Commercial Space Transportation

QUARTERLY LAUNCH REPORT

Featuring the launch results from the 3rd quarter 2004 and forecasts for the 4th quarter 2004 and 1st quarter 2005

Quarterly Report Topic:

Overview of the U.S. Small Launch Industry

4th Quarter 2004

United States Department of Transportation • Federal Aviation Administration
Associate Administrator for Commercial Space Transportation
800 Independence Ave. SW • Room 331
Washington, D.C. 20591

Introduction

The Fourth Quarter 2004 Quarterly Launch Report *features launch results from the third quarter of 2004 (July-September 2004) and forecasts for the fourth quarter of 2004 (October-December 2004) and first quarter of 2005 (January-March 2005). This report contains information on worldwide commercial, civil, and military orbital and commercial suborbital space launch events. Projected launches have been identified from open sources, including industry references, company manifests, periodicals, and government sources. Projected launches are subject to change.*

This report highlights commercial launch activities, classifying commercial launches as one or both 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 Associate Administrator for Commercial Space Transportation of the Federal Aviation Administration under 49 United States Code Subtitle IX, Chapter 701 (formerly the* Commercial Space Launch Act)

Special Note

Previous Quarterly Launch Reports have focused solely on orbital launches. However, due to increased suborbital space activity in the United States, and the possibility that it may occur in other countries in the future, this and subsequent Quarterly Launch Reports will now record FAA-licensed and equivalent international suborbital launches in addition to orbital space activity.

Contents

Cover (photo courtesy of Scaled Composites, copyright © 2004 Mike Massee): SpaceShipOne, developed by Scaled Composites, lands at Mojave Airport on September 29, 2004, following its first successful flight in pursuit of the Ansari X Prize. On September 29 and October 4, 2004, SpaceShipOne conducted two flights within a two-week period that carried the weight equivalent of three passengers to an altitude of over 100 kilometers, thereby winning the Ansari X Prize.

Third Quarter 2004 Highlights

In August 2004, after more than 12 years of service, the final flight of an Atlas 2-series vehicle took place as an Atlas 2AS lofted a National Reconnaissance Office (NRO) payload to low Earth orbit. The launch marked a perfect record of 63 successful launches for the Atlas 2, Atlas 2A, and Atlas 2AS vehicles, which were powered by ATK Thiokol and Rocketdyne engines.

Under the European Space Agency (ESA) Future Launcher Preparatory Program, European Aeronautic Defense and Space Group (EADS) is forming a 70-30 partnership with Italy's Finmeccanica to develop the next generation European launcher, which will succeed the Ariane 5, due for retirement around 2020.

Budget limitations will delay the maiden flight of the Russian Angara launcher until 2008 at the earliest, according to the head of Russia's Space Forces. Most of Russia's space budget will instead be allocated towards developing the Plesetsk Cosmodrome as the country's prime launch site.

On September 6, Israel launched a Shavit booster from Palmachim Air Force Base carrying the Ofeq 6 reconnaissance satellite. However, the third stage failed, sending the payload into the Mediterranean Sea. Israel's Ministry of Defense and Israel Aircraft Industries will investigate the failure, and have initiated plans to launch an identical replacement satellite, dubbed Ofeq 6.5, within the next two years.

Russia, the Ukraine, Kazakhstan, and Belarus—the four member states of the Single Economic Space (SES) organization—have decided to merge their space enterprises. The SES will conduct Zenit test launches of the proposed Kliper, a six-crew replacement module for the Soyuz TMA, beginning in 2008.

NASA reports it is turning over operation of the X-37 technology demonstrator to the Defense Advanced Research Projects Agency (DARPA). NASA confirmed it had talked with Scaled Composites about using a company aircraft for drop tests, but the SpaceShipOne carrier aircraft, White Knight, was not specified.

DARPA has awarded 10-month Phase 2 contracts, ranging in value from $8 million to $11.7 million, to four companies seeking to meet the government's demand for a Force Application and Launch from Continental U.S. (FALCON) small launch vehicle. The companies—AirLaunch LLC, Lockheed Martin, Microcosm, and SpaceX—are in various stages of progress on the project. SpaceX is perceived to be furthest along, and is set to perform an "early, responsive launch demonstration" in 2005.

NASA Ames Research Center and SpaceDev announced they are collaborating to develop new low-cost launch vehicles in support of NASA's Vision for Space Exploration, including a piloted suborbital spaceplane.

Ukraine and Brazil have agreed to invest $50 million each to build a launch pad for Ukraine's new Tsyklon 4 booster at Alcantara, expected to be ready around 2007. Meanwhile, Brazil still plans to proceed with its VLS launcher program, aiming for another test flight in 2006.

NASA's Kennedy Space Center (KSC) was hit by several hurricanes and a tropical storm during the third quarter. KSC's Vehicle Assembly Building lost large sections of wall paneling, and the Orbiter Processing Facilities sustained minor damage. All three orbiters and several launchers onsite were undamaged.

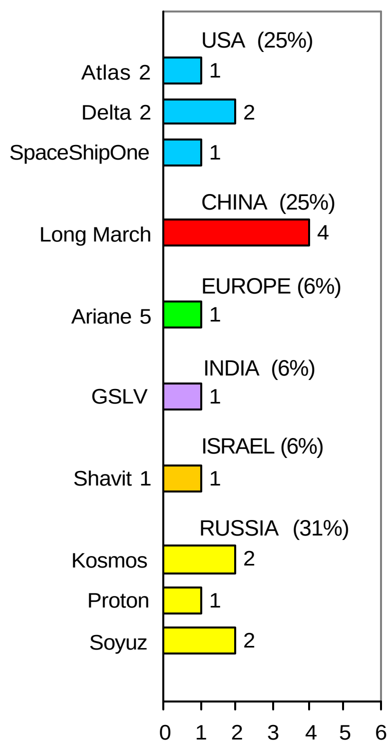
Sir Richard Branson's Virgin Group has joined with Paul Allen's Mojave Aerospace Ventures to modify the SpaceShipOne craft for commercial tourist suborbital spaceflights. Branson's venture, Virgin Galactic, will invest US$21.5 million for a 15-year license covering five "SpaceShipTwo" vehicles. The first of these vehicles, named *Virgin SpaceShip (VSS) Enterprise*, could begin operating by 2007, and would carry five passengers paying US$198,000 each for three days' training and a suborbital flight over 100 kilometers.

Scaled Composites, builder of the Tier One suborbital system composed of the carrier aircraft White Knight and suborbital reusable launch vehicle SpaceShipOne, conducted the first of two required Ansari X Prize flights on September 29. SpaceShipOne successfully reached an altitude of 102.9 kilometers, despite an unplanned 29 rolls during ascent. The next flight of SpaceShipOne, carried out successfully on October 4, resulted in Mojave Aerospace Ventures, the sponsor of the Scaled Composites team, winning the $10 million Ansari X Prize.

Vehicle Use

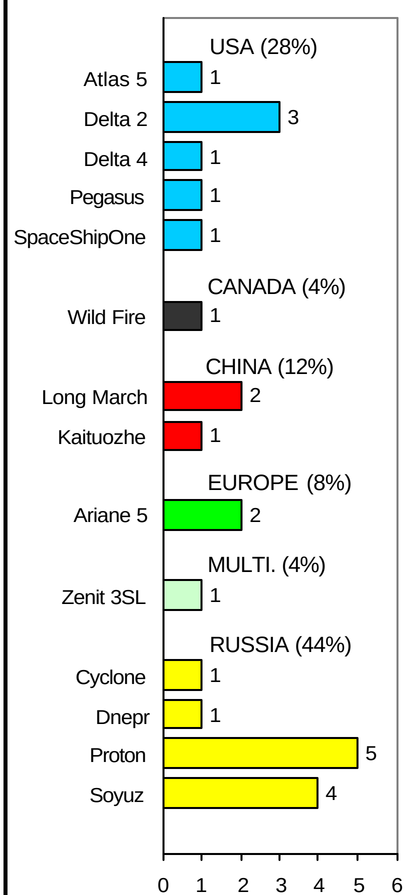
(July 2004 – March 2005)

Figure 1: Third Quarter 2004 Total Launch Vehicle Use



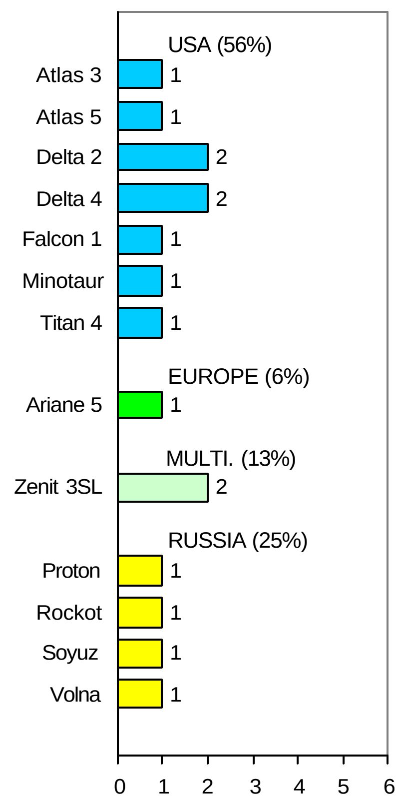
Total = 16

Figure 2: Fourth Quarter 2004 Total Projected Launch Vehicle Use



Total = 25

Figure 3: First Quarter 2005 Total Projected Launch Vehicle Use



Total = 16

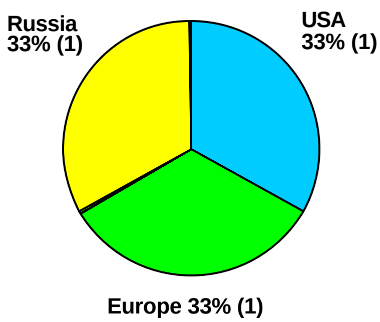
Figures 1-3 show the total number of orbital and suborbital launches (commercial and government) of each launch vehicle and the resulting market share that occurred in the third quarter of 2004, as well as projecting this information for the fourth quarter of 2004 and first quarter of 2005. The launches are grouped by the country in which the primary vehicle manufacturer is based. Exceptions to this grouping are launches performed by Sea Launch, which are designated as multinational.

Note: Percentages for these and subsequent figures may not add up to 100 percent due to rounding of individual values.

Commercial Launch Events by Country

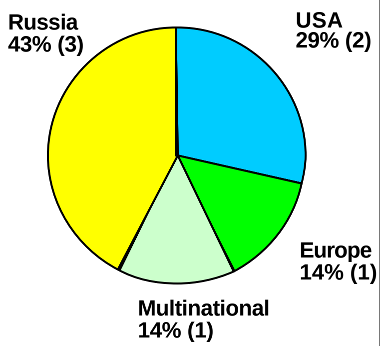
(July 2004 – March 2005)

Figure 4: Third Quarter 2004 Commercial Launch Events by Country



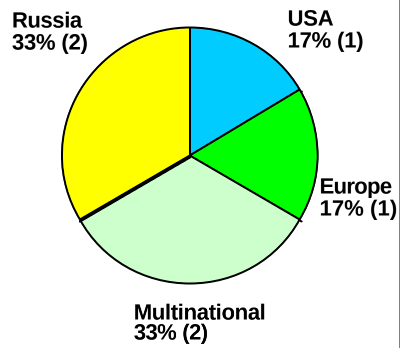
Total = 3

Figure 5: Fourth Quarter 2004 Projected Commercial Launch Events by Country



Total = 7

Figure 6: First Quarter 2005 Projected Commercial Launch Events by Country



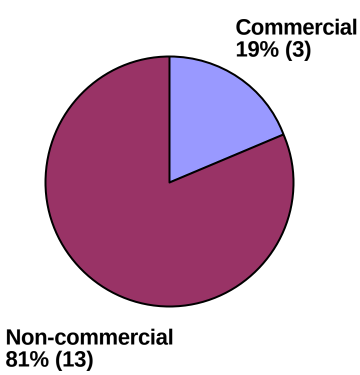
Total = 6

Figures 4-6 show all *commercial* orbital and suborbital launch events that occurred in the third quarter of 2004 and that are projected for the fourth quarter of 2004 and first quarter of 2005.

Commercial vs. Non-commercial Launch Events

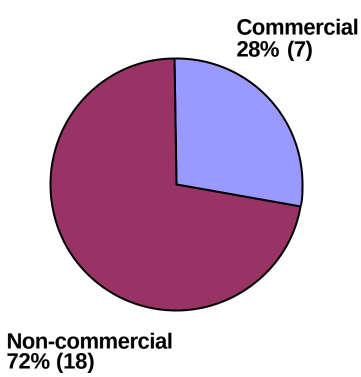
(July 2004 – March 2005)

Figure 7: Third Quarter 2004 Commercial vs. Non-commercial Launch Events



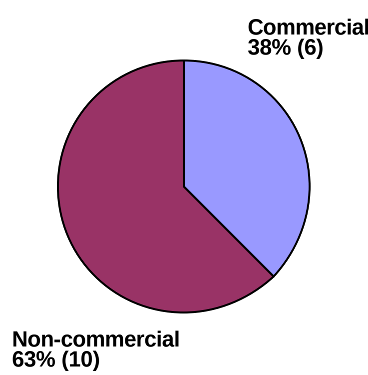
Total = 16

Figure 8: Fourth Quarter 2004 Projected Commercial vs. Non-commercial Launch Events



Total = 25

Figure 9: First Quarter 2005 Projected Commercial vs. Non-commercial Launch Events



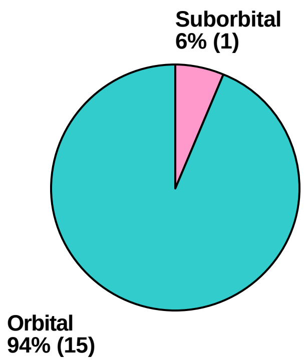
Total = 16

Figures 7-9 show commercial vs. non-commercial orbital and suborbital launch events that occurred in the third quarter of 2004 and that are projected for the fourth quarter of 2004 and first quarter of 2005.

Orbital vs. Suborbital Launch Events

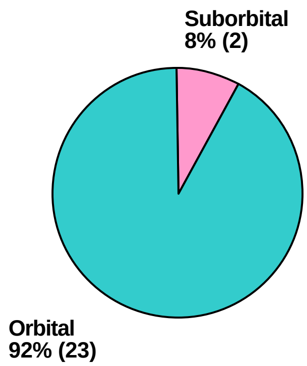
(July 2004 – March 2005)

Figure 10: Third Quarter 2004 Orbital vs. Suborbital Launch Events



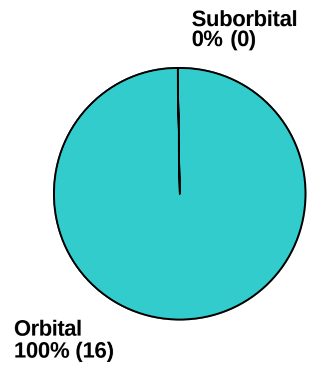
Total = 16

Figure 11: Fourth Quarter 2004 Projected Orbital vs. Suborbital Launch Events



Total = 25

Figure 12: First Quarter 2005 Projected Orbital vs. Suborbital Launch Events



Total = 16

Figures 10-12 show orbital vs. suborbital launch events that occurred in the third quarter of 2004 and that are projected for the fourth quarter of 2004 and first quarter of 2005.

Launch Successes vs. Failures

(July 2004 – September 2004)

Figure 13: Third Quarter 2004 Launch Successes vs. Failures

Total = 16

Figure 13 shows orbital and suborbital launch successes vs. failures for the period from July 2004 to September 2004. Partially-successful orbital launch events are those where the launch vehicle fails to deploy its payload to the appropriate orbit, but the payload is able to reach a useable orbit via its own propulsion systems. Cases in which the payload is unable to reach a useable orbit or would use all of its fuel to do so are considered failures.

Payload Use (Orbital Launches Only)

(July 2004 – March 2005)

Figure 14: Third Quarter 2004 Payload Use

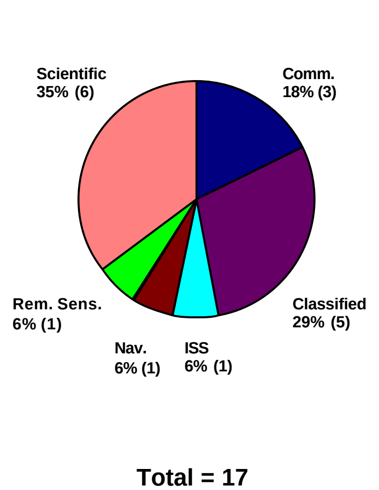


Figure 15: Fourth Quarter 2004 Projected Payload Use

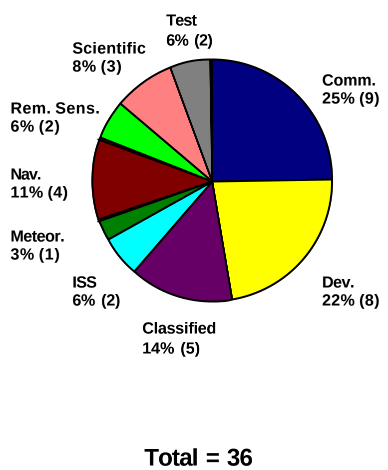
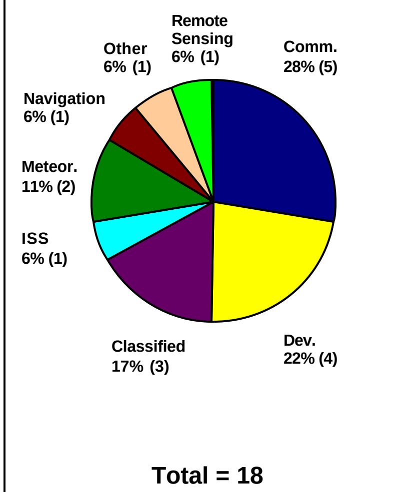


Figure 16: First Quarter 2005 Projected Payload Use



Figures 14-16 show total payload use (commercial and government), actual for the third quarter of 2004 and projected for the fourth quarter of 2004 and first quarter of 2005. The total number of payloads launched may not equal the total number of launches due to multi-manifesting, i.e., the launching of more than one payload by a single launch vehicle.

Payload Mass Class (Orbital Launches Only)

(July 2004 – March 2005)

Figure 17: Third Quarter 2004 Payload Mass Class

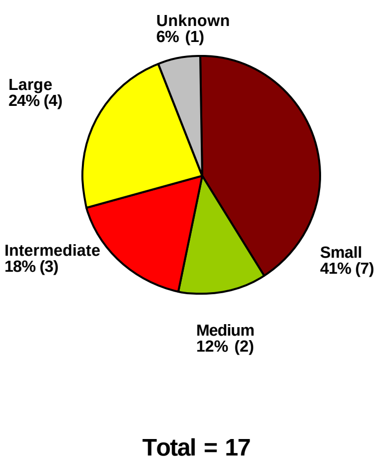


Figure 18: Fourth Quarter 2004 Projected Payload Mass Class

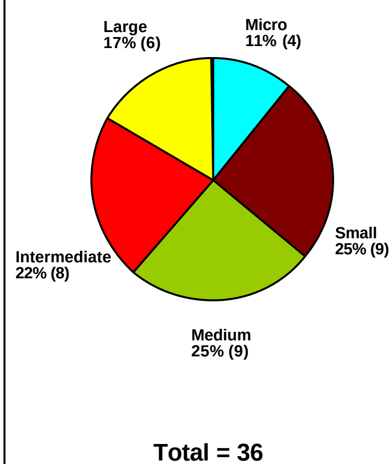
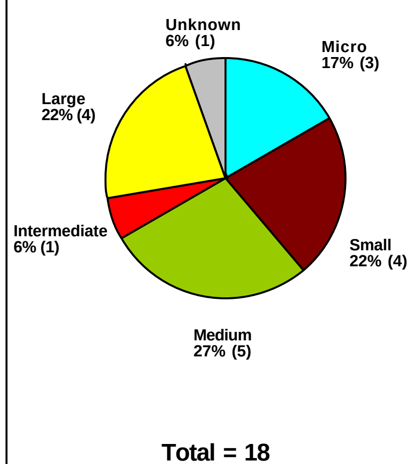


Figure 19: First Quarter 2005 Projected Payload Mass Class



Figures 17-19 show total payloads by mass class (commercial and government), actual for the third quarter of 2004 and projected for the fourth quarter of 2004 and first quarter of 2005. The total number of payloads launched may not equal the total number of launches due to multi-manifesting, i.e., the launching of more than one payload by a single launch vehicle. Payload mass classes are defined as Micro: 0 to 91 kilograms (0 to 200 lbs.); Small: 92 to 907 kilograms (201 to 2,000 lbs.); Medium: 908 to 2,268 kilograms (2,001 to 5,000 lbs.); Intermediate: 2,269 to 4,536 kilograms (5,001 to 10,000 lbs.); Large: 4,537 to 9,072 kilograms (10,001 to 20,000 lbs.); and Heavy: over 9,072 kilograms (20,000 lbs.).

Commercial Launch Trends (Orbital Launches Only)

(October 2003 – September 2004)

Figure 20: Commercial Launch Events, Last 12 Months

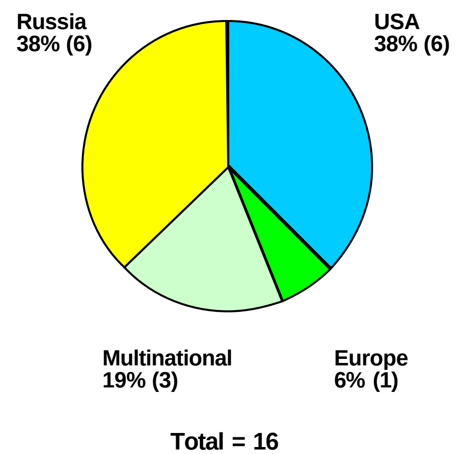


Figure 20 shows commercial orbital launch events for the period of October 2003 to September 2004 by country.

Figure 21: Estimated Commercial Launch Revenue, Last 12 Months

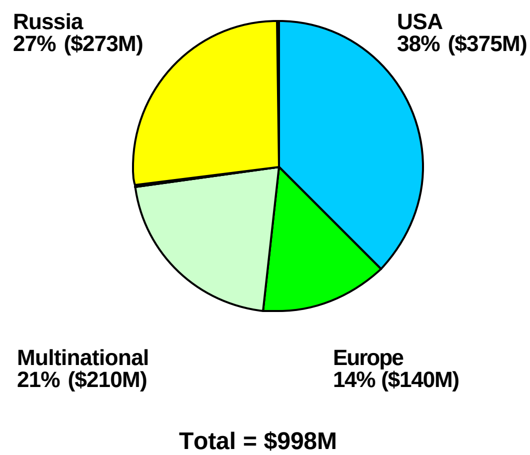


Figure 21 shows estimated commercial launch revenue for orbital launches for the period of October 2003 to September 2004 by country.

Commercial Launch Trends (Suborbital Launches Only)

(October 2003 – September 2004)

Figure 22: Commercial Launch Events, Last 12 Months

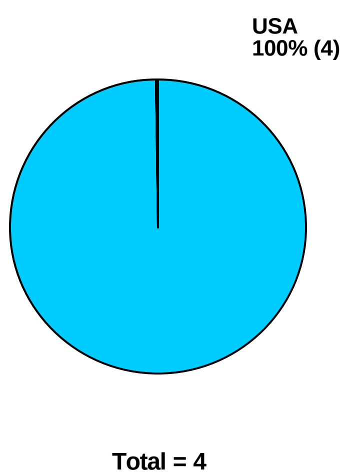


Figure 22 shows commercial suborbital launch events for the period of October 2003 to September 2004 by country.

Commercial Launch History

(January 1999 – December 2003)

Figure 23: Commercial Launch Events by Country, Last Five Years

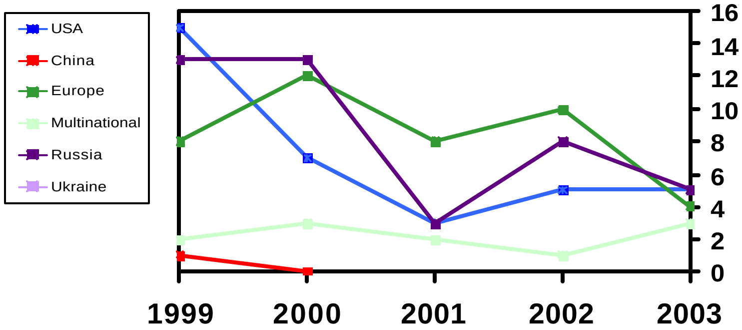


Figure 23 shows commercial launch events by country for the last five full years.

Figure 24: Estimated Commercial Launch Revenue (in $ million) by Country, Last Five Years

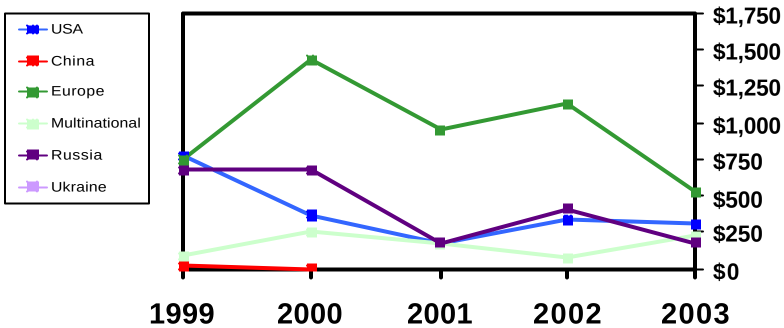


Figure 24 shows estimated commercial launch revenue by country for the last five full years.

Overview of the U.S. Small Launch Industry

Introduction

In recent years, several factors have converged to make the market for small launch vehicles more attractive than before. The trend towards miniaturization in electronics has helped reduce the size and weight of spacecraft hardware, enabling the emergence of smaller satellites, or smallsats, that can perform many functions once reserved for more massive buses. These small payloads do not require large and sometimes prohibitively expensive launch vehicles to be lofted into orbit. Although smallsat builders and operators can and often do deploy their satellites alongside others in multi-manifested launches, surveys show that for reasons of schedule assurance, flexibility, and simplicity, they generally prefer a dedicated launch, promoting a market for smaller vehicles. Meanwhile, U.S. government and military planners have placed greater emphasis on developing a more robust responsive launch capability in order to strengthen American command and control in space. Small launchers—lighter, more mobile, less expensive, and, in some cases, promising faster launch pad turnaround times than their larger counterparts—can play a key role in this regard.

Scope and Purpose of Report

The growing relevance of the small launch sector makes it a topic worthy of closer examination. It is also a timely subject, given the anticipated entry of a new small launch provider, Space Exploration Technologies (SpaceX), into the market, with the maiden launch of its Falcon I vehicle expected early next year. As such, the Associate Administrator for Commercial Space Transportation (AST) has prepared this Special Report, which provides a top-level overview of the U.S. small launch industry. For the purposes of this report, small launch vehicles are defined as having a capacity to low Earth orbit (LEO) of 2,268 kilograms (kg), or 5,000 pounds (lbs), and under.

This report catalogs the main builders and providers of small launch vehicles, profiling their vehicle offerings and programs. As a preface to this overview, the report also highlights the major builders of small satellites—defined as weighing 907 kg (2,000 lbs) or less—to illustrate the potential supply of smallsats that may drive demand for these small launch vehicles. While the focus throughout is on American companies, the report briefly cites small satellite and small launch vehicle activities abroad to place the U.S. small launch industry in a global context. Finally, the report closes with a short outlook section assessing where the U.S. small launch industry stands today.

The goal of this report is not to forecast demand for small launchers, but rather to provide a snapshot of the current U.S. small launch sector in order to inform discussions about its status, future market prospects, competitive dynamics, and overall direction. The report draws mainly from publicly-available information found in company documents and websites. In certain cases, information is also derived from company interviews.

Small Satellite Highlights

To understand the forces driving the small launch industry, it is necessary to examine the small payloads that spur demand for small launchers. As stated earlier, although small payloads have often been launched through multi-manifesting, dedicated launches, if sufficiently inexpensive, offer advantages in schedule assurance, flexibility, and tailored service.

In the past five years, the number of small payloads launched has varied widely. The peak was in 1999, when 74 payloads weighing 907 kg or under were launched worldwide. However, it is worth recalling that this was also the peak of optimism about non-geosynchronous orbit (NGSO) communications systems: 49 of those payloads were part of the Globalstar, ORBCOMM, and Iridium constellations, all three of which have faced financial difficulties and restructuring in the years since. More recent numbers are significantly smaller: 33 small payloads were launched in 2003, and 31 are projected to launch in 2004 (18 have launched in the first three quarters of the year, with 13 projected for the fourth quarter). Moreover, these numbers shrink dramatically when only U.S. payloads are considered—probably the most useful framework for analysis, since U.S. payloads are typically prevented from launching on foreign boosters by export restrictions, while foreign payloads tend to launch on indigenous vehicles when possible. In 1999, 60 U.S. payloads weighing 907 kg or less were launched, but that number drops to 11 after discounting the 49 Globalstar, ORBCOMM, and Iridium satellites. In 2003, seven such small U.S. payloads were launched. In 2004, two have launched so far, with an additional four projected during the fourth quarter.

On their face, these numbers may not inspire confidence. Nonetheless, a number of American firms are either specializing primarily in smallsats or devoting a portion of their resources to them. They perceive small satellites as a growth area because smallsats are aligned with current technological trends, face less risk of quick obsolescence, are cheaper to launch and insure than larger satellites, and promise military, scientific, remote sensing, and other applications that have yet to be fully explored.

Four companies in particular stand out as the major U.S. suppliers of small satellites: Ball Aerospace, General Dynamics C4 Systems (formerly Spectrum Astro), Orbital Sciences Corporation, and SpaceDev.

Ball Aerospace has produced numerous small spacecraft for remote sensing and earth science applications, and is currently supplying the Cloudsat and Deep Impact spacecrafts for the National Aeronautics and Space Administration (NASA). It offers two main smallsat buses that support payload masses of up to 91 kg (200 lbs) and 379 kg (835 lbs), respectively.

General Dynamics C4 Systems acquired Spectrum Astro in July 2004. Spectrum Astro has produced such small payloads as Deep Space 1 and the Reuven Ramaty High Energy Solar Spectroscopic Imager (RHESSI) for NASA, MightySat 2.1 for the Air Force Research Lab (AFRL), and Coriolis. It recently invested in a “Factory of the Future” which, when complete, will accommodate the manufacture of 20 satellites simultaneously. It offers three smallsat buses capable of supporting payloads weighing up to 100 kg (220 lbs), 200 kg (440 lbs), and 600 kg (1,320 lbs), respectively.

Orbital Sciences Corporation, with extensive smallsat experience, built ORBCOMM's 35 “Little LEO” communications satellites, has produced a number of small payloads for NASA and the military, and offers various small satellite buses supporting payload masses up to 10 kg (22 lbs), 25 kg (55 lbs), 68 kg (150 lbs), 238 kg (525 lbs), and 778 kg (1,715 lbs), respectively.

Lastly, there is SpaceDev, which built the CHIPSat astronomy payload and in April 2004 won a contract from the Missile Defense Agency (MDA) for up to six microsatellites. SpaceDev has developed a miniature flight computer and an advanced Internet Protocol system for smallsats, and offers a variety of other smallsat components and modules.

Small Launch Vehicle and Provider Overview

Despite this industry activity, many small satellite manufacturers feel constrained by lack of a responsive, inexpensive spacelift capability. There are, however, certain options in this regard, and this section will examine them, highlighting both existing and planned U.S. small launch vehicles. Existing small launch vehicles include Orbital Sciences Corporation’s Pegasus XL, Taurus, and Minotaur boosters, as well as Lockheed Martin’s Athena 1 and Athena 2 launchers—which are technically still in service although they have not been used since 2001. Planned vehicles include SpaceX’s Falcon I launcher and Orbital Sciences Corporation’s Minotaur IV booster.

In addition to these vehicles, government programs are supporting research into several other small launch concepts. This section will close with a short outline of two such government programs, and five small launch concepts they have recently selected for further development.

Orbital Sciences Corporation

As the manufacturer and service provider of the Pegasus XL, Taurus, Minotaur, and Minotaur IV vehicles, Orbital Sciences Corporation (OSC) is perhaps the country's foremost small launch provider. The company was the first private entrant onto the small launcher scene in the late 1980s, and since then has been a dominant market player. Its announced backlog of 12 launches over the next four years makes it the current incumbent in the U.S. small launch services sector.

Pegasus XL

The first small launch vehicle OSC introduced was the Pegasus, in the early 1990s. Launched in midair from a modified airplane, the Pegasus XL is a three-stage solid propellant winged rocket (with an optional fourth stage Hydrazine Auxiliary Propulsion System, or HAPS). The Pegasus XL is suspended beneath a Lockheed L-1011 aircraft, named Stargazer, which climbs to an altitude of about 11,900 meters (39,000 feet) over the open ocean. At that altitude, the Pegasus rocket is released and freefalls for five seconds, at which point its engines ignite, sending it on an orbital trajectory. About ten minutes later, the payload is delivered to low Earth orbit.

Since its inception in 1994, Pegasus has launched between two and six times every year with the exception of 2001, when it did not launch at all. Its first scheduled launch in 2004 is of NASA's DART payload, planned for launch during the fourth quarter.

The Stargazer plane that carries the Pegasus normally takes off from sites in California, Virginia, Florida, the Canary Islands, and Kwajalein Atoll. One benefit of the rocket's midair launch design is that it may help customers avoid the paperwork and fees required for a ground launch.

Taurus

The Taurus vehicle, introduced in 1994, is a four-stage solid-propelled vehicle that is essentially a larger, ground-launched version of the Pegasus. It can be launched from Vandenberg Air Force Base (VAFB), Cape Canaveral Air Force Station (CCAFS), Wallops Flight Facility (WFF) in Virginia, and Kodiak Launch Complex, Alaska. So far, however, the Taurus has only launched from VAFB.

OSC advertises several different configurations for the Taurus, with different LEO lift capacities depending on how the vehicle's two fairing sizes (160 centimeters, or 63 inches, and 234 centimeters, or 92 inches) are combined with two different lower and upper stage options each. Of the seven Taurus launches that have taken place since 1994, only two have employed the larger 234-centimeter fairing. However, this bigger fairing is likely to become more used in the future, as the larger Taurus XL configuration becomes the norm.

Taurus launches are infrequent. The first took place in 1994, but the second did not occur until 1998. Thereafter, the Taurus vehicle launched at a rate of about 1 per year, until a 2001 launch failure. The first Taurus launch since that failure took place on May 20, 2004, successfully inserting Taiwan's Rocsat 2 into low Earth orbit.

Minotaur

The Minotaur, developed through the U.S. Air Force's (USAF) Orbital/Suborbital Program (OSP), is a four-stage solid propellant launcher that combines a recycled Cold War-era Minuteman missile with newer components supplied by the Orbital Sciences Corporation. Its two lower stages utilize M55A1 and S19 engines from decommissioned Minuteman missiles. Its two upper stages feature Orion 38 and Orion XL motors similar to those used in the Pegasus XL.

Active U.S. Small Launch Vehicles

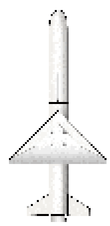
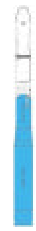
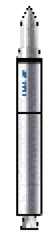
				
Vehicle	Pegasus XL	Taurus	Minotaur	Falcon I
Manufacturer/ Provider	Orbital Sciences Corp.	Orbital Sciences Corp.	Orbital Sciences Corp.	SpaceX
LEO Capacity	Up to 443 kg (997 lbs)	Up to 1,590 kg (3,505 lbs)	Up to 607 kg (1,339 lbs)	Up to 670 kg (1,475 lbs)
Launch Sites	Launched Midair. Plane deploys from VAFB, CCAFS, WFF, the Canary Islands, and Kwajalein Atoll	VAFB, CCAFS, WFF, Kodiak Launch Complex	VAFB, CCAFS, WFF, Kodiak Launch Complex	VAFB, Marshall Islands; other sites TBD

Table 1. Active U.S. Small Launchers and their manufacturers, LEO capacities, and launch sites. Falcon I has been included because it is expected to enter service in 2005.

The Minotaur is authorized to launch from VAFB, Wallops Island, CCAFS, and Kodiak Island. Although it has only launched twice so far, in 2000, the Minotaur's first two launches successfully deployed twelve microsatellites. The vehicle is slated to launch several other military payloads in the next two years. It should be noted that the Minotaur is restricted by the terms of the Orbital/Suborbital Program to launching only government-sponsored payloads.

Minotaur IV

Orbital Sciences Corporation also has a new vehicle under development: the Minotaur IV, which was recently awarded a 10-year funding contract by the USAF's Space and Missile Systems Center. Like the Minotaur I, the Minotaur IV is being facilitated under the USAF's Orbital/Suborbital Program, and its cargo will therefore be limited to government-sponsored payloads. It will use decommissioned Peacekeeper missiles as lower stage engines, while its upper stages will feature Orion 38 motors—similar to the way the first Minotaur vehicle incorporates Minuteman missiles into its stage configuration. The Minotaur IV's powerful engines and 234-centimeter fairing will give it a LEO capacity of up to 1,733 kg (3,820 lbs)—nearly three times that of the first Minotaur. The vehicle is expected to launch from VAFB, Wallops Island, CCAFS, and Kodiak Island.

SpaceX

SpaceX, founded in 2002 by entrepreneur Elon Musk, presents what is probably the most anticipated small launcher story in recent years: the unveiling of the new Falcon I vehicle, whose first launch is expected in early 2005. (The Falcon I launcher should not be confused with the FALCON government initiative, which will be outlined at the end of this section.) According to Musk, who made a fortune from two Internet startups, Falcon I development costs have been higher than expected. But the result is a new launch vehicle designed "from the ground up" to provide inexpensive, reliable, regular access space with minimal launch pad turnaround times.

Falcon I

One of the most noteworthy aspects of Falcon I is its advertised price: about $6 million, plus range fees. Musk hopes this low cost will make the two-stage, liquid oxygen/kerosene-powered Falcon I the world's premier small launcher. To achieve this relatively inexpensive launch price, SpaceX has designed the Falcon I to be as light as possible, fuel-efficient, and partially reusable. The launcher is constructed from lightweight aluminum alloys that yield high strength-to-weight ratios, decreasing vehicle mass and, in turn, the amount of thrust and fuel needed to reach orbit. Additionally, the vehicle's first stage is parachuted back to Earth, where it can be reused—a feature that translates into a lower cost for the launch system overall.

Falcon I's design concept also stresses vehicle dependability. SpaceX commissioned a study that found that historically, 91 percent of launch failures across vehicle types have been linked to problems with engines, stage separation, and, to a lesser extent, avionics. To guard against malfunctions in these areas, Falcon I is designed to avoid complications by featuring the minimum level of hardware complexity that is pragmatically possible: one engine per stage, and one stage separation event only. SpaceX has also fitted the Falcon I with a "hold-before-release" engine that restrains liftoff until thrust levels are registered as normal, state-of-the art stage separation bolts that have a 100-percent success rate, and a fully-redundant avionics package.

Falcon I currently has launches scheduled from VAFB and the Marshall Islands. At last report, SpaceX had contracted three customers for the Falcon I vehicle: the U.S. Department of Defense (DoD), the Defense Advanced Research Projects Agency (DARPA), and an undisclosed international government. The DARPA launch may be of particular interest to the government and military responsive space community: it will be a demonstration flight aimed at showcasing the Falcon I's ability to cut launch pad processing time and "rapidly add satellite coverage when needed"—widely seen as one of the major advantages of small launch vehicles over larger ones.[1]

Falcon I is currently undergoing engine tests, and the vehicle is still in the regulatory process to gain final clearance for launch from VAFB. If the initial flight is successful, Musk has said that "more than a half dozen" customers have expressed interest in purchasing launch services from SpaceX.[2] According the Musk, the Falcon I could average five or six launches annually by 2007.

Lockheed Martin

During the 1990s, Lockheed Martin's launch services arm marketed two versions of its Athena small launch vehicle. Although Athena launches gradually petered out, and no new launch contracts have been signed since the late 1990s, both Athena 1 and Athena 2 are technically still in service.

Athena 1

Athena 1 was introduced in 1995, and through 2001, it launched four times at a rate of about one launch every other year. It is a two-stage, solid-propelled booster with a LEO capacity of up to 796 kg (1,755 lbs). Its last launch successfully deployed four smallsats on September 29, 2001.

Athena 2

Introduced in 1998, Athena 2 offers a larger LEO capacity than the Athena 1: up to 1,991 kg (4,390 lbs). It is essentially an Athena 1 with an additional Castor 120 solid propellant rocket engine. The vehicle launched once in 1998 and twice in 1999. The first of its two 1999 launches failed; the second, five months later, was a success. This was the last launch of the Athena 2 to date.

Government-Supported Concepts Under Development

Through the Defense Advanced Research Projects Agency (DARPA) and the Air Force Research Lab (AFRL), among other agencies, the government is sponsoring some alternative small launch concepts. Of numerous concepts on the drawing board, five have recently received government funding for further research. Four are funded by DARPA under its Force Application and Launch from

Continental U.S. (FALCON) program. The fifth is funded by AFRL.

DARPA's FALCON initiative seeks to develop a U.S. global strike capability via a hypersonic cruise aircraft. Since small launch vehicles are needed to test hypersonic technology while at the same time enabling responsive space access, the FALCON program calls for a launcher that can put a 454 kg (1,000 lbs) payload into LEO for $5 million or less. Phase I of the program, already completed, asked for concept submissions and cost estimates from 11 companies. Phase II, just getting underway, lasts for 36 months and funds "preliminary design and development efforts." Phase III, lasting 30 months, sets the stage for demonstration flights.[3]

On September 20, 2004, four companies—AirLaunch LLC, Lockheed Martin, Microcosm, and SpaceX—received DARPA contracts, valued at between $8 and $11.7 million, under the FALCON program.

AirLaunch LLC's proposed QuickReach small launcher would be a two-stage liquid fueled booster deployed from the cargo bay of a USAF C-17 or a privately chartered Antonov 124 aircraft in mid-flight. Subcontractors involved with vehicle planning include Space Vector, Inc., Universal Space Lines LLC, HMX Inc., and Delta Velocity.[4]

Lockheed Martin's Michoud division is planning a small launcher based on an all-hybrid propulsion concept. Booster stages would be propelled by a combination of solid, non-explosive fuel and liquid oxidizer.[5]

Microcosm's proposed Scorpius Sprite Mini-Lift vehicle would be a three-stage launcher that would place up to 318 kg (700 lbs) into 185 km (100 nautical mile) low Earth orbit. It would also require only an eight-hour turnaround between arrival at launch pad and launch.[6]

SpaceX's DARPA award, as mentioned earlier, will support a demonstration flight of its Falcon I launch vehicle.

AFRL also seeks low-cost small launchers, and has a particular interest in hybrid propulsion. As such, it has awarded a $1.5 million contract, under Phase II of its Small Business Innovation Research Program, to SpaceDev. The contract supports SpaceDev's hybrid propulsion (solid fuel and liquid oxidizer) small launch concept.[7]

Non-U.S. SmallSat and Small Launch Manufacturers and Providers

Outside the United States, several countries are engaging in their own efforts to develop small satellites and small launch capabilities. Although these may not be directly relevant to the U.S. small launch industry, they are useful in placing American initiatives within a global context.

At least 15 countries currently have some capacity to build small satellites. These include Australia, China, Canada, Germany, Italy, Israel, Japan, Malaysia, Russia, Saudi Arabia, Singapore, South Korea, Sweden, Turkey, and the UK. Most of these smallsats are used for scientific experiments, remote sensing, and earth observing (including disaster monitoring). A notable exception is Israel, whose Ofeq smallsats are used for military reconnaissance. The Ofeq bus has also been used in EROS A1, a commercial remote sensing satellite operated by Imagesat International.

Russia, Israel, China, Brazil, and the European Space Agency (ESA) have either developed small launch vehicles or are in the process of doing so. North and South Korea have also mounted small launch vehicle efforts, but it is unclear whether those efforts are still underway.

Of these countries, Russia's small launch capability is the most robust. It has five small launch vehicles—Cosmos, Rockot, Shtil, START 1, and Volna—currently operational, with another, the Strela, under development.

Israel's Shavit booster suffered a launch failure in 1998 and one other in early September 2004. Otherwise, the small launch vehicle, operational since 1988, has performed successfully, albeit infrequently, with only six launches overall.

China's small Kaituozhe booster, still under development, underwent two failed orbital launch tests in 2002 and 2003. A third test flight is scheduled for the fourth quarter of 2004.

Similarly, Brazil's indigenous small launch effort, the "Veiculo Lançador de Satellites" (commonly known as VLS), has never launched successfully, although attempts were made in 1997 and 1999. A third launch attempt was slated for August 2003, but three days before the scheduled launch the VLS vehicle exploded on Brazil's Alcantara launch pad, killing 21 people and destroying both payloads. Poor communication and lax oversight, rather than vehicle defects, were cited as the cause of the accident, and the latest reports indicate that Brazil plans to press on with its VLS program, hoping for another test launch in 2006.

Finally, ESA is developing a small launch vehicle, the Vega, with a target capacity of roughly 1,500 kg (3,300 lbs) to LEO. The vehicle is slated for introduction in 2006, and is expected to launch at a rate of three to four launches per year.

As mentioned, North and South Korea have also sought their own small launch capabilities. In 1998, North Korea made a failed attempt to deploy a small test satellite in LEO using a converted Taepo Dong missile. This is believed to have been North Korea's only launch attempt thus far. Meanwhile, in 2001, South Korea announced plans to develop a small launcher capable of lofting 1,000 kg (2,200 lbs) into LEO by 2010.[8] However, it is unclear whether any progress has been made toward this goal.

Outlook

Although this Special Report cannot speculate on the future demand for U.S. small launchers, it seems clear that several major aerospace companies have made a carefully-considered choice to either specialize in small satellite manufacturing or include smallsats in their core competencies. They made this choice in response to technological trends toward miniaturized hardware that can do more for less, the advantages small satellites have over large ones when it comes to launch and insurance costs, and the growing emphasis government decision-makers have placed on a robust strategic and tactical small spacelift capability. These factors together do not automatically signal increased demand for small launch vehicles. Although many appealing launch price figures have been bandied about in the industry-wide conversation on small launchers, the low-cost breakthrough that could reshape the launch industry in a larger sense has yet to be made. Additionally, for all the talk about smallsats, there is still a healthy supply of payloads with a mass of over 907 kg, many of which weigh well over this threshold and therefore require the services of heavy launchers. Nonetheless, it seems safe to say that there are real reasons —in the form of technological, governmental, and market forces—behind the increased attention small launch vehicles have received of late. It is AST's hope that this Special Report has assisted in providing an understanding of some of those forces, as well as an overview of the U.S. small launch industry as a whole.

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Third Quarter 2004 Orbital and Suborbital Launch Events

Date		Vehicle	Site		Payload or Mission	Operator	Use	Vehicle Price	L	M
7/15/04		Delta 2 7920	VAFB		Aura	National Aeronautics and Space Administration (NASA)	Remote Sensing	$45-55M	S	S
7/17/04	√	Ariane 5G	Kourou	*	Anik F2	Telesat Canada	Communications	$125-155M	S	S
7/22/04		Kosmos 3M	Plesetsk		Kosmos 2407	Russian Ministry of Defense (MoD)	Navigation	$12M	S	S
7/25/04		Long March 2C	Taiyuan		Double Star Polar	Chinese National Space Administration	Scientific	$20-25	S	S
8/3/04		Delta 2 7925H	CCAFS		Messenger	NASA	Scientific	$45-55M	S	S
8/5/04	√	Proton M	Baikonur	*	Amazonas 1	Hispasat	Communications	$70M	S	S
8/11/04		Soyuz	Baikonur		Progress ISS 15P	Russian Federal Space Agency (Roscosmos)	ISS	$30-50M	S	S
8/29/04		Long March 2C	Jiuquan		FSW 19	China National Space Administration	Scientific	$20-25M	S	S
8/31/04		Atlas 2AS	CCAFS		NRO L-1	U.S. Air Force (USAF)	Classified	$65-75M	S	S
9/6/04		Shavit 1	Palmachim AFB		Ofeq 6	Israeli Ministry of Defense (MoD)	Classified	$10-15M	F	F
9/9/04		Long March 4B	Taiyuan		SJ 6A	China National Space Administration	Scientific	$25-35M	S	S
					SJ 6B	China National Space Administration	Scientific		S	S
9/20/04		GSLV	Satish Dhawan Space Center		Edusat	Indian Space Research Organization (ISRO)	Communications	$35-45M	S	S
9/23/04		Kosmos 3M	Plesetsk		Kosmos 2409	Russian MoD	Classified	$12M	S	S
					Kosmos 2408	Russian MoD	Classified	$12M	S	S
9/24/04		Soyuz	Plesetsk		Kosmos 2410	Russian MoD	Classified	$30-50M	S	S
9/27/04		Long March 2D	Jiuquan		FSW 20	China National Space Administration	Scientific	$20-25M	S	S
9/29/04	√ +	SpaceShipOne	Mojave Airport	*	SpaceShipOne Flight 16P (suborbital)	Scaled Composites	Development	N/A	S	S

√ Denotes commercial launch, defined as a launch that is internationally competed or FAA-licensed.
\+ Denotes FAA-licensed launch.
* Denotes a commercial payload, defined as a spacecraft that serves a commercial function or is operated by a commercial entity.

Notes: All prices are estimates, and vary for every commercial launch. Government mission prices may be higher than commercial prices.

Ariane 5 payloads are usually multi-manifested, but the pairing of satellites scheduled for each launch is sometimes undisclosed for proprietary reasons until shortly before the launch date.

Fourth Quarter 2004 Projected Orbital and Suborbital Launch Events

Date		Vehicle	Site		Payload or Mission	Operator	Use	Vehicle Price
10/4/04	√ +	SpaceShipOne	Mojave Airport	*	SpaceShipOne Flight 17P (suborbital)	Scaled Composites	Development	N/A
10/14/04		Soyuz	Baikonur		Soyuz ISS 9S	Roscosmos	ISS	$30-50M
10/15/04	√	Proton M	Baikonur	*	AMC 15	SES Americom	Communications	$70M
10/19/04		Long March 3A	Taiyuan		Fengyun 2C	China Meteorological Administration	Meteorological	$45-55M
10/25/04		Delta 2 7925-10	CCAFS		Navstar GPS 2R-13	USAF	Navigation	$45-55M
10/26/04		Pegasus XL	VAFB		DART	NASA	Development	$14-18M
10/28/04		Proton K	Baikonur	*	Express AM1	Russian Satellite Communciation Co.	Communications	$60-85M
10/29/04		Soyuz 2	Plesetsk		Oblik	Roscosmos	Development	$30-50M
10/2004		Wild Fire	Kindersley	*	Wild Fire Test Flight (suborbital)	Da Vinci Project	Development	N/A
11/8/04	√	Ariane 5 ECA	Kourou	*	XTAR EUR	XTAR	Communications	$125-155M
				*	MaqSat B2	Arianespace	Test	
					SloshSat-FLEVO	European Space Agency (ESA)	Development	
11/8/04		Delta 2 7320	CCAFS		Swift	NASA/Goddard Space Flight Center (GSFC)	Scientific	$45-55M
11/18/04		Delta 4 Heavy	CCAFS		HLVOLSDP	USAF	Test	$140-170M
					3CSat 1	New Mexico State University (NMSU)	Development	
					3CSat 2	NMSU	Development	
					NMSUSat 1	NMSU	Development	
11/2004		Cyclone 3	Plesetsk		Sich 1M	Ukraine Space Agency (NKAU)	Remote Sensing	$20-25M
					MS-1TK	NKAU	Development	
12/9/2004	√	Proton M	Baikonur	*	WORLDSAT-2	SES Americom	Communications	$70M
12/16/04	√ +	Atlas 5 521	CCAFS	*	AMC 16	SES Americom	Communications	$70M
12/23/04		Soyuz	Baikonur		Progress ISS 16P	Roscosmos	ISS	$30-50M
12/30/04		Delta 2 7925H	CCAFS		Deep Impact	JPL	Scientific	$45-55M
12/2004	√ +	Zenit 3SL	Odyssey Launch Platform	*	Intelsat Americas 8	Intelsat	Communications	$70M
12/2004		Proton K	Baikonur	*	Express AM2	Russian Satellite Communciation Co.	Communications	$60-85M
12/2004		Ariane 5G	Kourou		Helios (Intelligence) 2A	Delegation Generale pour l'Armement (DGA)	Classified	$125-155M
					Parasol	Centre National d'Etudes Spatiales (CNES)	Scientific	
					Essaim 1	French Ministry of Defense (MoD)	Classified	
					Essaim 2	French MoD	Classified	
					Essaim 3	French MoD	Classified	
					Essaim 4	French MoD	Classified	
12/2004		Long March 3B	Xichang		Apstar 6	China Academy of Space Technology (CAST)	Communications	$50 - 70M
12/2004	√	Soyuz	Kourou	*	Galaxy 14	Pan American Satellite Corp.	Communications	$30-50M
4Q/2004		Dnepr 1	Baikonur		Egyptsat	National Authority for Remote Sensing and Space Sciences	Remote Sensing	$8-11M
4Q/2004		Kaituozhe 1	Taiyuan		KT 1 TBA	China National Space Administration	Development	$10M
4Q/2004		Proton K	Baikonur		Glonass M R10	Russian MoD	Navigation	$60-85M
					Glonass M R11	Russian MoD	Navigation	
					Glonass M R12	Russian MoD	Navigation	

√ Denotes commercial launch, defined as a launch that is internationally competed or FAA-licensed.
+ Denotes FAA-licensed launch.
* Denotes a commercial payload, defined as a spacecraft that serves a commercial function or is operated by a commercial entity.

Notes: All prices are estimates, and vary for every commercial launch. Government mission prices may be higher than commercial prices.

Ariane 5 payloads are usually multi-manifested, but the pairing of satellites scheduled for each launch is sometimes undisclosed for proprietary reasons until shortly before the launch date.

First Quarter 2005 Projected Orbital and Suborbital Launch Events

Date		Vehicle	Site		Payload or Mission	Operator	Use	Vehicle Price
1/27/05		Atlas 3B	CCAFS		NRO A5	USAF	Classified	$65-75M
1/2005	√	Ariane 5G	Kourou	*	Telkom 2	PT Telkomunikasi	Communications	$125-155M
1/2005	√ +	Zenit 3SL	Odyssey Launch Platform	*	Spaceway 1	Hughes Network Systems	Communications	$70M
1/2005		Delta 4 Medium	CCAFS		GOES N	National Oceanic and Atmospheric Administration (NOAA)	Meteorological	$75M
2/1/05		Delta 2 7320	VAFB		NOAA N	NOAA	Meteorological	$45-55M
2/1/05		Delta 2 7925-10	CCAFS		Navstar GPS 2RM-14 ProSEDS 2	USAF NASA	Navigation Development	$45-55M
2/20/05		Titan 4B	VAFB		NRO T1	National Reconnaissance Office (NRO)	Classified	$350-450M
2/27/05	√ +	Atlas 5 431	CCAFS	*	Inmarsat-4 F1	Inmarsat	Communications	$70M
2/28/05		Soyuz	Baikonur		Progress ISS 17P	Roscosmos	ISS	$30-50M
3/1/05		Delta 4 Medium-Plus TBA	VAFB		NRO L-22	NRO	Classified	$75M
3/25/05	√	Rockot	Plesetsk		Cryosat	ESA	Remote Sensing	$12-15M
3/2005		Proton K	Baikonur	*	Express AM3	Russian Satellite Communciation Co.	Communications	$60-85M
1Q/2005		Minotaur	VAFB		XSS-11	USAF	Development	$12-17M
1Q/2005	√ +	Zenit 3SL	Odyssey Launch Platform	*	XM 3	XM Satellite Radio, Inc.	Communications	$70M
1Q/2005		Falcon 1	VAFB	 *	TacSat 1 Celestis 5	USAF Celestis, Inc.	Development Other	$6M
1Q/2005	√	Volna	Barents Sea		Cosmos 1	Planetary Society	Development	$1.15M

√ Denotes commercial launch, defined as a launch that is internationally competed or FAA-licensed.

\+ Denotes FAA-licensed launch.

* Denotes a commercial payload, defined as a spacecraft that serves a commercial function or is operated by a commercial entity.

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