Commercial Space Transportation

QUARTERLY LAUNCH REPORT

Featuring the launch results from the 3rd quarter 2001 and forecasts for the 4th quarter 2001 and 1st quarter 2002

Quarterly Report Topic:

The Evolution of Commercial Launch Vehicles

4th Quarter 2001

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 2001 Quarterly Launch Report features launch results from the third quarter of 2001 (July-September 2001) and launch forecasts for the fourth quarter of 2001 (October-December 2001) and the first quarter of 2002 (January-March 2002). This report contains information on worldwide commercial, civil, and military orbital 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 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)

Contents

* Fourth quarter launch events include all launches projected for the fourth quarter as well as those projected to occur at some point in 2001 but not assigned to a specific month or quarter.

Cover: Cape Canaveral Air Force Station, Florida, July 23, 2001 - An Atlas 2A rocket successfully carries the GOES-M weather satellite into space for the National Oceanic and Atmospheric Administration. Courtesy of International Launch Services.

Third Quarter 2001 Highlights

Ariane 5 Launch Failure

On July 12, the launch of the European Space Agency's Artemis communications and navigation technology satellite and Japan's BSAT-2B commercial communications satellite failed when the Ariane 5 launch vehicle was unable to deliver them into the proper orbits. The failure was due to a malfunction in the upper stage of the booster. Arianespace officials say that a "combustion instability" during the upper stage engine's ignition reduced thrust and also led to the premature shutdown of the engine when it exhausted its propellants. BSAT-2B has been declared a loss while efforts are continuing to use Artemis' on-board thrusters to achieve a proper orbit.

Japanese Launch Vehicle Completes Successful Maiden Voyage

Japan's H-2A launch vehicle completed its initial flight in an August 29 launch from the Tanegashima launch site. The vehicle successfully carried the 3,000 kilogram Vehicle Evaluation Payload-2 (VEP-2), which contained sensors to measure launch vibrations and thermal conditions during flight.

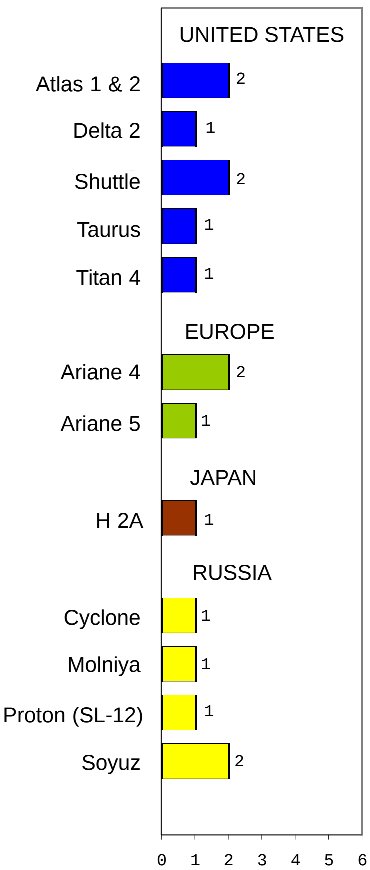
Satellites Lost Due To Taurus Failure

A Taurus launch vehicle built by Orbital Sciences Corporation failed in a September 21 launch from Vandenberg AFB in California. NASA's QuikTOMS and Orbimage's OrbView 4 satellites, as well as a Celestis funerary payload, were lost when the vehicle's second stage veered off course at T+83 seconds. Though the rocket was soon brought under control, the change in course caused payload separation at an altitude too low for recovery and the launch and missions were failures.

Vehicle Use

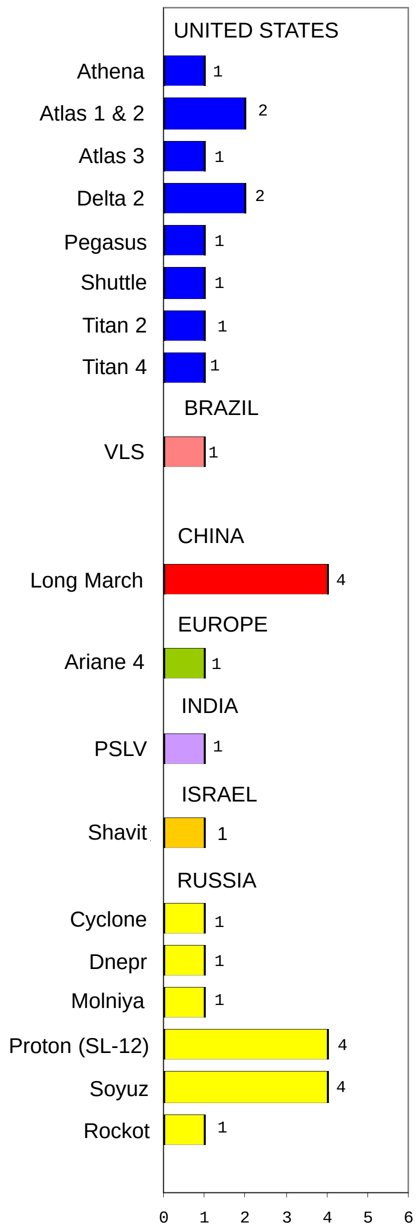
(July 2001 – March 2002)

Figure 1: Third Quarter 2001 Total Launch Vehicle Use



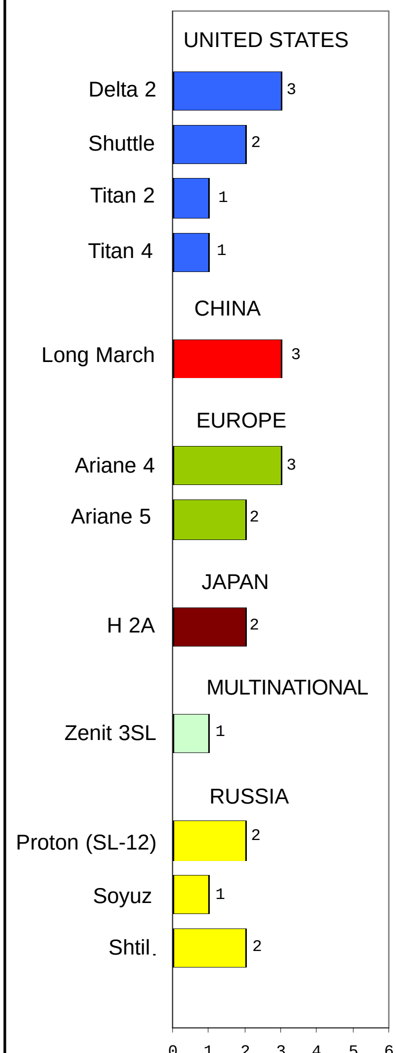
Total = 16

Figure 2: Fourth Quarter 2001 Total Projected Launch Vehicle Use



Total = 30

Figure 3: First Quarter 2002 Total Projected Launch Vehicle Use



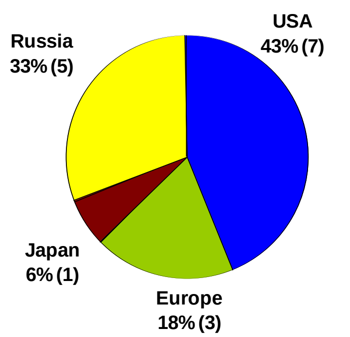
Total = 23

Figures 1-3 show the total number of orbital launches (commercial and government) of each launch vehicle that occurred in the third quarter of 2001 and that are projected for the fourth quarter of 2001 and first quarter of 2002. These 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.

Total Launch Events by Country

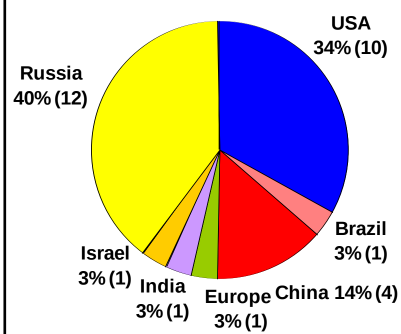
(July 2001 – March 2002)

Figure 4: Third Quarter 2001 Total Launch Events by Country



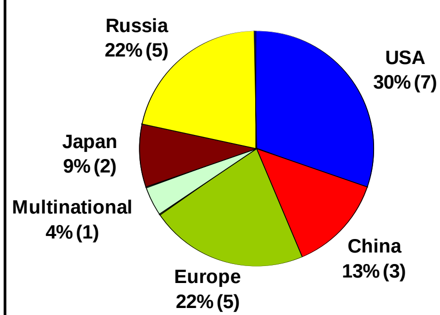
Total = 16

Figure 5: Fourth Quarter 2001 Total Projected Launch Events by Country



Total = 30

Figure 6: First Quarter 2002 Total Projected Launch Events by Country



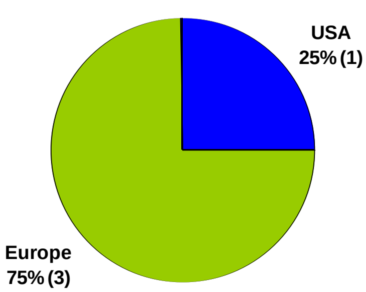
Total = 23

Figures 4-6 show all orbital launch events (commercial and government) that occurred in the third quarter of 2001 and that are projected for the fourth quarter of 2001 and first quarter of 2002.

Commercial Launch Events by Country

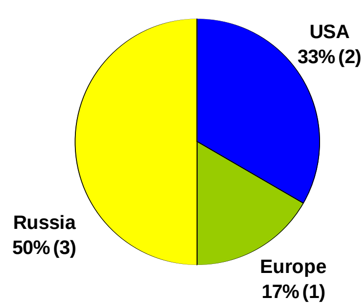
(July 2001 – March 2002)

Figure 7: Third Quarter 2001 Commercial Launch Events by Country



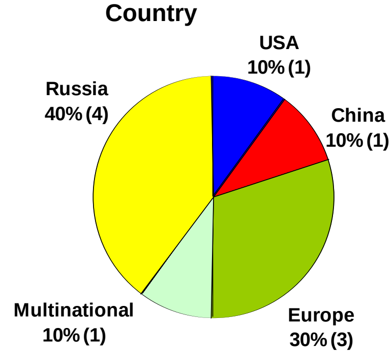
Total = 4

Figure 8: Fourth Quarter 2001 Projected Commercial Launch Events by Country



Total = 6

Figure 9: First Quarter 2002 Projected Commercial Launch Events by Country

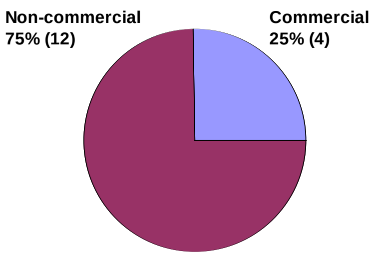


Total = 10

Figures 7-9 show all *commercial* orbital launch events that occurred in the third quarter of 2001 and that are projected for the fourth quarter of 2001 and first quarter of 2002.

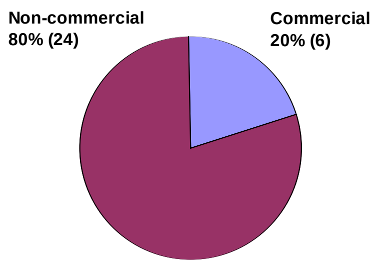
Commercial vs. Non-commercial Launch Events
(July 2001 – March 2002)

Figure 10: Third Quarter 2001 2001 Commercial vs. Non-commercial Launch Events



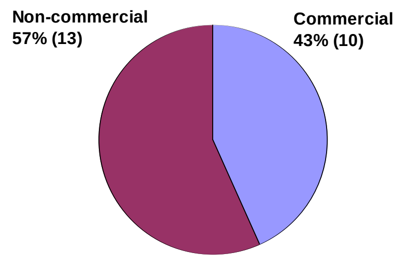
Total = 16

Figure 11: Fourth Quarter 2001 Commercial vs. Non-commercial Projected Launch Events



Total = 30

Figure 12: First Quarter 2002 Commercial vs. Non-commercial Projected Launch Events

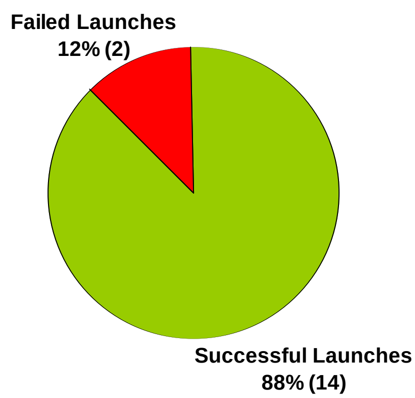


Total = 23

Figures 10-12 show commercial vs. non-commercial orbital launch events that occurred in the third quarter of 2001 and that are projected for the fourth quarter of 2001 and first quarter of 2002.

Third Quarter 2001 Launch Successes vs. Failures
(July 2001 – September 2001)

Figure 13: Total Launch Successes vs. Failures



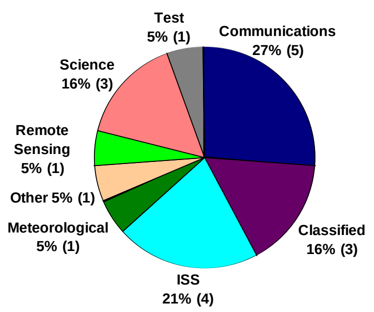
Total = 16

Figure 13 shows successful vs. failed orbital launch events that occurred in the third quarter of 2001.

Payload Use

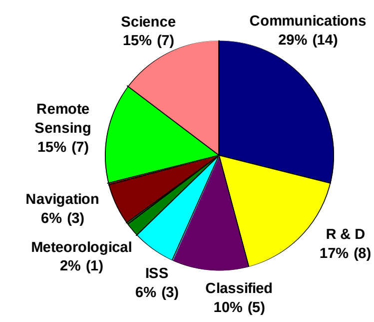
(July 2001 – March 2002)

Figure 14: Third Quarter 2001 Payload Use



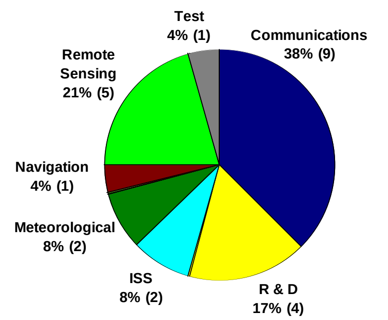
Total = 19

Figure 15: Fourth Quarter 2001 Projected Payload Use



Total = 48

Figure 16: First Quarter 2002 Projected Payload Use



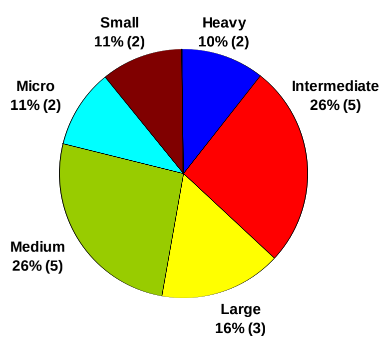
Total = 24

Figures 14-16 show total payload use (commercial and government), actual for the third quarter of 2001 and that are projected for the fourth quarter of 2001 and first quarter of 2002. 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

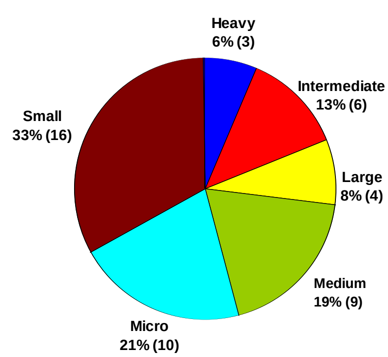
(July 2001 – March 2002)

Figure 17: Third Quarter 2001 Payload Mass Class



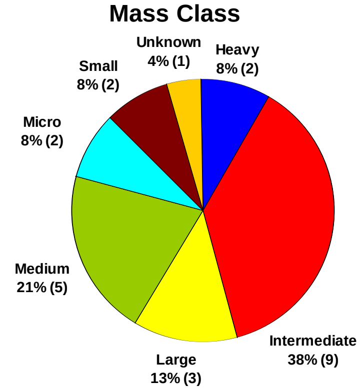
Total = 19

Figure 18: Fourth Quarter 2001 Projected Payload Mass Class



Total = 48

Figure 19: First Quarter 2002 Projected Payload Mass Class



Total = 24

Figures 17-19 show total payloads by mass class (commercial and government), actual for the third quarter of 2001 and projected for the fourth quarter of 2001 and first quarter of 2002. 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 9,073 kilograms (20,000 lbs.).

Commercial Launch Trends

(October 2000 – September 2001)

Figure 20: Commercial Launch Events, Last 12 Months

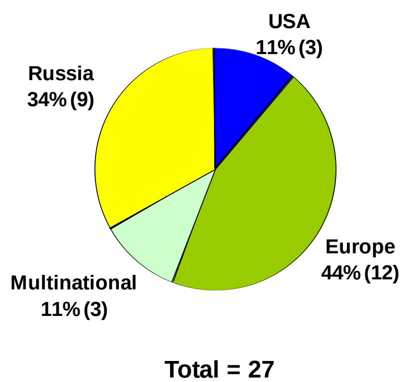
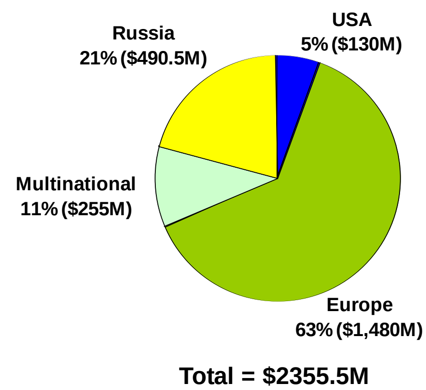


Figure 21: Commercial Launch Revenue, Last 12 Months



Figures 20 shows commercial launch events for the period October 2000 to September 2001 by country.

Figures 21 shows commercial launch revenue for the period October 2000 to September 2001 by country.

Figure 22: Commercial Launch Events by Country, Last Five Years

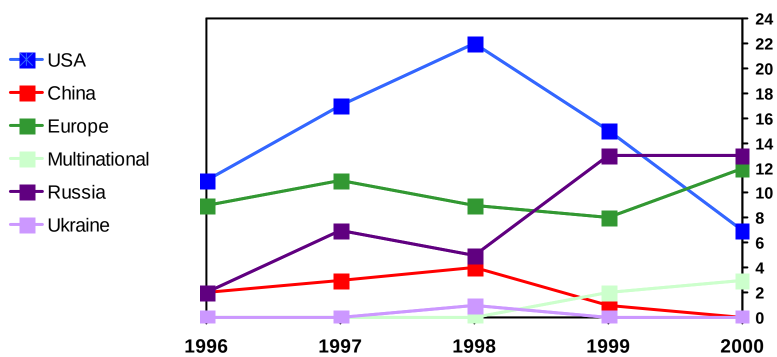


Figure 22 shows commercial launch events by country for the last five full years.

Figure 23: Commercial Launch Revenue (in $ million) by Country, Last Five Years

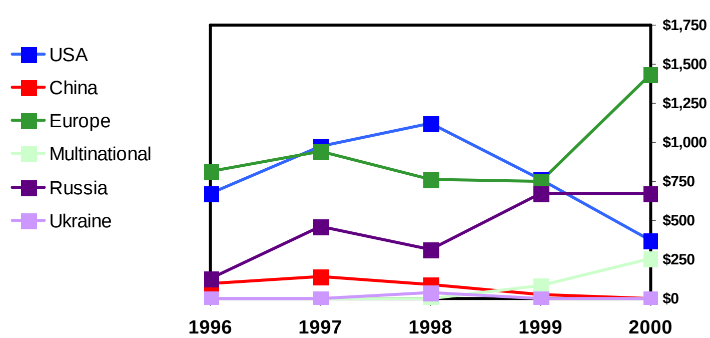


Figure 23 shows commercial launch revenue by country for the last five full years.

The Evolution of Commercial Launch Vehicles

INTRODUCTION

On February 14, 1963, a Delta launch vehicle placed the Syncom 1 communications satellite into geosynchronous orbit (GEO). Thirty-five years later, another Delta launched the Bonum 1 communications satellite to GEO. Both launches originated from Launch Complex 17, Pad B, at Cape Canaveral Air Force Station in Florida. Bonum 1 weighed 21 times as much as the earlier Syncom 1 and the Delta launch vehicle that carried it had a maximum geosynchronous transfer orbit (GTO) capacity 26.5 times greater than that of the earlier vehicle.

Launch vehicle performance continues to constantly improve, in large part to meet the demands of an increasing number of larger satellites. Current vehicles are very likely to be changed from last year's versions and are certainly not the same as ones from five years ago. In many cases this is true even though the commonly used name for a vehicle has not changed.

This report will detail vehicle performance improvements over the last four decades. Evolutionary paths will be traced for the Atlas and Delta launch vehicles. Patterns of growth and reliability of these vehicles are also examined.

Atlas and Delta vehicles, in particular, have been chosen because they were part of the original generation of U.S. launch vehicles and exhibit increased capacity with only moderate technical change from one generation to the next. Later vehicles, designed from the beginning as launch vehicles, (for instance the European Ariane series, or the Russian Proton) have not undergone the same degree of evolution and, hence, are less interesting for this study.

LAUNCH VEHICLE ORIGINS

The initial development of launch vehicles was an arduous and expensive process that occurred simultaneously with military weapons programs; launch vehicle and missile developers shared a large portion of the expenses and technology. The initial generation of operational launch vehicles in both the United States and the Soviet Union was derived and developed from the operating country's military ballistic missile programs. The Russian Soyuz launch vehicle is a derivative of the first Soviet intercontinental ballistic missile (ICBM) and the NATO-designated SS-6 Sapwood. The United States' Atlas and Titan launch vehicles were developed from U.S. Air Force's first two ICBMs of the same names, while the initial Delta (referred to in its earliest versions as Thor Delta) was developed from the Thor intermediate range ballistic missile (IRBM) coupled with the upper stages of the unsuccessful Vanguard launch vehicle (the first launch vehicle developed as a launch vehicle from the start).

This evolution followed the pattern set by the development of the atmospheric sounding rocket, the use of which was pioneered when the U.S. Army launched German-built V-2s after World War II. In this program, scientists were offered the chance to place scientific instruments in V-2s that were to be launched for weapons development reasons. As the explosive warheads had been removed from the missiles, increased room and lifting capacity allowed for scientific and weapons research on the same flights.

LAUNCH VEHICLES VS. BALLISTIC MISSILES

The most basic difference between launch vehicles and ballistic missiles is that launch vehicles have the ability to modify their trajectories once they achieve orbital velocities. While a ballistic missile may have the ability to achieve an orbital velocity, it cannot change its path to circle the Earth instead of following a parabola that returns it (regardless of its speed) to the Earth because it does not have the additional propulsion capacity to change its path once it reaches orbital speed and altitude (see Figure 1 for a visual depiction of the difference).

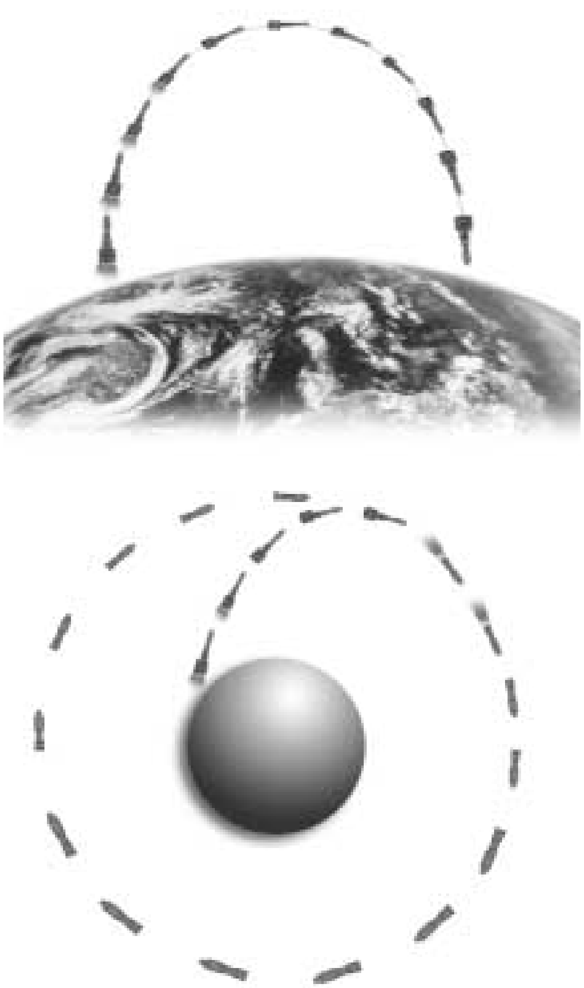


Figure 1. Ballistic Missile Parabola (top) vs. Launch Vehicle Orbital Path (bottom)

Due to these considerations, the first step in modifying a ballistic missile to fill a launch vehicle role is to give it an upper-stage maneuvering capability. In the case of the Thor Delta, this was achieved by the addition of the Vanguard launch vehicle's upper stages to the Thor IRBM that served as the Thor Delta launch vehicle's first stage. In the case of the Atlas, new hardware was developed to allow the payload to achieve a stable orbit (although the Atlas Able also used Vanguard stages).

These early launch vehicles had the capacity to lift a payload to low Earth orbit (LEO). As time progressed, however, the desire to place satellites into higher orbits such as GEO became more prevalent. Additional systems to increase capacity from that of a ballistic missile or a LEO-capable launcher became necessary. Launch vehicles were soon given an extra upper stage to place payloads into GEO orbits.

ATLAS VEHICLE EVOLUTION

As described in the previous section, the first step in the evolution of launch vehicles was the addition of stages that allowed missiles to perform a launch vehicle role. Following this basic modification, a continuing series of major and minor modifications occurred that increasingly optimized the vehicle for its role as a launch vehicle. First government and then industry (after the Challenger accident) incrementally increased the launch capacity of the Atlas launch vehicle (Figure 2 and Table 1show the evolution of Atlas GEO capable vehicles).

For the Atlas launch vehicle, the first major change following its introduction in 1958 (an Atlas B carrying the world's first communications satellite for Project SCORE) was the ability to release its payload. The initial SCORE payload remained attached to the launch vehicle while the Mercury capsule that was the Atlas' next payload was able to detach from the launch vehicle upon reaching orbit. The use of the Atlas as a crew-rated vehicle also involved structural enhancements to the Atlas D ICBM-based launch vehicle. The first Atlas capable of launches to GEO was the 1959 Atlas Able, which married the Atlas ICBM with an upper stage based on Vanguard's second stage. This combination was not a success, however, failing in four out of four launch attempts.

The Atlas D ICBM was the basis of almost all early Atlas launch vehicles. In its space launch version, the Atlas D was referred to as the Atlas LV-3 (standing for launch vehicle 3). The LV-3A was an Atlas D with an Agena upper stage, the LV-3B carried the Mercury spacecraft, and the LV-3C used the Centaur upper stage. Unfortunately, as each launch vehicle was individually converted from an ICBM, the LV-3 was not an optimal vehicle. Large-scale missile production was cheap but converting ICBMs to launch vehicles was a lengthy and cumbersome process. As a result, in 1962 the Air Force awarded General Dynamics a contract to resolve this problem and develop a standardized Atlas D-based launch vehicle. The SLV-3 (standardized launch vehicle, as this vehicle was designated) was a more reliable, standardized version of the Atlas D ICBM with three Rocketdyne MA-3 engines (with a total of 1725 kN thrust), replacing the original three Rocketdyne MA-2 engines (with a total of 1630 kN thrust).

In 1965 General Dynamics received a further Air Force contract to improve the Atlas SLV-3 by lengthening the vehicle to increase its fuel load, reducing overall vehicle weight, and replacing the engines with Rocketdyne MA-5 engines (1950 kN total thrust). This program resulted in the SLV-3A and SLV-3C. These versions differed in the method of engine cut-off and choice of upper stage. The Atlas SLV-3A used a radio-controlled engine cut-off and an Agena upper stage. The Atlas SLV-3C used a Centaur upper stage with engine cut-off caused by fuel depletion.

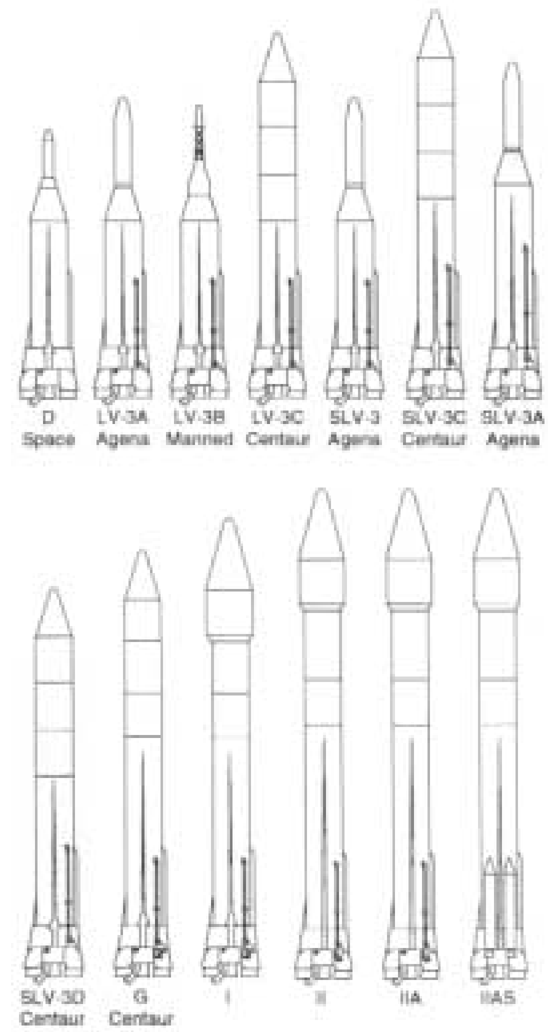


Figure 2. Atlas Launch Vehicle Evolution

The Agena upper stage's development ended with the SLV-3A, but the success of the SLV-3C with its Centaur upper stage led to an evolution into the SLV-3D. This vehicle used the Centaur's autopilot and guidance systems to control the entire vehicle unlike previous vehicles, which used Atlas-based control systems for the initial part of the launch and then transferred control to the Centaur upper stage to complete the mission.

The final government-initiated version of the Atlas was the Atlas G, which was first launched in 1984. As with the previous SLV-

3D, the Atlas was once again lengthened to increase fuel capacity and received improved versions of the MA-5 engines.

The Atlas G led directly to the commercial Atlas vehicle program initiated by General Dynamics in 1987 after the destruction of the Space Shuttle Challenger, previous to which government-funded production had been canceled. For the first time, Atlas vehicles were built with no assured government customer. These first commercial Atlas launch vehicles (dubbed Atlas 1) were very similar to the Atlas G but offered two new payload fairings and were entirely funded by General Dynamics. The first Atlas 1 was launched in 1990.

The Atlas 1 was followed in 1991 by the Atlas 2, which was originally developed to launch Air Force Defense Satellite Communications System satellites under the Medium Launch Vehicle (MLV) 2 contract. The Atlas 2 uses upgraded Rocketdyne MA-5A engines (2155 kN thrust), a lengthened booster for greater fuel capacity, improved structures, a new stabilization system, and a lengthened Centaur upper stage to provide more fuel and hence better upper-stage performance.

The final versions of the Atlas 2 series, the Atlas 2A (1992) and the Atlas 2AS (1993), differ from the Atlas 2 by having more powerful Pratt & Whitney RL-10 engines in the Centaur upper stage. In the case of the 2AS, four Thiokol Castor 4A solid rocket motors add an additional 173.6 kN of thrust to the first stage of the vehicle. Following these modifications, Lockheed Martin (the current owner of the Atlas line) replaced the three Rocketdyne engines with a single, more powerful, NPO Energomash / Pratt & Whitney RD-180 engine.

With the Atlas 3, the slow incremental process that characterized the development of previous Atlas vehicles was replaced by a more revolutionary approach. The Atlas 3 represents an initial effort to reduce vehicle complexity while increasing performance. This model uses improved first-stage fuel tank construction, contains less-complicated components and increases overall launch vehicle performance. As an example, the Atlas 3's first stage thrust section undergoes only one staging event and the engine is supplied by only seven fluid interfaces. By contrast, previous Atlas models had up to six staging events and 17 fluid interfaces.

New and improved versions of the Centaur Upper Stage were also introduced on the Atlas 3 series. The Centaur Upper Stage used by the Atlas 3A uses a single engine. The removal of one RL10A-4-1 engine and the centering of the remaining engine along the Centaur's axis differentiate it from earlier Centaur versions. The upper stage for the Atlas 3B is a lengthened version of the Centaur outfitted with two RL10A-4-2 engines. These engines include upgrades (such as chiller modifications and a health monitoring system) designed to increase reliability and operational standards. Both the single-engine Centaur and the lengthened Centaur with dual RL10A-4-2 engines will be used on the Atlas 3 series as well as on the Atlas 5 series.

Built under the U.S. Air Force’s Evolved Expendable Launch Vehicle (EELV) program with funding from both the Air Force and Lockheed Martin, the Atlas 5 will continue the trend of radical change toward bigger, more capable launch vehicles initiated with the Atlas 3. The Atlas 3 will provide valuable experience needed for Atlas 5 production and operation and, once the Atlas 5 is operational, the Atlas 3 will be phased out. More than twice the weight of Atlas 3, Atlas 5 will be able to carry twice the payload mass. The Atlas 5 will have approximately 125 potential single point failures, as opposed to over 250 for the Atlas 2AS, will be able to launch in higher wind conditions,

Vehicle	Intro Year	Vehicle Weight (kg)	GTO Performance (kg)
Atlas B	1958	110740	N/A
Atlas Able	1959	120051	250
Atlas D	1959	117730	N/A
Atlas LV-3B Mercury	1959	116100	N/A
Atlas LV-3A/Agena	1960	123990	800
Atlas LV-3C/Centaur	1962	136124	1800
Atlas SLV-3/Agena	1964	N/A	N/A
Atlas SLV-3C/Centaur	1967	148404	1800
Atlas SLV-3A/Agena	1968	N/A	700
Atlas SLV-3D/Centaur	1972	148404	1900
Atlas G/Centaur	1984	166140	2255
Atlas 1	1990	164300	2255
Atlas 2	1991	187600	2810
Atlas 2A	1992	185427	3039
Atlas 2AS	1993	233750	3630
Atlas 3A	2000	220672	4055
Atlas 3B	2001	225392	4500
Atlas 5 (551)	2002	540340	8200

Table 1: Evolution of Atlas Mass and GTO Payload Capacity

and will dispense with the pressure-stabilized fuel tanks used on all previous Atlas vehicles. Unlike its predecessors, the Atlas 5 will be able to stand under the weight of its payload without being fully fueled because it will have structurally-stable booster propellant tanks. By contrast, previous Atlas vehicles used the pressure of the fuel in their tanks to bear part of the load of the payload.

DELTA VEHICLE EVOLUTION

The Delta launch vehicle was initially adapted from an IRBM by Douglas Aircraft Company for the U.S. Air Force. In April 1959, NASA's Goddard Space Flight Center contracted with Douglas to create a civilian launch vehicle based on the Air Force's Thor-Able vehicle. Douglas (later as McDonnell Douglas) continued to produce Delta vehicles for the U.S. Government until production was ended in 1984 due to the U.S. policy decision to launch all payloads on the Space Shuttle. Following the Challenger accident, production was restarted as a commercial venture with the vehicle called the Delta 2. McDonnell Douglas captured the U.S. Air Force's MLV-1 contract with this vehicle in 1987 and then offered the Delta 2 on the commercial market.

Between Delta's first flight in 1960 and today's Delta 2 vehicles the Delta launch vehicle has gone through a set of evolutions similar to that of the Atlas vehicle. Extensive changes have been made that have resulted in substantially greater capacity (see Figure 3 and Table 2). During this period, the Delta's first stage has received five different engines and has been lengthened twice to increase propellant mass. The second stage has had five different engines and has also been lengthened twice to increase propellant mass. The third stage has seen seven engine changes and overall, the Delta vehicle has received two avionics upgrades, four increasingly large fairings, and two sets of strap-on solid rocket motors.

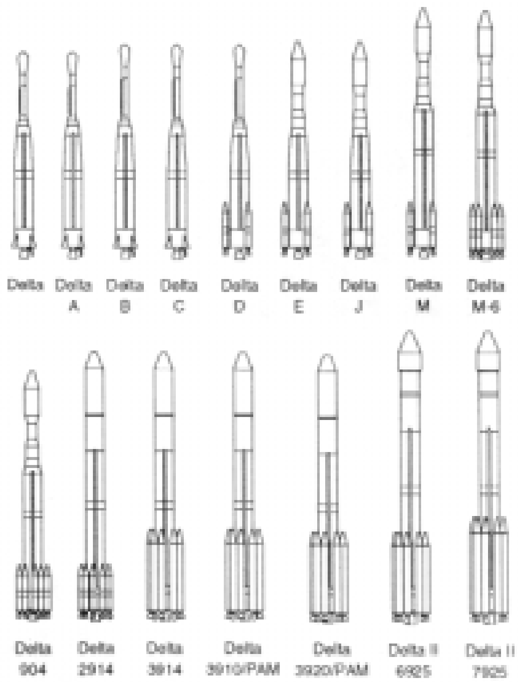


Figure 3. Delta Launch Vehicle Evolution

Following the slow evolution of the Thor to the Delta and then to the Delta 2, there has been a more radical improvement with the development of the Delta 3 and then the Delta 4 EELV. The Delta 3 has a larger diameter first-stage fuel tank than Delta 2 and uses nine solid fuel graphite-epoxy motors derived from those on Delta 2 but with 25 percent more thrust. The Delta 3's second stage carries more propellant than Delta 2 and burns cryogenic fuels, which produce more energy than those used by the Delta 2, allowing it to launch heavier payloads.

The Delta 4 involves even more improvements. It consists of a new "common booster core" first stage using the new Rocketdyne RS-68 engine. This engine has 95 percent fewer parts than the Space Shuttle Main Engine (which is a comparable engine in terms of thrust) and requires only 8,000 hours of touch labor, compared with 171,000 hours for the Shuttle engine. It is supplemented by solid fuel graphite-epoxy motors, two types of upper stages, and three payload fairings depending on customer needs. A heavy lift version will also be available and will involve a combination of three core boosters with an upper stage and larger fairing. Boeing offers five different versions of the Delta 4 addressing a broad range of payload mass classes. Like the Atlas 3 and Atlas 5, the Delta 4 will replace the Delta 3 once it is introduced into service over the next few years.

LAUNCH VEHICLE GROWTH TRENDS

As can be seen from the development of the Atlas and Delta launch vehicles, the tendency in launch vehicle development has been for vehicles to grow in capacity and, hence, in size. Although micro-satellites have been developed, the tendency has been to produce larger, more capable commercial satellites rather than to stabilize or reduce satellite size. Thus, there is a continuous interplay between satellite and launch vehicle size. Neither set of designers wishes to exceed the other's needs or capabilities, but both seek to use greater capacity as a selling point. No signs at this point indicate that either satellite or launch vehicle growth has reached its end (although it is possible to get too far ahead of the market and suffer accordingly, as the failure of the commercial Titan 3 demonstrated).

A case that proves this is that of the Delta Lite launch vehicle sought by NASA under its Med Lite launch vehicle contract in the mid-1990s. This program was intended to produce a lower-priced version of the Delta launch vehicle by reducing its payload size and payload capacity. Ultimately, McDonnell Douglas determined that there was insufficient market demand for such a vehicle and chose to provide NASA with launches on larger Delta variants rather than pay to develop the Delta Lite for the limited number of launches planned under the Med Lite launch procurement contract.

Vehicle	Intro Year	Vehicle Weight (kg)	GTO Performance (kg)
Thor	1957	49340	N/A
Thor Able	1958	51608	N/A
Thor Agena A	1959	53130	N/A
Thor Able-Star	1960	53000	N/A
Thor Agena B	1960	56507	N/A
Delta	1960	52442	45
Delta A	1962	51555	68
Delta B	1962	51984	68
Delta C	1963	52004	82
Delta D	1964	64679	104
Delta E	1965	69023	150
Delta J	1968	69497	263
Delta M	1968	89881	356
Delta M-6	1969	N/A	454
Delta 904	1971	N/A	635
Delta 2914	1972	130392	724
Delta 3914	1975	190799	954
Delta 3910/PAM	1980	191633	1156
Delta 3920/PAM	1982	190721	1270
Delta 4920	1989	200740	1270
Delta 5920	1989	201580	1360
Delta 2 6925	1990	217920	1447
Delta 2 7925	1990	229724	1820
Delta 3	1998	301450	3810
Delta 4 Medium	2002	249500	5845
Delta 4 Medium-Plus (4,2)	2002	N/A	4640
Delta 4 Medium-Plus (5,2)	2002	N/A	4640
Delta 4 Medium-Plus (5,4)	2002	N/A	6565
Delta 4 Heavy	2002	733400	13130

Table 2: Evolution of Delta Mass and GTO Payload Capacity

Also interesting to note is that this phenomenon of vehicle growth does not seem to be dependent on the country or company developing the vehicle. Table 3 shows the growth in payload capacity of selected Russian and European launch vehicle families over the course of their development.

VEHICLE RELIABILITY

Over time, reliability has improved for both the Delta and Atlas vehicles. The Atlas vehicle's cumulative reliability has ranged from a low of 29 percent after seven launches in 1960 to the current level of 87 percent first achieved in 1997 (see Figure 4). Delta's cumulative reliability has improved from a low of 91 percent after 23 launches in 1965 to 97 percent since 1998 (see Figure 5).

CONCLUSION

Launch vehicles are have tended to become increasingly capable over time. It is clear that both capacity and reliability can be increased considerably if the demand for greater capability remains and resources are directed towards those ends. The Delta 4

Initial Vehicle	GTO Capacity (kg)	Intro Year	Current Vehicle	GTO Capacity (kg)	Intro Year	Increase in GTO Capacity
Ariane 1	1,850	1979	Ariane 44L	4,520	1989	144%
Sputnik (LEO)	1,300	1957	Soyuz (LEO)	7,000	1963	438%
Proton (SL-8, LEO)	12,200	1965	Proton SL-12 (LEO is SL-13)	20,900	1967	71%

Table 3. Launch Capacity Growth in Vehicles Worldwide

and Atlas 5 are particular examples of how much vehicles can grow if their development is sustained. While the availability of resources and demand for launch services cannot be guaranteed at any given time in the future, one thing is clear: later versions of a launch vehicle, possessing the operational understanding and technological refinement that are developed over time, are likely to be far more capable and less risky than their familial predecessors.

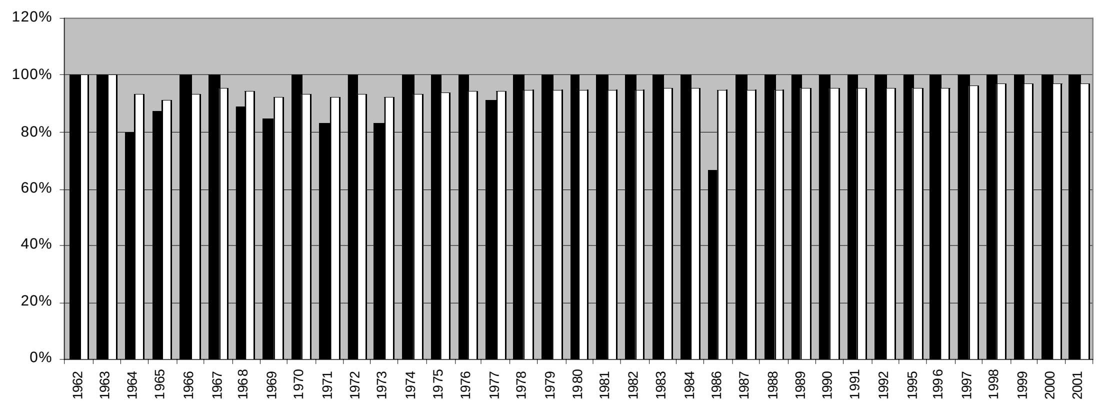


Figure 4. Atlas Launch Vehicle Reliability

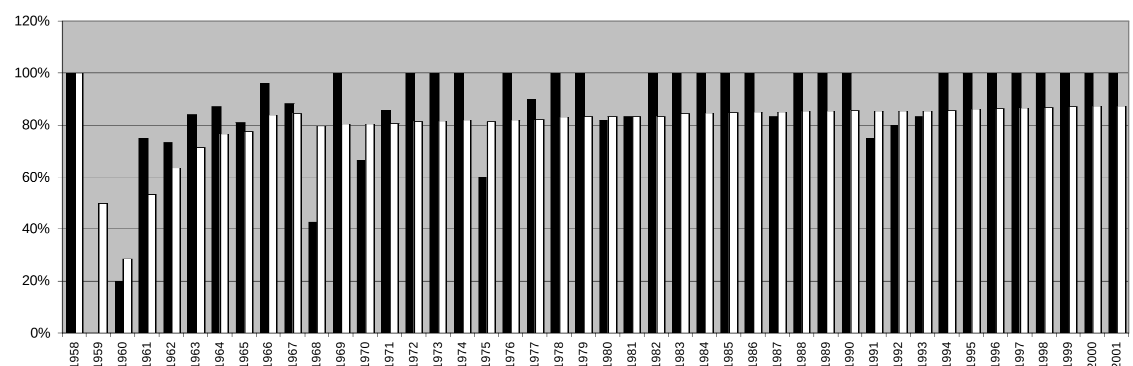


Figure 5. Delta Launch Vehicle Reliability

Third Quarter 2001 Orbital Launch Events

Date	Vehicle	Site	Payload or Mission	Operator	Use	Vehicle Price	L	M
7/12/01	Shuttle Atlantis	KSC	ISS 7A	NASA	ISS	$300M	S	S
			STS 104	NASA	Crewed			
7/12/01 √	Ariane 5 G	Kourou	* ARTEMIS	European Space Agency	Communications	$150-180M	F	P
			* BSat 2B	Broadcasting Satellite System Corp.	Communications			
7/20/01	Molniya	Plesetsk	Molniya 3K	Russian Ministry of Defense	Communications	$30-40M	S	S
7/23/01	Atlas 2AS	CCAFS	GOES 12	NOAA	Meteorological	$90-105M	S	S
7/31/01	Cyclone 3	Plesetsk	Coronas F	Izmiran and Lebedev Physical Institute	Scientific	$45-55M	S	S
8/6/01	Titan 4B/IUS	CCAFS	DSP 21	USAF	Classified	$350-450M	S	S
8/8/01	Delta 2 7326-10	CCAFS	Genesis	NASA/ JPL	Scientific	$45-55M	S	S
8/10/01	Shuttle Discovery	KSC	ISS 7A.1	NASA	ISS	$300M	S	S
			STS 105	NASA	Crewed			
8/21/01	Soyuz	Baikonur	Progress ISS 5P	Russian Space Agency	ISS	$30-40M	S	S
8/24/01	Proton (SL-12)	Baikonur	Kosmos 2379	Russian Ministry of Defense	Classified	$75-95M	S	S
8/29/01	H 2A 202	Tanegashima	Vehicle Evaluation Payload 2	Japanese National Space Development Agency	Test	$75-95M	S	S
8/30/01 √	Ariane 44L	Kourou	* Intelsat 902	Intelsat	Communications	$100-125M	S	S
9/8/01	Atlas 2AS	VAFB	NRO A1	NRO	Classified	$90-105M	S	S
9/15/01	Soyuz	Baikonur	Pirs	Russian Space Agency	ISS	$30-40M	S	S
9/21/01 √	+ Taurus 1	VAFB	* OrbView 4	Orbital Imaging Corp.	Remote Sensing	$18-20M	F	F
			QuikTOMS	NASA	Scientific			
			* Celestis 4	Celestis, Inc.	Other			
9/25/01 √	Ariane 44P	Kourou	* Atlantic Bird 2	Eutelsat	Communications	$80-100M	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.
L and M refer to the outcome of the **L**aunch and **M**ission: S = success, P = partial success, F = failure

Fourth Quarter 2001 Projected Orbital Launch Events

Date	Vehicle	Site	Payload or Misson	Operator	Use	Vehicle Price
10/1/01	Athena 1	Kodiak Launch Complex	PICOSAT 1	USAF	Development	$16-17M
			PCSat	US Naval Academy	Communications	
			SAPPHIRE	Stanford University	Scientific	
			Starshine 3	NASA	Scientific	
10/5/01	Titan 4B	VAFB	NRO T3	NRO	Classified	$350-450M
10/6/01	Proton (SL-12)	Baikonur	Kosmos 2380	Russian Ministry of Defense	Classified	$75-95M
10/10/01	Atlas 2AS	CCAFS	NRO A2	NRO	Classified	$90-105M
10/11/01	Molniya	Plesetsk	Molniya TBA	Russian Ministry of Defense	Communications	$30-40M
10/18/01 √	+ Delta 2 7320	VAFB	* QuickBird 2	Digital Globe	Remote Sensing	$45-55M
10/21/01	Soyuz	Baikonur	Soyuz ISS 3S	NASA	ISS	$30-40M
10/XX/01	PSLV	Sriharikota Range (SHAR)	TES	Indian Space Research Organization	Remote Sensing	$15-25M
			PROBA	European Space Agency	Scientific	
			BIRD	Deutschen Zentrum für Luft- und Raumfahrt	Development	
10/XX/01	Long March 2F	Jiuquan	Shenzhou 3	Chinese National Space Administration	Development	N/A
10/XX/01	Soyuz	Baikonur	Kosmos 2381	Russian Ministry of Defense	Classified	$30-40M
11/13/01	Atlas 2A	CCAFS	TDRS F9	NASA	Communications	$90-105M
11/14/01	Soyuz	Baikonur	Progress ISS 6P	Russian Space Agency	ISS	$30-40M
11/14/01	Titan 2	VAFB	DMSP 5D-3-F16	USAF	Meteorological	$30-40M
11/15/01 √	Dnepr 1	Svobodny	Unisat 2	Agenzia Spaziale Italiana	Development	$10-20M
			Tropnet 1	One Stop Satellite Solutions	Development	
			Tropnet 2	One Stop Satellite Solutions	Development	
			Tropnet 3	One Stop Satellite Solutions	Development	
11/19/01	Proton (SL-12)	Baikonur	Glonass M R1	Russian Ministry of Defense	Navigation	$75-95M
			Glonass M R3	Russian Ministry of Defense	Navigation	
			Glonass M R2	Russian Ministry of Defense	Navigation	
11/26/01 √	Proton (SL-12)	Baikonur	* Intelsat 903	Intelsat	Communications	$75-95M
11/27/01 √	Ariane 4 TBA	Kourou	* DirecTV 4S	DirecTV, Inc.	Communications	N/A
11/29/01	Shuttle Endeavour	KSC	ISS UF-1	NASA	ISS	$300M
			STS 108	NASA	Crewed	
11/30/01	Rockot	Plesetsk	GRACE 1	NASA/Deutschen Zentrum für Luft- und Raumfahrt	Scientific	$12-15M
			GRACE 2	NASA/GFZ (Germany)	Scientific	

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Fourth Quarter 2001 Projected Orbital Launch Events

Date			Vehicle	Site		Payload or Misson	Operator	Use	Vehicle Price
11/XX/01			Pegasus XL	CCAFS		HESSI	NASA	Scientific	$12-15M
12/7/01			Delta 2 7920	VAFB		TIMED	NASA	Scientific	$50-60M
						Jason 1	NASA/Centre Nationale d' Etudes Saptiale	Remote Sensing	
12/19/01	√	+	Atlas 3B	CCAFS	*	EchoStar 7	EchoStar Satellite Corp.	Communications	$90-105M
4th Quarter			Long March TBA	TBA		OlympicSat 1	China	Development	N/A
						OlympicSat 2	China	Remote Sensing	
4th Quarter			Shavit 1	Palmachim AFB		Ofeq 5	Israel Space Agency	Classified	$10-15M
4th Quarter			Cyclone 3	Plesetsk		Gonets D1 7	Russian Space Agency	Communications	$45-55M
						Gonets D1 8	Russian Space Agency	Communications	
						Gonets D1 9	Russian Space Agency	Communications	
						Kosmos TBA 2	Russian Ministry of Defense	Communications	
						Kosmos TBA 3	Russian Ministry of Defense	Communications	
						Kosmos TBA 4	Russian Ministry of Defense	Communications	
2001	√		Proton (SL-12)	Baikonur	*	DirecTV 5	DirecTV, Inc.	Communications	$75-95M
2001			VLS	Alcantara		SCD 3	Instituto Nacional de Pesquisas Espaciais	Remote Sensing	$6-7M
2001			Long March 1D	Jiuquan		Tansuo 1	China	Remote Sensing	$10-15M
2001			Long March TBA	Taiyuan		Chuang Xing 1	Chinese Academy of Sciences	Communications	$25-35M
2001			Soyuz	Plesetsk		Resurs F2	Russian Space Agency	Remote Sensing	$30-40M

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

First Quarter 2002 Projected Orbital Launch Events

Date			Vehicle	Site		Payload or Mission	Operator	Use	Vehicle Price
1/14/02			Titan 4B/Centaur	CCAFS		Milstar F5	USAF	Communications	$350-450M
1/17/02			Shuttle Columbia	KSC		Hubble Servicing Mission 3B	NASA	Development	$300M
						STS 109	NASA	Crewed	
1/XX/02	√		Ariane 4 TBA	Kourou	*	NSS 7	New Skies Satellites N.V.	Communications	N/A
1/XX/02			Ariane 5 G	Kourou		ENVISAT 1	European Space Agency	Remote Sensing	$150-180M
2/8/02	√	+	Delta 2 7920	VAFB	*	Iridium MS-12	Iridium LLC	Communications	$50-60M
2/15/02			Soyuz	Baikonur		Progress ISS 7P	Russian Space Agency	ISS	$30-40M
2/28/02			Shuttle Atlantis	KSC		ISS 8A	NASA	ISS	$300M
						STS 110	NASA	Crewed	
2/XX/02	√		Ariane 5 G	Kourou	*	Astra 3A	SES Astra	Communications	$150-180M
3/6/02			Delta 2 7925-10	CCAFS		Navstar GPS 2R-8	USAF	Navigation	$45-55M
3/15/02			Ariane 42P	Kourou		SPOT 5	SPOT Image	Remote Sensing	$65-85M
3/21/02			Titan 2	VAFB		NOAA M	NOAA	Meteorological	$30-40M
3/24/02			Delta 2 7920	VAFB		Aqua	NASA	Remote Sensing	$50-60M
3/XX/02	√		Proton (SL-12)	Baikonur		Express A2A	Russian Satellite Communciation Co.	Communications	$75-95M
3/XX/02	√		Ariane 44L	Kourou	*	Intelsat 904	Intelsat	Communications	$100-125M
1st Quarter			H 2A 202	Tanegashima		ADEOS 2	Japanese National Space Development Agency	Remote Sensing	$75-95M
1st Quarter	√	+	Zenit 3SL	Sea Launch Platform	*	Galaxy 3C	Pan American Satellite Corp.	Communications	$75-95M
1st Quarter	√		Shtil	Barents Sea		Cosmos 1 Deployment Test 2	The Planetary Society	Development	$0.1-0.3M
1st Quarter	√		Shtil	Barents Sea		Cosmos 1	The Planetary Society	Development	$0.1-0.3M
1st Quarter			Long March 4B	Taiyuan		FSW 18	China	Meteorological	$25-35M
1st Quarter	√		Proton (SL-12)	Baikonur	*	EchoStar 8	EchoStar Satellite Corp.	Communications	$75-95M
1st Quarter			Long March 4B	Taiyuan		CBERS/Ziyuan 2	China/Instituto Nacional de Pesquisas Espaciais	Remote Sensing	$25-35M
1st Quarter	√		Long March 3A	Xichang	*	Atlantic Bird 1	Eutelsat	Communications	$45-55M
1st Quarter			H 2A 202	Tanegashima		MDS 1	Japanese National Space Development Agency	Development	$75-95M
						Vehicle Evaluation Payload 3	Japanese National Space Development Agency	Test	

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