GEO 36E	19400 nMi	19400 nMi	N/A	N/A	8 Ku	N/A	N/A
ChinaSat 8	Communications	$92.7 M	GEO 115.5E	19400 nMi	19400 nMi	N/A	N/A	36 C, 16 Ku	N/A	N/A
Eutelsat W2	Communications	Unknown	GEO 16E	19332 nMi	19305 nMi	6599 lb/ 3000 kg	N/A	24 Ku	N/A	N/A
Eutelsat W3	Communications	Unknown	GEO 7E	19332 nMi	19305 nMi	6599 lb/ 3000 kg	N/A	24 Ku	N/A	N/A
Eutelsat W4	Communications	Unknown	GEO 36E	19400 nMi	19400 nMi	N/A	N/A	24 Ku	N/A	N/A
Galaxy 11	Communications	Unknown	GEO 261E	19400 nMi	19400 nMi	9921 lb/ 4500 kg	N/A	24 Ku, 24 C	N/A	N/A
GBS 9	Communications	$190 M	GEO	19400 nMi	19400 nMi	6305 lb/ 2866 kg	N/A	UHF	N/A	2500 W
GBS 10	Communications	$190 M	GEO	19400 nMi	19400 nMi	6305 lb/ 2866 kg	N/A	EHF, UHF	N/A	2500 W
GE 5	Communications	Unknown	GEO 281E	19400 nMi	19400 nMi	3890 lb/ 1760 kg	N/A	16 Ku	N/A	N/A
Globalstars 21-32,45-48	Communications	$14.7 M	LEO	764 nMi	764 nMi	988 lb/ 449 kg	N/A	L, C, S	N/A	875 W
Hot Bird 5	Communications	$226 M	GEO 13E	19400 nMi	19400 nMi	6380 lb/ 2900 kg	N/A	22 Ku	N/A	N/A
ICO 1	Communications	Unknown	MEO	5592 nMi	5592 nMi	6050 lb/ 2750 kg	N/A	1 C, 1 S	N/A	N/A
ICO 2	Communications	Unknown	MEO	5592 nMi	5592 nMi	6050 lb/ 2750 kg	N/A	1 C, 1 S	N/A	N/A
Insat 3B	Communications	Unknown	GEO	19400 nMi	19400 nMi	N/A	N/A	18 C, 6 Ku	N/A	N/A
Intelsat K-TV	Communications	Unknown	GEO 95E	19400 nMi	19400 nMi	7150 lb/ 3250 kg	N/A	30 Ku	N/A	N/A
Iowasat	Communications	Unknown	TBA	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Iridiums 83-94	Communications	Unknown	LEO	419 nMi	419 nMi	1496 lb/ 680 kg	N/A	N/A	N/A	N/A
JCSAT 6	Communications	Unknown	GEO 150E	19400 nMi	19400 nMi	N/A	N/A	32 Ku	N/A	N/A
MegSat 0	Communications	Unknown	LEO	N/A	N/A	111 lb/ 50 kg	N/A	N/A	N/A	N/A
MUBLCOM	Communications	Unknown	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Nimiq 1	Communications	Unknown	GEO 269E	19400 nMi	19400 nMi	7956 lb/ 3600 kg	N/A	32 Ku	N/A	N/A
Orion F2	Communications	Unknown	GEO 348E	19400 nMi	19400 nMi	8398 lb/ 3800 kg	N/A	34 Ku	3-axis	N/A
Orion F3	Communications	Unknown	GEO 139E	19400 nMi	19400 nMi	7072 lb/ 3200 kg	N/A	33 Ku, 10 C	N/A	N/A
PANSAT 1	Communications	Unknown	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
PAS 6B	Communications	Unknown	GEO 217E	19400 nMi	19400 nMi	7943 lb/ 3594 kg	N/A	32 Ku	N/A	N/A
PAS 8	Communications	Unknown	GEO 166E	19400 nMi	19400 nMi	8398 lb/ 3800 kg	N/A	24 Ku, 24 C	N/A	N/A

Characterisitcs of Cited Payloads

Payload	Use	Price	Orbit	Apogee	Perigee	Launch Mass	Mass in Orbit	Freq. Bands & Trans.	Stab.	Power
Communications (cont.)										
Raduga 34	Communications	Unknown	GEO	19400 nMi	19400 nMi	N/A	N/A	N/A	3-axis	N/A
SatMex 5	Communications	Unknown	GEO	19400 nMi	19400 nMi	9158 lb/ 4144 kg	N/A	24 Ku, 24 C	N/A	N/A
SCD 2	Communications	Unknown	LEO	427 nMi	392 nMi	253 lb/ 115 kg	N/A	N/A	N/A	N/A
Sedsat-1	Communications	Unknown	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Sesat	Communications	Unknown	GEO 36E	19400 nMi	19400 nMi	5720 lb/ 2600 kg	N/A	18 Ku	N/A	N/A
Sirius 3	Communications	Unknown	GEO 28.2E	19400 nMi	19400 nMi	3190 lb/ 1450 kg	N/A	15 Ku	N/A	N/A
Skynet 4E	Communications	Unknown	GEO 53E	19400 nMi	19400 nMi	3321 lb/ 1510 kg	N/A	3 X	3-axis	N/A
Sputnik 41	Communications	Unknown	LEO	N/A	N/A	9 lb/ 4 kg	N/A	N/A	N/A	N/A
Telkom 1	Communications	$78.4 M	GEO 108E	19400 nMi	19400 nMi	5525 lb/ 2500 kg	N/A	36 C	N/A	N/A
Telstar 6	Communications	Unknown	GEO 267E	19400 nMi	19400 nMi	7683 lb/ 3492 kg	N/A	28 Ku, 24 C	N/A	N/A
Telstar 7	Communications	Unknown	GEO 231E	19400 nMi	19400 nMi	7683 lb/ 3492 kg	N/A	28 Ku	N/A	N/A
Crewed										
Soyuz TM-29	Crewed	Unknown	LEO	221 nMi	213 nMi	15587 lb/ 7070 kg	14969 lb/ 6790 kg	N/A	N/A	N/A
Development										
ARD	Development	Unknown	LEO	N/A	N/A	6002 lb/ 2716 kg	N/A	N/A	N/A	N/A
Argos	Development	Unknown	LEO	450 nMi	450 nMi	N/A	N/A	N/A	N/A	N/A
Deep Space 1	Development	$132.6M	EXT	N/A	N/A	946 lb/ 430 kg	N/A	N/A	N/A	N/A
Deep Space 2	Development	Unknown	EXT	N/A	N/A	9 lb/ 4 kg	N/A	N/A	N/A	N/A
MightySat 1	Development	Unknown	LEO	N/A	N/A	150 lb/ 68 kg	N/A	N/A	N/A	N/A
Rocsat 1	Development	$61 M	LEO	324 nMi	324 nMi	878 lb/ 399 kg	N/A	N/A	3-axis	N/A
SAC A	Development	Unknown	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
STEX	Development	$85.6 M	LEO	370 nMi	370 nMi	N/A	1523 lb/ 689 kg	N/A	3-axis	N/A
TSX 5	Development	$85 M	LEO	N/A	N/A	286 lb/ 130 kg	N/A	N/A	N/A	N/A
Tubsat C-DLR	Development	Unknown	LEO	540 nMi	540 nMi	N/A	N/A	N/A	N/A	N/A
Intelligence										
DSP 19	Intelligence	Unknown	GEO	19400 nMi	19400 nMi	5171 lb/ 2340 kg	N/A	N/A	N/A	N/A
Meteorological										
FY-1C	Meteorological	Unknown	LEO	470 nMi	470 nMi	1938 lb/ 881 kg	N/A	N/A	N/A	N/A
GOES L	Meteorological	Unknown	GEO	19330 nMi	19323 nMi	3991 lb/ 1814 kg	N/A	N/A	N/A	N/A
Meteor 3M-1	Meteorological	Unknown	LEO	500 nMi	500 nMi	1980 lb/ 900 kg	N/A	N/A	N/A	N/A
Microgravity										
Takesaki 7	Microgravity	Unknown	SUB	N/A	N/A	N/A	N/A	N/A	N/A	N/A

Characterisitcs of Cited Payloads

Payload	Use	Price	Orbit	Apogee	Perigee	Launch Mass	Mass in Orbit	Freq. Bands & Trans.	Stab.	Power
Navigation										
Kosmos 2361	Navigation	Unknown	ELI	21982 nMi	226 nMi	N/A	N/A	N/A	N/A	N/A
Kosmos 2362	Navigation	Unknown	MEO	10338 nMi	10322 nMi	N/A	N/A	1 L	N/A	N/A
Kosmos 2363	Navigation	Unknown	MEO	10338 nMi	10322 nMi	N/A	N/A	1 L	N/A	N/A
Kosmos 2364	Navigation	Unknown	MEO	10338 nMi	10322 nMi	N/A	N/A	1 L	N/A	N/A
Nadezhda 5	Navigation	Unknown	LEO	N/A	N/A	1823 lb/ 825 kg	N/A	N/A	N/A	N/A
Navstar GPS 2R- 3	Navigation	Unknown	MEO	10899 nMi	10899 nMi	4470 lb/ 2032 kg	N/A	1 L	N/A	N/A
Other										
Celestis 3	Other	Unknown	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Remote Sensing										
Badr 2	Remote Sensing	Unknown	LEO	540 nMi	N/A	N/A	155 lb/ 70 kg	N/A	N/A	N/A
IKONOS 1	Remote Sensing	Unknown	LEO	367 nMi	367 nMi	1797 lb/ 817 kg	1216 lb/ 550 kg	N/A	3-axis	N/A
IRS P4	Remote Sensing	Unknown	LEO	497 nMi	481 nMi	2970 lb/ 1350 kg	N/A	N/A	N/A	N/A
Kitsat 3	Remote Sensing	Unknown	LEO	470 nMi	470 nMi	220 lb/ 100 kg	N/A	N/A	N/A	N/A
Landsat 7	Remote Sensing	Unknown	LEO	381 nMi	381 nMi	4862 lb/ 2200 kg	N/A	1 X	N/A	N/A
Okean O1	Remote Sensing	Unknown	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
SACI 2	Remote Sensing	Unknown	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Scientific										
Abrixas	Scientific	$32.4 M	LEO	324 nMi	324 nMi	990 lb/ 450 kg	N/A	N/A	N/A	N/A
Astrid 2	Scientific	$1.5 M	LEO	540 nMi	540 nMi	77 lb/ 35 kg	N/A	N/A	N/A	N/A
Chandra	Scientific	$1400 M	ELI	75600 nMi	5400 nMi	62166 lb/ 28200 kg	N/A	N/A	N/A	N/A
Coronas F	Scientific	Unknown	LEO	270 nMi	270 nMi	4752 lb/ 2160 kg	N/A	N/A	N/A	N/A
FUSE	Scientific	$100 M	LEO	432 nMi	432 nMi	2992 lb/ 1360 kg	N/A	N/A	N/A	N/A
Mars Climate Orbiter	Scientific	Unknown	EXT	N/A	N/A	990 lb/ 450 kg	N/A	N/A	N/A	N/A
Mars Polar Lander	Scientific	Unknown	EXT	N/A	N/A	1362 lb/ 618 kg	N/A	N/A	N/A	N/A
Maxus 4	Scientific	Unknown	SUB	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Oersted	Scientific	Unknown	LEO	459 nMi	281 nMi	136 lb/ 62 kg	N/A	N/A	N/A	44 W
QuickSCAT	Scientific	$36.1 M	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Spartan 201-04R	Scientific	Unknown	LEO	168 nMi	159 nMi	2800 lb/ 1270 kg	N/A	N/A	N/A	N/A
Stardust	Scientific	$75.1 M	EXT	N/A	N/A	840 lb/ 380 kg	N/A	N/A	3-axis	N/A
Sunsat	Scientific	Unknown	LEO	464 nMi	243 nMi	132 lb/ 60 kg	N/A	N/A	N/A	N/A
SWAS	Scientific	Unknown	LEO	324 nMi	324 nMi	623 lb/ 283 kg	N/A	N/A	N/A	N/A
TERRIERS	Scientific	Unknown	LEO	297 nMi	297 nMi	268 lb/ 122 kg	N/A	N/A	N/A	N/A
UoSat 12	Scientific	Unknown	LEO	N/A	N/A	330 lb/ 150 kg	N/A	N/A	N/A	N/A
WIRE	Scientific	Unknown	LEO	270 nMi	270 nMi	649 lb/ 295 kg	N/A	N/A	N/A	N/A

Characterisitcs of Cited Payloads

Payload	Use	Price	Orbit	Apogee	Perigee	Launch Mass	Mass in Orbit	Freq. Bands & Trans.	Stab.	Power
Scientifc (cont.)										
SJ 5	Scientific	Unknown	LEO	N/A	N/A	751 lb/ 340 kg	N/A	N/A	N/A	N/A
Space Station										
Pressurized Mating A 1&2	Space Station	Unknown	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Unity	Space Station	Unknown	LEO	N/A	N/A	N/A	N/A	N/A	N/A	N/A
Zarya	Space Station	$185.2 M	LEO	211 nMi	211 nMi	42500 lb/ 19278 kg	N/A	N/A	3-axis	N/A
Supply										
Progress M-40	Supply	Unknown	LEO	N/A	N/A	15983 lb/ 7250 kg	N/A	N/A	N/A	N/A
Progress M-41	Supply	Unknown	LEO	N/A	N/A	15983 lb/ 7250 kg	N/A	N/A	N/A	N/A
Test										
Galaxy 11 Mock-up	Test	Unknown	LEO	N/A	N/A	7683 lb/ 3492 kg	N/A	N/A	N/A	N/A
Maqsat 3	Test	Unknown	ELI	N/A	N/A	6019 lb/ 2730 kg	N/A	N/A	N/A	N/A

Launch Events
October - December 1998

Launch Date	Vehicle	Payload	Operator	Manufacturer	Int'l Comp	Launch Type	Launch Outcome	Mission Outcome
China								
				Long March				
December 19, 1998	Long March 2C	Iridium 92 Iridium 93	Iridium, Inc. Iridium, Inc.	Lockheed Martin Lockheed Martin	Yes	Commercial	Success	Success
Europe (ESA)								
				Ariane 4				
October 5, 1998	Ariane 44L	Eutelsat W2 Sirius 3	Eutelsat NSAB	Aerospatiale Hughes	Yes	Commercial	Success	Success
October 28, 1998	Ariane 44L	AfriStar 1 GE 5	WorldSpace, Inc. GE Americom	Alcatel Espace Aerospatiale	Yes	Commercial	Success	Success
December 4, 1998	Ariane 42L	SatMex 5	Telecomm Mexico	Hughes	Yes	Commercial	Success	Success
December 21, 1998	Ariane 42L	PAS 6B	PanAmSat	Hughes	Yes	Commercial	Success	Success
				Ariane 5				
October 21, 1998	Ariane 5	Maqsat 3 ARD	Kayser-Threde ESA	Kayser-Threde Aerospatiale	No	Non-Commercial	Success	Success
Japan								
				TR 1A				
November 19, 1998	TR 1A*	Takesaki 7	NASDA	NASDA	No	Non-Commercial	Success	Success

*High-profile suborbital launch events included.

Launch Events
October - December 1998

Launch Date	Vehicle	Payload	Operator	Manufacturer	Int'l Comp	Launch Type	Launch Outcome	Mission Outcome
Russia								
				Cosmos				
December 10, 1998	Cosmos	Nadezhda 5 Astrid 2	Russia Swedish National Space Board	NPO PM Swedish Space Corp.	No	Non-Commercial	Success	Success
December 24, 1998	Cosmos	Kosmos 2361	Russia	NPO Lavochkin	No	Non-Commercial	Success	Success
				Proton				
November 4, 1998	Proton	PAS 8	PanAmSat	Space Systems/Loral	Yes	Commercial	Success	Success
November 20, 1998	Proton	Zarya	International	Krunichev/Salyut	No	Non-Commercial	Success	Success
December 30, 1998	Proton	Kosmos 2362-2364	Russian MoD	NPO PM	No	Non-Commercial	Success	Success
				Soyuz				
October 25, 1998	Soyuz	Progress M-40 Sputnik 41	RKK Energia AMSAT France	RKK Energia AMSAT France	No	Non-Commercial	Success	Success
Sweden								
				Maxus				
November 24, 1998	Maxus*	Maxus 4	ESA	DaimlerChrysler & Swedish Space Corp.	No	Non-Commercial	Success	Success

*High-profile suborbital launch events included.

Launch Events
October - December 1998

Launch Date	Vehicle	Payload	Operator	Manufacturer	Int'l Comp	Launch Type	Launch Outcome	Mission Outcome
USA								
Atlas								
October 9, 1998	Atlas 2AS	Hot Bird 5	Eutelsat	Matra Marconi	Yes	Commercial	Success	Success
October 20, 1998	Atlas 2A	GBS 9	DoD	Hughes	No	Commercial	Success	Success
Delta 2								
October 24, 1998	Delta 2 7326	Deep Space 1 Sedsat-1	NASA NASA	Spectrum Astro, Inc. Univ. of Alabama Huntsville	No	Non-Commercial	Success	Success
November 6, 1998	Delta 2 7920	Iridiums 83-87	Iridium, Inc.	Lockheed Martin	Yes	Commercial	Success	Success
November 22, 1998	Delta 2 7925	Bonum 1	Media Most	Hughes	Yes	Commercial	Success	Success
December 11, 1998	Delta 2 7425	Mars Climate Orbiter	NASA	Lockheed Martin	No	Non-Commercial	Success	Success
Pegasus								
October 22, 1998	Pegasus 1	SCD 2	INPE	INPE	Yes	Commercial	Success	Success
December 5, 1998	Pegasus XL	SWAS	Smithsonian Astrophys. Obs.	NASA Goddard	No	Non-Commercial	Success	Success
Shuttle								
October 29, 1998	Shuttle Discovery	STS 95 PANSAT 1 Spartan 201-04R	NASA Naval Postgraduate School NASA	Rockwell International Naval Postgraduate School NASA	No	Non-Commercial	Success	Success
December 4, 1998	Shuttle Endeavour	STS 88 Unity MightySat 1 Pres. Mating A 1&2 SAC A	NASA NASA DoD NASA NASA	Rockwell International NASA CTA Space Systems NASA Bariloche Company Invap.	No	Non-Commercial	Success	Success
Taurus								
October 3, 1998	Taurus 1	STEX	NRO	Lockheed Martin	No	Non-Commercial	Success	Success

*High-profile suborbital launch events included.

Launch Events
January 1999 - June 1999

Launch Date	Vehicle	Payload	Operator	Manufacturer	Int'l Comp	Launch Type	Site
Brazil							
			VLS				
June 1999	VLS	SACI 2	INPE	INPE	No	Non-Commercial	Alcantara
China							
			Long March				
January 1999	Long March 3B	ChinaSat 8	Chinese Broadcst. Satellite Corp.	Space Systems/Loral	No	Non-Commercial	Xichang
February 1999	Long March 4	FY-1C SJ 5	Chinese Academy of Space Tech. Chinese Academy of Space Tech.	Shanghai Inst. of Sat. Engineering Chinese Academy of Space Tech.	No	Non-Commercial	Taiyuan
Europe (ESA)							
			Ariane 4				
February 3, 1999	Ariane 44L	Arabsat 3A Skynet 4E	Arabsat British Defense Ministry	DASA Matra Marconi	Yes	Commercial	Kourou
March 12, 1999	Ariane 44P	Intelsat K-TV	New Skies Satellites, N.V.	Matra Marconi	Yes	Commercial	Kourou
April 13, 1999	Ariane 44L	Galaxy 11	PanAmSat	Hughes	Yes	Commercial	Kourou
May 1999	Ariane 44LP	Orion F2	Orion Network Services	Space Systems/Loral	Yes	Commercial	Kourou
2nd Qtr 1999	Ariane 4-TBA	Astra 2B	SES	Matra Marconi	Yes	Commercial	Kourou
			Ariane 5				
April 1999	Ariane 5	Eutelsat W4 Telkom 1	Eutelsat PT Telekom	NPO Prikladnoi Mekhaniki Lockheed Martin	Yes	Commercial	Kourou
May 1999	Ariane 5	AsiaStar 1 Insat 3B	WorldSpace, Inc. ISRO	Alcatel ISRO	No	Commercial	Kourou

Launch Events
January 1999 - June 1999

Launch Date	Vehicle	Payload	Operator	Manufacturer	Int'l Comp	Launch Type	Site
India							
			PSLV				
1st Qtr 1999	PSLV	IRS P4 Kitsat 3 Tubsat C-DLR	ISRO Korean Advanced Inst. of Science Technical University of Berlin	ISRO Surrey Satellite Technology Technical University of Berlin	No	Non-Commercial	Sriharikota Range
Russia							
			Cosmos				
April 28, 1999	Cosmos	Abrixas MegSat 0	DLR Meggiorin	OHB System Unknown	Yes	Commercial	Kapustin Yar
			Cyclone				
2nd Qtr 1999	Cyclone 3	Coronas F	Izmiran & Lebedev Physical Inst.	NPO Yuzhnoye	No	Non-Commercial	Plesetsk
			Dnepr				
April 1999	Dnepr	UoSat 12	Surrey Satellite Technology Ltd.	Surrey Satellite Technology	Yes	Commercial	Baikonur
			Proton				
January 30, 1999	Proton	Telstar 6	Skynet	Space Systems/Loral	Yes	Commercial	Baikonur
February 21, 1999	Proton	AsiaSat 3S	Asiasat	Hughes	Yes	Commercial	Baikonur
February 1999	Proton	Sesat	Eutelsat	NPO PM	Yes	Commercial	Baikonur
March 21, 1999	Proton	Astra 1H	SES	Hughes	Yes	Commercial	Baikonur
March 1999	Proton	Raduga 34	Russia/CIS PTT	NPO Prikladnoi Mekhaniki	No	Non-Commercial	Baikonur
April 1999	Proton	ICO 1	ICO Global Communications	Hughes	Yes	Commercial	Baikonur
May 1999	Proton	Nimiq 1	Telesat Canada	Lockheed Martin	Yes	Commercial	Baikonur
June 1999	Proton	ICO 2	ICO Global Communications	Hughes	Yes	Commercial	Baikonur

Launch Events
January 1999 - June 1999

Launch Date	Vehicle	Payload	Operator	Manufacturer	Int'l Comp	Launch Type	Site
Russia (cont.)							
			Soyuz				
February 2, 1999	Soyuz	Globalstars 21-24	Globalstar, Inc.	Space Systems/Loral	Yes	Commercial	Baikonur
February 22, 1999	Soyuz	Soyuz TM-29	RKK Energia	RKK Energia	No	Non-Commercial	Baikonur
March 10, 1999	Soyuz	Progress M-41	RKK Energia	RKK Energia	No	Non-Commercial	Baikonur
1st Qtr 1999	Soyuz	Globalstars 29-32	Globalstar, Inc.	Space Systems/Loral	Yes	Commercial	Baikonur
1st Qtr 1999	Soyuz	Globalstars 25-28	Globalstar, Inc.	Space Systems/Loral	Yes	Commercial	Baikonur
			Zenit				
2nd Qtr 1999	Zenit 2	Meteor 3M-1 Badr 2	Russia SUPARCO	VNII Elektromekhaniki SUPARCO	No	Non-Commercial	Baikonur
Ukraine							
			Zenit				
February 1999	Zenit 2	Okean O1	NSAU	NPO Yuzhnoe	No	Non-Commercial	Baikonur
USA							
			Athena 1				
January 26, 1999	Athena 1	Rocsat 1	Natl' Space Program Office	TRW	Yes	Commercial	Spaceport Florida
			Athena 2				
June 1999	Athena 2	IKONOS 1	Space Imaging Inc.	Lockheed Martin	No	Commercial	VAFB

Launch Events
January 1999 - June 1999

Launch Date	Vehicle	Payload	Operator	Manufacturer	Int'l Comp	Launch Type	Site
USA (cont.)							
			Atlas 2				
January 13, 1999	Atlas 2AS	JCSAT 6	Japan Satellite Systems (JSAT)	Hughes	Yes	Commercial	CCAS
March 12, 1999	Atlas 2AS	Eutelsat W3	Eutelsat	Aerospatiale	Yes	Commercial	CCAS
March 31, 1999	Atlas 2A	GOES L	NOAA	Space Systems/Loral	No	Non-Commercial	CCAS
May 15, 1999	Atlas 2A	GBS 10	DoD	Hughes	No	Commercial	CCAS
			Atlas 3				
June 15, 1999	Atlas 3A	Telstar 7	Skynet	Space Systems/Loral	Yes	Commercial	CCAS
			Delta 2				
January 3, 1999	Delta 2 7425	Deep Space 2 Mars Polar Lander	NASA NASA	JPL Lockheed Martin	No	Non-Commercial	CCAS
January 14, 1999	Delta 2 7925	Argos Oersted Sunsat	Space Test Program Office, USAF Danish Space Research Institute University of Stellenbosch	TRW Computer Resources International Stellenbosch University	No	Non-Commercial	VAFB
February 6, 1999	Delta 2 7426	Stardust	NASA	Lockheed Martin	No	Non-Commercial	CCAS
March 1, 1999	Delta 2 7920	Iridiums 88-94	Iridium, Inc.	Lockheed Martin	Yes	Commercial	VAFB
April 15, 1999	Delta 2 7920	Landsat 7 Iowasat	NASA Unknown	Lockheed Martin Unknown	No	Non-Commercial	VAFB
April 22, 1999	Delta 2 7925	Navstar GPS 2R- 3	DoD	Lockheed Martin	No	Non-Commercial	CCAS
May 20, 1999	Delta 2 7320	FUSE	NASA	Orbital Sciences Corp. (OSC)	No	Non-Commercial	CCAS
May 1999	Delta 2 7420	Globalstars 45-48	Globalstar, Inc.	Space Systems/Loral	Yes	Commercial	CCAS

Launch Events
January 1999 - June 1999

Launch Date	Vehicle	Payload	Operator	Manufacturer	Int'l Comp	Launch Type	Site
USA (cont.)							
			Delta 3				
March 8, 1999	Delta 3	Orion F3	Orion Network Systems	Hughes	Yes	Commercial	CCAS
			Pegasus				
1st Qtr 1999	Pegasus XL	WIRE	NASA	NASA Goddard	No	Non-Commercial	VAFB
2nd Qtr 1999	Pegasus XL	TERRIERS Celestis 3 MUBLCOM	Boston University/NASA Celestis ARPA	AeroAstro Celestis Orbital Sciences Corp. (OSC)	Yes	Commercial	VAFB
2nd Qtr 1999	Pegasus XL	TSX 5	DoD	Orbital Sciences Corp. (OSC)	No	Non-Commercial	VAFB
			Sea Launch				
March 1999	Sea Launch	Galaxy 11 Mock-up	Sea Launch	Hughes	No	Commercial	Sea Launch Platform
			Shuttle				
April 8, 1999	Shuttle Columbia	STS 93 Chandra	NASA NASA	Rockwell International TRW	No	Non-Commercial	KSC
May 13, 1999	Shuttle Discovery	STS 96	NASA	Rockwell International	No	Non-Commercial	KSC
			Titan 2				
April 27, 1999	Titan 2	QuickSCAT	NASA	Ball Aerospace	No	Non-Commercial	VAFB
			Titan 4				
February 27, 1999	Titan 4B/IUS	DSP 19	DoD	TRW	No	Non-Commercial	CCAS
March 15, 1999	Titan 4B	USA 1999-03	DoD	Unknown	No	Non-Commercial	VAFB