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The Commercial Space Industry and Launch Market

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Summary

The space industry refers to economic activities related to the manufacture and delivery of components that go into Earth's orbit or beyond. The space industry is a subset of the U.S. aerospace industry and U.S. strength in aerospace has helped to provide U.S. strength in space. The space industry was originally developed by government entities, and government policies and spending continue to exercise a strong influence on commercial space activities in the United States and elsewhere. Space-oriented manufacturing, which includes launch vehicles, spacecraft, satellites, and parts and equipment, has created a large space-industrial infrastructure that enables a much larger space services sector that includes satellite telecommunications and broadcasting services, and satellite remote sensing, among others. Together, these are an important part of the U.S. industrial and technology base. The focus of this report is the global commercial space manufacturing sector (launch vehicles, spacecraft, and satellites). Although relatively small, accounting for less than $6 billion of expenditures in 2010, it enables an estimated $276 billion in spending for ground equipment and satellite services.

The United States manufactures more launch vehicles, spacecraft, and satellites than any other country, but the relative U.S. competitive position has eroded as other countries have made large investments in commercial and government space activities. The U.S. government remains the world's largest customer for space equipment and services. With the end of the Space Shuttle era, the government will increasingly depend on the U.S. commercial space industry for transport of humans and cargo, and on commercial satellites for communications and data. The extent and nature of government demand are likely to be significant factors shaping the U.S. commercial space industry. U.S. policy has gradually shifted toward encouraging more competition among firms that manufacture launch equipment, spacecraft, and satellites, encouraging the participation of smaller, entrepreneurial firms in an industry segment traditionally dominated by large aerospace firms.

Several policy issues appear to have significant effects on the growth and competitiveness of the U.S. space manufacturing industry:

- In 1998, Congress passed legislation that reclassified all satellites and satellite parts and equipment as weapons under the International Traffic in Arms Regulations, limiting the ability of U.S. manufacturers of commercial space equipment to sell abroad and encouraging foreign rivals to increase their global market share at the expense of U.S. manufacturers. On April 18, 2012, the Department of Defense (DOD) and Department of State issued a congressionally mandated report that assessed risks associated with removing satellites and related components from the United States Munitions List (USML). Bills have been introduced in the 112th Congress to reauthorize and amend U.S. export control laws (H.R. 2122, H.R. 2004, H.R. 1727, H.R. 3288).
- The rapid growth in technologies that consume large amounts of bandwidth threatens to destabilize the current system that allocates spectrum and orbital position to specific users. Spectrum is a scarce resource, but increasingly, commercial satellite operators are developing technological solutions to increase capacity.
- DOD is now a major user of commercial satellites. From a surge related to the wars in Iraq and Afghanistan, it now places greater reliance on commercial satellites. Hosted payloads are also likely to become a more common feature of the commercial satellite industry in the future.

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Introduction

The space industry refers to economic activities related to the manufacture and delivery of components that go into Earth's orbit or beyond. The space industry is a subset of the U.S. aerospace industry and U.S. strength in aerospace has helped to provide U.S. strength in space. Bolstered by a large research and development establishment, the commercial space industry has a manufacturing component and a services component. The focus of this report is the global commercial space manufacturing sector (launch vehicles, spacecraft, satellites, and parts and equipment). The space industry also builds space ports, ground stations, and ground equipment. Together, the space and ground infrastructure enables a much larger space services sector that includes satellite telecommunications and broadcasting services and satellite remote sensing, among many other services. The space industry, broadly defined, is an important part of the U.S. industrial and technology base.

Because of its economic importance and its close link to government space programs, the U.S. space manufacturing industry has historically been of great interest to Congress. This report discusses the current structure of the industry, looks at trends that may promote or inhibit space manufacturing, and examines current space manufacturing activities. It then lays out a number of federal policy issues that may affect the industry's growth.

The U.S. commercial space manufacturing sector is small, but the companies that manufacture commercial satellites also manufacture satellites for the U.S. government. U.S. commercial satellite manufacturing generated estimated revenues of $3.4 billion (of $5.6 billion in total U.S. satellite manufacturing revenues[1]) and employed 26,611 private sector workers in 2010, while the U.S. commercial launch industry generated revenues of $307 million (of $1.2 billion in total U.S. launches) and employed 49,195 private-sector workers.[2]

In 2010, global revenues from satellite-enabled activities (i.e., the commercial products and services that are created using satellites) totaled $101.3 billion. Major products include direct-to-home television ($79.1 billion), satellite communications ($17.3 billion), satellite radio ($2.8 billion), consumer broadband ($1.1 billion), and Earth observation ($1.0 billion). Satellite services also generated worldwide sales of ground equipment that totaled $51.6 billion, including all of the infrastructure and technology needed to communicate with and manage satellites ($7.5 billion), as well as all of the end-user consumer equipment (satellite radios, satellite phones, satellite TV receivers and dishes, and satellite navigation equipment) ($44.1 billion). (See **Figure 1**.)[3]

The U.S. government is by far the largest consumer of space products and services, accounting for 23% of global spending. The commercial space sector overlaps the government (civil and military) space sector in a number of different ways. Many manufacturers sell to both commercial and government customers, making use of common systems (for instance, satellites use standard

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[1] This total includes satellites for commercial and government use.

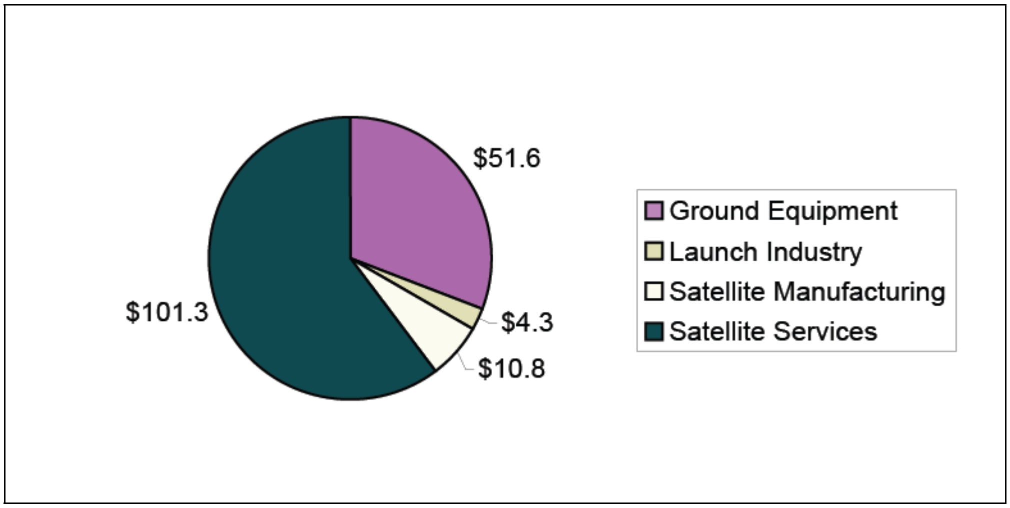
[2] Launch and satellite manufacturing revenues are from the Federal Aviation Administration (FAA), FAA, *Commercial Space Transportation: 2010 Year in Review*, January 2011, p. 5, the Space Foundation, *The Space Report 2011*, p. 34, and the Satellite Industry Association/Futron Corporation (SIA/Futron), *State of the Satellite Industry Report 2011*, August 2011, p. 15 and 18; employment data is from SIA/Futron, *State of the Satellite Industry Report 2011*, August 2011, p. 24.

[3] SIA/Futron, *State of the Satellite Industry Report 2011*, August 2011, pp. 10-22.

buses[4]), common launch vehicles, and interdependent supply chains. Many of the largest commercial aerospace companies play a major role in the space industry, and some are almost entirely dependent on government space programs for their space-related work.

Figure 1. Global Satellite Industry Revenues by Segment, 2010

Billions of Dollars



Source: Satellite Industry Association/Futron Corp. (SIA/Futron), *State of the Satellite Industry Report*, August 2011, p. 8.

Military and civil (i.e., non-military government) space programs provide economies of scale and scope to companies that are federal contractors. During the post-Cold War period, numerous mergers resulted in industry consolidation, with fewer firms spanning multiple sectors. Because of the size of government space programs, some of the largest U.S. space companies, especially those engaged in launch activities, withdrew from the commercial space sector to focus nearly exclusively on government contracts that are not open to foreign competitors. Nevertheless, the international commercial launch industry has continued to develop even as some of the largest U.S. space companies ceased to compete for those launches.

During the last decade, the United States increasingly offered opportunities to smaller private companies to encourage entrepreneurial approaches to space activities as a means of spurring innovation, reducing costs, and promoting commercial engagement in space manufacturing and service provision. Orbital Sciences Corporation and Space Exploration Technologies Corporation (SpaceX) are two newer American companies that have successfully competed for commercial and government contracts.

Launch vehicle, spacecraft, and satellite manufacturing is highly competitive internationally, with European, Russian, Chinese, Indian, and Japanese companies vying with U.S. firms for contracts to provide launch vehicles, spacecraft, and satellites to commercial customers. Some manufacturers of launch vehicles specialize in the manufacture and launch of those vehicles,

[4] A satellite has a mission system and a bus system. The mission system is the payload that enables a satellite to achieve its specific mission (or purpose), such as communications, weather monitoring, remote sensing, etc. The bus system consists of equipment that provides satellite functionality and includes the gyroscope, power supply, antenna, telemetry and tracking command, mechanical, and thermal control subsystems.

while others also make spacecraft, satellites, and civil and defense aviation products, in addition to building and launching rockets. The supply chain for launch vehicles is moderately globalized, while satellites vary according to customer: military (low level of globalization), civil (moderate level of globalization), commercial (moderate to high level of globalized components).[5]

The major policy issues discussed in this report are limited to those that appear to have large effects on the competitiveness of the U.S. space manufacturing sector: classification of commercial satellites as munitions subject to stringent U.S. export controls laws and regulations; domestic and international spectrum regulations that may not have kept pace with the emergence of new technologies that appear to require much greater flexibility in terms of spectrum use; and the dramatically increased use of commercial satellites for Department of Defense communications needs.

One major caveat regarding the statistical data used in this report needs to be mentioned. Publicly available U.S. government data for the manufacture of launch vehicles, spacecraft, satellites, and electronic components (especially search, detection, and navigation systems and instruments) are deficient in many respects. In some cases, data are suppressed because they would make it possible to identify a specific company; in others, data are aggregated to a level that makes it virtually impossible to distinguish between manufacturing for space activities, aviation, and telecommunications. Missiles, space launch equipment, and spacecraft cannot be differentiated using government data sources: for example, satellites, which are grouped with terrestrial telecommunications and broadcasting, are invisible in the data. CRS has used government data when available, but draws on reports by Futron Corporation, the Space Foundation, and others that provide estimates of the size of the global market and, in some cases, the U.S. market. Futron Corporation's data, in particular, are used by government agencies, the Government Accountability Office (GAO), and others as a basis for analyzing the space industry.

Manufacturing for Commercial Space

The space equipment industry comprises three distinct segments. Launch vehicles are used to place satellites and other spacecraft into orbit.[6] Spacecraft and space systems are manned or unmanned vehicles that transport passengers or cargo. Satellites, with functions such as telecommunications and weather sensing, are the most common payloads aboard spacecraft. Most of the major companies manufacturing commercial space equipment compete in more than one of these sectors (see **Table 1**).

[5] The Tauri Group, *U.S. Industrial Base Analysis for Space Systems*, Presentation, Defense Manufacturing Conference 2011, Anaheim, CA, November 29, 2011.

[6] All discussions of launch vehicles in this report should be understood to refer to the manufacture of these vehicles. In cases where launches are discussed, it should generally be understood that such launches are being conducted by the manufacturer of the launch vehicle (unless otherwise specified).

Table 1. Competition in Commercial Space Equipment

Products	Companies/Competitors
Space Launch Vehicles	Orbital Sciences Corporation (Virginia) Space Exploration Technologies Corp. (SpaceX) (California) United Launch Alliance (ULA)(Lockheed Martin and Boeing)(Colorado and Alabama) Lockheed Martin Corporation (Maryland) Alliant Techsystems Inc. (ATK) (Virginia) Russian, Indian, and Chinese launch vehicles could represent competition for commercial, as opposed to U.S. government, launches[a]
Spacecraft/Space Systems	Space Exploration Technologies Corp. (California) Orbital Sciences Corporation (Virginia) Boeing (Texas) Sierra Nevada Corporation (Nevada) European Space Agency (Europe) Japan Aerospace Exploration Agency (Japan) Russian Federal Space Agency (Russia)
Satellites	Lockheed Martin Corporation (Maryland) Loral Space & Communications Inc. (New York) Boeing (California) ATK (Virginia) Orbital Sciences Corporation (Virginia) Ball Aerospace (Colorado) Northrop Grumman Corporation (Virginia) Sierra Nevada Corporation (Nevada) Thales Alenia (Europe) EADS Astrium (Europe) Surrey Satellite Technology Limited (an EADS Astrium subsidiary) (Europe) Mitsubishi Electric (Japan)

Source: Adapted from Orbital Sciences Corporation, *2011 Annual Report*, p. 4.

a. Russian, Indian, and Chinese launch vehicles are manufactured by state-owned firms. U.S. government space launches are subject to the Buy America Act (41 U.S.C. 10(a) et seq.) unless a waiver is granted pursuant to obligations of the United States under international agreements.

Launch Vehicles

Commercial launch vehicles carry various payloads into space, including manned or unmanned spacecraft and commercial satellites.[7] The demand for commercial launch vehicles is small, and is tied directly to the demand for commercial launch services. In 2010, 23 commercial launches carried a worldwide total of 31 commercial payloads and 13 noncommercial payloads.[8] Many commercial launch vehicles are also used for, or can readily be adapted for, government purposes, both civil and military. The main driver of commercial launch activity is commercial satellites, although many government-owned satellites also are launched with the same vehicles. Some, but not all, launch vehicle manufacturers also provide launch services. A commercial customer, such as a private company wishing to place a satellite in space, may contract separately for a launch vehicle and launch services or may obtain them from the same provider.

[7] The Space Foundation, *The Space Report 2011*, pp. 39-40.

[8] Examples of noncommercial payloads include government civil (a National Oceanic and Atmospheric Administration (NOAA) weather satellite), government military (a classified U.S. Army satellite); or non-profit (a university-owned earth observation satellite).

The Federal Aviation Administration (FAA) defines a "commercial" launch as "a launch that is internationally competed or FAA-licensed, or privately-financed launch activity." Although many commercial launches carry commercial payloads, some carry mixed payloads (commercial and noncommercial) or purely military or civil government payloads. Boeing Launch Services,[9] a Boeing subsidiary, and SpaceX were the only U.S. companies to conduct commercial launches in 2010, but, under the FAA's definition, Boeing's payloads were noncommercial. In 2011, there were 84 worldwide orbital launch attempts, of which 66 were non-commercial and 18 were commercial.[10]

With 18 commercial launches in 2011, Russia, with 10 commercial launches, had a 56% share of the international market, followed by Europe (4 commercial launches, 22%), China (2 commercial launches, 11%), and 2 commercial launches (11% of the commercial market in 2011) by Sea Launch AG, a company that the FAA describes as multinational: "a Swiss-based Russian majority-owned company."[11] No U.S. commercial launches occurred in 2011. Worldwide commercial launch revenues amounted to $1.9 billion in 2011, a decrease of $526 million from 2010,[12] with Russian commercial launch revenues at $707 million, European revenues at $808 million, Chinese revenues at $140 million, and Sea Launch revenues at approximately $200 million. U.S. commercial launch revenues were $0 in 2011.[13] U.S. companies engaged in 18 non-commercial launches that carried 28 payloads into orbit, including 10 military payloads, and 9 civil and 9 non-profit payloads. Russia conducted 31 non-commercial launches with 53 payloads.

U.S. companies engaged in commercial launch vehicle development, production, and launch activities include Boeing, Lockheed Martin, Orbital Sciences, and Space Exploration Technologies Corporation (SpaceX). Boeing, Lockheed Martin, and their 50/50 joint venture, United Launch Alliance (ULA), are focused primarily on the government launch market. In 2010, Boeing Launch Services placed two non-commercial payloads into orbit using ULA-built Delta launch vehicles: a National Oceanic and Atmospheric Administration weather satellite that was manufactured by Boeing and an Italian radar satellite built by Thales Alenia Space. One factor that may prevent Boeing and Lockheed Martin from more aggressively pursuing commercial launch opportunities has been a heavy U.S. government launch schedule that may crowd out commercial cargos.

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[9] Boeing Launch Services is a commercially focused Boeing subsidiary that uses Delta launch rockets built by United Launch Alliance (ULA). ULA is a joint venture company formed in 2005 by Lockheed Martin and Boeing to build and launch payloads for the U.S. government. The joint venture combined the design, manufacturing, and launch assets of the two largest U.S. aerospace companies. Before the merger, Boeing built Delta rockets and Lockheed Martin built Atlas rockets. Both had been workhorses for the government and commercial sectors, but Russian and European competitors gradually eroded both companies' shares of the commercial launch market.

[10] Of the 84 launch attempts, six launch failures occurred. Of the six, four were Russian (including one commercial launch failure), one was Chinese, and one was an Orbital Sciences' Taurus XL launch vehicle carrying a National Aeronautics and Space Administration (NASA) Earth science satellite and three university satellites. FAA, *Commercial Space Transportation: 2011 Year in Review*, January 2012, p. 2.

[11] Sea Launch AG, a Long Beach, California-based company went through U.S. bankruptcy reorganization in 2009 and 2010. After the U.S. Committee on Foreign Investment in the United States (CFIUS) approved the purchase of Sea Launch by RSC Energia, a Russian space company, it emerged from bankruptcy as a Swiss-registered company. Sea Launch's business model is based on the launch of commercial satellites.

[12] FAA, *Commercial Space Transportation: 2011 Year in Review*, January 2012, p. 5.

[13] Ibid.

In 2011, U.S. launches were conducted by

- ULA, with 11 launches for the U.S. government;
- United Space Alliance (a Boeing/Lockheed Martin joint venture), with three successful Space Shuttle launches; and
- Orbital Sciences Corporation, with four launches. Three were successful.

Orbital is an established commercial space company that manufactures launch vehicles, spacecraft, and satellites. In 2011, it had revenues of $1.3 billion, of which 71% came from the U.S. government. According to company reports, 38% of its revenues came from the Department of Defense and intelligence agencies; 33% from the National Aeronautics and Space Administration (NASA), other civilian government agencies, and universities; and 29% from commercial and international satellite operators.[14] The company's newest launch vehicle, the Antares (formerly Taurus II) rocket, is expected to undergo its first test in summer 2012.[15]

SpaceX is a privately owned company founded 10 years ago by Elon Musk, a cofounder of PayPal and currently CEO of Tesla Motors. The company designs and builds launch vehicles and has launch contracts with NASA and numerous satellite companies that provide communication and broadcasting services to government and industry. The SpaceX order book includes future launches of communications satellites for Iridium (eight scheduled missions through 2017); ORBCOMM; Space Systems/Loral; and a number of foreign firms, such as SES (Europe), Thaicom (Thailand), AsiaSat, Spacecom (Israel), and EADS Astrium (Europe).[16] SpaceX has made a strong push to develop a commercial order book for its Falcon 9 launch vehicle.

Seeking lower costs and greater efficiencies, the U.S. Air Force, the National Reconnaissance Office (NRO), and NASA announced an agreement in October 2011 on a process that will allow a number of new U.S. companies to compete for contracts for space launch missions with the U.S. Air Force, the NRO, and NASA.[17] In particular, the Air Force has announced that the Evolved Expendable Launch Vehicle (EELV) program, a Department of Defense program that dates back to 1995, will reserve two launches for SpaceX, Orbital, Virgin Galactic, or other commercial launch companies that are building EELV-class launch vehicles.[18] This will allow smaller competitors to gain a foothold in a market currently served by one company, the United Launch Alliance.[19] Both the SpaceX Falcon 9 and Orbital Antares launch vehicles are EELVs. SpaceX has been cleared by NASA for a mission to the International Space Station (ISS) under the

[14] Orbital Sciences Corp., *2011 Annual Report*, p. 2.

[15] *Aviation Week & Space Technology*, "Orbital Sees Midsummer Launch of First Antares," February 27, 2012.

[16] See SpaceX website: http://www.spacex.com/launch_manifest.php.

[17] U.S. Air Force, "New Entrant Certification Strategy Announced," October 14, 2011. http://www.af.mil/news/story.asp?id=123275888; *Aviation Week & Space Technology*, "Launch Vehicle Market Making A Slow Rebound," January 23, 2012.

[18] *Washington Post*, "Air Force sets up competition for rocket launches," March 5, 2012.

[19] For a discussion of the Evolved Expendable Launch Vehicle (EELV) program, see U.S. Government Accountability Office, *Space Acquisitions: Uncertainties in the Evolved Expendable Launch Vehicle Program Pose Management and Oversight Challenges*, GAO-08-1039, September 2008, p. 8; for further discussion of the challenges of the EELV program and the emergence of competitors that are building EELV-class launch vehicles, see Stewart Money, "Competition and the future of the EELV program," *The Space Review*, December 12, 2011. http://www.thespacereview.com/article/1990/1.

Commercial Orbital Transportation Services (COTS) program, and Orbital is expected to be cleared in 2012.

Spacecraft

Spacecraft manufacturing has entered a new phase of development that is based on the provision of space transportation in commercially developed and launched vehicles. NASA will rely on commercial transportation of cargo and crews to the ISS through 2020—a decision taken by NASA in 2005 with the establishment of the Commercial Crew and Cargo Program. According to the Government Accountability Office (GAO), "NASA's decision to rely on the new commercial vehicles is inherently risky because the vehicles are still in development and not yet proven or fully operational."[20]

U.S. spacecraft currently under development are scheduled to begin ferrying cargo to the ISS in 2012 and are projected to begin using crew vehicles to transport astronauts to the ISS in 2017.[21] In a recent editorial on the shift from a government-run manned space program managed entirely by NASA to a more entrepreneurial private sector-based approach, Joseph Anselmo, of *Aviation Week and Space Technology*, noted: "To be sure, outsourcing the job of launching astronauts to private companies is fraught with risk. SpaceX may have proven it can return a spacecraft from orbit, but safely transporting humans to space takes things to a whole new level. Given budget constraints, there may be no other choice."[22]

The United States government is funding commercial spacecraft development through NASA's Commercial Crew Development (CCDev) Program "to stimulate efforts within the private sector to develop and demonstrate safe, reliable, and cost-effective space transportation capabilities."[23] Companies involved in the program (with or without NASA funding) include SpaceX (Hawthorne, CA), Orbital (Dulles, VA), Blue Origin (Kent, WA), Boeing (Houston, TX), Paragon (Tucson, AZ), United Launch Alliance (Denver, CO), and Sierra Nevada (Sparks, NV). Each of these companies is involved in developing commercial spacecraft capable of carrying passengers and cargo into space.

In 2010, SpaceX conducted the first successful test flight of its Dragon spacecraft and, in 2012, is expected to rendezvous with the ISS on the first 2 of 12 flights scheduled through 2016. The SpaceX Dragon spacecraft will have the capability of returning significant amounts of cargo, including the results of scientific experiments, to Earth.[24] Orbital Sciences' Cygnus spacecraft is currently scheduled to make one resupply flight to the ISS in 2012. Together, SpaceX and Orbital

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[20] GAO, *NASA: Significant Challenges Remain for Access, Use, and Sustainment of the International Space Station*, Statement of Cristina T. Chaplain, Director, Acquisition and Sourcing Management before the Committee on Science, Space, and Technology, House of Representatives, GAO-12-587T, March 28, 2012.

[21] NASA will also rely on European and Japanese cargo deliveries to the ISS from 2012 through 2016 and possibly beyond. The European Space Agency (ESA) operates expendable, unmanned Automated Transfer Vehicles (ATVs) that are built by prime contractor EADS Astrium and a number of European and Russian subcontractors. ATV resupply missions occurred in 2008, 2011, and 2012. The Japanese Aerospace Exploration Agency (JAXA) uses the Mitsubishi Heavy Industries-built, unmanned and expendable H-II Transfer Vehicle (HTV). HTV resupply missions took place in 2009 and 2011, with another two scheduled for 2012.

[22] Joseph Anselmo, "Human Spaceflight's New, Different Age," *Aviation Week & Space Technology*, April 2, 2012, p. 15.

[23] NASA, Commercial Crew and Cargo Program Office (C3PO). http://www.nasa.gov/offices/c3po/home/index.html.

[24] GAO, GAO-12-587T, March 28, 2012, p. 6.

will fly 20 (71%) of the 28 scheduled resupply missions through 2016. In testimony before the House Science, Space, and Technology Committee on March 28, 2012, Christina Chaplain of GAO warned that "if the commercial vehicle launches do not occur as planned in 2012, the ISS could lose some ability to function and sustain research efforts due to a lack of alternative launch vehicles to support the ISS and return scientific experiments back to earth."[25] Another witness, Lieutenant General Thomas P. Stafford, USAF (ret.), chairman of the NASA International Space Station Advisory Committee, testified that the NASA Aerospace Advisory Committee and his committee conducted a joint assessment and

> concluded that the commercial vehicle launch schedule was overly optimistic and we have not received sufficient data to conclude with confidence that the schedule could be met. This was the unanimous conclusion of both groups. Both commercial cargo contractors (Orbital Science Corporation and Space Exploration Corporation) continue to experience significant delays in their development, testing and launch dates.[26]

In his testimony, NASA Associate Administrator William H. Gerstenmaier stated that NASA was "pleased with the steady progress both companies [SpaceX and Orbital] continue to make in their cargo vehicle and launch systems development efforts." He also told the committee that the Commercial Crew Program "is a partnership between the Agency and the private sector to incentivize companies to build and operate safe, reliable, and cost-effective commercial human space transportation systems."[27] Gerstenmaier also stated that safety was the key issue for the agency and said that both SpaceX and Orbital had to successfully reach each milestone before they would be paid.

Satellites

The major manufacturers of satellites include Boeing (U.S.), Lockheed Martin Space (U.S.), Space Systems/Loral (U.S.), Thales Alenia Space (Europe), and EADS Astrium (Europe). Other manufacturers include ATK (Virginia), Ball Aerospace (Colorado), Northrop Grumman Corporation (Virginia), and Sierra Nevada Corporation (Nevada). In the United States, as in Europe, commercial satellite manufacturers also build the government (military and civil) satellites that have been major drivers of space-enabled consumer products. Military satellites provide global positioning system (GPS) data, and the NOAA satellites furnish weather-related data for consumer electronics (cell phones, GPS devices, automobile navigation systems, etc.). The demand for mobile devices has also increased demand for commercial communications and broadcast satellites—a synergistic combination of government and commercial technologies that have created new markets and, in turn, new demand for space equipment.

Because satellites are complex, custom-built platforms designed to operate in the harsh environment of space, the time it takes to order, design, build, and launch a satellite can be measured in years. U.S. satellite orders and deliveries rise and fall from year to year (see **Figure 2**), as does the U.S. share of global satellite manufacturing revenues, which are recorded only

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[25] Ibid.

[26] U.S. Congress, House of Representatives, Committee on Science, Space and Technology, "Written Testimony of Lieutenant General Thomas P. Stafford, USAF (ret.), Chairman, International Space Station Advisory Committee," *Securing the Promise of the International Space Station: Challenges and Opportunities*, Hearing, March 28, 2012.

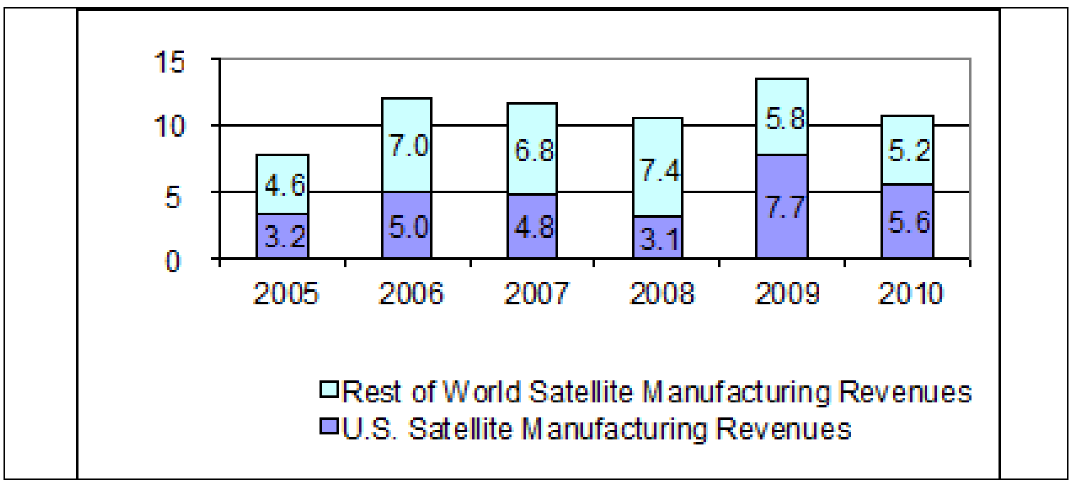
[27] Committee on Science, Space and Technology, "Statement of William H. Gerstenmaier, Associate Administrator for Human Exploration and Operations, National Aeronautics and Space Administration," Hearing, March 28, 2012.

when a satellite is delivered. In 2010, U.S. revenues fell 27%, to $5.6 billion (including $3.4 billion in commercial satellite revenues), from $7.7 billion the previous year.[28]

Although U.S. satellite manufacturers captured nearly 52% of global satellite revenues in 2010, the U.S. share of global satellite revenues has fallen from 75% in 1995. U.S. aerospace industry groups assert that the decline in U.S. satellite market share has been exacerbated by 1998 legislation classifying all satellites and satellite parts and equipment as weapons subject to licensing under more stringent arms export control rules (see discussion below).[29] The aerospace and satellite manufacturing industry believes that other countries have looked to non-U.S. manufacturers for satellites that do not contain U.S. parts or components that are subject to U.S. arms export controls. The U.S. commercial space industry may have become more dependent on U.S. military sales as foreign suppliers actively sought to displace U.S. manufacturers from the commercial satellite market.

Figure 2. U.S. and Global Satellite Manufacturing, 2005-2010

Billions of Current Dollars



Source: Satellite Industry Association, *State of the Satellite Industry Report*, August 2011, p. 17.

Between 2001 and 2010, the United States manufactured 386 satellites of a global total of 1,012, or 38.1%. European and Russian manufacturing shares remained relatively stable at 18.6% and 21.6%, respectively (see **Figure 3**).[30] Other countries, including those with space programs (China, Japan, South Korea, and India), accounted for the remaining 21.7% of output.[31] These data include satellites manufactured for commercial and government customers. The U.S. share of global satellite manufacturing revenues (at nearly 52%) in 2010 is well above the U.S. share of

[28] SIA/Futron, *State of the Satellite Industry Report 2011*, August 2011, p. 15.

[29] The Strom Thurmond National Defense Authorization Act for Fiscal Year (FY) 1999 (P.L. 105-261, 112 Stat. 1920, 2173-74 (1998), 22 C.F.R. U.S.C. 2278).

[30] Futron Corp., *Futron's 2011 Space Competitiveness Index: A Comparative Analysis of How Countries Invest In and Benefit from Space Industry*, Bethesda, MD: Futron Corp., 2011, p. 12.

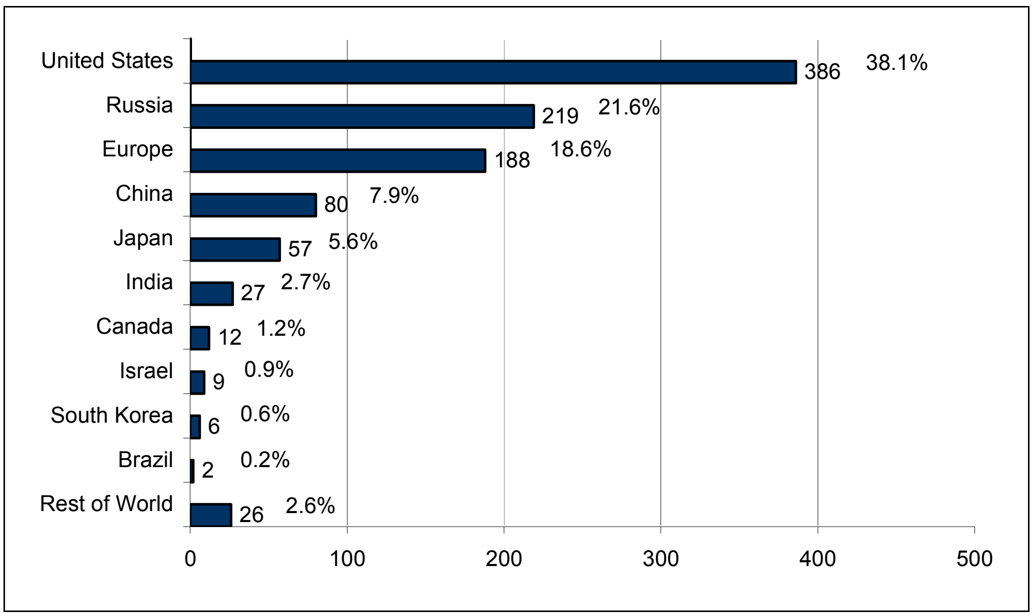
[31] Satellite Industry Association, *State of the Satellite Industry Report*, prepared by Futron Corporation, August 2011, pp. 15-16. The data do not include government-built, university-built, or research satellites.

the total number of satellites built worldwide between 2001 and 2010 (38%). This difference reflects the higher value of U.S.-manufactured commercial satellites.[32]

In 2011, 11 U.S.-built commercial communications satellites were manufactured by Orbital Sciences (4), Space Systems/Loral (4), Lockheed Martin (1), and Spacequest (2). Three U.S.-built satellites were launched by Arianespace (a European company), one by Land Launch (using a Ukrainian Zenit vehicle launched from the Baikonur Cosmodrome in Kazakhstan); five by International Launch Services (ILS)[33] (using a Russian Khrunichev-built Proton rocket launched from Baikonur, Kazakhstan), and two by International Space Company Kosmotras (using a Dnepr rocket launched from Dombarovskiy, Russia).[34]

Figure 3. Number of Satellites Manufactured by Country or Region

2001-2010



Source: Futron Corp., *Futron's 2011 Space Competitiveness Index: A Comparative Analysis of How Countries Invest In and Benefit from Space Industry*, Bethesda, MD: Futron Corp., 2011, p. 12.

[32] In 2010, 10 commercial satellites manufactured in the United States were launched. U.S.-manufactured commercial satellites were valued at $1.75 billion, or, on average, $175 million each. The 17 non-U.S. manufactured commercial satellites that were launched in 2010 were valued, on average, at $98 million apiece. See The Space Foundation, *The Space Report 2011*, p. 34.

[33] According to ILS's parent company's website, "ILS company registered in the U.S. in 1995, is headquartered in Reston, Virginia. Controlling stake in ILS owned by the Russian State Research and Production Space Center Khrunichev (Moscow), developer and manufacturer of the rocket 'Proton' …" Translated from Russian. http://www.khrunichev.ru/main.php?id=67.

[34] Kosmotras launched two Spacequest microsatellites into low-Earth orbit. Spacequest is a Fairfax, Virginia company.

Employment in the U.S. Space Industry

U.S. government data on space-related employment provide only a broad indication of the number of workers employed in the space industry, and, because of industry definition issues and suppression of nondisclosable data, employment in specific manufacturing sectors cannot be accurately gauged. Data suppression makes it difficult to compare data from year to year. The Space Foundation provides estimates of employment in the space industry, broadly defined. The Space Foundation uses six broad categories that are defined in the North American Industry Classification system (NAICs)[35] (see **Table 2**), some of which may contain non-space industry workers (e.g., search, detection, and navigation instruments) or include service sector (information technology) workers or NASA civilian employees engaged in launch or satellite operations.

Other NAICS categories that contain space industry workers are omitted because they do not provide enough information to determine the number of space industry jobs. Another issue is that workers in three of the NAICS categories involving production of guided missiles and space vehicles are combined so that it is impossible to distinguish between workers who manufacture weapons from those who make launch equipment and/or spacecraft. Nevertheless, the Space Foundation's choice of data provides insight into the overall group of workers that comprise the space industry labor force, including engineers, scientists, and highly skilled production workers.

Annual average earnings in the aerospace sector for production workers and engineers tend to be higher than the average for all industries.[36] According to the Bureau of Labor Statistics, "Above-average earnings reflect, in part, the high levels of skill required by the industry due to the high quality standards of their products. The earnings may also reflect longer average hours worked each week in the industry. Nonproduction workers, such as engineering managers, engineers, and computer specialists, generally command higher pay because of their advanced education and training."[37] BLS data (see **Table 3**) also indicate that employees in the space sector were, on average, somewhat better paid than workers in aircraft and aircraft parts manufacturing.

In 2010, aircraft manufacturing workers averaged $88,737 in annual earnings, while guided missile and space vehicle manufacturing employees had average annual earnings of $106,830. The approximately 20,000 workers who manufactured propulsion units and parts or parts for guided missiles and space vehicles had lower average annual earnings than those involved in assembling guided missiles and space vehicles. Employees in the search, detection, and navigation instruments category earned more than aircraft manufacturing workers and more than guided missile propulsion and parts workers and guided missile and space vehicle parts and auxiliary equipment employees. The higher average annual earnings reflect the skills involved in creating and assembling the sophisticated electronics products that are critical to guided missiles, spacecraft, satellites, and ground infrastructure. The search, detection, and navigation instruments industry also includes jobs associated with the creation and assembly of consumer navigation equipment for automobiles and cell phones.

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[35] The North American Industry Classification System (NAICS) is the standard used by Federal statistical agencies in classifying business establishments for the purpose of collecting, analyzing, and publishing statistical data related to the U.S. business economy.

[36] Aerospace Industries Association: http://www.aia-aerospace.org/assets/stat14.pdf; BLS, *Career Guide to Industries, 2010-11 Edition*, "Aerospace Product and Parts Manufacturing." http://www.bls.gov/oco/cg/cgs006.htm.

[37] BLS, "Aerospace Product and Parts Manufacturing." http://www.bls.gov/oco/cg/cgs006.htm.

Table 2. U.S. Space Industry Employment by Sector

Category Name and NAICS Code	**2005**	**2008**	**2009**	**2010**
Search, Detection, and Navigation Instruments (NAICS 334511)[a]	155,492	153,741	150,415	147,519
Guided Missile and Space Vehicle Manufacturing (NAICS 336414)[b]	53,316	54,339	55,303	53,911
Guided Missile and Space Vehicle Propulsion Unit and Parts Mfg. (NAICS 336415)[c]	13,115	15,272	14,638	12,673
Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment Mfg. (NAICS 336419)[d]	7,423	7,842	8,033	7,964
Satellite Telecommunications (NAICS 517410)[e]	16,349	12,937	13,159	11,668
Federal Space Research and Technology (NAICS 927110)[f]	18,766	18,474	18,448	18,580
Space Industry Employment Total	264,461	262,605	259,996	252,315

Source: The Space Foundation, *The Space Report 2011*, p. 103. The data in this table are from Bureau of Labor Statistics (BLS), *Quarterly Census of Employment and Wages*.

Notes: This table reflects the broad pool of workers who manufacture products for the space industry, engage in satellite and spacecraft operations, or engage in space research and technology development.

a. Includes the manufacturing of search, detection, navigation, guidance, aeronautical, and nautical systems and instruments.

b. Includes the manufacturing of complete guided missiles and space vehicles and/or developing and making prototypes of guided missiles or space vehicles.

c. Includes the manufacturing of guided missile and/or space vehicle propulsion units and propulsion unit parts and/or developing and making prototypes of guided missile and space vehicle propulsion units and propulsion unit parts.

d. Includes the manufacturing of guided missile and space vehicle parts and auxiliary equipment (except guided missile and space vehicle propulsion units and propulsion unit parts) and/or developing and making prototypes of guided missile and space vehicle parts and auxiliary equipment.

e. Includes telecommunications services provided to other establishments in the telecommunications and broadcasting industries by forwarding and receiving communications signals via a system of satellites or reselling satellite telecommunications.

f. Includes government establishments primarily engaged in the administration and operations of spaceflights, space research, and space exploration. Included in this industry are government establishments operating space flight centers.

With the exception of search, detection, and navigation instruments (NAICS 334511), data on space manufacturing employment are not available on a state-by-state basis. BLS data are available for California, but are suppressed for nearly all other states. California, with the largest number of workers in the aerospace industry (109,663 in 2010), had 59,580 employees in the space industry, of which nearly 41,000 (69%) worked in search, detection, and navigation instrument manufacturing. Missile and spacecraft manufacturing (NAICS 336414) had 106,830 employees in 2010, of which 15,585 (14.6%) worked in California. Eighteen states employed more than 1,000 workers in the manufacture of search, detection, and navigation instruments, with average annual earnings ranging from $130,414 in Colorado to $51,936 in Georgia.[38]

[38] BLS, *QCEW*.

Table 3. U.S. Space Industry Average Annual Pay by Manufacturing Sector

Category Name and NAICS Code	2005	2008	2009	2010
Search, Detection, and Navigation Instruments (NAICS 334511)	83,750	91,393	93,363	96,174
Guided Missile and Space Vehicle Manufacturing (NAICS 336414)	90,176	103,111	105,081	106,830
Guided Missile and Space Vehicle Propulsion Unit and Parts Mfg. (NAICS 336415)	68,100	75,362	80,267	87,570
Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment Mfg. (NAICS 336419)	71,174	83,709	87,014	89,861

Source: Bureau of Labor Statistics (BLS), *Quarterly Census of Employment and Wages*.

Policy Issues

Federal laws and regulations are of major importance to the space equipment manufacturing industry. Although many of these measures were developed principally with reference to military concerns, they may also affect the U.S. commercial space industry because of the interrelationship between commercial and government use of space described earlier.

Export Controls and Commercial Satellites[39]

In 1998, Congress passed the Strom Thurmond National Defense Authorization Act for Fiscal Year 1999,[40] which reclassified all satellites, including commercial satellites and their parts and components, as munitions. This transferred jurisdiction of export licensing approvals for satellites from the Department of Commerce, which licenses "dual-use" exports (i.e., exports that are primarily for civilian use, but which potentially have military uses) under the Export Administration Act,[41] to the State Department, which administers the International Traffic in Arms Regulations (ITAR).[42] ITAR designation means that satellites were placed on the U.S. Munitions List (USML) and thus became subject to a much higher degree of scrutiny because of a presumption that the export of munitions potentially threatens U.S. national security. In testimony before the House Foreign Affairs Committee in February 2012, Patricia Cooper, president of the Satellite Industry Association, noted that the reclassification of satellites "arose from concerns in the late 1990s that U.S. technology was not protected after two failures of Chinese launches of

[39] For a discussion of the Export Administration Act (EAA) and debate over reauthorization in the 112th Congress, see CRS Report R41916, *The U.S. Export Control System and the President's Reform Initiative*, by Ian F. Fergusson and Paul K. Kerr.

[40] P.L. 105-261, 112 Stat. 1920, 2173-74 (1998), 22 C.F.R. U.S.C. 2278.

[41] The Export Administration Act of 1979 ("EAA", P.L. 96-72; 93 Stat. 503) authorizes the President to restrict exports of dual-use commodities for national security, foreign policy, or short supply purposes. The EAA, which most recently expired in 2001, has not been significantly revised since 1988, before the fall of the Soviet Union, in spite of numerous attempts by those who favor expanding U.S. exports, focusing the legislation on current national security threats, and increasing penalties for violations.

[42] ITAR is a set of U.S. regulations that control U.S. exports of items and services on the United States Munitions List (USML). Items on the USML are licensed by the Department of State. *International Traffic in Arms Regulations*, 22 C.F.R. 120.3.

U.S.-made satellites."[43] Cooper testified that a blanket imposition rather than a country-specific one had harmed the U.S. satellite industry.

The reclassification of commercial satellites as munitions was highly controversial within the U.S. aerospace industry, due in part to the decision by the United States to impose unilateral export controls on commercial satellites without corresponding actions by European and Japanese governments. Foreign competitors immediately grasped the competitive disadvantage facing U.S. satellite exporters. In the early 2000s, Alcatel, a French company, announced that it would produce "ITAR-free" satellites for export and by 2004 had doubled its market share.[44] Leading firms joined a European Space Agency (ESA) initiative in 2004 to develop technologies and systems hitherto available only from U.S. companies in an effort to boost European market share.[45]

Thales Group, formerly known as Thomson-CFS, acquired Alcatel's space business in 2007, and the space subsidiary, now Thales Alenia Space, sells ITAR-free satellites. According to *SpaceNews.com*, for more than three years the State Department has been conducting a so-called "Blue Lantern" inquiry into whether sales of the Spacebus, a satellite produced by Thales Alenia Space, violate U.S. export control laws. The company and the State Department are reportedly at an impasse over a State Department request for the complete design of the Spacebus and a list of all components. In a January 5, 2012, interview with *Space News International*, Edgar Buckley, Thales Group senior vice-president for Europe and NATO, said that the company could not provide the satellite design: "We will give an outline of the design. And we cannot give you a complete list of components. We cannot do that under French law."[46]

In her testimony, Cooper said that the number of ITAR-free satellites launched rose from 6 by April 2009 to 13 by February 2012, with another 7 on order. She also cited a Department of Defense study that estimated the amount of lost export sales due to ITAR controls between 2003 and 2006 at $2.35 billion.[47] According to the Satellite Industry Association (SIA), a U.S.-based trade association that represents many U.S. and foreign satellite operators, service providers, manufacturers, launch service providers, and ground equipment suppliers, U.S. satellite manufacturers saw their share of the global market fall from 75% in 1995 to 41% in 2005; it has hovered between 35% and 50% since.

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[43] U.S. House of Representatives, Committee on Foreign Affairs, Export Controls, Arms Sales, and Reform: Balancing U.S. Interests (Part II), Hearing, Written Testimony of Patricia A. Cooper, Satellite Industry Association, February 7, 2012.

[44] Antonella Bini, "Export control of space items: Preserving Europe's advantage," *Space Policy* 23 (2007), p. 70-72.

[45] Ibid., p. 70.

[46] See Peter B. de Selding, "U.S., Thales at Odds Over Request for ITAR-Free Satellite Design Information," *SpaceNews.com*, January 6, 2012. Blue Lantern is an end-use monitoring program required under Sect. 40A of the Arms Export Control Act that allows the State Department to verify the end-users and end-uses of U.S. exports of defense articles. The investigations are carried out by U.S. Embassy personnel. Among other reasons, Blue Lantern inquiries are carried out in response to "high interest by Congress, media, and non-governmental organizations." "U.S. Department of State. Blue Lantern Program," presentation by Judd Stitziel, Bureau of Political-Military Affairs, at the Eighth International Export Control Conference, Bucharest, 6-8 March 2007. http://exportcontrol.org/library/conferences/1379/STITZIEL_—_Blue_Lantern_PPT_for _Bucharest_Conference_March_06.pdf.

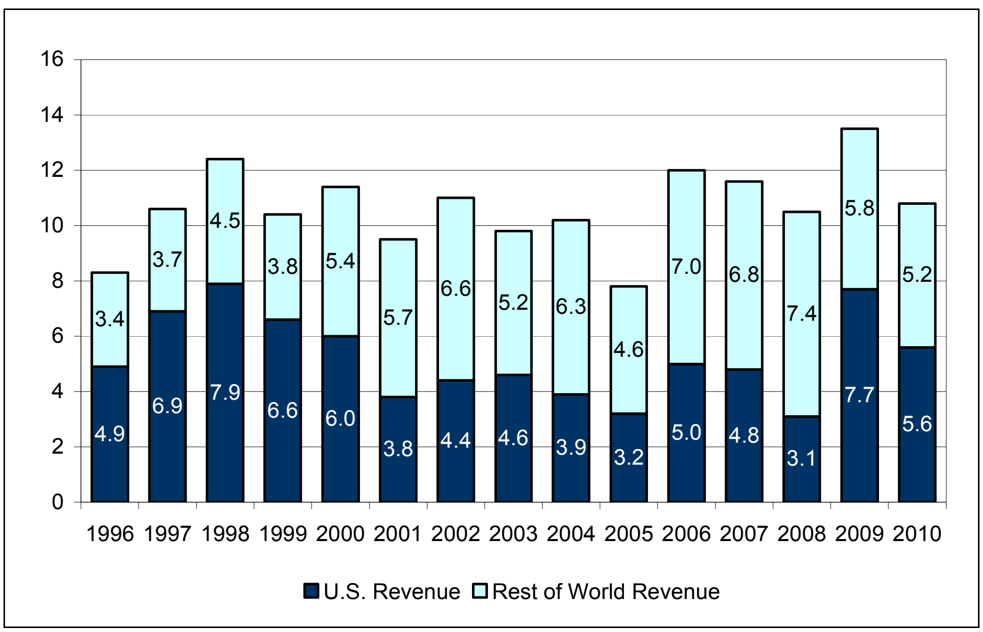
[47] See U.S. Department of Defense, *Defense Industrial Base Assessment: U.S. Space Industry*, August 31, 2007, p. 34.

Satellite revenues for the United States and the rest of the world averaged $10.7 billion per year between 1996 and 2010 (see **Figure 4**). The average U.S. share of global satellite manufacturing revenues for the period 1996 to 2010 was 49%. For 1996 to 1999, the U.S. share of the satellite market averaged 63%. From 2000 through 2010, when ITAR controls on satellite exports were fully in effect, that share fell to an annual average of 40%. After hitting a low below 30% in 2008, satellite deliveries recovered in 2009 (to 57%) before declining to 52% in 2010. U.S. satellite manufacturers' share of global revenues declined from an average of $6.6 billion per year between 1996 and 1999 to $4.7 billion per year between 2000 and 2010. Sales in 2009 and 2010 were generally more favorable, but whether this represents a trend or a bunching up of deliveries is not clear.

In 2009, the Obama Administration initiated a comprehensive review of U.S. export controls, and in April 2010, then-Defense Secretary Robert Gates outlined measures for reform, including a single agency responsible for dual-use and munitions exports, a unified export control list, a single agency to coordinate enforcement activities, and an integrated information technology system to prevent exports to sanctioned and denied parties. The United States also participates in a number of multilateral export control regimes that are focused on chemical and biological weapons (the Australia Group); missile technologies (the Missile Technology Control Regime); nuclear materials, equipment, and technology (the Nuclear Suppliers Group); and the promotion of regional and international security and stability (the Wassenaar Arrangement). None of these international regimes control satellites as munitions.

Figure 4. Share of Satellite Manufacturing Revenues

1996-2010 (Billions of Nominal U.S. Dollars)



Source: Satellite Industry Association/Futron Corp., *State of the Satellite Industry Report*, various years.

The National Defense Authorization Act for Fiscal Year 2010 (P.L. 111-84, Section 1248) provides that the Secretary of Defense and the Secretary of State shall carry out an assessment of the national security risks of removing satellites and related components from the United States Munitions List (USML). On April 18, 2012, the Departments of Defense and State issued a report to Congress that found that "if authorized by the Congress, the risks due to removing space-related dual-use items from the USML could be acceptably managed through controls and licensing policies under the CCL [Commodity Control List]."[48] The report identified two types of satellites and related items "that are not purely defense-related": communications satellites that do not contain classified components and remote sensing satellites with performance parameters below certain thresholds, as well as the systems, subsystems, parts, and components associated with those satellites and with performance parameters below certain thresholds.[49]

The report calls for relaxed controls on allies and partners, continued controls as agreed upon in multilateral trade control arrangements, and "strict controls on transfers of non-critical space-related items to end-users and for end-uses that are likely to be used against the U.S. national interests," including prohibitions of exports or re-exports to countries that are subject to U.S. arms embargoes or to which exports or sales are prohibited under the ITAR.[50] The report also calls for a return to the President of the authority to determine the export control jurisdictional status of satellites and related items.[51]

Legislation has been introduced in the 112th Congress to shift control of satellites from the U.S. Munitions List to the Commodity Control List. Representative Rohrabacher introduced an amendment to the National Defense Authorization Act of 2012 (H.Amdt. 331, H.R. 1540) on May 25, 2011, to allow the President to transfer satellites and related components from the USML. The amendment's sponsor subsequently withdrew the amendment pending the release of the final Section 1248 report. Legislation (H.R. 3288) to allow the President to transfer satellites and components from the USML was introduced by Representative Berman on November 1, 2011. That bill would continue the prohibition on satellite sales to or launches by China, or to countries designated as state sponsors of terrorism (Cuba, Iran, Sudan, Syria) and North Korea.[52]

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[48] U.S. Departments of Defense and State, *Risk Assessment of United States Space Export Control Policy: Report to Congress*, April 18, 2012, p. 6.

[49] Ibid., p. 1.

[50] Ibid., p. 4.

[51] Ibid., p. 9.

[52] Additional analysis is contained in CRS Report R41916, *The U.S. Export Control System and the President's Reform Initiative*, by Ian F. Fergusson and Paul K. Kerr.

In remarks to the Defense Trade Advisory Group on November 9, 2011, Assistant Secretary of State for Political-Military Affairs Andrew Shapiro said, "Our work is focused now on the removal of the majority of parts and components from the USML to the Commerce Control List (CCL)[53] in these categories."[54] However, as Shapiro pointed out, unlike the other items on the U.S. Munitions List, which can be reclassified by the President, satellites were placed on the list by law and congressional action would be required to remove them. Although there have been numerous discussions in committees about the issue of commercial satellites, export control legislation has generally been difficult to pass.

The Aerospace Industries Association, representing the majority of U.S. aerospace firms, published a study in January 2012 that contends that the United States' space and defense industrial base is weakening as exporters large and small encounter difficulties exporting commercial communications satellites and parts and components that are incorporated in commercial satellites.[55]

Spectrum Allocation, Regulation, and Demand for Satellite Services

The allocation of spectrum and orbital location have posed, and will continue to pose, large problems for an international industry that could consume an almost unlimited amount of both, were physical supply not an issue. However, both spectrum and satellite orbital position are scarce resources and governments regulate and allocate the use of radio spectrum on earth and in space.[56] Spectrum allocation is intended to prevent signal interference, but it also imposes a limit on the amount of capacity available to satellite and terrestrial service providers.[57] Domestic and international regulatory regimes are limited in terms of their ability to respond to capacity problems that affect satellite operators and consumers. But satellite network operators and their customers have increasingly sought technological solutions to the challenge of limited spectrum. With the increasing use of high-power Ku- and Ka-bands, larger amounts of data can be transmitted without increasing the number of transponders.

[53] The Commerce Control List (CCL) is maintained by the Department of Commerce Bureau of Industry and Security. The list includes items (commodities, software, and technology) that are subject to export licensing requirements. The CCL is included in the Export Administration Regulations (EAR), which are published in 15 C.F.R. 774, Supplement 1. See http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&sid=ba2d5996d28cc22033ea2bfb857555cc&rgn=div5&view=text&node=15:2.1.3.4.45&idno=15.

[54] A/S Shapiro, "Remarks to the Defense Trade Advisory Group," November 9, 2011.

[55] Aerospace Industries Association, *Competing for Space: Satellite Export Policy and U.S. National Security*, January 2012.

[56] Matlaxen Sánchez Aranzamendi, *Economic and Policy Aspects of Space Regulations in Europe. Part 2: Space Related Regulations—On Track for Space Technologies and Space Based Services*, European Space Policy Institute, Report 36, June 2011, p. 10.

[57] The amount of capacity is measured in transponder equivalents (TPEs). A TPE is a standardized measure that "is used to define the total transmission capacity on satellites having a bandwidth of 36 [megahertz] MHz." See Anil K. Maini and Varsha Agrawal, *Satellite Technology: Principles and Applications*, 2nd ed., 2011, p. 381.

U.S. regulations provide for government approval of the allocation of bandwidth and the use and positioning of satellites for communications (under the jurisdiction of the Federal Communications Commission) and for remote sensing (for which NOAA regulates commercial operators).[58] Other countries also have varied laws and regulations for communications, navigation, and remote-sensing satellites. The United Nations, through the International Telecommunications Union (ITU), manages an international treaty, known as the Radio Regulations, to "ensure the rational, equitable, efficient and economical use of the radio-frequency spectrum by all radio communication services, including those using satellite orbits."[59] One problem that is widely acknowledged is that some countries file an excessive number of applications for orbital locations and frequency assignments in order to reserve space, even though they are unlikely to deploy satellites that would use the frequencies or orbits. This practice deters other users from expanding their services or entering the market.[60] Although there are rules that allow for periodic review of underutilization of spectrum and orbital placement, the process is time consuming. Conflicts over satellite spectrum and positioning also occur, and the ITU lacks enforcement mechanisms for resolving such disputes.[61]

The rapid evolution and proliferation of new bandwidth-intensive consumer, civil, and military technologies (such as broadband Internet services; satellite television and high definition television [HDTV] channels;[62] growth in corporate enterprise networks; and military purposes such as airborne intelligence, surveillance, and reconnaissance, satellite links to ground troops, and intensified use of unmanned aerial vehicles) threatens to destabilize existing regulatory regimes that have been characterized as "command and control" models that award a specific amount of bandwidth to specific users. Once placed in its specified orbit, a satellite is limited to the bandwidth allocated to it and the option to switch transmission to a different bandwidth is not feasible.[63] From the perspective of bandwidth-hungry consumers, this leads to a less than optimal allocation of spectrum and underutilization of existing capacity.[64] Greater use of fiber to transmit signals could mitigate this problem slightly by reducing demand to some degree. Fiber costs are not trivial, however.

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[58] Joseph Fuller, Jr., Jeffrey Foust, Chad Frappier, Dustin Kaiser, and David Vaccaro, "The Commercial Space Industry: A Critical Spacepower Consideration," in Charles D. Lutes and Peter L. Hays (eds.), *Toward a Theory of Space Power: Selected Essays*, Washington, DC: National Defense University Press, 2011, Electronic version unpaginated.

[59] "Space-related Activities," ITU Presentation. 28th United Nations Inter-Agency Meeting on Outer Space Activities, Geneva, 16-18 January 2008; ITU portal: http://www.itu.int/ITUR/index.asp?category=information&rlink=iturwelcome&lang=en.

[60] Government Accountability Office (GAO). *Competition, Capacity, and Costs in the Fixed Satellite Services Industry*, GAO-11-777, September 2011, pp. 24-29.

[61] *SpaceNews.com*, "ITU Board Fails To Resolve Dispute over Iranian Service," November 4, 2011, and "Ariane 5 Picked To Launch Satellite to Disputed Slot," March 12, 2012. After a number of meetings to consider a dispute over rights to an orbital position between Iran and Saudi Arabia, on one side, and France and Qatar, on the other, over the placement of a Eutelsat/Qatari satellite within one-half degree of a Saudi Arabian/Iranian satellite, the ITU "has repeatedly asked Iran, France, Qatar and Saudi Arabia to resolve frequency coordination issues around 26 degrees east on their own—with no success so far."

[62] In Europe in 2011, satellite television (with 86 million homes) surpassed terrestrial television (or over-the-air television) (with 79.4 million homes) for the first time, as well as cable television (with 69.2 million homes), according to a market survey sponsored by SES, a European satellite fleet operator. *SpaceNews.com*, "Satellite Overtakes Terrestrial Television in Europe," March 29, 2012.

[63] Ibid., pp. 10-11.

[64] Ibid., pp. 12-13.

In Europe, the demand for capacity has outpaced the available spectrum, and regulators are under pressure to adapt to more flexible systems that allow for greater and more efficient use of fixed satellite services, but there appear to be limits to finding a solution to the problem. European satellite operators are unwilling to cede their exclusive frequency bands, and they see the Radio Regulations as a bulwark against a move to a more liberal regime.

In its most recent forecast of satellite services demand, Futron concluded that "ongoing debates regarding spectrum allocation could result in operators facing a constrained or reduced ability to maintain certain types of supply and to meet the needs of certain markets effectively in the future."[65] But Futron also points to the adoption of operating efficiencies and fleet optimization strategies that have allowed satellite operators to better meet demand, and while the number of satellites or transponders may be limited by spectrum or orbital locations, technical solutions allow greater throughput for a given number of transponders per satellite. The shift to multiband payloads (using high-power frequency bands that are capable of carrying much higher capacities) and the use of higher power applications produce higher levels of throughput that overcome some of the limitations imposed by spectrum scarcity. Futron forecasts that the supply of fixed satellite capacity of major operator fleets will decline slightly through 2019 (with capacity measured in terms of transponder equivalents) even as demand continues to grow in terms of throughput capacity.[66]

Increased DOD Use of Commercial Satellites

Unlike the previous section, which focused on the challenges posed by limited spectrum and orbital position, this section discusses the shift by the Department of Defense from a near total reliance on military-owned and -operated satellites to a reliance on leased commercial communications satellite capacity to meet its needs for additional satellite bandwidth.

With increased satellite efficiency and the ability to increase the amount of throughput per transponder, the Department of Defense, which has experienced dramatic increases in demand for satellite bandwidth, has turned to commercial satellites to handle a significant portion of military communications, thus preserving capacity on military satellites for high-level intelligence data. Military satellites are much more expensive than commercial satellites. Military satellites also take much more time to build and launch than commercial satellites.

Futron has estimated that global demand consumed approximately 79% of fixed satellite service (FSS)[67] capacity in 2011. In part, the spare capacity serves as a reserve in the event of a loss of one or more satellites. But even with some surplus capacity, the U.S. Department of Defense has

[65] Futron, *2010 Futron Forecast of Global Satellite Services Demand, Executive Summary*, Bethesda, MD: Futron, 2010, p. 4.

[66] Ibid.

[67] Fixed satellite service (FSS) "refers to the two-way communication between two Earth stations at fixed locations via satellite. It supports the majority of commercial applications including satellite telephony, satellite television and data transmission services." Maini and Agrawal, *Satellite Technology: Principles and Applications*, p. 277. FSS, or geosynchronous, communications satellites are positioned at an altitude of 22,236 miles above the Equator in an orbit that is geostationary. The satellite rotates with the Earth's orbit in a position that is stationary or fixed relative to the Earth. This allows ground-based antennas (television satellite dishes or antennas that connect to cable TV company head-ends) to permanently point at a satellite from a fixed position.

run up against capacity constraints in the Middle East, in part because of a shortage of satellites that meet DOD requirements.[68]

The increased use of commercial capacity by the military has provided a stimulus to private-sector investment in satellites. In part, short-term sales of satellite capacity or bandwidth, for contractual periods of up to a year, have allowed satellite operators to command premium prices. Demand has risen steadily for nearly a decade. However, the unplanned and unbudgeted demand for commercial satellite bandwidth does not provide a stable business model for satellite service providers if that demand is temporary and subject to termination years before a satellite's effective lifespan is up. Satellites are typically built to meet the specific requirements of long-term customers and few, if any, satellite operators will buy and launch a satellite unless long-term customers have contracted for most of the available capacity of the satellite. With the wars in Iraq and Afghanistan winding down, satellite operator Eutelsat has warned investors that its sales of short-term capacity to DOD will not continue to increase as rapidly as in the recent past, although the company has taken the position that DOD demand will likely remain strong as satellite capacity for troops in Iraq and Afghanistan is switched over to data-intensive streaming of videos from unmanned aerial vehicles.[69]

One of the issues of concern to the military and to commercial satellite operators has been the shift from a need for surge capacity to increased reliance on commercial satellites for core communications capabilities that meet military requirements. This shift has been the focus of a debate within DOD and among commercial satellite service providers and satellite manufacturers about a more integrated approach to the acquisition of commercial satellite services.[70] According to one observer, "Current estimates are that more than 80 percent of DOD's satellite bandwidth is purchased from commercial [satellite communication] companies. With increased use of unmanned aerial vehicles (UAVs) and other intelligence, surveillance, and reconnaissance assets in theatre, as well as high-definition video, that bandwidth allocation is expected to very quickly grow to more than 90 percent."[71] Under Secretary of Defense for Intelligence Michael G. Vickers noted at a November 2011 conference that the volume of intelligence, surveillance, and reconnaissance data collected in Afghanistan increased from a single terabyte (a terabyte of data equals 1,000 gigabytes) of data per day at the start of the war to 53 terabytes of data per day—an amount equivalent to 2.5 million full-length films.[72]

Because of the high level of demand for commercial satellite communications by DOD and other government agencies, the General Services Administration (GSA) and the Defense Information Systems Agency (DISA) established the Future Comsatcom Services Acquisition (FCSA) program in 2009 and extended and expanded it in 2012. The FCSA program allows commercial satellite providers to bypass a small group of middlemen and resellers who previously were the only authorized agents for commercial satellite contracts.[73] This will allow satellite operators to

[68] Futron, *2010 Futron Forecast of Global Satellite Services Demand, Executive Summary*, Bethesda, MD: Futron, 2010, p. 4.

[69] *SpaceNews.com*, "Eutelsat Forecasts Slower Pentagon Sales Growth," February 17, 2012. Eutelsat, a Paris-based company, provides coverage of Western Europe, Africa, Central and Eastern Europe, the Middle East, Central and South Asia, and Russia. In the second-half of 2011, DOD accounted for 12.5% of Eutelsat revenues.

[70] *Defense Systems*, "DOD's reliance on commercial satellites hits new zenith," February 25, 2010.

[71] Keith Norton, "Commercial Satcom remains vital to military operations," *Defense Systems*, August 22, 2011.

[72] *SpaceNews.com*. "Pentagon Struggles with Avalanche of Data," October 19, 2011, and *Defense Systems*, "Big data poses big challenge for military intelligence," March 29, 2012.

[73] According to the GAO, only "three vendors, all satellite service providers, were eligible to compete for fixed satellite (continued...)

expand their military customer base and better utilize capacity by allocating satellite capabilities between military and commercial users, while providing government agencies with greater efficiencies and costs that are similar to those for commercial users.[74]

GAO and DOD conducted studies that found that the cost of acquiring commercial bandwidth increased from 2003 through 2010 (GAO) and 2005 through 2009 (DOD). With the new FCSA program, the number of satellite service vendors will not be limited (previously there were only three eligible vendors), and satellite operators will also be allowed to compete to provide bandwidth. GAO and the Department of Justice Antitrust Division expect that increased competition under FCSA will result in lower bandwidth prices.[75] However, one major impediment to competition in the satellite sector is the cost of manufacturing, launching, and insuring a fixed service, or geosynchronous, communications satellite. According to GAO, the cost of manufacturing, launching, and insuring a fixed service satellite runs $200 million to $500 million. A basic network requires three or more satellites, so the high cost of satellites is a barrier to entry for new operators.[76]

The Department of Defense is a large user of geosynchronous satellites, and it could potentially play a significant role in encouraging more competition in the commercial satellite sector—especially if it is successful in deploying hosted payloads on commercial satellites. A hosted payload provides the military with the ability to include transponders and specialized military equipment on a commercial satellite, including observation, communications, space situational awareness, and space weather forecasting payloads that can be operated by the specific DOD customer. In March 2011, seven satellite manufacturers and operators formed a coalition to promote the use of hosted payloads.[77] Some concerns have been raised about allowing satellites with hosted payloads containing extremely sensitive U.S. military technologies to be launched anywhere but in the United States.[78]

Conclusion

The outlook for the United States commercial satellite sector is generally positive, notwithstanding the regulatory challenges mentioned in the last section. In 2010, the United States commercial satellite industry launched a total of 34 satellites for commercial and government customers—more than Russia (26) or Europe (24). According to Futron, the United States also claims four of the five largest space manufacturers, in terms of revenue (see **Table 4**). Even with the rise of countries such as China, India, and Brazil, the United States continues to enjoy a significant, albeit slowly diminishing, advantage in space, at least in part because the United States has a dynamic private sector that produces most of its output.

(...continued)

services task orders under DOD's DSTS-G contract. With the FCSA transponded capacity and subscription services contracting vehicles, there is no limit to how many eligible vendors, including satellite operators, can compete directly for fixed satellite services task orders." GAO, 11-777, p. 35.

[74] *Defense Systems*, "DOD's reliance on commercial satellites hits new zenith," February 25, 2010.

[75] GAO, 11-777, p. 12-13.

[76] Ibid., p. 30.

[77] *SpaceNews.com*, "7 Satellite Firms Form Hosted Payload Alliance," April 4, 2011.

[78] U.S. Departments of Defense and State, *Risk Assessment of United States Space Export Control Policy: Interim Report to Congress*, May 2011, p. 4.

The drawn-out transition from NASA's Space Shuttle program to a successor program may delay government procurement of the commercial equipment intended to replace the shuttle. Nonetheless, as military and NASA programs become more reliant on the private sector for transportation into space, U.S. commercial space equipment manufacturers will have access to a market that is largely closed to foreign competitors.

The prospects for the U.S. space equipment manufacturing industry in markets that are open to international competition are less certain. The rapid expansion of new consumer technologies and services that are space-enabled has led to the emergence of new competitors from many countries. U.S. manufacturers of launch vehicles, spacecraft, and satellites have a number of distinct advantages over many foreign competitors, including a very large aerospace industrial base capable of supporting commercial and government demand for space technologies and equipment. Additionally, the United States is pursuing policies that support and encourage competition, and numerous entrepreneurial firms are investing and developing launchers and spacecraft that may open new avenues for space exploration and travel. The United States also has a well-educated workforce and higher education system that is highly competitive internationally.

In its analysis of space competitiveness, Futron ranked the relative position of the United States, compared to other countries, and found that the U.S. decline in recent years is mainly attributable to advances achieved by Russia, China, Japan, and India. As the U.S. government's role in promoting human spaceflight has transitioned from the Space Shuttle to a strategy that relies on the private sector to develop products that are competitive and serve the broad U.S. goals and activities that were identified in the National Space Policy of June 2010, the U.S. launch industry has become dependent on government payloads and has continued to face stiff competition from Russia and Europe.[79] U.S. industry still maintains a wide lead in manufacturing for space. Although there are some vulnerabilities in the space industrial base (primarily in areas where some critical products are available from only one supplier or from limited foreign sources), the sector as a whole generates significant revenues and value-added and tends to be more entrepreneurial than in most other countries engaged in space activities.

A major weakness, however, that has been identified by some Members of Congress and a number of analysts is the general lack of public support for government funding of civil and military space programs. The authors of the Futron study, for instance, have observed that the U.S. space program may be perceived as not providing sufficient value to the nation. One consequence could be a further loss of competitiveness as other countries continue to strengthen their own space manufacturing capabilities and programs.

[79] Futron, "Executive Summary," *2011 Space Competitiveness Index: A Comparative Analysis of How Countries Invest In and Benefit from Space Industry*, 2011, p. 1-12.

Table 4. Global Ranking of U.S. and European Space Companies

RANK	Company	Total 2009 Sales (US$Million)	2009 Space Revenue (US$Million)
1	Lockheed Martin (Bethesda, MD)	$45,189	$10,900
2	Boeing (Chicago, IL)	68,281	7,310
3	EADS Astrium (Europe)	61,373	6,878
4	Northrop Grumman (Falls Church, VA)	33,755	6,010
5	Raytheon (Waltham, MA)	24,881	4,609
6	Garmin (Olathe, KS)	2,946	2,946
7	Thales Alenia Space (Europe)	2,902	2,902
8	Intelsat (Europe)	2,500	2,500
9	SES (Europe)	2,440	2,440
10	Computer Sciences Corp. (Falls Church, VA)	16,100	2,300
11	United Space Alliance (Houston, TX)	1,817	1,817
12	L-3 Communications (New York, NY)	15,600	1,700
13	General Dynamics (Falls Church, VA)	32,000	1,669
14	Alliant Techsystems (ATK) (Eden Prairie, MN)	4,808	1,600
15	Arianespace (Europe)	1,475	1,475

Source: Futron Corp., *Futron's 2011 Space Competitiveness Index: A Comparative Analysis of How Countries Invest In and Benefit from Space Industry*, Bethesda, MD: Futron Corp., 2011, p. 93.

Note: Some companies' total sales and space revenues are identical because their products are all space related.

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