SPACE FOUNDATION

THE SPACE REPORT

2012

The Authoritative Guide to Global Space Activity

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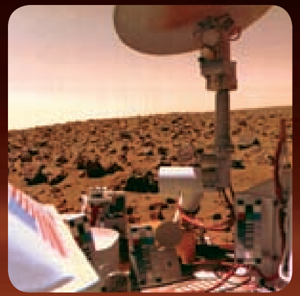
As humans we have a desire to know more, to learn about what is beyond our reach, beyond our view, and beyond our understanding. In 2011, we wished a safe journey to our surrogate space traveler, the Mars Science Laboratory, Curiosity, sending this latest rover to the Martian surface with new assignments and greater capability.

Curiosity is projected to touch down on August 5, 2012, near Gale Crater, which is shown on the cover of this book. The image is generated from data gathered by the Mars Orbiter Laser Altimeter, dramatically depicting the red planet between darkness and daylight.

The fascination with Mars, visible with the naked eye, began long before the invention of the telescope in the 1600s or the earliest attempts by the Soviet Union to send missions to Mars in 1960. Mars has been the focus of more than 40 missions, some successful and some not, all of which fueled human resolve to continue to develop the technologies needed to explore. Significant missions include Mariner 4's flyby in 1965, providing the first close-up photographs; the Viking landers in 1976; Mars Global Surveyor and Mars Pathfinder, which deployed the Sojourner rover, in 1997; Mars Odyssey in 2001; Mars Express in 2003; the Spirit and Opportunity rovers in 2004; Mars Reconnaissance Orbiter in 2006; and the Phoenix lander in 2008. Additional missions are underway or being considered by nations, space agencies, and collaborators around the globe.

Curiosity is the human characteristic that has sustained exploration throughout the centuries.



1976–1982 VIKING 1 and VIKING 2

Launched on August 20 and September 9, 1975, atop Titan III-E rockets with Centaur upper stages, Viking was an ambitious and groundbreaking mission. The Viking 1 and Viking 2 orbiters successfully detached landers for descent and soft landing on the surface of Mars, where they obtained images of the Martian surface, studied the atmosphere and surface of the planet, and searched for evidence of life on Mars. The Viking 2 lander operated 3 years, 7 months, 8 days, and Viking 1 continued 6 years, 3 months, 22 days until its shutdown on November 13, 1982.

1997 MARS PATHFINDER and SOJOURNER

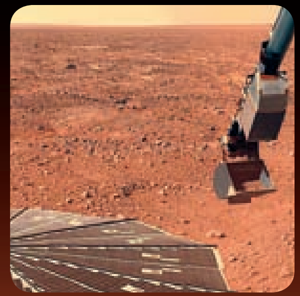
Launched by a Delta II rocket one month after Mars Global Surveyor left Earth's atmosphere, Mars Pathfinder landed in the rocky Ares Vallis on July 4, 1997. Upon landing, Pathfinder began taking pictures and atmospheric measurements. A day later, it deployed Sojourner, the first successful Mars rover. Sojourner provided 550 photographs and used its Alpha Proton X-ray Spectrometer to analyze 16 locations within 12 meters (40 feet) of Pathfinder. Despite expected lifetimes of one month for Pathfinder and seven days for Sojourner, the mission lasted nearly three months.

2004–2010 SPIRIT

The two Mars Exploration Rovers were launched separately, with Spirit landing on January 4, 2004, 21 days before Opportunity. Spirit last communicated with Earth in March 2010 after getting stuck in soft sand and freezing during the harsh winter. It remained operational about 24 times longer than its planned 90-day life. Among Spirit's notable accomplishments are the capture of more than 124,000 images and the discovery of silica deposits and carbonates. We learned from Spirit that Mars was once a geologically violent place, with hot springs, steam vents, and volcanic explosions.

2004–Present OPPORTUNITY

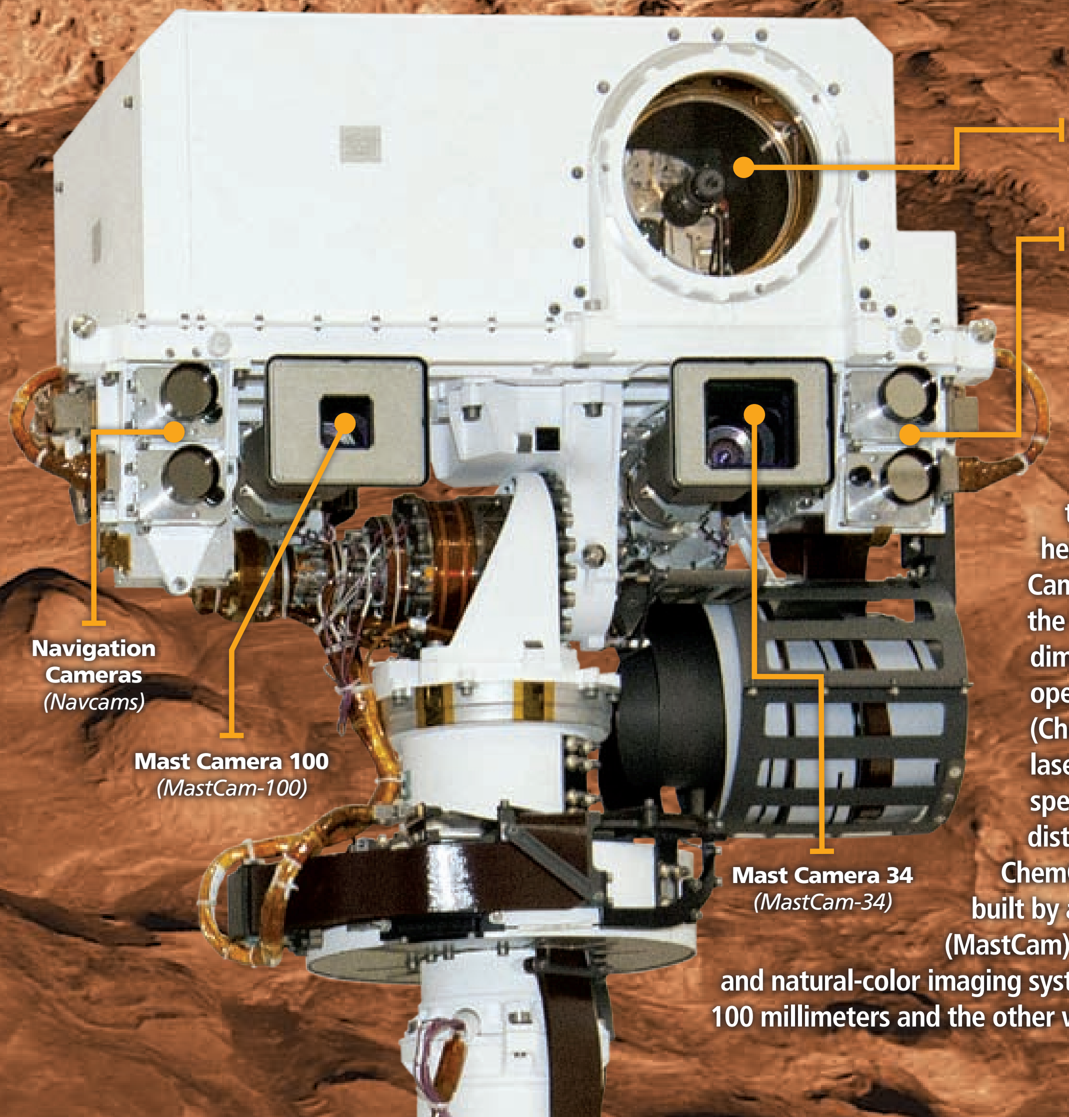
Designed to last just three months, the six-wheel, solar-powered Opportunity surpassed the endurance record set by Viking I and continues to explore Mars. In 2011, Opportunity arrived at the 22-kilometer (14-mile) wide Endeavour crater after a three-year journey to begin a new mission. Scientists now have access to geological deposits from an earlier period than any examined by previous Mars missions. Pushing the limits of survivability, Opportunity has spent the dangerous winter studying Martian wind and sending a radio signal that scientists on Earth can use to measure how much Mars "wobbles" as it rotates.



2008 PHOENIX

Landing in a polar region of Mars on May 25, 2008, Phoenix's mission was to search for environments suitable for microbial life on Mars, to research the geological history of water on Mars, and to evaluate planetary habitability. Phoenix was the first mission to return data from either of the poles and contributed to NASA's main strategy for Mars exploration, "Follow the Water." The Phoenix spacecraft was a joint project involving universities in the United States, Canada, Switzerland, Denmark, Germany, and the United Kingdom, as well as NASA, the Canadian Space Agency, the Finnish Meteorological Institute, and private aerospace companies.

The records are measured in Earth time. A Martian year is equivalent to 687 Earth days, or nearly two Earth years. A Martian day lasts 24 hours and 39.6 minutes.



CURIOSITY

This view of the remote sensing mast on the Mars rover Curiosity shows seven of the 17 cameras on the rover. On each side of Curiosity's head are two pairs of Navigation Cameras, which will be used to guide the rover and to capture three-dimensional images. The large circular opening is the Chemistry and Camera (ChemCam) instrument, which uses a laser and telescopic camera for remote spectroscopic analysis of rocks at a distance of up to 7 meters (23 feet). ChemCam was conceived, designed, and built by a U.S.-French team. The Mast Camera (MastCam) instrument includes two scientific and natural-color imaging systems, one with a focal length of 100 millimeters and the other with a focal length of 34 millimeters.

Cover Image:
Gale Crater separates the broad, flat, and young northern plains from the much older and rougher southern highlands of Mars. There is evidence that water may have flowed across this topographic boundary, from highland to lowland, perhaps pooling locally within Gale Crater and forming the lowermost strata that fill the crater. Gale Crater is 154 kilometers (96 miles) in diameter and holds a layered mountain rising about 5 kilometers (3 miles) above the crater floor. Gale Crater is the landing site for the Mars Science Laboratory mission; the rover will be placed on the ground in a northern region of the crater in August 2012.

This computer-generated view was created using three-dimensional information from the Mars Orbiter Laser Altimeter (MOLA), which flew on NASA's Mars Global Surveyor orbiter. The vertical dimension is not exaggerated. Color information is based on general Mars color characteristics. *Credit: NASA/JPL-Caltech.*

Inside Cover:
Background Image: *NASA/JPL-Caltech/ESA/University of Arizona. Original Image has been manipulated for design purposes.*
Curiosity Mast: *NASA/JPL-Caltech/MSSS*
Viking 1 and Viking 2: *NASA/JPL*
Mars Pathfinder and Sojourner: *NASA/JPL*
Spirit: *NASA/JPL-Caltech/Cornell University*
Opportunity: *NASA/JPL/Cornell University*
Phoenix: *NASA/JPL-Caltech/University of Arizona/Texas A&M University*

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EXECUTIVE SUMMARY

THE SPACE REPORT 2012

Out of more than 12,000 regions of the sky, this part of the Milky Way was voted the Favorite Nebula for 2011. The nebula, from the constellation of Scutum, was picked by the pool of 35,000 citizen scientist volunteers that study images from the Spitzer Space Telescope. The nebula can only be seen by an infrared telescope like Spitzer because it is hidden behind dust clouds. *Credit: NASA/JPL-Caltech/University of Wisconsin*

Introduction

Each passing year brings advances in space systems and technologies, as well as new applications and services that rely on them. There is a natural evolution of capabilities as governments and companies push the boundaries of what is possible, seeking ways to improve the lives of their citizens or customers. A number of events in 2011 marked a period of transition during this long-term process of capacity-building, as some major programs ended while others started or expanded, often leveraging the knowledge and physical assets left behind by their predecessors.

Space Shuttle *Atlantis*, now retired along with the rest of the shuttle fleet, is towed to a temporary storage area in the Vehicle Assembly Building at the Kennedy Space Center in Florida. Once it is prepared for public display, *Atlantis* will be relocated to the nearby Kennedy Space Center Visitor Complex. *Credit: NASA*

In the United States, the Space Shuttle Program drew to a close, resulting in the loss of national human space launch capabilities. Parts of the program will live on as some shuttle technology is adapted for NASA's next-generation Space Launch System, as existing infrastructure is modified to support future commercial and government launch vehicles. New ideas continue to flourish, ensuring that the utilization and exploration of space will continue to lead to scientific discoveries and improvements in life on Earth. Rising stars in the field of human spaceflight include nations such as China, which launched its first orbital laboratory module in 2011 and conducted an automated rendezvous with the laboratory using an uncrewed spacecraft.

Government spending, of which human spaceflight budgets constitute a minority, is just one element of space activity. Taking the commercial space industry into account along with government programs, the global space economy increased by more than $31 billion in 2011. Despite this very healthy growth, governments and companies anticipate pressure on spending in the near term due to conditions in the broader economy. To counteract this effect, spacefaring nations and the private sector increased efforts to cooperate and pool resources. Long a feature of scientific efforts to study and understand the space environment, collaboration among organizations active in space appears to be on the rise in non-scientific space endeavors as well. Although there will always be limits on the extent to which governments can share information and companies can discuss business practices, partnerships in space situational awareness and hosted payloads demonstrate the commitment of many space participants to maximize the returns on their investments by working together.

An application for phones and tablets running the Android operating system, Satellite AR offers an "augmented reality" experience that shows the user where spacecraft are in the sky. The user can zoom in for a closer view, touch a satellite icon on the screen for more detailed information, or plot an orbit as a ground track on Google Maps. *Credit: AGI*

In several major spacefaring countries, a significant portion of the space workforce is approaching retirement. This has caused concern that valuable skills, acquired over the course of decades of experience, may be lost as older employees leave the workforce. Recruitment and training will be essential to ensuring continuity of skills and operational capabilities. Each year, more than 1.5 million people worldwide receive bachelor's-equivalent degrees in space-relevant disciplines. This base of newly minted science, technology, engineering, and mathematics (STEM) graduates provides the labor pool to support future space activities that will generate benefits we can only imagine at present.

1.0 Space Products and Services

We rely on space products and services in countless ways every day. They quite literally help us find our way in the world, connect with each other, and learn about our environment. Space technology also generates spinoff products that have a space heritage but no longer require space systems in order to be useful. Although they may not be the primary motivator for engaging in space activity, these spinoffs have had a profound impact on society. In 2011, NASA reported the results of an effort to quantify some of the benefits of space spinoffs. Approximately 100 companies using spinoff technologies responded to NASA's survey, collectively reporting that more than 12,000 lives have been saved, more than 9,200 jobs have been created, and more than $6.2 billion in cost savings have been achieved. Taking into account the vast number of spinoffs that have emerged from space programs around the world, the ultimate impact of spinoffs is considerably higher than that reported by survey participants.

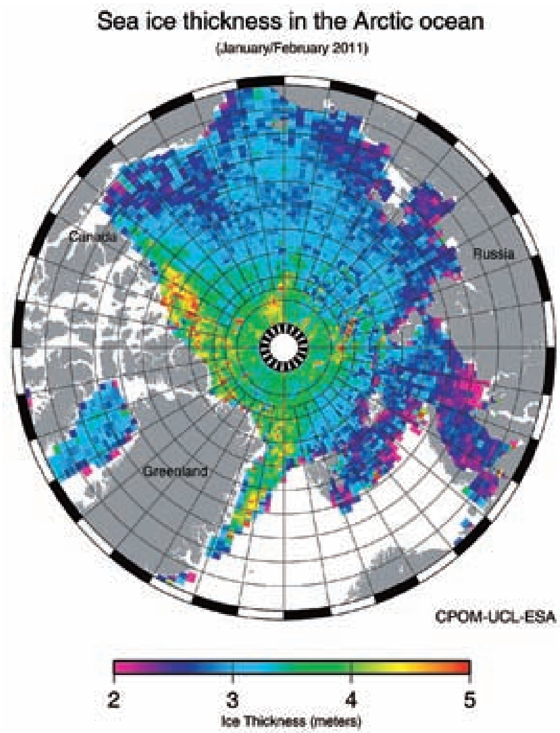
Each year, the Space Foundation recognizes the role of space products and services through its Space Technology Hall of Fame and its Space Certification Program. In the case of the Space Technology Hall of Fame, the Space Foundation works with NASA to recognize and honor the organizations and individuals that have developed products based on space technology that improve the quality of life on Earth. With the Space Certification Program, the Space Foundation provides a way for companies that produce and market these products to tie their business to space and to help inform the public of how space activities have benefits on Earth.

Using NASA satellite imagery, archaeologists discovered 17 buried pyramids in Egypt, as well as more than 1,000 tombs and 3,000 ancient settlements. Infrared images, taken by satellites orbiting 700 kilometers (430 miles) above the Earth, showed the below-ground structures. *Credit: Sarah Parcak/Univ. of Alabama at Birmingham*

The most rapid expansion of space products and services is occurring in the field of location-based services, which rely on positioning, navigation, and timing (PNT) satellites such as the U.S. Global Positioning System (GPS). Parents can use applications on their smartphones to monitor their children's safety, while other applications can help with planning a family trip to a theme park or finding roadside entertainment during a long journey. Businesses are using location information provided by customers to offer timely coupons, special deals, or more convenient methods of payment. Governments rely on PNT systems to aid law enforcement, monitor wildlife, and better understand and improve traffic flow in urban areas. Scientific studies have already resulted in better traffic conditions in parts of Beijing, and researchers are engaged in a variety of programs around the world to learn more about the way people travel from one place to another as they go about their daily lives.

Scientific research often relies on additional space systems besides PNT satellites. In 2011, infrared satellite images were used to find more than 3,000 ancient settlements in Egypt, and they may also be used to help protect archeological sites from looters. Biotechnology company, Amgen, launched 30 mice on NASA's final shuttle mission in July 2011 to test an antibody that could help prevent bone loss, which occurs at an accelerated pace in living creatures in space. Lessons learned from this research could lead to more effective treatments of bone loss among people on Earth. In the field of physics, an orbiting experiment helped to reaffirm Albert Einstein's theory of relativity by measuring the distortion in space caused by the Earth's gravitational field.

Sharing the joy of scientific discovery with the public is a key part of many space endeavors. NASA's Eyes on the Solar System computer program allows users to see space as it is observed by NASA satellites and probes. Some efforts rely on public participation, such as the Planet Hunters game, which allows anyone on the internet to help search for planets around other stars by analyzing data collected by the Kepler Space Telescope. In September 2011, NASA announced that gamers had identified two previously undiscovered planets.



ESA's CryoSat gathers detailed data that is used to generate maps showing sea-ice thickness in the Arctic. CryoSat's orbit allows it to take measurements of ice thickness within two degrees of the poles, closer than any previous satellite. By measuring the changes in the thickness of ice, the CryoSat mission will lead to a better understanding of how Earth's icy regions are responding to climate change. *Credit: CPOM/UCL/ESA*

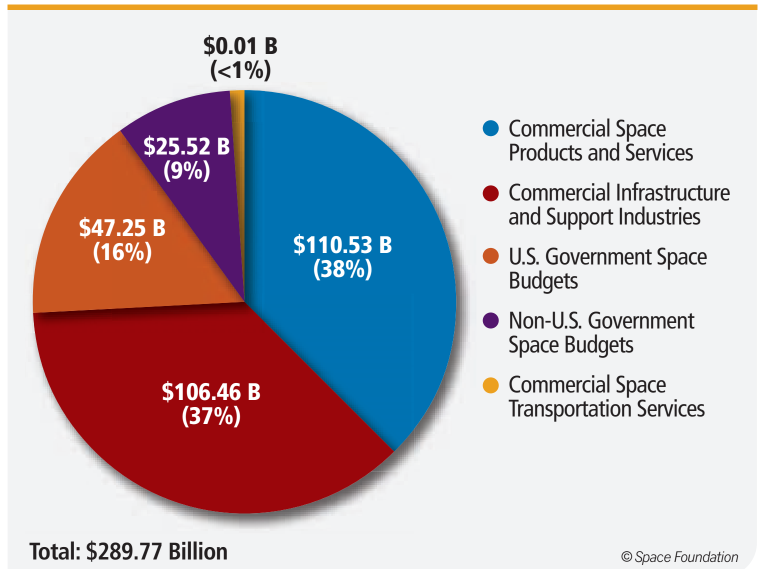
From their location high above the Earth's surface, satellites can provide a global perspective on changes in the world around us. In 2011, the Aqua satellite monitored the record-breaking heat wave in the United States, CryoSat created a detailed map of ice near the poles, and the SAC-D/Aquarius satellite provided comprehensive data on the salinity of the world's oceans. When Japan was devastated by an earthquake and tsunami in March 2011, more than 63 satellite observations were made in the first 48 hours following the event, facilitating more timely and effective disaster relief efforts. The value of such capabilities is immense and is one of the major reasons that countries around the world invest in space systems.

2.0 The Space Economy

The space economy increased in size for the sixth year in a row, growing at a faster rate than in previous years, likely due to improving conditions in some sectors of the broader global economy. The space economy grew by 12% in 2011, reaching an estimated total of $289.77 billion. As in past years, the majority of this growth resulted from commercial success rather than increases in government spending.

The space economy's strength was evident as commercial infrastructure and support industries grew at an impressive rate of 22% in 2011, reaching a total of $106.46 billion. The vast majority of the nearly $19 billion increase is attributable to growth in ground stations and equipment, including personal navigation devices and chipsets, which added more than $18 billion in value during the year.

EXHIBIT ES1. Global Space Activity, 2011

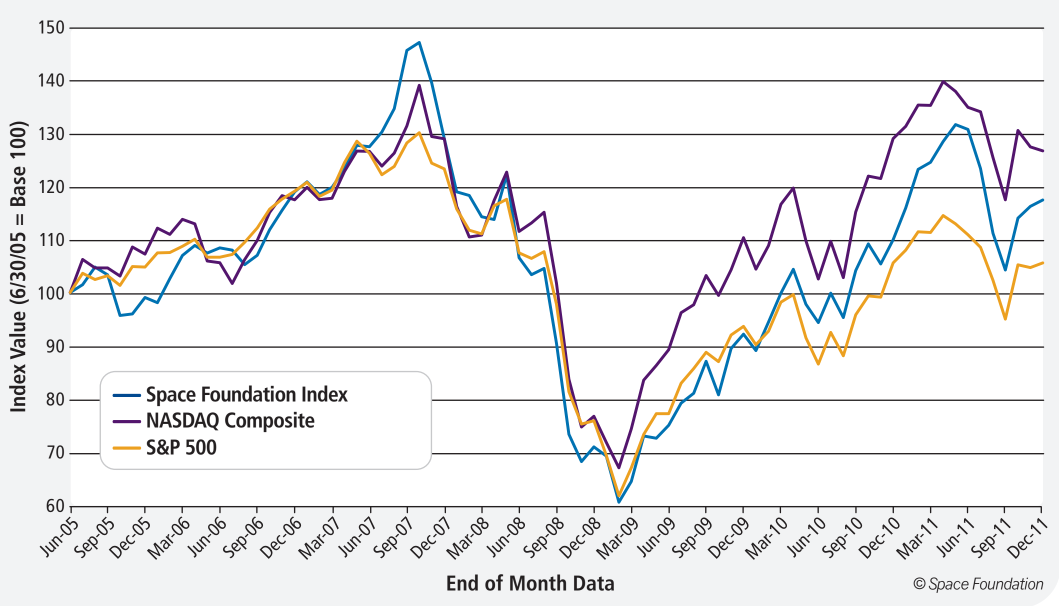


Commercial space products and services remain the largest part of the space economy, growing to $110.53 billion in 2011, 9% more than 2010. Most of the nearly $9 billion increase occurred in the direct-to-home (DTH) broadcasting sector, which added more than $7 billion in value.

The commercial space transportation services sector, consisting of companies such as Space Adventures and Virgin Galactic, remained relatively static in terms of revenue because no commercial human spaceflights occurred in 2011, although companies continued to collect deposits for future flights. A number of flight tests are scheduled to occur in 2012, indicating the possibility of growth in the near future as new services begin to carry passengers into space.

Globally, government spending on space increased even though its percentage of the overall space economy declined to 25% in 2011 from 27% in 2010. The aggregate growth rate for government space budgets was 6%,

EXHIBIT ES2. **Space Foundation Index vs. Other Market Indexes**



bringing spending to $72.77 billion in 2011. The governments of Brazil, India, and Russia all increased their space budgets by more than 20%. Some space agencies experienced more modest growth, as was the case for the European Space Agency (ESA), whose budget increased by 7% in spite of the ongoing fiscal problems in some of its member states. Space agencies in other nations, such as the United States and Japan, operated under flat or diminished budgets. Spending in the United States on government space projects was $47.25 billion in 2011, a decline of less than 1% from the amount spent in 2010.

The Space Foundation Indexes, which measure the performance of space-related companies on U.S. stock exchanges, demonstrated investor confidence in the health of the industry. In a year notable for its market swings, the Space Foundation Indexes grew at rates of 4% to 7% in 2011, outperforming both the NASDAQ and the S&P 500. The number of mergers and acquisitions in the space sector grew by 14% in 2011 and the median value of deals increased by 60%. Most of these transactions were funded by cash reserves and other assets, as companies and investors decided to use their strong financial position to add to their business portfolios, positioning themselves for future growth.

Space Exploration Technologies (SpaceX) completes a full-duration, full-thrust firing of its new SuperDraco engine prototype at the company's rocket development facility in McGregor, Texas. Eight SuperDracos will be built into the side walls of the Dragon capsule to carry astronauts to safety should an emergency occur during launch or ascent. *Credit: NASA*

3.0 Space Infrastructure

Orbital launch activity increased by 14% in 2011, rising to 84 launches from a total of 74 in 2010. Russia conducted the most launches, with a total of 31. China followed with a total of 19 launches, outpacing the United States for the first time in history. While the U.S. total of 18 successful launches was not the highest, it contained the greatest launch vehicle diversity, with eight different types of orbital rockets. One of these vehicles, the Space Shuttle, landed for the final time on July 21, 2011, ending the Space Shuttle Program after three decades of flights. With the shuttle's retirement, astronauts traveling to the space station will rely solely upon the Russian Soyuz until a new launch vehicle becomes available, whether it is NASA's Space Launch System or an alternative provided by a commercial company.

Two major developments were underway in 2011 at the European spaceport in Kourou, French Guiana, in addition to the usual launches of Europe's Ariane 5 rocket. Efforts to enable the launch of Russia's Soyuz rocket from the facility were completed in 2011, with two successful launches taking place during the year. ESA also prepared for the first flight of its new Vega rocket, which took place in February 2012.

Spaceport infrastructure in the United States is in transition as NASA makes changes at the Kennedy Space Center in Florida to accommodate new launch systems in the post-shuttle era. Construction continued on new and upgraded facilities at Vandenberg Air Force Base in California, the Mid-Atlantic Regional Spaceport in Virginia, and Spaceport America in New Mexico. China and Russia also continued development of new spaceports during 2011.

At the end of 2011, there were an estimated 994 active satellites in orbit around the Earth. The broadcasting industry is a huge driver of demand for communications satellites, largely due to global growth in the number of high-definition television channels, which require more bandwidth than their standard-definition counterparts. Consumer broadband internet service is also seen as an area with potential for growth, particularly in regions where the installation of terrestrial infrastructure is impractical.

On February 13, 2012, the first Vega launch vehicle lifted off on its maiden flight from Europe's Spaceport in French Guiana. The Vega delivered its primary payload, the LARES laser relativity satellite, along with the ALMASat-1 technology microsatellite and seven tiny university-sponsored picosatellites. *Credit: S. Corvaja/ESA*

Development of observatories and robotic exploration systems continued in 2011, with plans for several observatories with capabilities that will exceed those of existing telescopes. In July 2011, Russia launched a radio telescope called Spektr-R, marking the return of the Russian space program to scientific missions after a hiatus of several years. As with many scientific missions, other countries will participate in the research, in this instance by providing ground-based observations that can be combined with those from Spektr-R to produce images with even greater detail and clarity.

4.0 Workforce and Education

For the fourth straight year, the U.S. civil and commercial space workforce continued to shrink. Nearly 8,000 jobs were lost in 2010, according to the most recent data available from the U.S. Bureau of Labor Statistics, resulting in a workforce of approximately 252,000 people. This was the second-lowest employment level recorded during the previous 10 years. The trend of job losses is likely to continue once data is available for 2011, due to layoffs associated with the end of the Space Shuttle Program. As of July 2011, when the last shuttle flight took place, the number of employees associated with the program had dropped to 6,000 from a high of 32,000 during the 1990s. Even as U.S. space employment decreased, average annual salaries for these workers reached a new high as they earned 15% more than the average salary for the 10 STEM careers that employ the largest number of people in the United States. In contrast to the declining employment in civil and private space sectors, the U.S. military space workforce increased by 6% over a two-year period, rising from 15,791 in 2009 to 16,739 in 2011.

While the overall number of space employees decreased in the United States, employment increased in other parts of the world, especially Europe. European space employment surged 9% in 2010, the last year for which data is available. The European space workforce has expanded by 20% over five years, reaching a total of more than 34,000 in 2010. France, Germany, Italy, the United Kingdom, and Spain accounted for 85% of these jobs, reflecting their status as the European nations with the largest populations and economies.

As of 2010, the Japanese space industry workforce consisted of nearly 6,900 employees, an 8% increase from 2009. The 2010 employment level was the second-highest recorded for Japan during the previous 10 years. The South

Korean space workforce consisted of approximately 2,900 people employed by industry, research institutions, and universities in 2009, according to the most recent data gathered by the Korea Aerospace Research Institute (KARI). While this represents a 4% drop from 2008, the workforce has experienced a net increase of 22% from 2006 to 2009. The vast majority of these new employees were added by the private sector, as the number of South Korean space-related companies tripled from 19 in 2000 to 57 in 2009.

A simulated Martian terrain and robotics laboratory is the newest addition to the Space Foundation Discovery Institute in Colorado Springs, Colorado. The Mars Yard, along with Space Foundation education programs, are part of the Space Foundation's mission to inspire students and build a better, stronger workforce for the future to support space exploration and utilization. *Credit: Space Foundation*

STEM achievement in primary and secondary schools is an indicator of how well the United States is ensuring that students are prepared to pursue STEM degrees, enabling them to enter the space workforce. It is likely that there will be demand for these skills, as the Bureau of Labor Statistics has predicted growth in the number of professionals in several U.S. space-related occupations, including aerospace engineers, astronomers, and atmospheric scientists. The U.S. National Assessment of Educational Progress shows that 34% of U.S. fourth-grade students and 30% of eighth-grade students performed at or above the proficient level on the science test in 2009. In the field of mathematics, 40% of fourth-grade students and 35% of eighth-grade students scored at proficient or higher levels, an improvement over past years. The Programme for International Student Assessment evaluation, which tests proficiency among 15-year old students, shows that many nations active in space, including South Korea, Canada, Germany, and the United States, achieved above-average scores in mathematics or science.

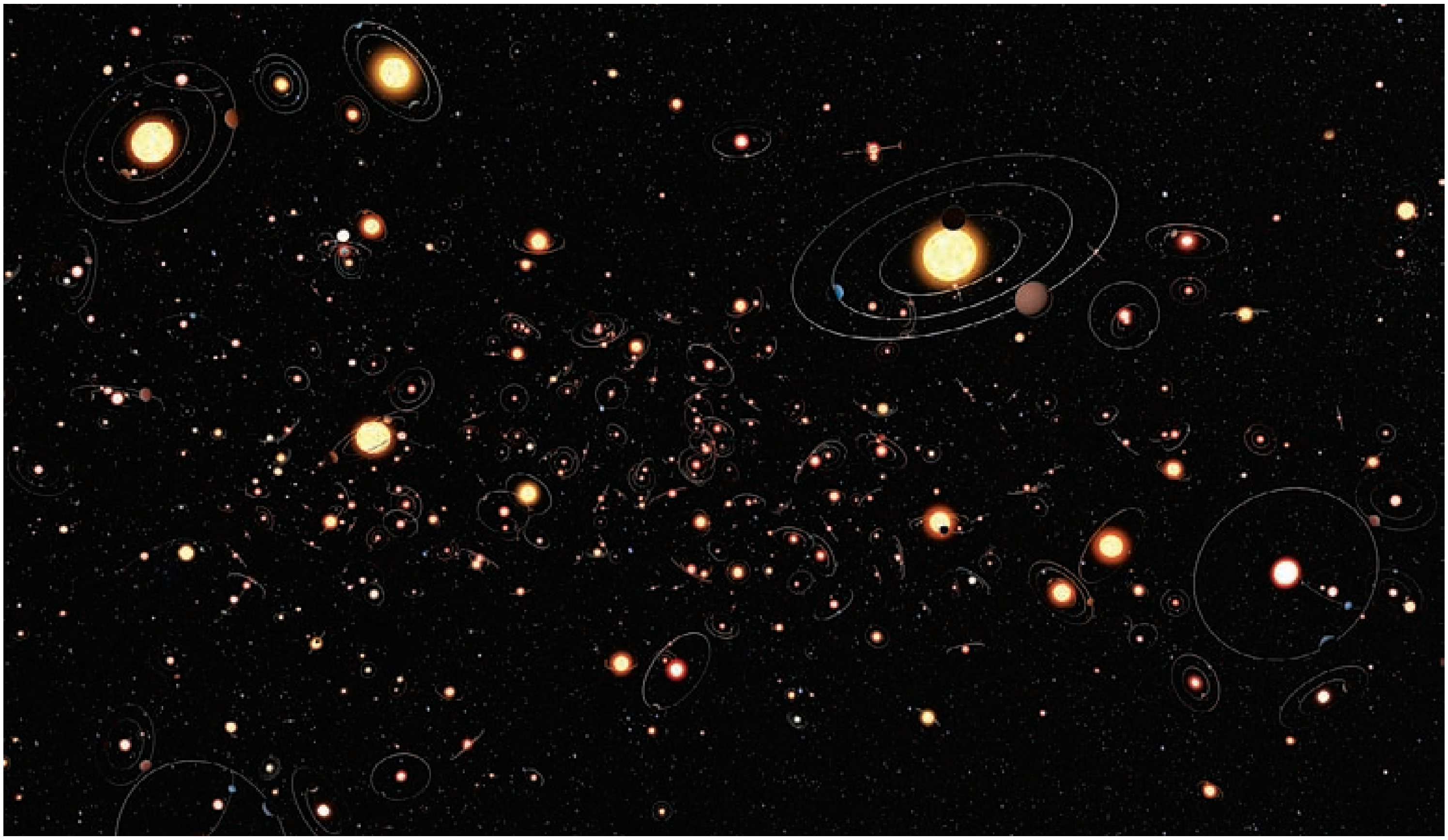
As veteran space workers begin to retire around the world, the training of new employees in critical STEM fields has become a focus for governments and industry leaders. China is the leading producer of STEM bachelor's-equivalent university graduates, doubling the number of graduating students between 2002 and 2006. The number of STEM graduates in other spacefaring nations also grew, but not as quickly. Similar trends are visible in space-related academic publications, which are still dominated by established spacefaring countries but are witnessing rapid growth by emerging nations and regions.

5.0 Outlook

For centuries, humans have looked to space and dreamed of its possibilities. Some of those dreams have become realities, and others provide the motivation for ambitious efforts to push the boundaries of what is achievable. One of those dreams is to expand the human sphere of influence and derive benefits from a greater presence in space. Partner nations in the International Space Station are eager to reap rewards from the station's completion and the corresponding transition from construction to research. Governments in most major spacefaring nations devoted time and energy in 2011 to planning the future of human spaceflight, determining the best way to direct their efforts while recognizing that there are insufficient funds for everything they may wish to undertake. This has led to decisions such as the cancellation of Russia's Rus-M rocket program, which had been intended to carry a next-generation human spaceflight capsule. While development of the capsule will continue, it will likely be launched by an existing rocket.

Budgetary concerns also extend beyond the realm of human spaceflight. In the midst of a sluggish economic climate and uncertain prospects for future growth, some governments are cutting future spending to control their total budgets. These cuts can have serious consequences if they affect critical capabilities such as weather forecasting, as may happen due to programmatic delays and reduced funding for U.S. weather satellite development. Uncertainty regarding the prospects for funding requires a rethinking of processes and programs, often leading to increased multinational collaboration. Outside of government, budget cuts affect industry plans and profits but may also stimulate innovative new approaches in government-industry relations. One outcome is the increasing interest in hosted payload arrangements, in which a sensor, instrument, or other payload owned by one organization is placed aboard a satellite operated by a different entity.

Governments increasingly see a need for formal space policies to provide a framework for coordination and integration of activities. In the absence of clear and effective space policy, government space activities are likely to develop in a manner that may prove challenging to sustain over the long term. Some policy documents, such as one published by the European Commission in April 2011, are intended to define why space activity is worthwhile, what the main space priorities are, and how space activity will benefit the public. Other government planning documents, such as ESA's Cosmic Vision 2015–2025, provide a framework for decisions about future science missions. Among the space agencies planning missions for launch in 2013 or 2014, NASA expects to send probes to orbit the Moon and Mars; ESA anticipates launching a mission to make a three-dimensional map of the galaxy; and the Japan Aerospace Exploration Agency (JAXA) plans to send a probe to study an asteroid. Further missions are planned for launch throughout the coming decade to study the Sun, other planets and their moons, and a host of deep-space and astronomical phenomena. With countless options for exploration and discovery, and with new technology developments that spur growth in the global space economy, the space sector is expected to remain vibrant and productive.



A new study has determined that the Milky Way galaxy likely contains at least 100 billion planets, with 1,500 planets within 50 light years of Earth. Observations taken over six years by telescopes participating in the PLANET (Probing Lensing Anomalies NETwork) collaborative effort have led scientists to conclude that our galaxy contains a minimum of one planet for every star on average. *Credit: NASA/ESA/ M. Kornmesser/ESO*

SPACE PRODUCTS AND SERVICES

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NASA technology designed to meet the challenges of bone loss and muscle deterioration for astronauts living and working in space has been adapted by Alter-G for medical rehabilitation here on Earth. By using precise adjustments in an air pressure system, the G-Trainer is able to reduce the effect of gravity, allowing patients to maintain a normal gait at reduced levels of pain while their injuries are still healing. The G-Trainer has been used in military hospitals, including after traumatic brain injury, to help patients relearn to stand, walk, or run. *Credit: Alter-G*

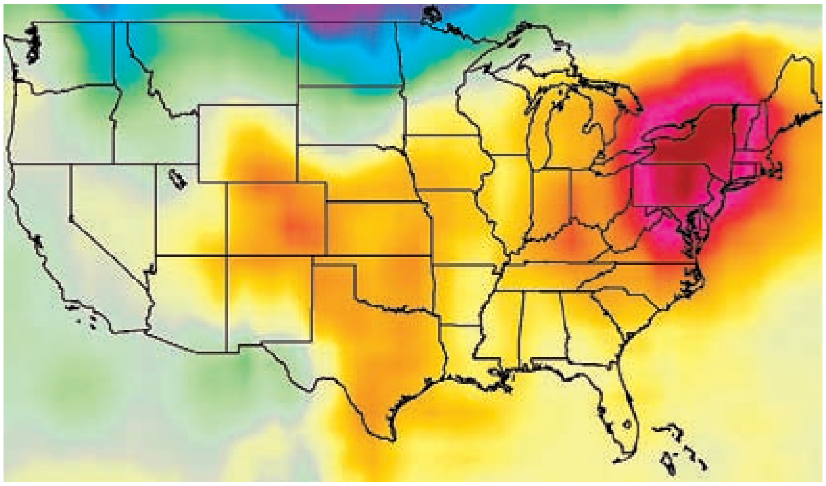
EXHIBIT 1a. Topics Covered in Space Products and Services

1.0 Introduction

Space products and services are things used by people on Earth which rely on the data or connections provided by satellites, as well as items that use technology originally developed for use in space activities but which are now applied to non-space applications. There are currently almost 1,000 operational satellites in orbit around the Earth. These communications, remote sensing, positioning, and scientific satellites have become essential to everyday life even if users are not aware of their role. These space assets are key to making new discoveries and developing new technologies. From the everyday applications on our phones, to questions about the nature of the Universe, space assets make important contributions to life on Earth.

The development of space products and services, which began not long after the first satellites were launched, continued in 2011 with strong growth of applications using the global positioning system (GPS). These GPS-enabled applications are changing the way that people and companies interact with each other, such as allowing local businesses to offer customer discounts and other perks to people who "check in," using their phones to share their location on social networks. The applications also help businesses learn more about their customers. GPS tracking helps officials to optimize school bus routes and other transportation plans. Satellites are also being used to monitor ships at sea and to watch for and respond to missiles launched anywhere in the world.

Satellites provide a global perspective on our changing Earth and help to further our understanding of its resources. In 2011, the Aqua satellite monitored the record-breaking heat wave in the United States, CryoSat created a detailed map of ice near the poles, and the Aquarius/SAC-D satellite provided comprehensive data on the salinity of the world's oceans. India used its satellites to identify a 30% decrease in the water volume of Kerala's scenic lagoons. Satellites assist in finding buried ancient cities and monuments. Infrared images from satellites led to the discovery of 17 new pyramids in Egypt in 2011 and are helping to watch and protect areas that have been recognized as World Heritage Sites.



The Atmospheric Infrared Sounder (AIRS) instrument on NASA's Aqua spacecraft monitored movement of a dome of heat across the United States during a heat wave that killed dozens and put nearly half of the nation's population under heat advisories during parts of July 2011. This image displays the daytime surface air temperature anomalies, showing the difference from the average temperature from the previous eight years. Some areas of the Northeast were more than 11 degrees Celsius (20 degrees Fahrenheit) hotter than usual. *Credit: NASA/JPL*

1.1 The Development of a Space Spinoff Product

It did not take long after space technologies were first developed for scientists to realize that spinoff technologies would be useful in non-space applications. Over time, thousands of products and services have been adapted from global space activities. For example, Water Security Corporation's water purification system is based on a technology first developed for the Space Shuttle Program.

Water Security's story began more than 30 years ago at Umpqua Research, a small lab in Oregon that had just been granted a NASA contract to develop a system to ensure the drinking water would not be contaminated on the Space Shuttle. Water is heavy and takes up a lot of room, two things that are undesirable when launching into space. Rather than taking enough water to last the entire mission, astronauts needed a system to recycle water in flight. Engineers and scientists at Hamilton Standard (now Hamilton Sundstrand) developed a waste water recycling system for the International Space Station (ISS) that also included the water purification technology developed by Umpqua for the Space Shuttle. Because it was developed for use in space, the system was designed to be safe, reliable, and use no electrical energy. For about 20 years, this technology was used only for human spaceflight.

In 2001, an entrepreneur from Silicon Valley interested in global water issues learned about the water purification system and its track record of successful space use. He quickly recognized that this high-tech space system could be used to help people in developing countries and remote villages on Earth have access to safe drinking water. A start-up company was formed with seed money from the Haws Corporation, an organization specializing in drinking fountains and other technologies related to drinking water. Haws eventually purchased the intellectual property rights for the water purification technology and created the minority-owned subsidiary, Water Security Corporation. Significant research and development was necessary to adapt the space technology to fit the conditions of villages around the world. Although the technology was safe and reliable, it also had to be very easy to use and cost-effective. The technology would be used in rural villages with a wide range of temperature and weather conditions, not the carefully controlled environment inside the Space Shuttle and International Space Station.

Water Security partnered with Eureka Forbes in India to incorporate the technology into systems that could be used in individual homes and worked with Sinergia Sistemas on large-scale systems to provide safe drinking water for entire villages. With these partners and others, Water Security refined its systems, learned about regulations and laws in various countries, and brought the products to market. The technology provides safe drinking water for hundreds of villages in Mexico, and efficient and cost-effective purification systems are being marketed to hundreds of millions of people in India. The company's portable systems are used for natural disasters, refugee camps, and civil emergencies all over the world.[1]

Community leaders in Cruz Quemada, Mexico, pose with a new water purification system designed by Water Security Corporation for use in remote locations. Hundreds of similar systems have been installed in rural villages around Mexico, reliably delivering safe, purified water from local sources. Water Security Corporation's proprietary technology is based on iodinated resins that have been used by NASA for nearly 30 years on the Space Shuttle and International Space Station. *Credit: Water Security Corporation*

1.2 How Space Products and Services are Used

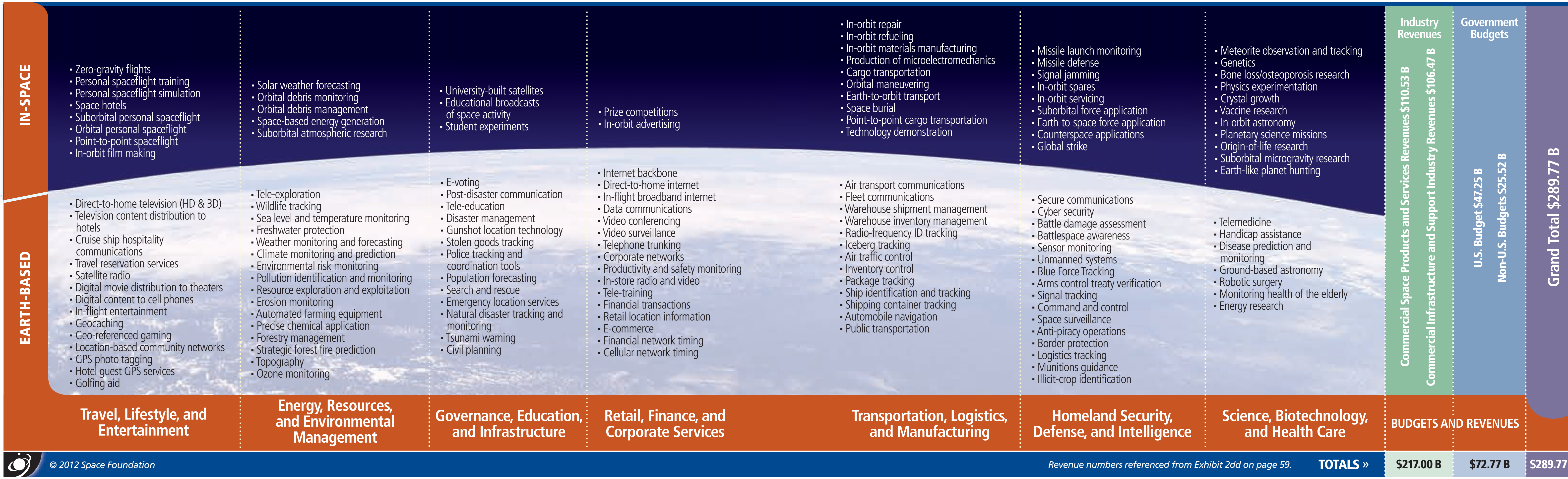
Space products and services are an integral part of many activities and sectors throughout the global economy. Exhibit 1b shows seven major categories in which space products and services make a strong contribution. Within these categories, space products and services include items that rely on space assets to work. For example, many applications require timing and positioning data, which come from global navigation satellites such as the GPS satellite constellation. Similarly, satellite remote sensing capabilities are essential to accurately monitor global environmental changes since they provide a level of full and detailed coverage of the globe that is often not technically or economically feasible for ground- or air-based sensors.

Spinoff technologies do not directly use space but are developed based on space technology. As with Water Security Corporation, people frequently recognize that a technology developed for space may also have important non-space uses. NASA, the European Space Agency (ESA), and the Japan Aerospace Exploration Agency (JAXA) all monitor the creation of spinoff technologies throughout the year. Exhibit 1c shows a selection of technologies from each of these agencies.

The Space Foundation also recognizes new space products and services each year through its Space Technology Hall of Fame and its Space Certification program. In its Space Technology Hall of Fame, the Space Foundation

Space Products and Services | 1.0

EXHIBIT 1b. Overview of Space Activity, 2011



works with NASA to recognize and honor the organizations and individuals that have developed products based on space technology that improve the quality of life on Earth. By increasing public awareness of the benefits of these types of technologies, the Space Foundation hopes to promote further innovation.

The Hall of Fame 2011 inductees were commercial Earth-imaging satellites and Intrifuge CellXpansion. For commercial Earth-imaging satellites, the award was presented to two of the leading companies in this sector, DigitalGlobe and GeoEye. The award recognized that geospatial technology from these satellites has improved national security, logistics and navigation, mapping, disaster tracking, and other important applications. The award for the Intrifuge CellXpansion innovation was presented to the NASA Johnson Space Center, Regenetech, and Synthecon. The technique developed by these groups makes it possible to cultivate three-dimensional cells and tissues on Earth, something that was previously possible only in the human body or in the microgravity environment of space. These cell structures are essential for a variety of research and therapy treatments, including cardiovascular diseases, skin ailments, and orthopedic applications. The technology is provided at an affordable cost to those researching medical remedies for rare diseases.[2]

EXHIBIT 1c. Selected NASA, ESA, and JAXA Spinoffs, 2011

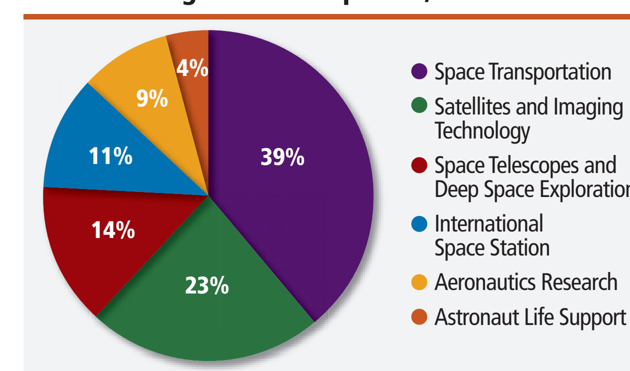
NASA	ESA	JAXA
Easy-to-use ventilator designed for space is now used by military and others in remote locations	Plasma physics experiments conducted on the ISS led to new type of hand sanitation system for hospitals	Thermal insulation material developed for use on launch vehicle fairings now used in home construction
Automated tool developed by NASA's Ames Research Center incorporated in a commercial product to improve efficiency of commercial air route selection in real time	Sensor developed to monitor oxygen atoms outside ISS now used to optimize glass coating process, resulting in energy-saving windows	Light, heat-resistant material used for rocket nozzles now used for household fireproof screens and fire-extinguishing cloth
Principles used for rocket engine design applied to creation of fire hose nozzles, improving performance of fire suppression systems, putting out fires more quickly and using less water	Antenna used on ESA's Planck space observatory to detect cosmic microwave background radiation now used in cars to help prevent collisions	Compact and efficient cell culture equipment developed for use on the ISS has labor-saving effects for research on the ground
High-strength aluminum alloy developed for NASA propulsion applications used in safety ventilation fans in rail and road tunnels	Software developed to analyze performance of composite materials for space program used to improve safety and efficiency of shipping containers	Manufacturing and quality management technique developed for H-II launch vehicles used to develop laminated rubber bearings to protect buildings and bridges from earthquakes
NASA technology used to monitor and treat motion sickness now monitors health and fitness of soldiers, first responders, professional athletes, and others	Carbon fiber rods used for Rosetta comet-visiting mission now being used by manufacturers to boost precision and efficiency of laser cutters	Reliable system used to ignite solid fuel rockets applied to ensure automobile airbags are deployed without fail

Source: NASA's Spinoff 2011, ESA, and JAXA

The rotating wall bioreactor, invented at NASA's Johnson Space Center, mimics the microgravity conditions of space, allowing for healthier cell cultures that closely resemble those in the human body. Biotechnology company Synthecon is further advancing this technology to help enable drug development and medical research into treatments for conditions such as diabetes and cancer. *Credit: Synthecon*

People often use space products and services without even realizing there is any connection to space. With the Space Certification program, the Space Foundation provides a way for companies that produce and market these products to tie their business to space and to help inform the public of how space activities have benefits on Earth. Once companies have demonstrated a product's clear connection to space, they can become certified and are able to use the official space certification seal on all of the packaging and marketing materials. Space certification has been awarded to a variety of products, from Tempur-Pedic pressure-relieving sleep surfaces to ProShot Golf's distance measuring system. The Space Certification program also has educational partners, including the Challenger Learning Centers and the Planet LLC Space Garden. Certified Imagination

EXHIBIT 1d. Origin of NASA Spinoffs, 2011

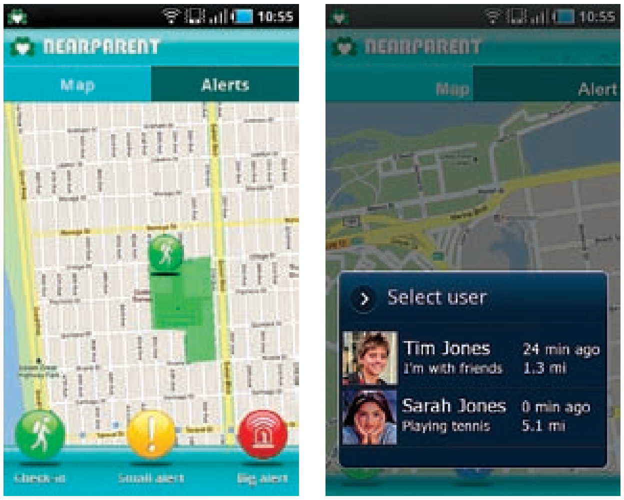


Source: NASA's Spinoff 2011

Products focus on items for entertainment, such as Motion Pixel Lab's Beer Drinker's Guide to Colorado and NORAD's Santa tracking website. A full list of Certified Space Products is included on page 159.

1.2.1 Travel, Lifestyle, and Entertainment

Space products and services directly help individuals with travel and entertainment. GPS-enabled phones have become ubiquitous in many parts of the world, and each day new applications are being developed to take advantage of these positioning capabilities for purposes such as helping to improve security in a variety of situations. Satellite television is a large and growing industry, and new innovations continue to improve this service; a recently developed product makes it possible for sailors to access TV in all regions of the world.



The Nearparent smartphone application uses check-in technology, based on GPS location data, to increase child safety. Parents can map out safe zones and receive alerts when a child arrives at or strays from the area. *Credit: Nearparent*

Many GPS-enabled smartphones focus on locating the essentials: restaurants, hotels, museums, and other tourist spots. However, some more unique options are also available. Roadside America by This Exit encourages road-trippers to take a detour by providing a map of thousands of the funniest and weirdest attractions, from the largest ball of twine to a park made entirely of concrete.[3] Visiting Disney World has been made easier, with an application by Undercover Tourist that locates nearby restaurants and amenities and shows real-time wait times for each ride. A "friend finder" feature shows the location of traveling companions using the application. At the end of the day, the GPS-enabled application will even help locate the user's car for the ride home.[4]

Many applications use a "check in" feature, in which users share their location information via phone, to encourage connections between friends and to help businesses reach customers. The Nearparent application uses this technology to increase personal safety, allowing children to check in at a location and automatically alert parents they have arrived safely at their destination. For younger children, parents can choose to monitor their child's real-time location continuously. In addition to everyday use, the application could be particularly helpful on special occasions such as Halloween, when children may be walking on their own to multiple neighborhoods. The application also provides a button that the child can press to alert parents if help is needed.[5] This type of GPS-tracking application has also been used on college campuses. Police at Northeastern State University in Oklahoma are offering the Personal Guardian application. If students activate the check in feature, police will be alerted if the student doesn't make it to their destination by a preset time. If the student does not arrive as planned, police are able to use the GPS tracker to locate the student. The "follow me" mode is more active, notifying police of the student's GPS location and allowing them to track the progress of students as they travel from one location on campus to another, ensuring they arrive safely. Activating the "danger mode" will cause an officer to be dispatched to that GPS location immediately.[6]

The KVH TracVision HD11 satellite television system provides high-definition entertainment at sea. The dish uses multi-axis dynamic tracking to maintain a constant connection with a satellite, even in rough seas. *Credit: KVH Industries*

Communications satellites continue to contribute dramatically to entertainment, particularly while traveling by sea. Seamless high-definition television (HDTV) service is now available to mariners as they travel around the globe. In the past, if sailors traveled to a new region and changed satellite TV service providers, they would need to install new hardware to access the signal in addition to signing up for the new service. KVH Industries developed the TracVision HD11 marine satellite TV system, which is compatible with satellite TV services around the globe, taking advantage of more than 100 satellites belonging

The cushioning technology used in this shoe was originally developed in the 1990s by ARTEC Aerospace. The Smart Passive Damping Device has been used on a number of satellites. ESA's Technology Transfer Program funded the study of spinoff applications of this technology. *Credit: CAP-K*

to various TV providers. This allows sailors traveling to different regions of the world to switch among services without any hardware or software updates.[7]

Although space technology might be expected to play a role in smartphone applications and high-tech mobile entertainment systems, it can also appear in completely unexpected places, such as shoes. CAP-K, a spinoff company of ARTEC Aerospace in Toulouse, France, is using damping technology originally developed for Europe's Ariane launch vehicle to create more compact and affordable shock absorption in the heels of shoes. ARTEC had developed the damping technology to help protect satellites from vibrations during launch. Because of space and weight restrictions for launches, it was important that this technology be lightweight and compact. CAP-K's solution takes advantage of this design to create comfortable shoes that are sleek and stylish.[8]

1.2.2 Energy, Resources, and Environmental Management

Remote sensing and communications satellites are now essential in the aftermath of natural disasters. Satellites often offer the only method of communication when terrestrial telephone systems are damaged. Remote sensing satellites make it possible to compare before and after images of an area to quickly assess which locations were hardest hit. With their wide field of view and their ability to pass over the same area many times, satellites are also essential for monitoring natural resources and environmental changes, allowing for advanced planning and management.

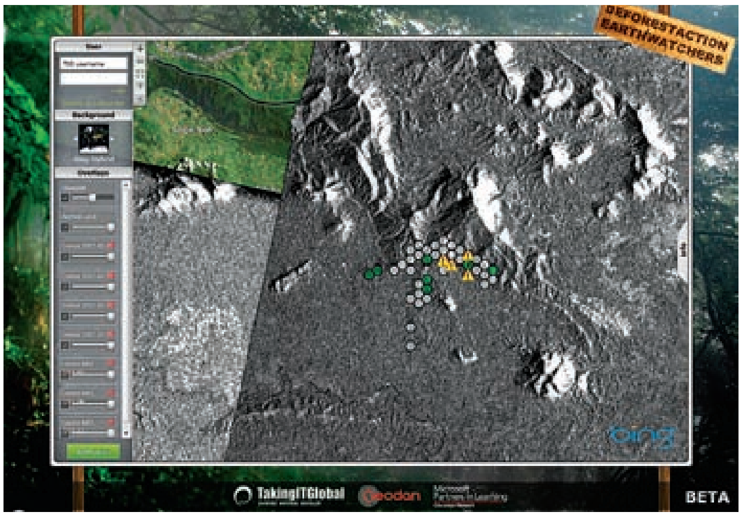
This image from the Moderate Resolution Imaging Spectroradiometer (MODIS) on the Terra satellite shows ash accumulating on the ground and a large plume streaming east from the Puyehue-Cordón Volcano in Chile, which eventually disrupted air traffic as far away as Australia. *Credit: NASA/GSFC/Jeff Schmaltz, MODIS Rapid Response Team*

When Japan was devastated by an earthquake and tsunami in March 2011, more than 63 satellite observations were made in the first 48 hours following the event. Japan invoked the International Charter on Space and Major Disasters, which ensures that satellite images are freely available to authorities and aid workers. Data was collected from a wide range of satellites, including spacecraft from the United States, Germany, and France.[9] In addition, groups like MercyCorps and the International Telecommunication Union set up satellite telephone services and internet terminals, allowing survivors to contact family members.[10]

In June 2011, the eruption of the Puyehue-Cordón volcano in Chile led to the evacuation of 3,500 people. Satellites were able to capture images of the eruption and provide details on the associated ash plume, monitoring its path for many days.[11] It is important to monitor an ash plume because it can be dangerous for jet engines and its path is difficult to forecast since it is influenced by local weather patterns. Satellites provided images showing that the ash plume from the Puyehue-Cordón volcano travelled around the globe, eventually causing flight cancellations as far away as Australia.[12]

In addition to providing important information during emergencies, remote sensing satellites can be useful for land use and urban planning, and natural resources management. In August 2011, the NigeriaSat-2 remote sensing satellite was launched.[13] NigeriaSat-2 is the first satellite in the African Resource Management constellation. It is capable of producing imagery distinguishing elements as small as 2.5 meters (8.2 feet) in size, allowing for the identification of individual buildings and roads. Nigeria plans to use the satellite to create a map of the entire country every four months. These maps can be used for urban development planning, such as deciding where to build new roads. This imagery will also be used to improve agricultural activities by providing more precise information on where fertilizer should be applied.[14]

In September 2011, scientists in India announced that satellite images had shown a nearly 30% reduction in the backwaters of the state of Kerala. These picturesque lagoons, near the Arabian Sea, are an important tourist attraction. Scientists plan to continue using satellites to investigate the cause of this reduction. The Indian Space Research Organisation (ISRO) plans to launch at least seven new remote sensing satellites in the next 10 years, which will improve its ability to monitor this and other natural resources.[15]



Satellite observation of Earth plays a crucial role in environmental monitoring, analysis, and modeling. The DeforestACTION project combines crowdsourcing efforts with satellite imagery to monitor and report illegal logging in Borneo, which threatens the habitat of native orangutans. *Credit: Geodan/ Earth Watchers/ESA (Envisat images)*

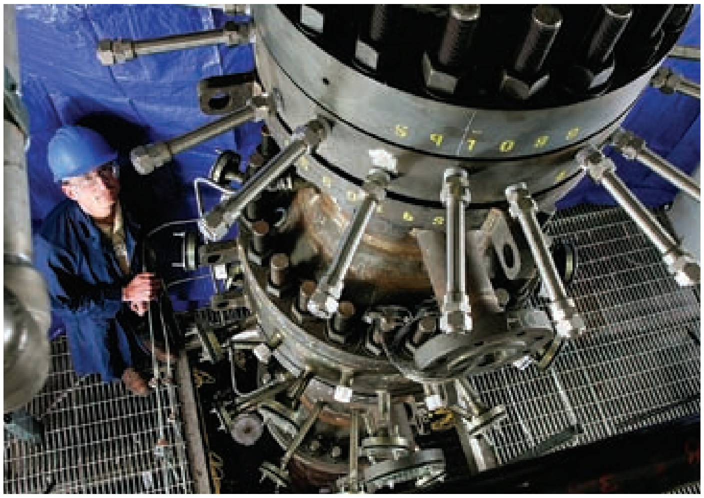
The DeforestACTION project is using satellite imagery to combat illegal logging through its Earth Watchers software tool, currently in beta testing. The difficulty of locating and identifying illegal deforestation often prevents law enforcement from limiting this activity. DeforestACTION allocates each person involved in the project a piece of land to monitor, providing them with an updated satellite image each week so they can locate changes and disturbances. The information is relayed back to the data center, and illegal activity is reported to and investigated by local authorities.[16]

Satellites are essential to understanding our environment and providing a global perspective on changes. Much of the United States experienced a record-breaking heat wave in July 2011. In addition to monitoring the temperature with sensors on the ground, satellites were also used. The Aqua satellite, which carries instruments able to capture highly accurate data about the lower atmosphere, showed that average July temperatures in Texas and Oklahoma were about 11 degrees Celsius (20 degrees Fahrenheit) warmer than those recorded in the past eight years. The Aqua satellite also helped to identify the atmospheric conditions that led to the heat wave, including abnormally strong domes of high atmospheric surface pressure over the Atlantic and Pacific oceans and a pattern of winds that drove hot and humid air from the tropics up into the continental United States.[17] The improved understanding of the characteristics and causes of extreme weather events can increase the ability to better predict and prepare for these events.

Though some areas of the globe may experience extreme heat, ice still covers about 10% of the Earth, and satellites are greatly improving our understanding of it.[18] In June 2011, ESA's CryoSat mission delivered the best view yet of sea-ice thickness across the entire Arctic Ocean basin. Unique instruments aboard CryoSat allow scientists to measure ice volume, not just the surface area, which is essential for understanding the true status of this element of nature, a key indicator of the extent of climate change. In addition, CryoSat's orbit allows it to monitor within two degrees of the poles, so it is able to see more of these areas than previous ice-observing satellites. CryoSat will measure multiyear changes in ice volume in the Arctic and Antarctic. Its mission is currently scheduled to end in 2013, but scientists are hoping to extend the mission until 2017 and incorporate similar instruments on operational satellites in the future.[19]

Satellites contribute not only to our understanding of the atmosphere and features on the ground, but also to our understanding of the oceans. The Aquarius/SAC-D satellite, launched in June 2011, is a collaboration between NASA and Argentina's space agency, Comisión Nacional de Actividades Espaciales (CONAE), that is able to detect variations in the salinity of the ocean surface. Differences in ocean salinity are related to large-scale patterns of rainfall and evaporation over the ocean and to river outflow. Monitoring this variable is important, as even small variations in sea surface salinity can have dramatic effects on the water cycle and ocean circulation. In the past, ocean salinity observations were made directly by dropping instruments into the water. Now, using Aquarius/SAC-D, it is possible to make continuous, consistent, global measurements of ocean salinity, including measurements in places that have never been sampled before. The satellite produced its first global map of ocean surface salinity in September 2011. Aquarius will monitor how patterns of salinity change and study their link to climate and weather variations.[20]

Changes in oceanic conditions are also opening up new habitats for animals, and satellites are helping to track how animals are adapting. In a 2011 study, scientists presented the first observations of the meeting of bowhead whales from two different oceans in the Northwest Passage. These observations were possible because the whales had been tagged with satellite transmitters years earlier. Bowhead whales exist in two separate populations, one in the Bering Sea, near Alaska, and the other in Baffin Bay, near Greenland. They have been separated by sea ice in the Northwest Passage for about 10,000 years. In August 2010, the Northwest Passage was largely free of sea ice, and two satellite-tagged bowhead whales traveled into this area, one from each of the two populations. The whales crossed paths before eventually returning to their respective home regions. This observation helped to support the theory that the loss of Arctic sea ice is facilitating the exchange of marine organisms between the Atlantic and Pacific oceans.[21]



Pratt & Whitney Rocketdyne leveraged experience with the Space Shuttle Main Engines to create a rapid mix injector that enables a quicker, more efficient gasification process, resulting in lower emissions than standard gasification technologies. Each commercial system deployed has an effect equivalent to removing 50,000 cars from the road. *Credit: Pratt & Whitney Rocketdyne*

In addition to monitoring the environmental changes happening around the globe, space technology is being used to advance clean energy, reducing the production of the types of greenhouse gases contributing to global warming. Using knowledge gained from developing the Space Shuttle Main Engines, Pratt & Whitney Rocketdyne developed an efficient system for combining coal or other carbon-containing materials, oxygen, and steam, creating a gas that can be burned to produce electricity. The shuttle engines operate at very high temperatures, and Pratt & Whitney Rocketdyne found that using high temperatures in the fuel-creation process on Earth allowed for more compact systems that were cheaper and reduced carbon dioxide emissions by up to 10% compared to standard technologies. As demand for electricity generated from coal rises, this technology has the opportunity to significantly reduce carbon dioxide emissions into the atmosphere.[22]

1.2.3 Governance, Education, and Infrastructure

Governments have made use of all types of satellites to help enforce laws, encourage education, and address infrastructure needs. Remote sensing satellites have been used to locate and monitor archeological sites, and GPS satellites have been used to improve the effectiveness of humanitarian aid, to track endangered animals, and to make recreationalists aware of rules in protected wildlife areas. Communications satellites connect students in remote areas to high-quality educational content in cities. More than 31 million students have benefited from ISS-related educational programs, with new projects and opportunities being introduced each year.

Scientists at the University of Alabama at Birmingham used infrared satellite images to reveal more than 1,000 tombs and 3,000 ancient settlements in Egypt, including 17 lost pyramids, generating excitement among archeologists, tourists, and local governments interested in uncovering these forgotten buildings. Ancient Egyptian

This satellite image, analyzed by the Global Heritage Network, indicates in orange the walls of the ancient city of Ninevah, Iraq, while red areas show encroaching urban development. *Credit: Global Heritage Network*

structures were built out of mud brick, which is much denser than the soil that surrounds it, so even though the structures are buried underground they retain heat differently than the surrounding soil. As a result, temples and tombs can be seen clearly in infrared images collected by satellites. Excavations at multiple sites have been carried out, verifying that the structures seen in satellite images exist. Scientists note that the same technology that allows them to identify these sites may also help detect looting. When unauthorized changes to the sites are seen, scientists can alert Interpol to watch out for antiquities from the era with which the site is associated.[23]

To protect sites around the world, the Global Heritage Fund, in cooperation with Google Earth and DigitalGlobe, has put together a program called the Global Heritage Network to provide satellite monitoring of World Heritage Sites. These cultural locations, which include places like Pompeii, Angkor Wat, and Machu Picchu, are deemed especially significant by the United Nations Educational, Scientific and Cultural Organization (UNESCO). The program includes satellite imagery of about 600 sites, each of which will get a regularly updated assessment. These assessments will help to identify not only looting, but also dangers posed by destructive tourism, natural disasters, and neglect. The program coordinators plan to use the network to raise awareness of what is being lost, in hopes that protection efforts will follow.[24]

The Satellite Sentinel Project, a collaboration between Google, the United Nations Operational Satellite Applications Programme (UNOSAT), the Harvard Humanitarian Initiative, and other nongovernmental organizations, is attempting to use similar technology to monitor, and hopefully deter, humanitarian abuses. Using satellite imagery, the project monitors areas susceptible to violence, such as Southern Sudan during the January 2011 referendum, when people voted on whether the region should split from the rest of the nation. The Sentinel project looks for evidence of troop buildup or movement that could signal impending violence. The project also watches for burned villages or other indicators of trouble. Project leaders hope this monitoring will lead to a reduction in violence, as would-be perpetrators see that they are being watched.[25]

Six gray smoke plumes from an artillery barrage rise above a ridge near the town of Toroge in Sudan's border region of South Kordofan in January 2011. The image also shows a chokepoint created by the Sudanese military to control the main evacuation route for refugees fleeing to South Sudan. Utilizing satellite imagery and the technologies of partner organizations, the Satellite Sentinel Project and the Enough Project work to inform the international community on issues requiring humanitarian action. *Credit: Enough Project*

Increasingly, United Nations and international nongovernmental workers dealing with humanitarian needs in war-torn countries, such as Iraq and Somalia, are relying on GPS technologies to coordinate aid remotely. Using information collected by GPS-enabled devices carried by local partners, humanitarian workers located in less-dangerous areas can document specific needs, pinpoint them on a map, and provide this information to a variety of agencies. During the first five years of Operation Iraqi Freedom, the United Nations moved the majority of its staff to Amman, Jordan, while more than 4,000 Iraqi nationals collected information on the ground. The use of GPS technology helps to increase the effectiveness of these types of humanitarian operations and allows aid to reach vulnerable populations that would otherwise be inaccessible.[26]
A number of space products and services focus on regional, rather than global, governance issues. The California Department of Fish and Game developed an application for mobile phones to help stop illegal fishing. The application allows fishermen to use a GPS-enabled phone to determine their location on a map of California's

marine protected areas. Fishermen can then access information about the prohibitions within these regions. Officials hope that the mobile site will help users avoid mistakenly fishing in prohibited areas.[27]

Many GPS-enabled applications allow walkers, runners, and cyclists to track the path of their exercise route, providing location, speed and other statistical information. The information collected is usually used for tracking personal progress toward fitness goals, but these applications can have other interesting benefits. In a number of cases, cyclists have been able to use the tracking data to help police reconstruct the events of a bicycle accident. By providing information on location, time, and speed, it is possible to understand with more certainty how fast the person was going before the accident occurred, whether brakes were used, and when the brakes were engaged.[28]

National Park Service wildlife ecologists use GPS tracking devices to follow mountain lions and other animals for a number of reasons, including tracking of illegal activity such as poaching. *Credit: National Park Service*

In addition to locating humans in danger, satellite tracking is also used to monitor animals. About six or seven mountain lions are believed to live in the Santa Monica Mountains in California, and the National Park Service had been tracking one of these animals for nearly two years using a GPS collar. The tracking showed that the mountain lion roamed the entire mountain range. However, in August 2011, the collar stopped transmitting signals, leading to a search for the animal. In September, it was discovered that poachers had killed the mountain lion and removed the collar. Investigators have launched an investigation to identify the individuals responsible.[29]

Many countries use satellite technology for education. With the August 2011 launch of the PAKSAT-1R communications satellite, Pakistan has joined this group of nations. The satellite, which provides TV broadcasting, internet, and data communication services, extends modern communications to the whole country. Pakistan's prime minister urged the national space agency to focus on tele-education for improving the quality of life in remote areas. The technology allows Pakistani students in outlying areas with little or no access to educational resources to link up with classrooms in major cities.[30]

More than 31 million students have participated in ISS-related educational demonstrations and more than 1 million students have conducted experiments linked to the space station. That number will grow even more with two new educational programs that began in 2011. The Plants in Space project, funded by the National Space Biomedical Research Institute, allows students to compare observations about ISS plant growth to those on Earth. In September 2011, astronauts on the space station planted *Brassica rapa* seeds with the goal of investigating the influence of light on root orientation. They took daily photographs of plant growth. Students are provided with the details of this experiment and have access to the images. They can design and conduct their own experiments, comparing their observations on the ground with the ISS observations. Combining the interest of students in designing their own experiments with student excitement about space activities is expected to engender a greater interest in science among students.[31] The YouTube Space Lab contest, open to students aged 14–18 around the world, challenges students to design an experiment that can be conducted in space. The two

Plants in Space examined plant root growth in microgravity. While astronauts grew plants on the International Space Station, students on Earth grew control plants in classrooms. Initial space-based experiments were completed in November 2011. The results were imaged and archived for future use by other teachers. *Credit: BioServe/NASA* winners of the contest will have their experiments performed by astronauts aboard the ISS, with results streamed live on YouTube. The contest is being carried out by YouTube, in cooperation with NASA, ESA, JAXA, the computer company Lenovo, and the private spaceflight company Space Adventures.[32]

1.2.4 Retail, Finance, and Corporate Services

Space can contribute not only to the products and services that individuals purchase and use, but also to those used by entire companies. A spinoff technology based on NASA's Nebula cloud computing platform is now helping companies to use their information technology resources more efficiently. NASA's complex organizational structure, with centers distributed throughout the country, has led to the creation of commercially-relevant IT systems, including the Object Oriented Data Technology (OODT) for sharing information, and Electronic Handbook (EHB) for documenting complex procedures.

Many NASA programs require significant data storage and processing capacity, and software developed to meet this requirement is now being made available to private companies. NASA's Nebula cloud computing platform was developed to allow scientists and engineers to pool IT resources, using only the services they need for the time period they need it, rather than building dedicated data centers to meet each program's needs. This service has saved NASA staff hundreds of hours and also makes it easier to provide data and products to the public.[33] Based on the technology developed for Nebula, NASA partnered with Rackspace to create OpenStack, an open-source cloud computing organization aimed at facilitating standardization of the cloud environment.[34] In 2011, this technology was further developed and spun off to a company called Piston Cloud Computing, which aims to provide cloud computing for private companies, adding in features that take into account concerns about complex configurations and security issues.[35]

The Object Oriented Data Technology was developed by a scientist at NASA's Jet Propulsion Laboratory to capture not only the planetary data being sent back by satellites, but also information about the history of the data and the links between different types of data. The OODT allows users to connect multiple, distributed databases and data sources and to search for information in a variety of data formats. Apache Software Foundation, a nonprofit organization supported by tech giants such as Google, Microsoft, and Yahoo!, further developed the software as an open source tool for non-space applications. OODT is now being used by the National Cancer Institute to share research about early cancer detection among many laboratories. The Children's Hospital of Los Angeles is using the technology to connect pediatric intensive care units around the country. This allows doctors to look at the outcomes of various interventions and make more informed treatment decisions.[36]

NASA's complex and distributed nature also led to the creation of an Electronic Handbook. The web-based EHB guides each user through complicated procedures that formerly required using multiple paper documents or legacy systems. Originally developed for NASA's Headquarters Directives Management process, the product was further developed by REI Systems of Herndon, Virginia, and is now used for a variety of other organizations and processes. The NASA-derived EHB model has more than 60,000 users with more than $6 billion in financial transactions per year. It is used to manage all of NASA's Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs, with 6,000 users in firms and NASA centers. The Department of Health and Human Services uses the EHB system to provide competitively awarded grant funding to states and localities, supporting more than 10,000 grantees.[37]

GPS-enabled phone applications are connecting businesses to their customers in new ways. Smartphone applications such as FourSquare, Google Latitude, and Yelp use GPS-enabled phones to allow users visiting a restaurant or store to check in and instantly share their location with friends. Now business owners are looking to benefit from the applications, partnering with their designers to offer real-time discounts and benefits when users check in. Since many of the applications share the check-in information with friends via social media sites, this can help increase awareness of a business and encourage others to visit. Several of the services also provide merchants with useful statistics based on the check-in data, giving them insights on their customers. For example, FourSquare provides a summary with the total daily check-ins, the most recent or frequent visitors, and the most popular time of day for check-ins.[38]

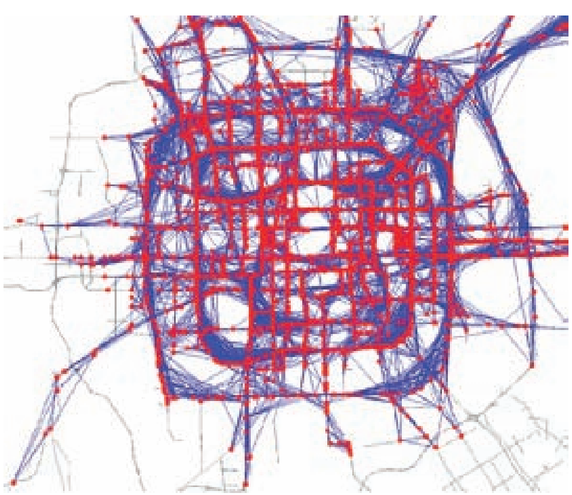
A company called Square is hoping to expand on these capabilities with its Card Case application, which allows users within 100 meters of a merchant that supports Square to pay for goods simply by saying their name at the checkout. The application uses GPS to detect that the user is near a merchant-enabled store, and opens up a tab on the merchant's Square application with the customer's name, account, and photo. The cashier can verify that the photo matches the customer before approving the charge. As of November 2011, Square accounts had been set up by 800,000 merchants.[39]

Applications such as Square Card Case combine geolocation and internet connectivity to enable new ways for customers and business to interact. A recent study by Juniper Research predicts that the total value of mobile payments will reach $670 billion by 2015. *Credit: Square*

1.2.5 Transportation, Logistics, and Manufacturing

GPS tracking has provided researchers and city planners with an important source of information for improving transportation systems. Studies using GPS tracking can help planners learn about where people are going, what methods of transportation they are taking, and how funds can best be spent to improve the system. It is being used to improve everything from school bus routes within a school district in Pennsylvania, to the whole transportation system of Beijing. GPS tracking coupled with software developed by NASA engineers is helping flyers save time and airlines save money by locating more efficient routes in real time. A sensor originally developed to monitor conditions in space is now playing an important role in optimizing the glass manufacturing process and leading to more energy efficient glass buildings.

The Baldwin-Whitehall School District Transportation Board, located near Pittsburgh, Pennsylvania, recently invested in almost 100 GPS systems for use on district buses. These GPS-enabled units are used not only for navigation, but also to monitor and improve safety and efficiency of the school buses. The system will identify potential fuel savings by sending alerts when buses have idled for too long. It can provide notifications when speed limits are reached or exceeded or when accidents occur. Bus routes can be downloaded, allowing the school to provide more accurate route information or design more efficient routes.[40]



Equipping taxicabs with GPS devices effectively turns them into persistent, ubiquitous sensors of a city's traffic flow and activity patterns. This approach has been used successfully in Beijing to help city planners manage traffic flows and develop transportation infrastructure. Further research is enabling prediction of traffic patterns and an adaptive route creation service for individual drivers. *Credit: Association for Computing Machinery*

In September 2011, the Nashville, Tennessee, Area Metropolitan Planning Organization selected firms that will use GPS monitors as part of a unique study of the connections between transportation and health. The study will begin with a survey of the daily travel and commuting patterns for 6,000 residents. The next step will examine in depth the health and activity levels of 600 people wearing GPS monitors. The monitors can be clipped onto the waist and are to be worn over a four-day period whenever research subjects travel outside the house. The study is expected to inform decisions on the spending of $6 billion in transportation funds.[41]

Researchers at Microsoft Research Asia used GPS data from more than 33,000 Beijing taxicabs over two years, amassing enough data to analyze every road in the city. This data not only showed areas where traffic slowed down, but also showed where journeys started and finished, and how a commuter traveled in between. This allowed researchers to identify the source of the problems, rather than just pointing out bottlenecks already familiar to regular commuters. They looked at what regions people were traveling to and from, and identified when the network of roads and subway lines could not support the number of people traveling between those regions. They urged urban planners to focus their attention on these areas and demonstrated improvements caused by changes made over the course of the monitoring period.[42]

Many U.S. cities, including Minneapolis, New York City, and Washington, D.C., have recently become home to citywide bike-sharing programs. These programs promote exercise and help to reduce automobile traffic, but one of the challenges is ensuring that bikes are not lost or stolen. Launching in mid-2012, the New York City bike share program is solving this problem by installing GPS tracking devices on all of the bikes. The GPS tracking also allows system operators to get real-time information on where bikes travel, allowing better planning for future development of the system.[43]

NYC Bike Share is planned to launch in mid-2012. The system uses state-of-the-art automated bike share equipment that is portable, solar-powered, wirelessly-integrated and sturdy enough to handle the demands of New York City's urban environment. GPS units are installed inside the bikes to allow tracking of routes and to prevent theft. *Credit: Alta Bicycle Share*

Air travel also benefits from space technology. As of March 2011, aircraft can use the satellite-based European Geostationary Navigation Overlay System (EGNOS), which improves the accuracy of GPS signals in Europe, to aid in the critical task of vertically guiding aircraft during landing approaches. EGNOS has been used for some navigation applications since 2009, but was not Safety-of-Life Service certified until 2011. The new signal will improve passenger safety and help to reduce flight delays, diversions, and cancellations.[44]

Building on research that started at NASA's Ames Research Center, Boeing incorporated flight path optimization technology into its Direct Routes product. This service, made commercially available in 2011, provides real-time advisories to aircraft for suggested shortcuts that have been pre-checked for traffic conflicts, wind conditions, and other factors. The system uses real-time information to locate routing opportunities that pilots or controllers may have missed. The technology has the potential to save commercial airlines thousands of hours in the air and up to 20 million gallons of fuel each year, reducing both cost and carbon emissions.[45]

Space technology also has a role to play in manufacturing. Technology originally developed to measure oxygen atoms outside space vehicles is now being used by glass manufacturers to produce energy-efficient windows. Oxygen is highly corrosive, so levels of this atom around the space station need to be carefully monitored. The University of Dresden, along with the German company, ESCUBE, developed an efficient sensor to carry out this task with minimal size, weight, and power consumption requirements. These attributes made the technology attractive for non-space use. Designed for the harsh space environment, it was well suited to the glass-production process, which involves high temperatures and reactive gases. Use of the technology has allowed optimization of the glass-coating process, so that the light passing through glass is nearly the same as standard glass, but there is significantly less heat loss in winter and heat gain in summer.[46]

1.2.6 Homeland Security, Defense, and Intelligence

Some of the earliest satellite applications were related to national defense and intelligence, and each year new military, intelligence, and homeland security space applications are developed and new technologies are created. Satellites can be used to track ships at sea, monitor the skies for missiles or other threats, and gather intelligence about remote locations. GPS tracking can help locate soldiers, police, or criminals, increasing the ability of commanders and law enforcement officials to do their jobs.

Satellite-based ship monitoring is expected to develop as a large new business in 2012, providing global coastal authorities with information about ships farther out at sea, beyond the reach of coastal radar systems. The International Maritime Organization mandates that ships weighing more than 300 metric tons carry onboard terminals to beam ship identity, cargo, speed, and heading data to the coast, and this information is currently collected by coastal radar. Implementing satellite-based automatic identification system (AIS) data does not require any additional technology to be added to ships. Both Com Dev of Canada and Orbcomm of the United State began launching AIS payloads aboard satellites in 2011 and began providing services shortly thereafter.[47]

The satellite component of the U.S. Missile Defense program made great strides in 2011. The Space Tracking and Surveillance System (STSS), launched in 2009, completed its last test focus area required by the Missile Defense Agency in April 2011, five months ahead of schedule. The system is made up of two satellites with a vantage point 800 miles above the Earth, which allows them to detect missiles in areas that ground-based radars and tracking systems cannot. It is the only system capable of tracking ballistic missiles through all phases of flight. The satellites can also pass a map of the missile's trajectory to sea- or land-based interceptors so they can destroy the threat.[48] Another missile defense satellite, the Spaced Based Infrared System (SBIRS) GEO-1, was launched in May 2011. SBIRS operates in geosynchronous orbit and provides real-time missile warning and defense monitoring. SBIRS GEO-1 is the first in a series of satellites planned to replace the aging Defense Support Program satellites.[49]

Surveillance satellites are used on a daily basis for military planning and intelligence. The military operation against Osama Bin Laden in 2011 is a prime example of how these space assets are used. After the CIA and U.S. military determined the potential location of Osama Bin Laden's compound in Abbottabad, Pakistan, satellite images were used to create a detailed map from above. The map was likely developed using assets belonging to the National Geospatial-Intelligence Agency, though a number of military and commercial satellites may have also provided relevant mapping data. This information included not only visible spectrum images, like those commonly seen on Google Earth, but also imagery in a variety of wavelengths. Using satellite imagery of the target over time can show the development of the site. In the case of the Bin Laden compound, images show an empty lot in 2001, a new building in 2005, and an expanded compound in 2011. When the operation was actually carried out, secure satellite communications were essential to connecting warfighters in the field with experts directing the operation. Some Navy SEALs likely also wore small, helmet-mounted cameras that sent a stream of encrypted video.[50]

Lockheed Martin engineers complete work on the Space Based Infrared System (SBIRS) GEO-1 spacecraft. SBIRS provides infrared surveillance capabilities that aid in missile warning and defense and battlespace awareness. *Credit: Lockheed Martin*

The military is finding that new smart devices, such as phones, enabled by space assets can improve soldiers' ability to carry out their missions. In the past, a helicopter pilot trying to locate U.S. troops under attack would have to find the group by locating the right map, unfolding it, and pinpointing the position of the troops. Now, the military is experimenting with the use of GPS-enabled iPads, allowing pilots to quickly move from one map to another, zooming in and out as needed. As of September 2011, Marines had more than 30 iPads in cockpits across their fleet of helicopters and fighter jets. Soldier Eyes aims to provide soldiers with a map based on a GPS position, which shows their location as well as the location of adjacent units. It could also show past information, such as the number of roadside bomb attacks that have occurred in the area and when they took place. Though research is underway to develop useful applications, some are concerned about security, particularly when using commercially available electronics. Information security firms hope to address this issue by developing services that could help secure these military networks.[51]

Laipac Technology has developed a bulletproof vest that incorporates GPS, sending an automatic alert when the vest is fired upon. This allows a separate team to immediately locate soldiers or police officers that have been attacked, providing backup or medical assistance.[52] Another technology, originally developed by NASA to track physiological conditions of astronauts during training to overcome motion sickness, can now be used to monitor the condition of soldiers on the battlefield. The Zephyr BioHarness is a thin material worn around the torso that continuously transmits data to rescue vehicles and field hospitals, alerting medics more quickly than a radio call. It also allows doctors to be up to date on the patient's medical status when they arrive at the hospital.[53]

Though GPS tracking can be an effective way of following suspected criminals, its use by police is now more restricted. In January 2012, the U.S. Supreme Court ruled unanimously that police erred in not obtaining a warrant before attaching a tracking device to a suspect's car. During the investigation of a drug conspiracy, rather than having an officer follow the suspect in person, FBI agents and local police placed a GPS device on the suspect's car. After tracking the car for one month, police were able to determine the location of a suburban house where drugs and money were being stored, and this evidence led to a conviction of the suspect. An appeal of that ruling later threw out the conviction because of the lack of a warrant.[54] The case represented the first review of GPS tracking by the Supreme Court, and though the finding was unanimous, the reasons provided by the justices differed. One group explained that the GPS device constituted an unreasonable search, in violation of the Fourth Amendment. Other judges argued that it was the suspect's expectation of privacy that had been violated.[55]

A 650-gallon Gravity Probe B thermal insulation vessel undergoes tests at Stanford University. It took Stanford, NASA, Lockheed Martin, and a host of physicists, engineers, and space scientists nearly 44 years to develop the ultra-precise gyroscopes and the other technology necessary to carry out this deceptively "simple" experiment. *Credit: Lockheed Martin Corporation/R. Underwood*

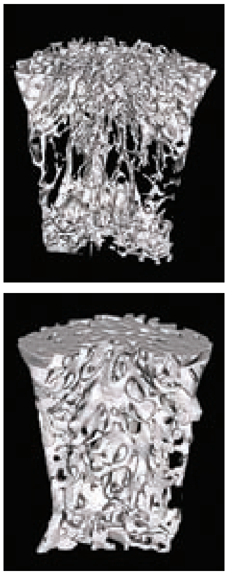
1.2.7 Science, Biotechnology, and Health Care

Space provides a unique environment that allows scientists to study how familiar materials and processes behave in microgravity. Experiments are carried out in space using satellites or with the help of astronauts aboard the International Space Station. In the future, suborbital space companies hope to provide more routine and less expensive access to space, allowing even more experiments to be conducted. The microgravity environment of space can also provide a unique perspective on health issues, and companies are conducting research aimed at developing new drugs. In addition to research actually carried out in space, space assets can be used to improve our understanding and awareness of medical issues on Earth, such as the outbreak of diseases associated with particular environmental conditions.

Our understanding of the Universe relies on scientific theories, and it is important that these theories be tested using available methods. In May 2011, scientists working on the Gravity Probe B project announced that a set of orbiting gyroscopes had reaffirmed Albert Einstein's theory of general relativity. The two carefully designed satellites orbited Earth and took measurements of the effects of space on these probes. Einstein's theory of relativity states that the pull of gravity from massive objects in the Universe, such as the Earth, causes space to distort. This distortion is similar to the way a mattress changes shape if a bowling ball is set on it. Another aspect suggests that space can actually spin as it is pulled by the spinning of a massive object. This is similar to the way twisting a straw in a cup of water causes the liquid around it to spin. The orbiting probes detected both of these effects in the space around the Earth, though the effects are miniscule. Each year, space near the Earth is turning by 37 one-thousandths of a second of arc, about the thickness of a human hair seen from 10 miles away. These findings are considered the most direct measurements ever of Einstein's theory of relativity.[56]

The Gravity Probe B project required an extended stay in space and cost about $750 million. However, suborbital spaceflight companies are hoping to provide future researchers with a quicker, cheaper method of carrying out research in space, even if only for a few minutes at a time. Given the unique conditions experienced on these flights, companies expect that scientists will use this opportunity to carry out experiments in many areas, including materials science, biology, astronomy, and climate research.[57]

Virgin Galactic has already taken deposits for its first science flights, at a cost $200,000 per seat. The flights, which carry six passengers and two pilots to more than 100 kilometers (62 miles) above the Earth, provide about four minutes of weightlessness while in space.[58] Scientists are also purchasing seats on XCOR Aerospace's Lynx suborbital vehicle, which charges $95,000 per seat and carries just one passenger and one pilot. One of the organizations that has already purchased flights, the Southwest Research Institute, is planning to carry out experiments that look at the way loose soil and rocks, like those on asteroids, behave in microgravity. The institute also plans to fly an ultraviolet telescope that once flew on the space station, and will monitor a scientist experiencing suborbital flight.[59]

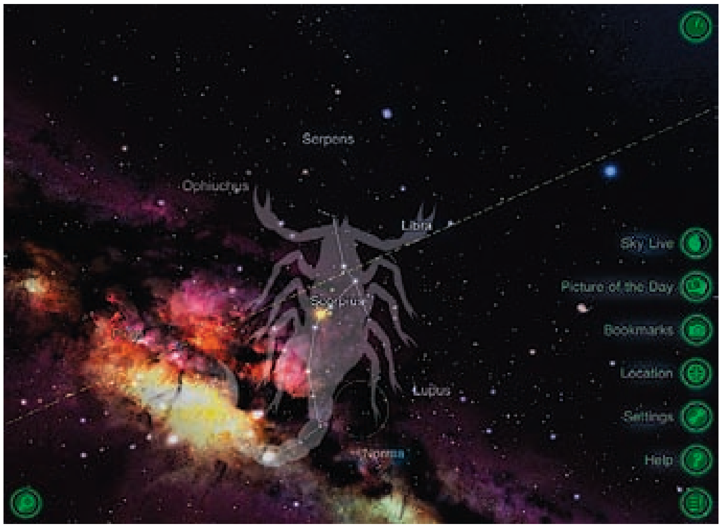


The top image shows the effect of zero gravity on a bone from a rodent treated with a placebo during drug testing on the final flight of Space Shuttle *Atlantis*. The bottom image shows a much denser bone from a rodent treated with a sclerostin antibody. *Credit: Amgen*

Since 2001, researchers at the Max Planck Institute for Extraterrestrial Physics have been studying plasma, which is electrically charged gas. Based on this research, these scientists are now developing a new way for hospitals to keep patients safe from infections. The new system would make use of plasma's innate antibacterial properties to make disinfection easy and quick. In the future, it could be expanded to medical instruments and other applications. Unlike ultraviolet light, which only sanitizes the surfaces it shines on, plasma would disinfect areas in hidden cracks and crevices. Better sanitation would help to avoid the spread of bacteria, including antibiotic-resistant super-bacteria, which cause tens of thousands of deaths each year.[60]

The world's largest biotechnology company, Amgen, launched 30 mice on NASA's final shuttle mission in July 2011 to test an antibody that could help prevent bone loss. The lack of gravity during space flight causes loss of bone mass in humans, and scientists are hoping that these experiments will determine whether the antibody can reduce this effect. Lessons learned from this research could be used to help deal more effectively with the bone-loss impacts from a number of causes including stroke, cerebral palsy, muscular dystrophy, spinal cord injury, and reduced physical activity.[61]

Another experiment used satellites to track disease-carrying mice on the Earth and showed that this method could provide early warning of outbreaks of the dangerous Hantavirus, a disease that kills about 42% of those infected. In the United States, Hantavirus is most prevalent in Arizona, California, Colorado, Montana, New Mexico, Texas, Utah, and Washington. Researchers at the University of Utah found that satellite images showing the level of "greenness," or vegetation cover, of an area is a good predictor of the population density of deer mice, which carry Hantavirus. Scientists noted that the same technique could be used to monitor outbreaks of other rodent-borne diseases, such as bubonic plague and salmonella infection.[62]

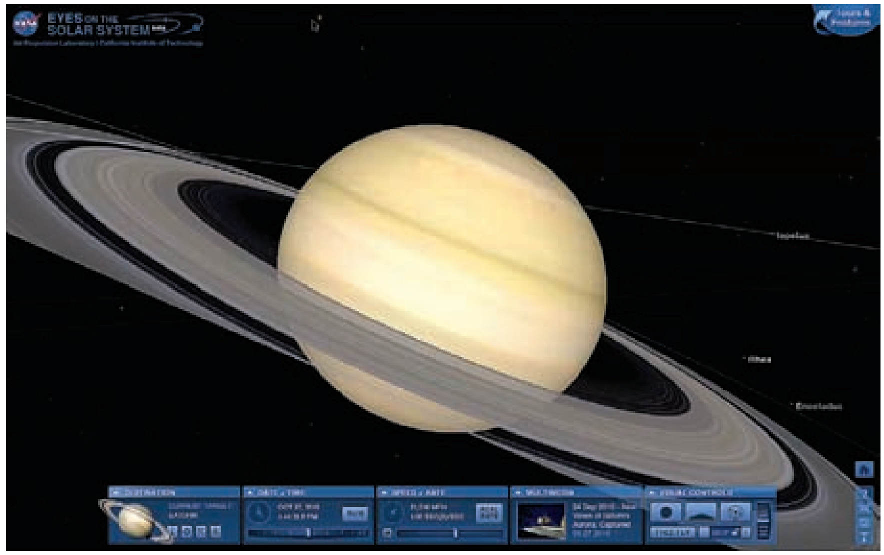


Star Walk is an educational iPad application that allows users to easily locate and identify more than 20,000 objects in the night sky. The 360-degree, touch-controlled star map displays constellations, stars, planets, satellites, and galaxies overhead from anywhere on Earth. *Credit: Vito Technology*

1.3 Products and Services About Space

Many products have been developed in the past year to help people learn about and connect to human knowledge and activities related to space. These applications can often help space professionals in addition to interested members of the public.

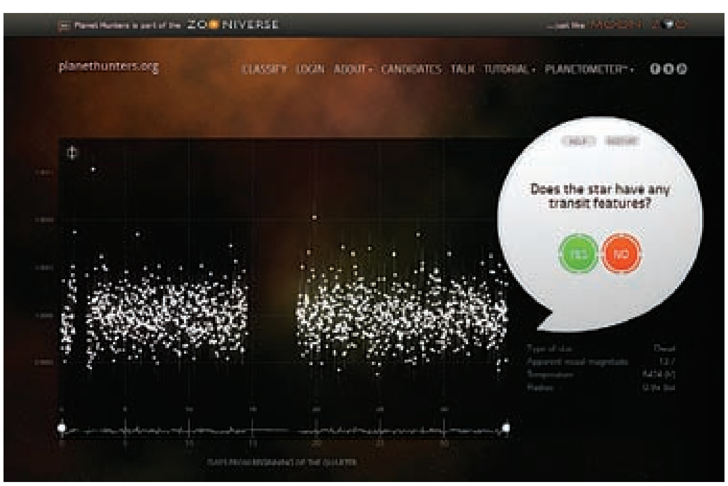
A number of smartphone applications have been developed for amateur astronomers. Many of these stargazing applications rely on GPS, but rather than helping people find things on the ground, these applications provide users with an accurate view of constellations in the night sky. Many applications go beyond star constellations and planet locations. The Star Walk application, by Vito Technology, provides information on moving satellites, on how the sky looked on past nights, and data about particular celestial objects. Many applications, including Google's free Sky Map, allow users both to view and search for constellations and other celestial objects in the sky.[63]



Eyes on the Solar System is a three-dimensional environment that uses actual NASA mission data to allow users to explore the cosmos from a computer. Played like a game, the program gives the user complete control. *Credit: California Institute of Technology*

Those interested in seeing more of the Universe than they can view from their backyard may be interested in NASA's Eyes on the Solar System tool, which debuted in September 2011. This internet-based program allows users to ride along with NASA satellites, seeing what they see, all from a home computer. The tool uses videogame technology and NASA data to allow users to explore space. Users can follow any spacecraft, such as the Juno probe currently on its way to explore Jupiter, and see where it is now and what lies ahead for its trip. NASA has included data from as far back as the 1950s, so users can even explore past missions. In all of these cases, users can choose from a variety of viewpoints in both 2D and 3D. The project is committed to sharing NASA science with everyone, encouraging interest in space exploration.[64]

Another activity based on NASA data, called Planet Hunters, allows anyone on the internet to help search for planets around other stars by analyzing data from the Kepler Space Telescope. In September 2011, NASA announced that participants had identified two new planets in a distant star constellation. As part of the Planet Hunters game, players are given images of fields of stars that have been tracked for 30 or more days. Players then hunt for "transit events," times when the star dims, an effect that occurs when a planet is passing in front of the star—recognizing patterns that were missed by automated processes. With more than 40,000 members logged since 2009, Planet Hunters has led to the discovery of 69 potential planets, which NASA is now analyzing in more depth.[65]



A collaboration between Yale University and the Zooniverse, a citizen-science project, Planet Hunters uses crowdsourcing and pattern recognition in the search for new planets. The program has already seen some success, with participants discovering two Earth-like planets in 2011. *Credit: Planet Hunters*

Recognizing that it does not have a monopoly on unique ways for the public and scientists to access its data, NASA partnered with TopCoder to launch a contest in April 2011, challenging people to come up with applications to allow exploration and analysis of the extensive information archived in its Planetary Data System. The system includes scientific data from NASA's planetary missions, astronomical observations, and laboratory measurements.[66] Entries were evaluated by judges from NASA and Harvard University, and winners were announced in May 2011 with more than $3,000 in prizes awarded. Though the contest focused on ideas rather than finished applications, NASA noted that a future challenge could focus on implementing the winning idea from this challenge.[67]

1.4 Emerging Technologies

There are many exciting technologies still in the initial phases that space assets and technology could help to make a reality. Although the long-term success and impacts are unknown at this time, history has demonstrated that investment in these technologies can create tremendous benefits.

The United States Army is working on initial testing of a plan that would use swarms of small, inexpensive satellites to meet warfighter needs on the ground. The first of these test satellites, SMDC-ONE, was launched at the end of December 2010. The small satellites can be built and launched more quickly and cheaply, and having many satellites in orbit should make it more likely that soldiers in valleys will have a satellite overhead, allowing them to transmit information without moving to higher ground. The size of the satellites also makes them harder for enemies to track and target. The first satellite launched was a communications tool, relaying data from sensors in the field back to bases. In 2012, the Army plans to test-fly another nanosatellite, Kestrel Eye, which would take pictures with a resolution of about 1.5 meters (5 feet). The goal would be to give warfighters the ability to request and receive pictures of their surroundings within one minute. These small satellites only last one or two years in space, compared to the 15 years typical of traditional, large military satellites. This allows them to take advantage of cutting edge technology but also means that launches must occur more frequently, a part of the plan that is currently cost prohibitive. The Army hopes that as new, cheaper launch vehicles are developed, nanosatellites could help to increase the amount of timely, valuable information available to troops on the ground.[68]

The first satellite built by the U.S. Army in 50 years, the SMDC-ONE is a 25-centimeter (10-inch) long, 4.5-kilogram (10-pound) nanosatellite. The performance is less than a single large traditional military satellite, but this is offset by the relatively low cost that allows for large numbers to be built and deployed for specific missions. *Credit: U.S. Army*

U.S. Special Forces Operations Command is also looking at the possibility of using very small satellites to meet its unique requirements. The Special Reconnaissance, Surveillance, and Exploitation program is responsible for locating high-value targets and covert tracking. When a special forces unit wants to follow a high-value target, it cannot simply take over an existing military satellite to carry out this tracking. However, if it could launch a small and inexpensive satellite, it would be possible to use this asset to focus exclusively on the target of interest. A special operations office announced that four satellites had been launched in 2011 to demonstrate the ability to collect tagging, tracking, and locating data. Though few details about the satellites and the demonstration testing are available, officials have said there are plans to move forward and improve the system.[69]

In another project making use of small satellites, British and Russian scientists hope to develop a satellite system that could provide earthquake warnings much earlier than is currently possible. Scientists already know that electromagnetic signals are released as stress builds up in the Earth prior to an earthquake. However, sensors on the ground experience too much interference and often are not located close enough to the earthquake site to be useful. By contrast, in space, the interference is much lower and the signal can be detected over a much wider region. Scientists working on the project, called TwinSat, are planning to put two very small satellites about 400 kilometers apart in low Earth orbit, allowing them to work in unison to collect and interpret electromagnetic signatures from the ground. The launch for these initial satellites is currently planned for 2015.[70]

Another technology in the early stages of research would use collars with both GPS receivers and accelerometers to transform the way wild animal populations are managed. The collars would use GPS to record the locations of the animals, and accelerometers to track their movements, providing biologists with an unprecedented amount of data. The collars would essentially provide a 24-hour diary of animal life, including where they were and what they were doing. Eventually, scientists could get to the point where they could issue warnings based on observed animal behavior. For example, if a mountain lion seems to be traveling beyond its normal range searching for

Neurosurgeons at Carle Foundation Hospital in Urbana, Illinois, are conducting research for the U.S. Department of Defense on the effects of cooling on brain injuries. The researchers are using a cooling head cover invented by William Elkins, a former NASA scientist with experience in space suit design. Mr. Elkins has been recognized for pioneering advancements in the use of mild hypothermia to treat multiple sclerosis and was inducted into the Space Technology Hall of Fame for his work in liquid cooling technology therapies. *Credit: Vanda Bidwell/The News-Gazette*

food, warnings could recommend that hiking be limited in a particular area or that small pets be kept indoors. Currently under production only in university research labs, these collars could be available for commercial production within a few years.[71]

New technologies for human health are also being developed. The benefits of putting an ice pack on a twisted ankle are familiar to most people. Dr. John Wang at the University of Illinois College of Medicine at Peoria noted that cooling the brain after traumatic head injuries may also have a beneficial effect, delaying damage to the brain to increase the amount of time a patient has to receive treatment. To develop the necessary cooling helmet technology, Dr. Wang collaborated with former NASA scientist William Elkins, who worked on the liquid-cooled garments within space suits designed to protect Apollo astronauts from high temperatures on the Moon. Initial research carried out by Dr. Wang showed that it is possible to cool the brain using the technology they developed. Now he plans to research how well the cooling helmet works in emergency medicine applications, testing it on head injury and stroke patients. In the future, many conditions may be treated by brain cooling.[72]

1.5 Measuring the Impacts of Spinoffs

The development of space products and services, and in particular space spinoffs, has been tracked for many years, and it is well known that space technologies result in many benefits for non-space areas. However, this tracking has been primarily qualitative. The few quantitative benefit studies that have been carried out have been sporadic, and because they were conducted by different groups, the methods used were not consistent. Researchers have looked at multiplier effects, revenue generation, and other factors, but results vary considerably.

For many years, NASA has published an annual report qualitatively describing recent spinoff technologies. Starting in 2011, the reports also show the quantitative benefits of these technologies. NASA has carefully selected metrics that will be collected consistently from all companies it includes in its annual *Spinoff* publication. The metrics chosen by NASA include lives saved, cost reductions, jobs created, and revenue increases. An initial study surveyed 250 companies using spinoff technologies developed before 2011, and approximately 100 companies had responded as of late 2011. NASA documented that more than 12,000 lives have been saved by spinoff technologies such as cardiovascular medical devices and life rafts. The numerous new and expanded companies associated with NASA spinoff technologies have created more than 9,200 jobs. Improved aircraft design, robot submersibles capable of inspecting dams, and other technologies resulted in more than $6.2 billion in cost savings. Finally, NASA has determined that as a primary or secondary result of NASA support, partner companies have generated more than $1.2 billion in revenue.[73] NASA plans to continue to collect and update these metrics to consistently document the quantitative benefits of spinoff technology.

THE SPACE ECONOMY

In the grasp of the International Space Station's Canadarm2, the Italian-built Permanent Multipurpose Module (PMM) is transferred from the payload bay of Space Shuttle *Discovery* to be attached to the Earth-facing port of the station's Unity node. Previously known as the Leonardo Multi-Purpose Logistics Module, the PMM was used by space shuttles to transport cargo to and from the ISS seven times before it became a permanent addition to the station. *Credit: NASA*

EXHIBIT 2a. **Topics Covered in The Space Economy**

2.0 Introduction

The global space industry showed very strong growth in 2011, increasing more than 12% from 2010. Commercial space revenue and government budgets reached a record total of $289.77 billion in 2011. This follows a trend of continuing expansion in the global space economy, demonstrating a five-year growth rate of 41% from $205.04 billion in 2006, with the largest growth registered in commercial infrastructure and support industries.

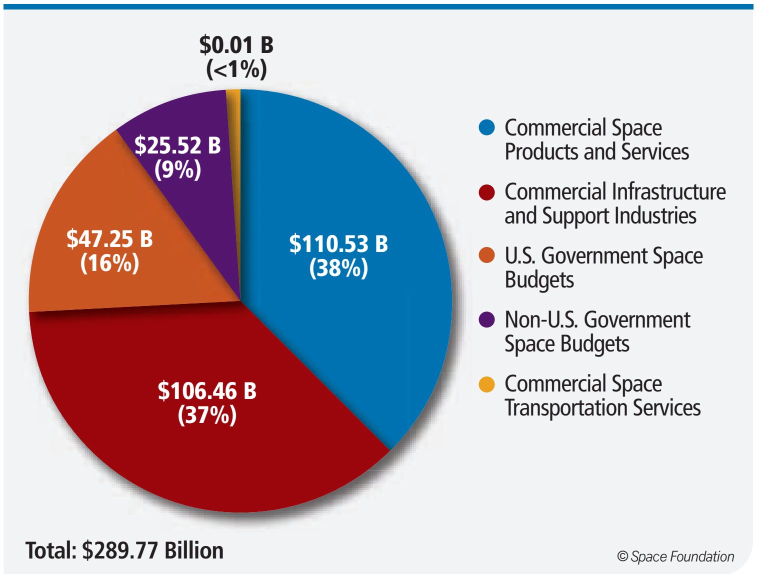
EXHIBIT 2b. **The Global Space Economy**

Year	Total*	Growth
2005	$177.34 B	–
2006	$205.04 B	15.6%
2007	$218.94 B	6.8%
2008	$229.54 B	4.8%
2009	$238.25 B	3.8%
2010	$258.21 B	8.4%
2011	$289.77 B	12.2%

** Figures for previous years were revised due to methodology changes noted in Section 2.4.*

Much of the space economy's continuing growth is driven by commercial space products and services, along with infrastructure investment necessary to deliver those services. Commercial space products and services, including telecommunications, Earth observation, and positioning services, remain the largest source of revenue in the space economy, growing to $110.53 billion in 2011, a 9% increase from $101.73 billion in 2010. Commercial infrastructure and support industries, including spacecraft manufacturing, in-space platforms, ground equipment, launch services, independent research and development, and insurance premiums, showed the strongest percentage growth of any space sector in 2011. Commercial infrastructure and support industries revenues totaled $106.46 billion in 2011, a 22% increase from $87.61 billion in 2010. This growth was driven primarily by sales of global navigation satellite systems (GNSS) receivers. Commercial space transportation services revenues are estimated to total $0.01 billion in 2011, the same as in 2010.

EXHIBIT 2c. **Global Space Activity, 2011**



Globally, government spending on space increased from 2010 to 2011. The aggregate growth rate was 6%, bringing government spending to $72.77 billion in 2011. Government spending accounted for 25% of the global space economy, a decrease from 27% in 2010. The U.S. government spent $47.25 billion in 2011, a 0.4% decrease from the $47.44 billion spent in 2010. Non-U.S. government space investment reached $25.52 billion in 2011. For non-U.S. countries reviewed in both 2010 and 2011, government space expenditure grew strongly, with combined spending increasing by 20% from 2010.

Most sectors of the space economy experienced growth in 2011, thanks to the efforts of a skilled workforce and successful business leaders. Combined with the multiyear growth trend in the overall space economy, this indicates positive prospects for developments in the space industry.[1]

2.1 Commercial Infrastructure and Support Industries

Revenue for commercial space infrastructure, which includes satellite manufacturing, launch services, space stations, ground stations, and associated equipment, totaled $106.46 billion in 2011. Information regarding government spending on space infrastructure can be found in Section 2.3, *Government Space Budgets*.

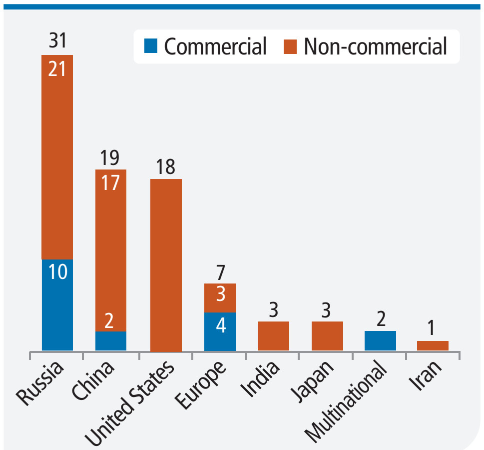
EXHIBIT 2d. Revenues for Space Infrastructure, 2011

Commercial Infrastructure and Support Industries	Revenue	Source
Ground Stations and Equipment	$99.24 B	Satellite Industry Association (SIA)/ Futron analysis
Satellite Manufacturing (commercial)	$4.24 B	SIA/Futron analysis
Launch Industry (commercial)	$1.93 B	Federal Aviation Administration (FAA)
Insurance	$0.86 B	AON/ISB
Independent Research and Development	$0.19 B	Futron
Total	**$106.46 B**	

2.1.1 Launch Industry

In 2011, 84 launches were attempted carrying 133 payloads, including satellites, interplanetary probes, and flights to the International Space Station (ISS). Compared to the 2010 total of 74 launches, this represents a 14% increase in launch rate.

EXHIBIT 2e. Orbital Launches, 2011



Source: Federal Aviation Administration

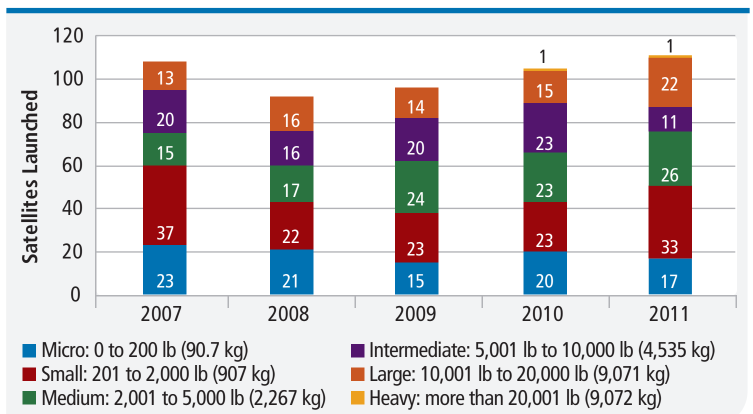
Of the 84 launches in 2011, 18 were conducted by commercial launch providers and 66 by governments. Space industry analysts at Futron Corporation estimate the total 2011 expenditure on orbital launches to be approximately $8.17 billion, an increase of 12% from the $7.32 billion total for launches in 2010. The total value of commercially operated launches was approximately $1.93 billion in 2011, a decrease of 21% from the $2.45 billion collected in 2010. Spending on launches to supply the ISS was approximately $2.3 billion for 2011.

As has been the case for the past several years, Russia led the global commercial launch market with 10 launches in 2011, representing 56% of the market. Europe captured 22% of the market, with four commercial Ariane 5 launches during the year. No commercial launches were conducted using U.S. vehicles in 2011. This decrease is due in part to a change in ownership of Sea Launch, now majority owned by a Russian company following emergence from bankruptcy. After a two-year hiatus, the multinational Sea Launch and Land Launch performed one launch each in 2011. China conducted two launches for commercial satellite operators in Europe and Nigeria. Launch industry forecasts can be found in Section 3.1.1, *Orbital Launch Vehicles*.

2.1.2 Satellite Manufacturing

In 2011, a total of 110 satellites—of which 40 were commercial—were launched into space, an increase of 5% from the 105 satellites launched in 2010. This total includes most spacecraft but excludes missions to the ISS or short-term technology demonstration missions. The 110 satellites represented approximately $11.9 billion in manufacturing revenue, compared to the 2010 total of $10.31 billion. During the past five years, the number of satellites in each mass class has remained relatively consistent, as shown in Exhibit 2f. The 40 commercially operated satellites launched in 2011 represent a 48% increase from the 27 launched in 2010. Commercial satellite manufacturing revenue increased from the 2010 total of $3.41 billion to $4.24 billion in 2011, a 24% increase. Twelve of the commercial satellites launched in 2011, valued at $1.59 billion, were manufactured in the United States, compared to the 10 U.S.-manufactured satellites launched in 2010. The U.S. share of commercial satellite manufacturing revenues fell in 2011, comprising 38% of the world market compared to 51% in 2010.

EXHIBIT 2f. Satellite Mass Class, 2007–2011



Source: Futron

EXHIBIT 2g. Satellite Manufacturing Revenue Estimates, 2011

Type	Revenue
Government	$7.66 B
Commercial	$4.24 B
Total	**$11.90 B**

Source: Futron

2.1.3 Space Stations

The ISS reached core completion in 2011. The largest funding contributor to the ISS, NASA, received $2.7 billion for the ISS in fiscal year (FY) 2011, compared to $2.31 billion in actual spending during FY 2010.[2] During 2011, the final three flights of the Space Shuttle occurred. Those flights delivered cargo, crew, the Permanent Multipurpose Module, the Alpha Magnetic Spectrometer, and the Robotic Refueling Mission testbed to the ISS.

The ISS hosts an international crew of up to six who conduct research and test technologies. During 2011, one Japanese H-II Transfer Vehicle (HTV), one European Automated Transfer Vehicle (ATV), and five Russian Progress space freighter vehicles conducted resupply missions to the ISS. Additionally, three Soyuz spacecraft missions transferred crew members to and from the ISS. NASA is planning to meet future ISS cargo transportation needs with commercial space vehicles contracted under the Commercial Resupply Services program. Crew transportation needs will be met by the Soyuz until other services become available. In the long-term, NASA is aiming to use its Commercial Crew Program to create a crew transportation capability that could be used to ferry crew members to and from the ISS.

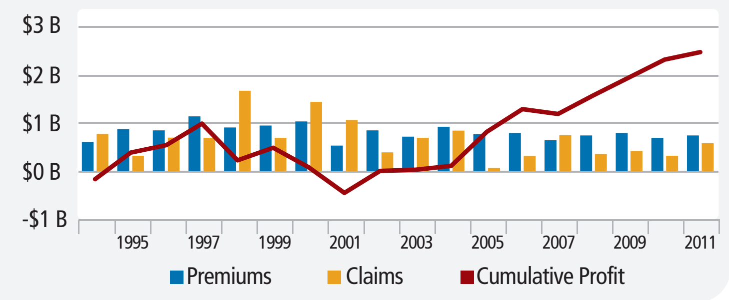
Bigelow Aerospace, a commercial company, is developing next-generation expandable space habitats that will support public and private sector activities in low Earth orbit (LEO) as well as beyond-LEO future human exploration missions. In February 2011, the Emirates Institute for Advanced Science and Technology (EIAST), a government entity responsible for Dubai's space activities, became the seventh organization to execute a Memorandum of Understanding with Bigelow Aerospace to explore the future use of the company's orbital space complex. However, due to lack of funding and subsequent delays to NASA's Commercial Crew Program, a service that Bigelow Aerospace is dependent upon to spur development of essential transportation capacity, the company adjusted its production plans and employee levels. This was done to ensure that the completion of the first operational Bigelow Aerospace system, the BA 330, would not occur years before crew transportation becomes available. By mid-2010, the company's founder, Robert Bigelow, had spent about $180 million of his own money and stated that he was willing to spend up to $320 million more. Company officials confirm that Mr. Bigelow continued to spend substantial funds on Bigelow Aerospace's operations, development, and BA 330 construction during 2011. Other activities that Bigelow Aerospace was involved in during the year included work as a member of the Boeing team in support of the CST-100 crew capsule and engaging in discussions with NASA to attach a Bigelow module to the ISS.[3]

JAXA technicians prepare the H-II Transfer Vehicle "Kounotori." These transfer vehicles resupply the International Space Station, are loaded with waste material from ISS, then burn up upon re-entering the atmosphere. *Credit: JAXA*

2.1.4 Ground Equipment

The ground equipment market totaled an estimated $99.24 billion in 2011, a 23% increase compared to $80.70 billion for 2010. Ground equipment includes all Earth-based infrastructure and technology necessary to communicate with and manage satellites: major network ground control stations, mobile satellite terminals such as very small aperture terminals (VSATs) for private networks, broadcast video distribution stations, and end-user consumer equipment. Consumers use a wide variety of products such as satellite radios, satellite phones, satellite television receivers, and satellite navigation chipsets, maps, and software. The revenue from these industry and consumer categories is combined into one figure representing the ground equipment market.[4] The largest component of the ground equipment market, geolocation and navigation equipment sales, accounts for 90% of revenue.

EXHIBIT 2h. Space Insurance Industry Estimates, 1994–2011



Source: Willis Inspace

2.1.5 Infrastructure Support Industries

The satellite insurance industry saw profits decline in 2011 but the industry was still profitable, continuing a decade of strong performance. Aon/ISB, an insurance brokerage, reported that the space insurance industry in 2011 collected premiums totaling approximately $859 million while spending totaled $602 million on claims.[5] Another broker, Willis Inspace, independently estimated that collective industry premiums totaled $750 million, while claims totaled $590 million in 2011.[6] Although profits decreased in 2011, the space insurance industry has gathered greater premiums than claims in the last nine out of ten years. The cumulative profits from 2002–2011, shown in Exhibit 2h, have steadily driven rates down to historic lows. However, reduced profitability in 2011 may slow the decline of space insurance rates, which averaged approximately 10% of the policy value for coverage of satellite launch plus one year of operation as of early 2012.[7]

Independent research and development (IR&D) is initiated and conducted by defense contractors independent of Department of Defense (DoD) control. Space IR&D is estimated by applying the ratio between DoD space R&D and total DoD R&D to the total DoD IR&D estimate developed by the Defense Contract Audit Agency. The total space IR&D value is estimated at $187.18 million for 2011.

EXHIBIT 2i. Revenues for Commercial Space Products and Services, 2011

Category	Revenue	Source
Direct-to-Home Television	$86.42 B	SIA/Futron analysis
Satellite Communications	$18.85 B	SIA/Futron analysis
Satellite Radio	$3.02 B	SIA/Futron analysis
Earth Observation	$2.24 B	Northern Sky Research
Total	**$110.53 B**	

2.2 Commercial Space Products and Services

The commercial sector continues to dominate the space economy. Total revenue for commercial space products and services in 2011 is estimated at $110.53 billion, 9% more than the $101.73 billion in 2010. This total includes revenues from satellite broadcasting, communications, and Earth observation. Although updates for the geolocation and navigation industry are discussed in this section, the associated revenues are included in the ground equipment sector because the majority of the revenue is derived from receiver sales. Satellite broadcasting still leads the commercial satellite service sector, with direct-to-home (DTH) television's estimated revenues reaching $86.42 billion in 2011, a 9% increase from $79.12 billion in 2010. The satellite communications segment, which includes fixed satellite services (FSS) and mobile satellite services (MSS), generated revenue of $18.85 billion in 2011, a 7% increase compared to the 2010 revenue of $17.67 billion.

2.2.1 Broadcasting

DTH television's estimated revenue of $86.42 billion for 2011 makes up 78% of the total revenue for the commercial space products and services sector. North American DTH companies DIRECTV and DISH Network remain the two market leaders, with combined estimated total revenues of $36.04 billion in 2011. As of September 2011, the companies reached a combined total of 33.7 million subscribers. Other DTH television providers generated the remaining revenue of $50.38 billion. Growth in high definition channels, digital video recorders, and interactive services continue to drive the DTH market in North America. There is still slow progress in the 3D television market for DTH in North America, with a total of only four channels for both DIRECTV and DISH since 2010.

EXHIBIT 2j. North American Direct-to-Home Television Revenue, 2011

Company	2009	2010	2011*
DIRECTV	$18.67 B	$20.27 B	$22.91 B
DISH Network	$11.66 B	$12.64 B	$13.13 B
Total	**$30.33 B**	**$32.91 B**	**$36.04 B**

**Estimated annual revenue*

India's DTH subscriber base of 33.4 million as of September 2011 nearly surpassed that of the North American market. Factors such as low average revenue per user, high acquisition costs for new content and subscribers, and various taxes have not prevented DTH operators from increasing their subscriber base in India. According to market research firm RNCOS, India is expected to reach 69 million DTH subscribers by 2014.[8] Another opportunity for the DTH sector is the Indian government's approval of cable digitization in October 2011. With this mandate, the pay television market will become more competitive as demand for digital channels increases. DTH operators believe they are better positioned to compete with their cable counterparts since they have the technology in place as well as steady capital to make further investments.[9] The Indian DTH market is served primarily by six companies: Dish TV India, Tata Sky, Sun Direct, Big TV, Airtel Digital TV, and Videocon D2H.

TataSky is a joint venture between India's Tata Group and the UK's Sky Broadcasting Group. TataSky offers subscribers 196 channels and recently became the first provider in India to offer a DTH Video on Demand service. *Credit: Kalakki*

The estimated revenue for satellite radio increased 7% from $2.83 billion in 2010 to $3.02 billion in 2011. Sirius XM is the sole contributor to the sector's revenue for 2011, since WorldSpace exited the market in 2010 amid bankruptcy. Sirius XM continues to leverage its North American subscriber base through auto installations, while expanding into installations for homes, businesses, restaurants, and overseas. In Europe, the two prospective entrants are Ondas Media in Spain and Onde Numérique in France. Ondas Media is still moving forward with its plan to launch satellite radio service in Europe in 2012. Onde Numérique is searching for partners in content, distribution, and technology to offer more than 50 commercial-free radio channels to homes in France. Onde Numérique is also developing a mobile satellite radio service targeting distribution to the automobile industry.[10]

2.2.2 Satellite Communications

Estimated 2011 revenue for satellite communications reached $18.85 billion, 7% higher than the $17.67 billion for 2010. The satellite communications segment includes both fixed satellite services and mobile satellite services. FSS refers to the delivery of satellite communications to stationary ground receivers that can be moved from one location to another but do not work while in transit. MSS systems can maintain a communications link with a mobile receiver, and include applications such as satellite telephones or in-flight communications. Both types carry video, voice, and data.

Gazprom Space Systems operates three satellites as well as ground telecommunications infrastructure in Russia and near the Arctic Ocean. The company has named each of its satellites Yamal, which means "edge of the Earth" in the language of the indigenous inhabitants of the Yamal peninsula. *Credit: Gazprom Space Systems*

The Middle East, Africa, and Asia-Pacific regions are still considered major areas for FSS expansion. In Africa, demand for satellite usage continues to surge as a result of new undersea fiber rollouts and announced 3G mobile network deployments in 2011. Fiber rollouts allow the internet to be accessible as well as affordable to large parts of Africa, igniting interest in telecommunications services. Rising demand from coastal areas with access to fiber also stimulates demand for the same services in areas where fiber is unavailable. Satellite usage in broadband internet and cellular backhaul in the mining and oil exploration sectors continues to grow in Africa. In the Middle East, established satellite operators such as SES, Eutelsat, and Intelsat, and regional players such as Arabsat, Nilesat, and Yahsat remain focused on delivering satellite capacity not just for telecommunications and broadcasting, but also for the transportation, oil, and gas industries. Other sectors driving satellite demand in both the Middle East and Africa regions are tourism and education. According to market researcher Global Industry Analysts, satellite transponder leasing revenue in the region continues to rise due to intercontinental video transmissions and DTH operator leasing of two-way satellite transponders.[11]

Global satellite operators Intelsat, SES, Eutelsat, and Telesat still dominate the FSS market with 60% of the satellite communications sector. All four operators continue to expand through strategic partnerships with regional satellite operators, satellite service providers, satellite manufacturers, and equipment providers. A primary driver of growth for SES during the first nine months in 2011 was a partnership with Russian-based satellite operator Gazprom Space Services, which generated new contracts in Europe. Intelsat strengthened its business by providing satellite capacity to regional service providers such as DIRECTV Latin America, which is Intelsat's largest single order to date, valued at more than $1 billion.[12] Eutelsat continues to expand by covering video markets in the Middle East, North Africa, and central Europe with the launch of its two new satellites, ATLANTIC BIRD 7 and W3C, in the second half of 2011. Telesat plans to augment its service by providing satellite capacity for broadband services to rural Canada using transponder capacity it owns on the ViaSat-1 satellite, which was launched in October 2011, and by partnering with a Canadian internet service provider, Xplornet Communications.

Satellite operators such as SES-backed O3b Networks and Telesat pursued new investors in 2011. O3b attracted $137 million in financing from a Luxembourg-based investment company, Luxempart, as well as HSBC, ING, CA-CIB, and Dexi, to construct four additional satellites. These satellites are scheduled for launch in 2014 and will augment O3b's existing fleet of eight satellites. Telesat continued to evaluate options for recapitalization or refinancing opportunities. In 2010, Telesat initiated a process to explore an initial public offering and other alternative strategic opportunities. While these efforts resulted in several acquisition offers in 2011, none was accepted by Telesat.

Consumer satellite broadband internet services generated an estimated $830.24 million of revenue in 2011, a 6% increase from 2010. American providers Hughes and ViaSat remain the major players with 1.6 million subscribers at the end of September. These two companies share 90% of the market between them. Both operators experienced a slowdown in subscriber growth in 2011 but believe they can reverse this in 2012.

The acquisition of Hughes by EchoStar in June 2011 was a major development in the consumer satellite broadband internet sector. EchoStar bought Hughes as a way to tap into new video and broadband data and to show the growing value of two-way satellite communications. EchoStar is looking to expand in Latin America and will likely deploy a large satellite, similar to Jupiter 1 serving North America, to provide internet services to Brazil using orbital slots purchased in an auction organized by the Brazilian telecommunication regulator.[13]

Satellite communications company Hughes provides video conferencing solutions with two-way satellite transmissions to students in the Brazilian state of Amazonas. Classes taught from the media center in Manaus are transmitted to more than 1,000 classrooms, improving the quality of education available to students. *Credit: Secretary of Education of the State of Amazonas, Brazil*

Hughes also reported that although it lost a large number of subscribers due to the overall economic climate in the third quarter of 2011, the company was still able to attract new customers with steep discounts in some markets. Hughes was able to provide these discounts because of a $59-million grant received as part of the U.S. government broadband stimulus package. ViaSat's WildBlue service also reported slower growth in its subscriber base for more than a year because of its insufficient satellite capacity to serve regions of the United States where there is increasing demand for broadband service. ViaSat expects a turnaround in subscriber growth by 2012 because of new capacity on the ViaSat-1 satellite, which was launched in October 2011. Both providers are looking forward to launching new Ka-band satellites. Hughes' Jupiter is scheduled for launch in the first half of 2012 and is expected to serve about two million subscribers. ViaSat plans to order ViaSat-2 in time for service in mid-2013.[14]

Obtaining government support for satellite broadband internet in the United States remains a challenge for satellite operators. Only $100 million of the $7.2 billion set aside in the American Recovery and Reinvestment Act for broadband projects was awarded to satellite companies in 2010. In Europe, the satellite sector, represented by Eutelsat and Avanti Communications, is pressing the European Parliament to consider satellites as a key part of meeting its goal of providing every European with internet access by 2013.[15]

The MSS market continued to grow in 2011 despite unfavorable economic conditions and regulatory setbacks. Major players such as Iridium and Globalstar continued product and infrastructure development. Iridium launched Iridium

Force in September 2011, which enables smartphones to access Iridium's satellite network. The company also launched its Iridium Extreme satellite phone equipped with a number of online tracking and mapping features. Globalstar continued to deploy its new second-generation satellites, launching its second batch of six satellites in July 2011 and a third set of six satellites in December 2011. The launch of Globalstar's second-generation satellite constellation was partially enabled by a $38 million investment made by Thermo Funding Company in June 2011.

MSS provider Inmarsat reported positive growth, due in large part to revenue generated from a spectrum cooperation agreement with LightSquared. Inmarsat continued preparation for its Global Xpress program following the launch of Inmarsat 5 in 2013. Global Xpress will offer Ka-band mobile broadband with speeds of 50 megabits per second (Mbps) to 60-centimeter (24-inch) terminals and 10 Mbps to 20-centimeter (8-inch) terminals.

LightSquared (first known as Mobile Satellite Ventures and then SkyTerra) and the GPS industry fought a regulatory battle in 2011. In January 2011, the Federal Communications Commission (FCC) granted LightSquared's request to offer terrestrial-only devices rather than having to incorporate both satellite and terrestrial services using its proposed 4G long term evolution (LTE) network. This authorization was strongly opposed by the GPS industry because of interference issues with many GPS devices. In February 2012, the FCC announced it would suspend LightSquared's terrestrial license.

EXHIBIT 2k. Earth Observation Revenue Estimates

Revenue Source	2009	2010	2011	2020
Data Sales	$0.83 B	$0.91 B	$0.99 B	$2.15 B
Value-Added Services	$1.06 B	$1.20 B	$1.25 B	$2.30 B
Total	**$1.89 B**	**$2.11 B**	**$2.24 B**	**$4.45 B**

Source: Northern Sky Research

2.2.3 Earth Observation

Earth observation revenue in 2011 is estimated to total $2.24 billion, 6% more than the $2.11 billion generated in 2010.[16] Revenues within the Earth observation sector are generated by data sales and value-added services.

Growth in the Earth observation data market is driven by demand from civil government and military organizations for defense, intelligence, surveillance, security, environmental, and climate change applications. Governments are expected to increase their purchase of higher resolution imagery. New services such as the ability to monitor activity at high-interest locations, such as nuclear facilities, enabled by automated imagery processing further drive government demand for satellite imagery. However, large programs, such as the National Geospatial-Intelligence Agency's (NGA) EnhancedView or the Global Monitoring for Environment and Security (GMES) in Europe, may see cuts as governments seek to reduce spending. The bankruptcy of German imagery provider RapidEye in 2011 underscored the difficulty for imagery providers in entering the market without well-established distribution networks and a solid anchor customer.[17]

These satellite images (left: 1985, right: 2010) show the impact of the Yacyretá Dam, a joint hydroelectric project between Paraguay and Argentina. River levels rose when the dam was completed, displacing 15,000 human residents and flooding the habitats of jaguars, giant river otters, maned wolves, giant anteaters, 650 species of birds, and more than 10,000 species of plants. *Credit: NASA*

Governments are expected to fund development of most Earth observation satellites during the next 10 years. While the majority of new Earth observation missions will be funded and used by government and military organizations, commercially oriented missions are expected to grow at a faster rate, representing 36% of all satellites launched by the end of 2020.[18]

Large Earth observation satellites are expected to comprise the majority of new satellites launched over the next five years. However, aggressive market expansion estimates for the latter part of the decade will be contingent upon smaller and more cost-effective satellite designs capable of providing high-resolution imagery. Developing space nations and smaller operators owning less expensive infrastructure may drive quicker delivery of lower-cost data in coming years as the use of Earth observation applications spreads globally.

The Earth observation data and value-added services markets are expected to grow at a yearly average of 9% and 7%, reaching $2.15 billion and $2.30 billion, respectively, by the end of 2020.[19] This growth is expected to be driven by long-term contract implementation, new commercial users, new satellite efficiencies, and enhanced image processing capabilities. However, as many Western nations seek to cut spending, there is some uncertainty in this forecast since most of the revenues are generated from publicly financed programs.

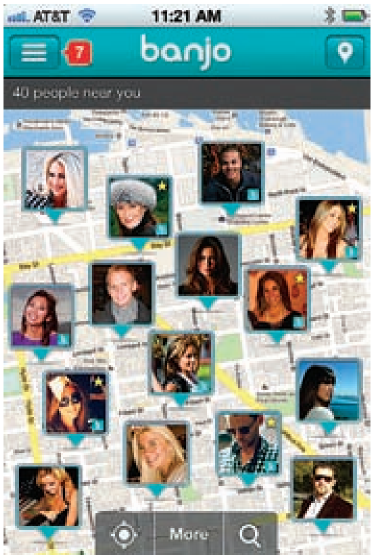
2.2.4 Geolocation and Navigation

Products and services that use satellite geolocation and navigation systems comprise one of the largest and fastest-growing markets in the space industry. Estimated global revenue for this market, as projected by the European GNSS Agency (GSA) in an October 2010 report, was $89.11 billion in 2011, compared to $71.29 billion in 2010.

The GSA report divides the global market into four segments: personal navigation devices and in-vehicle systems, location-based services, agriculture, and aviation. Location-based services include satellite navigation-enabled mobile phones and services. However, it only includes the parts of the phone's retail price that are attributable to geolocation services, such as navigation chipsets, maps, and navigation software.

Most navigation users are found in the automotive sector, followed by the mobile phone sector, with a 56% and 43% market share, respectively. The GSA expects that the worldwide market will increase at an average annual rate of 11% between 2011 and 2020, with revenue reaching $203 billion per year by 2020.

The double-digit growth rate in the global GNSS market continues to be driven by new applications and expansion of current products and services. The greatest growth will come from location-based services, since only a small portion of the world's mobile phones currently include a navigation capability. As navigation systems proliferate, new applications will further drive growth, such as futuristic in-vehicle systems that one day may partially or fully assist with driving. The developed world constitutes 65% of the navigation market. The share of the navigation market originating from developing nations is expected to increase but with demand for devices that are tailored for domestic use. For example, a nation where farming is not dependent on mechanization will likely not require geolocation services to guide mechanized farm equipment. However, if the state of the road network in the country is poor, demand for road navigation devices will be higher.[20]



Smartphone applications such as Banjo enable users to view the status updates of people nearby who are posting their location information on social networks. *Credit: Banjo*

A subset of the overall navigation market is composed of geolocation users that demand accuracy measured in centimeters, and who often rely on augmentation systems to boost geolocation signal accuracy. This precision market, according to a September 2011 report from ABI Research, comprises roughly 5% of the overall geolocation market and is moving into a new period of sustained growth that will result in a near doubling of shipments and revenues by 2016.[21] The high-precision geolocation market includes applications in agriculture, construction, aviation, geographic information system (GIS) mapping, and military use. With the cost of equipment positioned to fall sharply, suppliers are looking to generate revenues from software, firmware upgrades, applications, connectivity, and distributor support. Connectivity to real-time data enables users of precision equipment to streamline processes, resulting in even greater levels of performance.[22]

China became the second-largest navigation receiver market in 2010, even though the market there was practically non-existent just 10 years prior. China's market will help fuel growth, while new suppliers emerging from the nation will likely drive down equipment costs and profit margins for competing suppliers. It is currently estimated that

EXHIBIT 2l. European Satellite Navigation Competition Special Award Winners, 2011

Sponsor and Award	Concept	Developer
European GNSS Agency (GSA): Special Topic Prize	A traffic collision avoidance system for miniature unmanned aerial vehicles	CATUAV
European Space Agency (ESA): Special Topic Prize	A GNSS-based proximity detection service for large numbers of moving objects	twofloats
German Aerospace Center (DLR): Special Topic Prize	A system to detect fake GNSS signals to prevent jamming or spoofing	PanamNav
NAVTEQ: Special Topic Prize	A 3D head-up display that provides augmented-reality navigation guidance	MVS-California
GNSS Living Lab Prize: Special Topic Prize	A mobile phone application that provides on-demand coupon recommendations based on where the user has been	Industrial Technology Research Institute (ITRI)
NavCert/IFEN: GATE prize	A method and technology to safeguard critical infrastructure that relies on GNSS signals by authenticating GNSS time references	PanamNav
University Challenge: Special Topic Prize	A navigation device for blind and vision-impaired persons	Karlsruhe Institute of Technology
ITRI: Prototyping prize	A system that enables avoidance of road damage such as potholes	DLR

Source: European Satellite Navigation Competition

75% of navigation equipment produced in China is exported, mostly to the United States and Europe.[23]

Growth in the markets for navigation devices will be driven by the creation of new applications. To help spur innovation and entrepreneurship in the European market, the first European Satellite Navigation Competition (ESNC) was held in 2004. The competition has grown, with 820 participants in 2011 who submitted 401 ideas, up from 548 participants submitting 357 ideas in 2010. In 2011, ESNC is focused on special topic prizes sponsored by its partners. A list of sponsors and award recipients can be found in Exhibit 2l.

2.2.5 Commercial Space Transportation Services

New commercial transportation services are in development to carry cargo, passengers, and astronauts into space. In the United States, the retirement of the Space Shuttle in July 2011 creates an opportunity for new commercial cargo transportation services to resupply the ISS. The Commercial Orbital Transportation Services (COTS) program, started in 2006, is designed to help develop U.S. commercial cargo transportation systems. Through Space Act Agreements, SpaceX and Orbital will receive up to $684 million upon successful completion of their current agreements in 2012.[24] In April 2011, NASA estimated that it would invest a total of $800 million in the COTS program from its beginning in 2006 to its completion in 2012. This figure exceeds the original program cost estimate of $500 million.[25] The bulk of COTS funding has been directed to two launch vehicles and associated spacecraft: Orbital Sciences' Antares (formerly Taurus II) rocket with its Cygnus spacecraft, and SpaceX's Falcon 9 rocket with its Dragon spacecraft. Both SpaceX and Orbital have won contracts under NASA's Commercial Resupply Services (CRS) initiative, a follow-on to the COTS program, to provide cargo supply services to the ISS. Under these contracts, SpaceX and Orbital are required to launch a total of 20 tons of cargo each to the ISS through 2016.

A technician works on the primary structure of Sierra Nevada Corporation's Dream Chaser spacecraft at the University of Colorado. As of February 2012, work was progressing according to the schedule in Sierra Nevada's CCDev agreement with NASA. *Credit: Sierra Nevada Corporation*

SpaceX was selected to fly 12 missions under the program for $1.6 billion, with an option for additional missions that may bring the cumulative total to $3.1 billion. As of December 2011, SpaceX had collected $376 million of a total possible $396 million from NASA through its current COTS agreement by completing 36 of 40 milestones.[26] In June 2010, SpaceX successfully completed the first launch of the Falcon 9 launch vehicle and the first successful flight, maneuver, re-entry, and recovery of the Dragon capsule. In 2011, SpaceX continued to prepare for a second test flight that would combine the COTS Demo 2 and COTS Demo 3 into a single mission. During this mission, the Dragon spacecraft will approach the ISS, test radio cross-link and telemetry capabilities, then berth with the space station. This mission was scheduled for the first half of 2012 as of the end of 2011.

Orbital Sciences of Dulles, Virginia, has been contracted for eight flights for $1.9 billion. By December 2011, Orbital Sciences had completed 23 of 29 milestones, collecting $261.5 million of a possible $288 under its current COTS agreement. The Antares launch vehicle made significant progress toward a planned static fire test scheduled for early 2012, to be followed by as many as four launches to meet COTS development milestones under the CRS schedule. Construction of the Antares launch pad at NASA's Wallops Flight Facility, Virginia, will likely be completed during the first half of 2012.[27]

EXHIBIT 2m. Commercial Crew Development Round 2 Agreements

Company	Award
ATK and Astrium	**Unfunded** agreement to share information supporting further development of the Liberty rocket
Blue Origin	**$22 million** to advance development of an orbital vehicle, including launch abort systems and restartable engines
Boeing	**$92.3 million** to advance development of the seven-person CST-100 spacecraft
Excalibur Almaz	**Unfunded** agreement supporting development of a crew transportation spacecraft
Sierra Nevada	**$80 million** to advance development of the Dream Chaser lifting body space plane
SpaceX	**$75 million** to develop an integrated launch abort system within the Dragon spacecraft
United Launch Alliance	**Unfunded** agreement to share information on human-rating the Atlas V

Source: Space News

Although no spaceflights carrying commercial passengers have occurred since 2009, commercial companies are developing technologies and integrated systems that will one day carry people into space. These efforts continue to attract private and public investment. In March 2011, NASA announced the award of Commercial Crew Development 2 (CCDev 2) Space Act Agreements to Blue Origin, Boeing, SpaceX, and Sierra Nevada totaling $270 million. Funding and proposed work is divided among award recipients as shown in Exhibit 2m. In addition to selecting funded proposals, NASA also selected unfunded proposals submitted by United Launch Alliance, Excalibur Almaz, and a collaborative proposal by ATK and Astrium. In 2011, the U.S. Congress decided to cut NASA's requested funding for commercial crew vehicle development by more than 50%, resulting in an authorization of $406 million in 2012.[28] Consequently, NASA will continue the use of Space Act Agreements, a move that allows it the flexibility to continue working with its commercial partners to adjust the technical direction, milestones, and funding allocated to advance development of integrated human spaceflight capabilities. NASA hopes to support development of at least two competing crew transportation systems that will be capable of delivering astronauts to the ISS by 2017.

Development of suborbital spacecraft by a number of firms continued in 2011. Vertical takeoff, vertical landing (VTVL) vehicle developer Armadillo Aerospace signed an agreement with Space Adventures in 2010 to offer space tourism services on vehicles that Armadillo is developing. In August, the companies released a request for information in an effort to assess the industry's capabilities in designing and fabricating a space suit for suborbital spaceflight.[29] In May, Masten Space Systems signed a $400,000 contract with Space Florida to perform a series of demonstration flights of its reusable VTVL suborbital launch vehicle from Launch Complex 36 at Cape Canaveral Air Force Station.[30] Blue Origin, a low-profile private space exploration company created by Amazon.com founder Jeff Bezos, announced several test flights of its suborbital VTVL vehicle New Shepard I in 2011. The company also announced the vehicle's capability to fly suborbital research payloads.

Masten Space Systems prepares its Xaero vehicle for a tie-down test firing in January 2011 at the Mojave Air and Space Port. *Credit: NASA*

XCOR Aerospace and Virgin Galactic/Scaled Composites continued the development of winged suborbital spacecraft capable of carrying passengers and research experiments into space. XCOR Aerospace's Lynx vehicle will initially fly from the Mojave Spaceport and Civilian Aerospace Test Center. XCOR is also working with Space Expedition Curaçao (SXC) and the Yecheon Astro Space Center, located in South Korea, to supply wet leased Lynx spacecraft. In the airline industry, a wet lease means that the owner of the aircraft also provides the crew, maintenance, and insurance, while the entity leasing the aircraft is responsible for booking passengers and providing fuel and other supplies required for operation. XCOR and SXC announced a multi-million dollar transaction in September that secures the wet lease of a Lynx suborbital spacecraft for use in Curaçao.[31] SXC said 40 trips onboard a Lynx vehicle have been sold.[32] In February 2011, XCOR announced that the Southwest Research Institute, a commercial research entity, had purchased six suborbital flights to carry experiments and payload specialists.[33] The Planetary Science Institute and XCOR signed a memorandum of understanding (MoU) that lays the foundation for the use of the Lynx Spacecraft to carry a human-operated suborbital observatory that will image the inner Solar System and other targets while the Lynx vehicle is in space during the apex of its flight trajectory.

EXHIBIT 2n. NASA Flight Opportunities Program Participants

Company	Services
Armadillo Aerospace	Developer of rocket-powered reusable suborbital launch vehicles
Near Space	High-altitude/near-space operations services
Masten Space Systems	Developer and operator of rocket-powered reusable suborbital launch vehicles
Up Aerospace	Space launch and flight test service provider specializing in suborbital sounding rockets
Virgin Galactic	Suborbital spacecraft operator
Whittinghill Aerospace	Developer and provider of low-cost suborbital sounding rockets
XCOR Aerospace	Developer and operator of suborbital spacecraft

Source: NASA

Suborbital flight provider Virgin Galactic continued developing its vehicle that will carry six passengers into space on a suborbital trajectory. While Virgin Galactic has not released its full flight testing schedule, during 2011 it conducted 78 flights of WhiteKnightTwo, 15 captive carry flights of SpaceShipTwo, 16 glide tests of SpaceShipTwo, and eight firings of full-scale RocketMotorTwo.[34] It is estimated that Virgin Galactic founder Sir Richard Branson has invested some $200 million, and an additional $390 million investment was made by Aabar Investments through transactions in 2009 and 2011.[35] As of the end of 2011, Virgin Galactic reported signing up more than 475 potential passengers with deposits totaling more than $60 million.[36] Significant progress was made in 2011 toward the completion of Spaceport America's construction, including near-completion of many of the facilities to be used by Virgin Galactic. The spaceport is estimated to cost a total of $209 million to construct.[37]

EXHIBIT 2o. Government Space Budgets, 2011

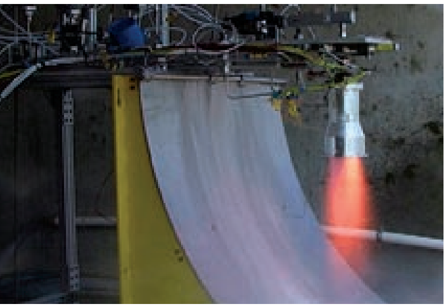
Country/Agency	Budget (U.S. Dollars)	Source	Description
United States	$47.25 B	See Exhibit 2q	2011 Enacted/Estimated
European Space Agency	$5.80 B	European Space Agency	Calendar Year 2011 Appropriation
European Union	$1.06 B	European Commission	Calendar Year 2011 Appropriation
EUMETSAT	$0.32 B	EUMETSAT	Calendar Year 2011 Estimated Spending
Brazil	$0.32 B	Government of Brazil	Calendar Year 2012 Authorization
Canada*	$0.38 B	Government of Canada	Fiscal Year 2011/2012 Appropriation
China	$3.08 B	Futron Estimate	Calendar Year 2011 Estimated Spending
France*	$1.11 B	Government of France	Calendar Year 2011 Appropriation
Germany*	$0.79 B	Government of Germany	Calendar Year 2011 Appropriation
India	$1.49 B	Government of India	Fiscal Year 2011/2012 Budget Estimates
Israel	$0.01 B	*The Marker*	Calendar Year 2011 Appropriation
Italy*	$0.63 B	Government of Italy	Calendar Year 2011 Planned Spending
Japan	$3.84 B	JAXA	Fiscal Year 2011/2012 Appropriation
Russia	$4.12 B	Roscosmos	Calendar Year 2011 Planned Spending
South Korea	$0.21 B	Government of South Korea	Calendar Year 2011 Appropriation
Spain*	$0.06 B	Government of Spain	Calendar Year 2011 Appropriation
United Kingdom*	$0.11 B	Futron Estimate	Fiscal Year 2011 Estimated Spending
Emerging Countries	$0.80 B	See Exhibit 2cc	See Exhibit 2cc
Non-U.S. Military Space	$1.39 B	Futron Estimate	Calendar Year 2011 Estimated Spending
Total	**$72.77 B**		

**Excludes ESA spending*

NASA's Commercial Reusable Suborbital Research (CRuSR) Program was combined with the Facilitated Access to the Space environment for Technology (FAST) program and renamed as the Flight Opportunities Program at the beginning of fiscal year 2011. The Flight Opportunities Program aims to provide researchers access to reduced-gravity environments and high-altitude atmospheric flights for technology development, and to create opportunities for the public to engage in NASA's space technology mission and the emerging commercial space industry. NASA indicates that the program will expand in 2012 to include other platforms and test environments. In May 2011, NASA selected 16 payloads for flights on commercial Zero-G parabolic aircraft and suborbital flight vehicles. In August, NASA selected seven companies to integrate and fly technology payloads on suborbital platforms. The two-year contracts, worth a combined total of $10 million, were awarded to the companies listed in Exhibit 2n. In October, the Flight Opportunities Program announced the selection of nine proposals to demonstrate new technologies that will be flown on the Zero-G aircraft and suborbital vehicles.[38] Virgin Galactic was chosen to provide NASA with up to three charter flights on SpaceShipTwo via a contract worth up to $4.5 million.[39]

2.2.6 In-Space Activities

In-space activities include research and development services, manufacturing, satellite refueling, and orbital debris clean-up. Most public and private funding for in-space activity is currently focused on research and development programs that will support future activities. NASA is a major provider of funding for these efforts, but additional funds are provided by non-federal institutions such as universities, companies, and private investors. Some of these efforts also rely on each participant's willingness to volunteer time in order to help advance exciting efforts, such as low-cost robotic exploration of the Moon.



In Huntsville, Alabama, the Dynetics-led Rocket City Space Pioneers (RCSP) Google Lunar X PRIZE team successfully completed a critical NASA contract milestone by delivering data from hot-fire tests of Dynetics' newly-developed "green" rocket engine. *Credit: Rocket City Space Pioneers/Dynetics*

A space technology program called NASA Innovative Advanced Concepts (NIAC) awarded approximately $100,000 to each of 30 research projects. The initiative funds one-year studies that will advance technologies aiming to transform future space missions, enable new capabilities, or significantly alter current approaches to launching, building, and operating space systems.[40] Teams receiving the funding include university laboratories and private companies who will also contribute employee time and funds to complete the research efforts. Some examples are a radiation protection method that uses high-temperature superconducting magnets, methods for space debris cleanup, low-power microbots, printable spacecraft, and new types of in-space propulsion. NASA plans to fund a second round of NIAC proposals in 2012.

The Google Lunar X PRIZE is a $30 million international competition among privately-funded teams to send robots to explore the lunar surface and transmit high resolution video and imagery back to Earth. Participants in the competition must seek out sources of funding to support their projects. As of 2011, 29 teams are officially competing for the prize. Competition for the prize heated up in 2010, when NASA allocated $30 million to purchase data from X PRIZE participants through 2012.

In December 2010, NASA awarded $500,000 to three organizations through its Innovative Lunar Demonstrations Data program to address the top technical risks associated with a low-cost lunar surface mission. Each team is required to improve a challenging technical component of its mission to a level of readiness necessary to actually conduct the spaceflight.[41] In 2011, the three teams all successfully completed their first milestones, each receiving an award of $500,000 from NASA. In August, Moon Express successfully demonstrated its Mini-Radar System technology.[42] In September, the Rocket City Space Pioneers announced a successful demonstration of a newly developed "green" rocket engine that is fueled by non-toxic hydrogen peroxide and kerosene.[43] Astrobotic successfully demonstrated results relating to the design and testing of its lunar lander's structure. In addition, Astrobotic received a separate $125,000 contract from NASA in November to develop robots that can work together to explore underground caves on the Moon, Mars, and other planetary bodies.[44]

2.3 Government Space Budgets

Overall government investment in space remains strong and growing, although the effect of smaller budgets is being seen in some places, including the United States, where 2011 government space spending was below the 2010 level. While the United States remains

EXHIBIT 2p. Government Space Budget Growth, 2011

Country/Agency	Currency	2009 Funding	2010 Funding	2011 Funding	2010-2011 Change
United States	U.S. Dollar	$46.48 B	$47.44 B	$47.25 B	-0.4%
European Space Agency*	Euro	€3.59 B	€3.74 B	€3.99 B	6.7%
Brazil*	Real	R$0.298 B	R$0.330 B	R$0.497 B	50.6%
Canada*†	Canadian Dollar	C$0.315 B	C$0.343 B	C$0.366 B	6.7%
France†	Euro	€0.738 B	€0.720 B	€0.761 B	5.7%
Germany*†	Euro	€0.537 B	€0.521 B	€0.543 B	4.2%
India*	Rupee	Rs49.6 B	Rs48.93 B	Rs66.41 B	35.7%
Italy*†	Euro	€0.33 B	€0.362 B	€0.434 B	19.9%
Japan	Yen	¥344.8 B	¥339.000 B	¥309.400 B	-8.7%
Russia*	Ruble	руб87.9 B	руб94.900 B	руб115.000 B	21.2%
South Korea*	Won	₩267.9 B	₩261.961 B	₩228.937 B	-12.6%
United Kingdom*†	Pound	£0.06 B	£0.070 B	£0.070 B	0.0%

**Civil space budget only*
†National budget only (Excluding ESA contributions)

responsible for 65% of global government space spending, other governments appropriate significant amounts. Some, such as Brazil, Israel, and Russia, are on the cusp or in the midst of major increases in government space appropriations. Other governments have implemented increases that only keep pace with inflation, while still others have experienced declines. Government space programs accounted for approximately $72.77 billion in spending during 2011, which represents 25% of the total global space economy.

EXHIBIT 2q. U.S. Government Agency Space Budgets, 2011

Agency	Budget	Source
Department of Defense (DoD)	$26.46 B	Futron Estimate
National Aeronautics and Space Administration (NASA)	$18.49 B	NASA
National Oceanic and Atmospheric Administration (NOAA)	$1.44 B	NOAA
National Science Foundation (NSF)	$0.64 B	NSF
United States Geological Survey (USGS)	$0.15 B	USGS
Department of Energy (DOE)	$0.04 B	DOE
Federal Aviation Administration (FAA)	$0.02 B	FAA
Federal Communications Commission (FCC)	$0.01 B	Futron Estimate
Total	**$47.25 B**	

Government investment in space worldwide increased by approximately 6% from 2010. The top line figures, however, do not fully depict how some countries significantly increased space spending while others made cuts, as can be seen in Exhibit 2p. Since not all governments operate under the same fiscal cycle, international space spending numbers were derived from the most recent budgetary information available for each country. The figures reported in the following country profiles are presented in the local currency and in U.S. dollars as of June 30 of the appropriate year.

2.3.1 United States

For all of FY 2011, the U.S. government operated under a series of budget measures known as Continuing Resolutions (CRs), culminating in the passage of *Public Law 112-10, the Department of Defense and Full-Year*

EXHIBIT 2r. NASA Fiscal Year 2012 Budget Request

Budget Authority, dollars in millions	FY 2010 Actual	FY 2011 Actual	FY 2012 Estimate*	FY 2013 Request	FY 2014 Notional
Science	**4,497.6**	**4,919.7**	**5,073.7**	**4,911.2**	**4,914.4**
Earth Science	1,439.3	1,721.9	1,760.5	1,787.8	1,775.6
Planetary Science	1,364.4	1,450.8	1,501.4	1,192.3	1,133.7
Astrophysics	647.3	631.1	672.7	659.4	703.0
James Webb Space Telescope	438.7	476.8	518.6	627.6	659.1
Heliophysics	608.0	639.2	620.5	647.0	643.0
Aeronautics	**497.0**	**533.5**	**569.4**	**551.5**	**551.5**
Space Technology	**275.2**	**456.3**	**573.7**	**699.0**	**699.0**
Exploration	**3,625.8**	**3,821.2**	**3,712.8**	**3,932.8**	**4,076.5**
Exploration Systems Development	–	2,982.1	3,007.1	2,769.4	2,913.1
Human Exploration Capabilities	3,287.5	–	–	–	–
Commercial Spaceflight	39.1	606.8	406.0	829.7	829.7
Exploration Research and Development	299.2	232.3	299.7	333.7	333.7
Space Operations	**6,141.8**	**5,146.3**	**4,187.0**	**4,013.2**	**4,035.1**
Space Shuttle	3,101.4	1,592.9	556.2	70.6	0.0
International Space Station	2,312.7	2,713.6	2,829.9	3,007.6	3,117.6
Space and Flight Support	727.7	839.8	800.9	935.0	857.5
Education	**180.1**	**145.4**	**136.1**	**100.0**	**100.0**
Cross-Agency Support	**3,017.6**	**2,956.4**	**2,993.9**	**2,847.5**	**2,847.5**
Center Management and Operations	2,161.2	2,189.0	2,204.1	2,093.3	2,093.3
Agency Management and Operations	766.2	767.4	789.8	754.2	754.2
Institutional Investments	27.2	–	–	–	–
Congressionally-Directed Items	63.0	–	–	–	–
Construction and Environmental Compliance and Restoration	**452.8**	**432.9**	**487.0**	**619.2**	**450.4**
Construction of Facilities	389.4	373.3	441.3	552.8	359.5
Environmental Compliance and Restoration	63.4	59.6	45.6	66.4	90.9
Inspector General	**36.4**	**36.3**	**38.3**	**37.0**	**37.0**
NASA Total	**18,724.3**	**18,485.0**	**17,770.0**	**17,711.4**	**17,711.4**
Year-to-Year Change		-1.28%	-3.87%	-0.33%	0.00%

** FY 2012 Estimate is $30 million less than NASA's FY 2012 appropriation due to a rescission included in the 2012 Appropriation Act.*
Source: NASA

Continuing Appropriations Act, 2011. A CR is a type of appropriations legislation passed by Congress to fund the government when a formal appropriations bill for the next fiscal year has not been passed and signed into law by the close of the preceding government fiscal year. Generally, a CR provides funding for existing government programs at the prior year's funding level or at a reduction. Usually, no new programs are able to start when a government agency is funded through a CR. However, CRs do allow agencies some flexibility in how funds are distributed among individual programs and activities. As a result of operating for a full year under a CR, most U.S. government space agencies saw the same or slightly reduced budgets in FY 2011 compared to FY 2010.

During FY 2011, U.S. government agency space budgets totaled $47.25 billion, a 0.4% decrease from 2010. Defense-related space activities, comprised of the U.S. Department of Defense (DoD), the National Reconnaissance Office (NRO), and the National Geospatial-Intelligence Agency (NGA), totaled $26.46 billion, or 56% of U.S. government space spending. The remaining 44% was comprised of space-related spending by NASA, the Department of Energy (DOE), the Federal Aviation Administration (FAA), the Federal Communications Commission (FCC), the Department of the Interior (DOI), the National Oceanic and Atmospheric Administration (NOAA), and the National Science Foundation (NSF), which collectively budgeted $20.79 billion for space activities. NASA, the largest U.S. civil government agency involved in space-related activities, operated with a budget of $18.49 billion in FY 2011, representing 89% of U.S. civil space agency budgets.[45] In FY 2011, civil space spending in the United States represented approximately 0.54% of the $3.82 trillion total estimated to be spent by the U.S. government.[46]

A J-2X rocket engine sits ready for testing in the assembly area at Marshall Space Flight Center. Designed to loft a launch vehicle's upper stage beyond low Earth orbit, the J-2X is built on decades of NASA spaceflight experience and technological advances. *Credit: NASA*

NASA's FY 2011 actual budget, reached as a result of seven CRs and *Public Law 112-10*, decreased by 1.3% from the agency's FY 2010 actual budget, including FY 2010 funds received from the American Recovery and Reinvestment Act economic stimulus package. Operating under the series of CRs impacted NASA's ability to effectively implement its programs. In 2010, Congress and the President agreed to cancel the planned Constellation Program. However, as a result of the CRs during FY 2011, NASA was required to continue spending funds on its existing programs, including Constellation. While flexibility in internal funds allocation allowed NASA to focus much of its Constellation spending during early 2011 on elements of the program which will continue in future years, including the Orion Multi-Purpose Crew Vehicle (MPCV) and the J-2X rocket engine, funds were nonetheless spent on elements of the Constellation program which would not continue in the future. The passage of *Public Law 112-10* formally cancelled Constellation and ended NASA's obligation to continue spending on the program. Prior to passage of the law, the NASA Inspector General estimated that NASA devoted approximately $1.4 million per day in potentially inefficient funding to the Constellation Program during the first six months of FY 2011.[47]

The full-year funding provided to NASA under *Public Law 112-10* was $516 million less than the amount requested for the agency in the President's FY 2011 budget request. The largest reduction was in the funding provided for the Aeronautics and Space Technology budget line, where NASA received $617 million less than the President's request. The law did not specify any funding for activities under Space Technology development, instead providing $535.5 million for Aeronautics Research. The Space Operations account received an increase of $621 million in order to enable complete fly-out of the Space Shuttle Program during FY 2011. NASA's Exploration account saw a large reduction of $455 million compared with the President's funding request. However, the total amount of $3.808 billion provided to Exploration by *Public Law 112-10* represented an increase of $62 million over the amount appropriated in 2010. Within the Exploration account, NASA received $1.2 billion in FY 2011 for crew vehicle development and $1.8 billion for the development of a heavy lift launch vehicle, which has evolved into the Space Launch System (SLS).[48]

Congress passed a full-year FY 2012 appropriation for NASA and several other agencies in November 2011. NASA's FY 2012 budget appropriation will be $17.8 billion, 3.7% below the FY 2011 funded level, and near the FY 2009 level. The FY 2012 appropriation provides $1.8 billion for the SLS, $1.2 billion for the MPCV, and $400 million for the Commercial Crew Program (CCP). The amount provided for the CCP is less than 50% of the amount requested by the President. The FY 2012 appropriation also funds the over-budget James Webb Space Telescope (JWST) to completion, including $529.6 million in 2012. To offset the JWST costs, other NASA science programs in Earth science, planetary science, and astrophysics received funding reductions, along with NASA's cross-agency support activities. The FY 2012 appropriation implements a $1.3 billion reduction compared to FY 2011 for the Space Operations account, reflecting the conclusion of the Space Shuttle Program.[49]

2.3.2 Brazil

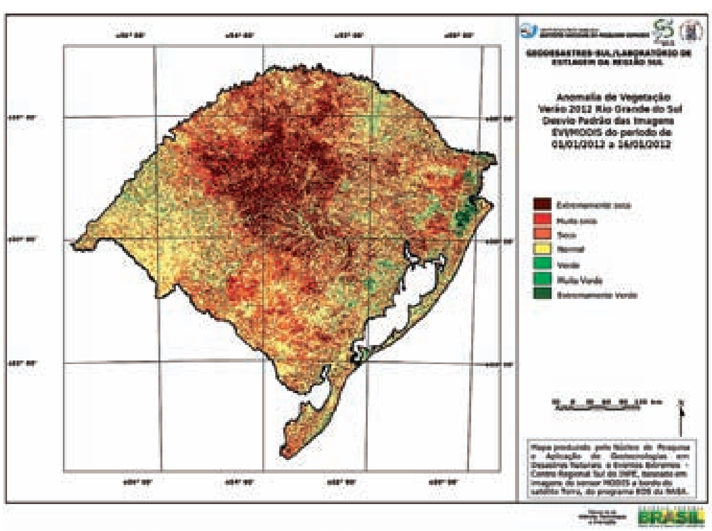
The National Congress of Brazil's 2012 Federal Budget authorized 497.1 million reais (US$318.6 million) in funding for civil space activities in two civil government agencies.[50] This represents an increase of 51% from the authorization for the previous year. The Brazilian space agency, Agência Espacial Brasileira (AEB), received an authorized funding level of 320.6 million reais (US$205.5 million), the majority of which goes toward implementing activities under Brazil's new Políctica Espacial, or Space Policy, program. The Ministério da Ciência, Tecnologia e Inovação, the AEB's parent organization, received additional authorization of 91.5 million reais (US$58.6 million) for its contribution to the Políctica Espacial program and 85 million reais (US$54.5 million) for continued development of the Alcântara Space Centre.

EXHIBIT 2s. Top Five Budget Priorities of the Agência Espacial Brasileira, 2012

Activities	Budget (U.S. Dollars)
Alcântara Space Complex	$52.55 M
CBERS-4 Satellite Development	$36.52 M
Amazonia-1 Satellite Development	$23.71 M
Satellite Launch Vehicle Development	$16.66 M
Upgrades for Space Vehicle Support Infrastructure	$16.02 M

Source: Brazilian Ministry of Science and Technology

The Políctica Espacial program is not a space policy in the traditional sense, but rather a name given to a set of projects and programs representing the focus of the Brazilian civil space program. Details of the Políctica Espacial program emerged in 2011 as an update to Brazil's National Program of Space Activities (PNAE), which had provided the organizational framework for Brazil's space activities in previous years. The Políctica Espacial program is part of a reorganization and expansion of the Brazilian civil space program, which has begun under the 2012 Federal Budget.[51]



The Moderate Resolution Imaging Spectroradiometer (MODIS) Enhanced Vegetation Index provides a look at vegetation around the globe throughout the year. This image shows drought conditions in the Brazilian state of Rio Grande do Sul in early 2012. *Credit: INPE–Instituto Nacional de Pesquisas Espaciais*

Under the Políctica Espacial program, the 2012 AEB budget continues and expands funding for existing projects and activities. Exhibit 2s lists the major activities and projects being conducted by the AEB under the 2012 Budget. The AEB is maintaining investment in the China-Brazil Earth Resources Satellite (CBERS) series and the Amazonia-1 communications satellite project, including providing 57 million reais (US$36.5 million) for the development of the CBERS-4 satellite. The FY 2012 AEB budget steps up investment in the country's space launch systems and infrastructure. The AEB's program for the development of satellite launch vehicles will receive 26 million reais (US$16.7 million) in funding in 2012, a 60% increase over funding in the previous year. The AEB will also receive 82 million reais (US$52.6 million) in funding toward infrastructure and capabilities development at the Alcântara Space Centre, a 107% increase over 2011 funding.[52] The purpose of Brazil's increased investment in launch systems and infrastructure is twofold: to ensure that infrastructure at the Alcântara facility is ready to support operations of the joint Ukraine-Brazil Cyclone-4 launch vehicle starting in 2012, and to enable a test flight of a Brazilian-developed satellite launch vehicle by 2013.[53]

The increased investments in the AEB's 2012 budget are the beginning of a multi-year expansion in Brazilian space activities and funding. Brazil's four-year Pluri-annual Plan 2012–2015, a national budget strategy planning document released in September 2011, envisions that the Políctica Espacial program will receive investment totaling US$2.1 billion during the plan's time frame. Brazil's increased investment in space is the result of an exhaustive review of Brazil's space policy and strategy, which was concluded in 2010.[54] With the renewed policy focus on space, Brazil's government hopes to leverage the space sector as an engine of broader technological development.[55]

EXHIBIT 2t. Canadian Space Agency Planned FY 2011 Spending by Program Activity

Program Activity	Funding* (U.S. Dollars)
Space Exploration	$158.04 M
Space Data, Information, and Services	$141.66 M
Future Canadian Space Capacity	$89.29 M
Internal Services	$51.23 M
Total	**$440.22 M**

**Planned spending, not reflecting FY 2011 final Canadian Budget. Planned spending is greater than budget appropriation by C$11.4 million. Source: Canadian Space Agency,* The Canadian Space Agency 2011–2012 Estimates. Report on Plans and Priorities.

2.3.3 Canada

The Canadian Space Agency (CSA) managed a FY 2011 budget of C$413.1 million (US$428.4 million).[56] This total, which included approximately C$50 million (US$51.9) of economic stimulus funding, represented a record high for the CSA. This figure included Canada's planned C$47.3 million (US$49.1 million) FY 2011 contribution to the European Space Agency (ESA).[57] The CSA-only budget, excluding ESA contributions, of C$365.8 million (US$379.3 million) represented a 7% increase from the previous year's CSA-only budget of C$343 million (US$323.1 million). During FY 2011, which ran from April 1, 2011, to March 31, 2012, Canada's space spending constituted approximately 0.16% of Canada's C$274 billion (US$284.1 billion) projected national spending.[58] The CSA plans spending for FY 2012 and FY 2013 of C$371.1 million (US$384.7 million) and C$317.5 million (US$329.3 million), respectively.[59] However, the figures for FY 2012 and FY 2013 reflect CSA planning only—not Canadian budgetary policy—and may change as formal Canadian government budgets are developed for those years.

The CSA organizes its activities and budgets into Program Activity (PA) areas. As a result of the FY 2011 budget and strategic planning process, the PAs were reorganized and renamed, making year-to-year comparison in program-level funding challenging, although top-level comparisons can be made. As of FY 2011, the CSA is operating in four PA areas: Space Data and Information Services, Space Exploration, Future Canadian Space Capacity, and Internal Services.[60]

The Fine Guidance Sensor engineering test unit of the James Webb Space Telescope (JWST) is being prepared for cryogenic testing at a Canadian Space Agency Lab in Ottawa prior to delivery to NASA in mid-2012. The sensor enables precise pointing of JWST so that it can obtain high-quality images. *Credit: CSA/COM DEV*

The Space Data and Information Services PA, with planned FY 2011 spending of C$136.6 million (US$141.7 million), covers Canada's satellite applications programs, including the RADARSAT Earth observation satellite program and the planned Polar Communication and Weather (PCW) mission. Two satellites in the RADARSAT program are currently operating, and the CSA has initiated development of the follow-on RADARSAT Constellation Mission (RCM), a three-satellite network intended to replace and improve upon the current system. In 2010, the Canadian government authorized C$497 million (US$515.4 million) for the RCM program over a five-year period. During FY 2010, the program spent an estimated C$118 million (US$122.4 million) and planned to spend C$88.5 million (US$91.8 million) during FY 2011.[61]

The Space Exploration PA planned to spend C$152.4 (US$158 million) in FY 2011. The Space Exploration PA covers Canada's participation in international space science and exploration, including the James Webb Space Telescope (JWST) project and the International Space Station.[62] In FY 2011, the CSA issued six contracts, valued at C$250,000 (US$0.26 million) each, for concept studies to define future areas of activity for Canadian space science. These included orbital debris mitigation, a Canadian-designed space telescope, ISS experiments in spacecraft servicing, radiation exposure, and Earth atmospheric chemistry.[63]

The Future Canadian Space Capacity PA planned to spend C$86.1 million (US$89.3 million) in FY 2011, much of which will be dedicated to executing Canada's coordination agreement with ESA. The fourth PA, Internal Services, with planned FY 2011 spending of C$49.4 million (US$51.2 million), is focused on internal administration and management of the CSA.[64]

The record-high budget levels seen in the CSA budget in FY 2011 are not likely to continue in the future. As the Canadian government develops its FY 2012 national budget, the CSA has been asked to prepare budget scenarios involving both 5% and 10% across-the-board spending cuts. The CSA is reviewing potential impacts of such cuts to each program it operates. While the ultimate results of these exercises are unknown, the most likely outcome for the CSA is a 2012 budget that is either stable or reduced.[65]

2.3.4 China

Responsibility for Chinese space activities is shared by several agencies, including the China National Space Administration (CNSA) and the People's Liberation Army (PLA), which operates the country's human spaceflight program and its launch centers. The structure and organization of the Chinese space program, and the delineation between civil and military aspects, is not transparent. This, along with the involvement of the PLA in operational space aspects, makes obtaining credible data on the Chinese national space budget difficult. One way to estimate Chinese space spending is by comparing China to its peers. On average, the major spacefaring countries—excluding the United States and Russia, where spending is significantly higher than in other countries—devote approximately 0.049% of their current-price gross domestic product (GDP) to civil space activities, as shown in Exhibit 2u. Using China's 2010 current-price GDP of 39.80 trillion yuan, the country's 2011 space spending can be estimated at 19.39 billion yuan (US$3.08 billion).[66]

EXHIBIT 2u. Space Spending as a Percentage of Gross Domestic Product (GDP), Selected Countries

Country	2010 GDP (current prices, national currency)	2011 Space Spending	% GDP Spent on Space
Brazil	R$3.675 T	R$0.50 B	0.014%
Canada*	C$1.625 T	C$0.37 B	0.023%
France*	€1.931 T	€1.56 B	0.081%
Germany*	€2.477 T	€1.30 B	0.052%
India	Rs75.122 T	Rs66.41 B	0.088%
Italy*	€1.549 T	€0.81 B	0.053%
Japan	¥479.173 T	¥309.40 B	0.065%
South Korea	₩1.173 T	₩0.23 B	0.020%
Spain*	€1.063 T	€0.24 B	0.023%
United Kingdom*	£1.455 T	£0.31 B	0.021%
		Average % GDP Spent on Civil Space	**0.049%**

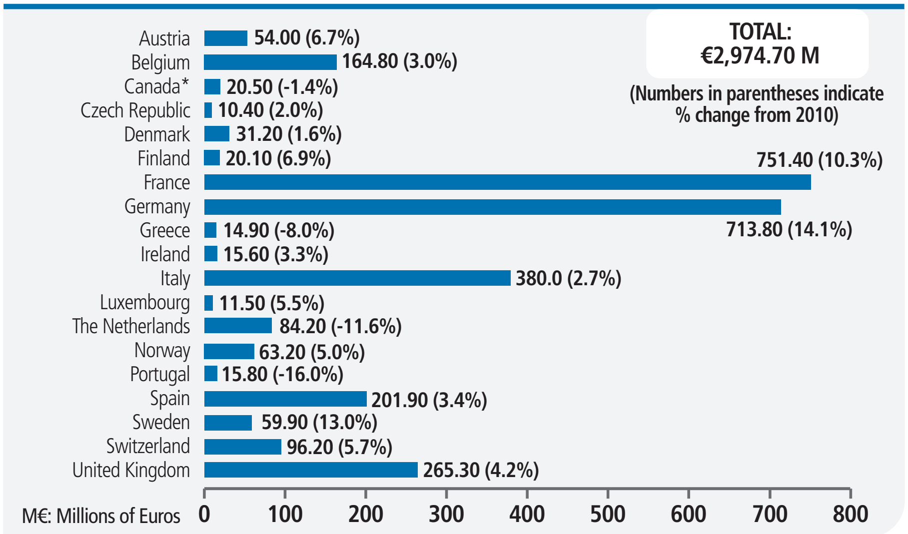
** Includes ESA Contribution*
Source: GDP Data: International Monetary Fund, World Economic Outlook Database, September 2011. Accessed December 12, 2011. Space spending sources as cited in this chapter.

In November, an uncrewed Chinese Shenzhou spacecraft docked with a small uncrewed space station module in Earth orbit, marking the latest milestone in China's incremental but steady human space flight development. More launches and crewed dockings are expected in 2012 and 2013, and a larger station as early as 2020. Officials from China's Manned Space Program Office report that 20 billion yuan (US$3.1 billion) was spent on the country's human spaceflight program in the 13 years from 1992 to 2005. From 2005 through 2011, approximately 15 billion yuan (US$2.3 billion) was spent, demonstrating the notable ramp-up in Chinese activity in recent years.[67]

China is also investing in space science. In July 2011, the Chinese Academy of Sciences opened the National Space Science Center (NSSC), which will provide a central planning function for all Chinese space science activities. The NSSC budget will grow from approximately 300 million yuan (US$46.4 million) in 2011 to approximately 700 million yuan (US$108.3 million) annually. Individual missions, such as the HXMT X-ray observatory scheduled for launch in 2014 with a budget of about 900 million yuan (US$139.2 million), are funded separately from the NSSC.[68]

In December 2011, the Chinese government released a white paper entitled *China's Space Activities in 2011*. The document provides a general outline of China's planned space activities over the next five years and confirms China's incremental approach to space development. It reiterates plans to develop a crewed space station, advance space science capabilities, and improve capabilities in a host of space applications, including Earth observation, communications, and navigation.[69]

EXHIBIT 2v. Member States' Contributions to the European Space Agency, 2011



**Canada is an associate member of ESA and contributes on an optional basis.*
Note: Total does not equal total ESA Budget due to contributions received from other sources such as the European Union.
Source: European Space Agency. ESA Budget for 2011.

2.3.5 Europe

Government spending on space programs and activities in Europe comes from four distinct sources: activities directed by the European Union (EU), executed by the European Commission (EC), and mostly implemented by ESA acting as the procurement and development agency; activities by ESA that are funded by its member states; activities of the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT); and activities carried out by European countries independent of the EU, EUMETSAT and ESA.

2.3.5.1 European Commission

The EC 2011 budget included €0.73 billion (US$1.06 billion) in funding for space-related programs (excluding EUMETSAT), a reduction of 45% from 2010 levels.[70] This represented approximately 0.5% of the EU's €141.9 billion (US$206 billion) 2011 budget.[71] EC budgets operate as yearly funding commitments within multi-year funding periods. Programs are given a top-level funding appropriation within a defined seven-year planning period; they must spend these funds within the time frame or return the remainder to the EC's general treasury. The year-to-year reduction in EC space funding can be attributed to changes in the two EU flagship programs in space: the Global Monitoring for Environment and Security (GMES) satellite program and the Galileo satellite navigation program.

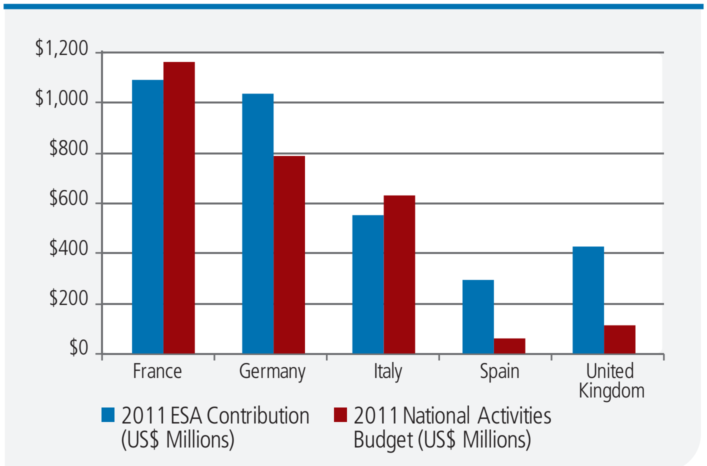
The EC's 2011 budget committed €200.1 million (US$290.5 million) toward the deployment of the Galileo system, the European counterpart to the U.S. Global Positioning System (GPS), and the associated European Geostationary Navigation Overlay Service (EGNOS), a GPS augmentation system. The EU has committed a total of €3.4 billion (US$4.9 billion) through 2014 in order to develop and launch the first 18 satellites of the Galileo constellation and implement the associated ground systems. The majority of this funding has already been obligated in the form of satellite and ground system manufacturing contracts and launch contracts. Under this funding, 18 Galileo satellites have been ordered, and launch contracts have been signed for 14 of them. In 2011, the EU announced two contracts, with a total combined value of €354.5 million (US$514.7 million), for the development of ground systems associated with Galileo.[72] The combination of these contracts with the previously announced launch and satellite manufacturing contracts leaves the Galileo program with approximately €200 million (US$290.4 million) in available funds that must be spent before 2014. The program intends to use these funds for an additional six satellites, bringing the Galileo constellation to 24 satellites, the minimum number required to provide global coverage.[73] EC policymakers will need to fund the additional six satellites required for full operational capability within the next seven-year financial plan, from 2014 through 2020. The EC has, on a preliminary basis, proposed €7 billion (US$10.2 billion) over that time frame for completion, maintenance, and operation of the Galileo constellation.[74]

EXHIBIT 2w. European Space Agency Budget by Program, 2011

Program	2011 Funding	Percent Change from 2010
Earth Observation	€843.9 M	19.1%
Navigation	€665.7 M	-6.8%
Launchers	€612.5 M	8.1%
Science	€464.8 M	13.5%
Human Spaceflight	€410.9 M	24.4%
Telecommunications	€341.3 M	4.9%
Associated to General Budget	€216.7 M	10.2%
General Budget	€179.9 M	-14.9%
Exploration	€129.4 M	26.9%
Technology*	€105.1 M	23.9%
Space Situational Awareness	€15.7 M	58.6%
European Cooperating States Agreement	€7.9 M	51.9%
Microgravity	€0.0 M	-100.0%

**Financed by third parties*
Note: Changes in ESA accounting for third party financing may limit utilty of year-over-year comparisons.
Source: ESA Budget for 2011.

EXHIBIT 2x. Comparison of ESA Contributions vs. National-only Expenditures



In response to potential cost overruns in the development of the GMES program, the EC has removed GMES from the seven-year budget plan that begins in 2014, hoping to shift the responsibility for the program to ESA and the national governments. Removing GMES from budgets beyond 2014 means there is no funding currently budgeted for operations of the program beyond the first year. This puts into question the sustainability of the investment in the first six GMES satellites, which are under construction and due to launch beginning in 2013. The EC had planned to contribute €5.8 billion (US$8.4 billion) to GMES over the period from 2014 to 2020. If the decision to remove GMES from the EC budget stands, ESA and its member states will have to cover the shortfall if the program is to continue.[75]

In addition to the Galileo and GMES programs, the EU provides funding for space and security research in its member states, with a 2011 funding commitment totaling €521.3 million (US$756.9 million). The 2011 appropriation for space and security research increased by approximately 22% compared to the 2010 level.[76] Spending in this area is intended to support the development of European space applications, including GMES applications.[77] This funding continues despite the funding uncertainty for the development and operations of GMES satellites and ground systems.

2.3.5.2 European Space Agency

ESA, representing 19 member states, had a 2011 budget of €3.99 billion (US$5.80 billion), a 7% increase over the 2010 budget of €3.74 billion (US$4.60 billion). As in the previous year, the largest three ESA funding line items are Earth observation activities at 21%, navigation activities at 17%, and activities related to the Ariane and Vega launch vehicles at 15% of the budget.[78]

The 2011 combined space spending of the five largest ESA member states, including both national space programs and ESA contributions, amounted to about €4.24 billion (US$6.15 billion). During 2011, Romania signed a formal Accession Agreement to become ESA's nineteenth member state.[79] Romania's mandatory contribution as an ESA member will begin to appear in ESA's budgets in 2012.

2.3.5.3 EUMETSAT

EUMETSAT, which operates a pan-European system of meteorological satellites, planned a 2011 budget of €306.5 million (US$445 million).[80] Approximately €87.5 million (US$127 million) of that budget was contributed to activities executed by ESA and is included in the ESA budget totals. EUMETSAT is responsible for the operations of a fleet of meteorological satellites and the associated ground control and data processing systems. EUMETSAT funds its programs through contributions made to the organization from its 26 member states and five cooperating states. Annual contribution levels are calculated on a scale proportional to the gross national income of member states, and cooperating states contribute on the basis of 50% of the scale. Nations are represented in EUMETSAT through their national meteorological agency.[81]

EXHIBIT 2y. EUMETSAT Budget by Program, 2011

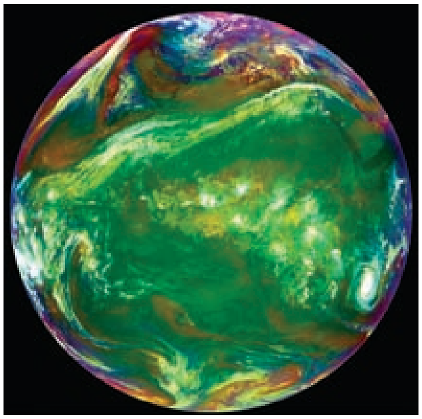
Program	Funding
EUMETSAT Polar System	€112.0 M
Meteosat Third Generation	€56.0 M
Meteosat Second Generation	€55.6 M
Core and Prospective Activities	€33.0 M
Jason-3	€26.5 M
GMES (Sentinel 3)	€7.4 M
Meteosat Transition Programme	€6.2 M
Meteosat Third Generation Preparatory Programme	€5.3 M
Jason-2	€4.1 M
Requirement Definition Process for Future EU Oceanography Systems	€0.4 M

Member States: Austria, Belgium, Croatia, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Romania, Italy, Latvia, Luxembourg, the Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland, Turkey, and the United Kingdom

Cooperating States: Iceland, Lithuania, Bulgaria, Estonia, and Serbia

Source: EUMETSAT

EUMETSAT's major focus in 2011 was the EUMETSAT Polar System (EPS), which includes the MetOp series of low Earth orbit satellites. One MetOp satellite is currently in orbit, and EUMETSAT plans the launch of additional satellites in the series in 2012 and 2016. EUMETSAT planned to spend €112 million (US$162.6 million), or 37% of the total budget on EPS in 2011. Other major programs include the Meteosat Second Generation (MSG) program—EUMETSAT's geostationary weather satellites—and the Jason series of satellites, a cooperative venture among France, NASA, and EUMETSAT focusing on ocean surface topography observation.[82]



The Airmass data product is based on infrared and water vapor information from the Meteosat Second Generation weather satellite system. It is designed to monitor the evolution of cyclones, in particular rapid cyclone development. *Credit: EUMETSAT*

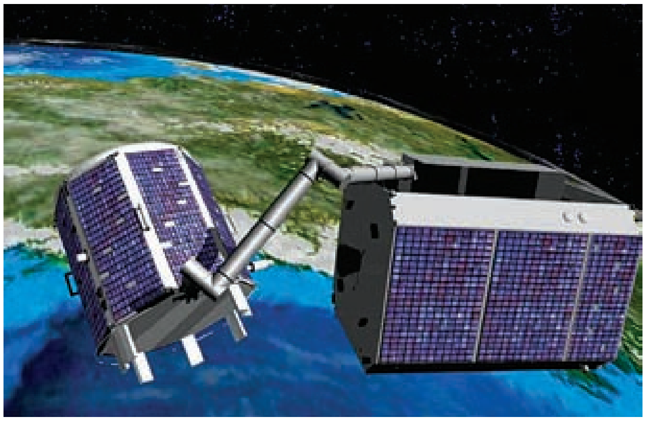
2.3.5.4 France

The French space agency, the Centre National d'Études Spatiales (CNES), operated on a government budget of approximately €761.2 million (US$1.11 billion) in 2011, excluding contributions made to ESA and EUMETSAT.[83] This represented a 4% increase from the 2010 budget of €720 million (US$899.3 million). Government spending was supplemented by €641 million (US$931 million) in revenue from activities such as launch services for ESA. In 2011, France contributed €755 million (US$1.05 billion) to ESA programs and €39.7 million (US$57.8 million) to EUMETSAT. France also spent €400 million (US$581 million) on defense-related space activities.[84] The combined French civil space budget, comprised of the CNES-only budget and the French contributions to ESA and EUMETSAT, totaled €1.56 billion (US$2.27 billion), representing approximately 0.29% of France's €539.9 billion (US$783.9 billion) national budget in 2011.[85]

French space budget levels are expected to remain stable despite pressures within France to reduce overall government spending. During 2011, and into 2012, CNES continued executing activities under a €500 million (US$635 million) French bond designed to support satellite and launch vehicle development programs. A joint U.S.-French satellite mission to study ocean water topography has been provided €170 million (US$246.8 million) for initial development. A follow-on project to the current Ariane 5 rocket will receive €220 million (US$319.4 million) in future years, including €83 million (US$120.5 million) that was released in 2011. French policymakers have indicated that maintaining an independent European space launch capability will remain the centerpiece of French space activities in the future.[86] However, some differences remain between Germany and France over the future direction of the Ariane program.

2.3.5.5 Germany

The Deutsches Zentrum für Luft- und Raumfahrt (DLR), Germany's national space agency, oversaw an authorized budget of €542.6 million (US$787.8 million) in 2011, excluding contributions made to ESA. This represents an increase of 4.2% from 2010.[87] In addition to the DLR-only spending, Germany made €713.8 million (US$1.04 billion) in ESA contributions in 2011.[88] Combined, the DLR authorization and ESA contribution total €1.26 billion (US$1.89 billion), representing approximately 0.4% of Germany's 2011 budget of €305.8 billion ($444 billion).[89]



The main goals of the Deutsche Orbitale Servicing Mission (DEOS) are to use a servicer vehicle to capture a non-cooperative satellite and to achieve a controlled re-entry for the two spacecraft at the end of the mission. *Credit: Space Tech GmbH*

In 2011, Germany began to execute programs under the *German Space Strategy* announced in November 2010. While the majority of German space efforts continue to be focused through ESA, the DLR does execute programs on a national basis. Two such programs in its space strategy are the Heinrich Hertz communications satellite, a joint civil-military project, and the Deutsche Orbitale Servicing Mission (DEOS). The Heinrich Hertz communications satellite has completed its initial concept definition phase, and the DLR is negotiating with OHB Technology for the manufacture of the satellite.[90] The DLR planned to spend €7 million (US$10.2 million) during 2011 on the preliminary design phase of the DEOS mission. DEOS is intended to be a system for removing dead satellites from orbit.[91] German officials have also indicated support for initiating work, within ESA, on a US$2 billion upgrade to the Ariane 5 launch vehicle, known as the Ariane 5 Mid-life Evolution (ME) project. France, the leading country behind the Ariane program, has not determined whether the ME program should be prioritized or whether an entirely new successor to the Ariane 5 should be developed.[92]

2.3.5.6 Italy

The Agenzia Spaziale Italiana (ASI), Italy's space agency, managed a planned budget of €434 million (US$630.1 million) in 2011, excluding contributions made to ESA.[93] This represents a 20% increase from ASI-only planned spending of €362 million (US$445 million) in 2010. Italy's contribution to ESA totaled €380 million (US$551.7 million) in 2011, an increase of 3% from 2010.[94] Combined, the ASI budget and Italy's ESA contribution totaled €814 million (US$1.18 billion), representing approximately 0.16% of Italy's planned 2011 budget of €500.5 billion (US$726.7 billion).[95] The total Italian space budget increased by 11% compared to the previous year.

EXHIBIT 2z. Italian, ASI-only Planned Space Spending, by Program Area

Budget Information by Topical Area	2011 (planned spending by calendar year)	2012
Earth Observation	€164 M	€100 M
Telecommunications and Integrated Applications	€73 M	€47 M
Exploration and Observation of the Universe	€56 M	€49 M
New Technologies and Technology Transfer	€19 M	€15 M
Human Habitability in Space and Microgravity	€15 M	€13 M
Space Transportation	€8 M	€8 M

Source: Agenzia Spaziale Italiana (ASI), Piano Triennale Delle Attivita 2010–2012.

Earth observation was ASI's main focus, receiving slightly more than one-third of ASI's non-administrative funding during 2011. Major programs in the Earth observation area include the operation and utilization of the COSMO-SkyMed constellation of radar Earth observation satellites, and the development of the PRISMA (PRecursore IperSpettrale della Missione Applicativa) medium-resolution Earth imaging satellite, due for launch in 2013.

The telecommunications and associated applications area received the second highest level of funding during 2011. The Athena-Fidus communications satellite project is funded jointly by ASI, CNES, the French defense procurement agency, and the Italian Ministry of Defense.[96] Athena-Fidus, anticipated to launch in 2013, is being manufactured by Thales Alenia Space under a contract valued at €280 million (US$406.5 million). The contract includes both the satellites and some elements of the ground control system.[97]

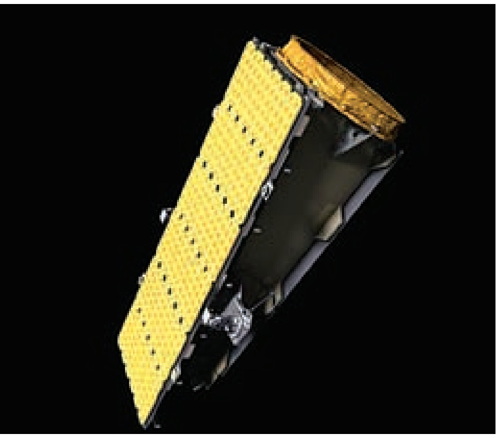
2.3.5.7 Spain

The Instituto Nacional de Técnica Aeroespacial (INTA), the primary organization responsible for space activities in Spain, received appropriations from Spain's national budget of €41.1 million (US$59.7 million) in 2011, an increase of 3% over 2010 levels.[98] INTA also receives revenue from its own commercial operations. Spain's contribution to ESA is not funded through INTA, but through the Center for the Development of Industrial Technology (CDTI). In 2011, Spain's ESA contribution was €201.9 million (US$293.1 million), an increase of 3% from the 2010 ESA contribution.[99] Combined, Spain's ESA contribution and government funding for INTA represented €243 million (US$351.4 million), or 0.07% of Spain's 2011 national budget of €362.8 billion (US$526.7 billion).[100]

Approximately 46% of INTA's budget is devoted to activities related to space technology, 40% to aeronautics, and the remaining 14% to energy, environment, road vehicles, and safety research. In the 2011 INTA budget, a small satellite development program received €1.3 million (US$1.9 million), an Earth observation program received €5.1 million (US$7.4 million) and an astrobiology research program received €2 million (US$2.9 million). INTA also received €5 million (US$6.35 million) for the operation of space research facilities and equipment, including three space tracking and telemetry ground stations.[101]

2.3.5.8 The United Kingdom

Civil space activities in the United Kingdom (UK) are primarily funded through the United Kingdom Space Agency (UKSA), which became operational in April 2011, and the Technology Strategy Board (TSB). Space budgets for



Surrey Satellite Technology Ltd (SSTL) and Astrium UK have combined forces to create NovaSAR, a small satellite that offers powerful radar remote sensing capabilities for approximately 20% of the cost of conventional radar missions. *Credit: SSTL/EADS Astrium*

FY 10/11, which ran from April 2010 through March 2011, had not been published by the UKSA as of January 2012. However, UK officials expected the FY 10/11 funding levels would be roughly the same as the previous year.[102] In FY 09/10, estimated space spending in the UK, including both ESA and national programs, totaled £312.5 million (US$467.4 million). National-only activities excluding the country's ESA contribution totaled £69.69 million (US$111.9 million).[103] UKSA-managed activities, including oversight of the country's ESA contributions, represent approximately two-thirds of UK space spending.[104] In calendar year 2011, the UK contribution to ESA totaled €265.3 million (US$313.2 million), an increase of 4% from 2010.[105]

As part of the British government's 2011 budget, the UKSA received a £10 million (US$16.1 million) line-item appropriation to implement a multi-year National Space Technology Programme (NSTP) designed to support and increase the competitiveness of the British space industry. The NSTP provides research funding for projects to increase the technology readiness levels of British aerospace technologies and components. Similarly, the TSB had oversight of a £2.4 million (US$3.86 million) program to stimulate innovation within the UK space sector. In 2011, the program provided grants to 77 different projects for the execution of space technology or concept feasibility studies. The UKSA also contributed funding during 2011 to ESA's General Support Technology Programme, which provides support to advance the technical and operational maturity of engineering concepts.[106]

Beyond these innovation-focused activities, the UKSA oversaw a number of operational and development programs in many areas of space activity, including exploration, science, and Earth observation. These activities included contributions to the James Webb, Herschel, and Planck space telescope missions; contributions to the ExoMars and BepiColombo Mars and Mercury exploration missions; the initiation of a UK-manufactured Synthetic Aperture Radar satellite mission, NovaSAR; and the operations of a UK-based Centre for Earth Observation Instrumentation.[107]

EXHIBIT 2aa. Indian Space Budgets

Budget Information by Application	Original Budget Estimates FY 2010/2011 (U.S. Dollars)	Revised Budget Estimates FY 2010/2011 (U.S. Dollars)	Budget Estimates FY 2011/2012 (U.S. Dollars)
Department of Space/ISRO			
Space Technology	$774.13 M	$581.07 M	$900.80 M
Space Applications	$160.98 M	$135.86 M	$190.32 M
Space Sciences	$77.84 M	$41.60 M	$78.73 M
INSAT (Operational)	$152.32 M	$165.50 M	$243.48 M
Direction and Administration	$79.71 M	$127.46 M	$70.25 M
Total	**$1,244.98 M**	**$1,051.49 M**	**$1,483.58 M**

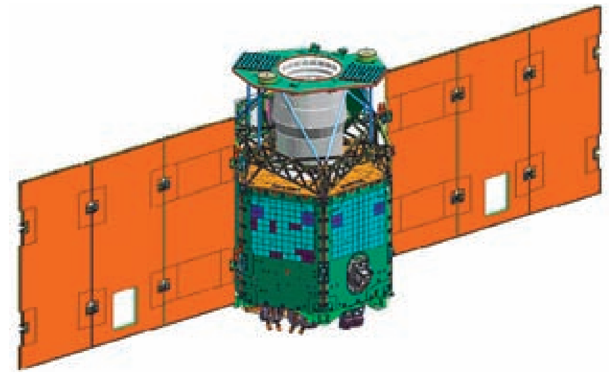
Source: Government of India, Department of Space Budget 2011–2012.

2.3.6 India

For FY 2011, covering April 2011 to March 2012, the combined budgets of India's Department of Space (DOS)—which includes funding for the Indian Space Research Organisation (ISRO) and the Ministry of Earth Sciences' Satellite Services program—totaled 66.4 billion rupees (US$1.49 billion), an increase of 15% from the amount planned in the previous fiscal year.[108] However, revised FY 2010 ISRO budget estimates indicated a reduction of 16% below original budget estimates for the year. Consequently, the ISRO planned budget for FY 2011 represents a 36% increase over the revised FY 2010 estimates. The civil space share of India's 12.6 trillion rupee (US$283 billion) overall planned government budget was approximately 0.53% in FY 2011.[109] Inflation in India stands at roughly 8% per year, and the space budget increase allows existing programs to continue but does not provide for any new program starts.[110]

As in the prior year, slightly more than 60% of the DOS budget was devoted to spending on space technology development. This includes 656.4 million rupees (US$14.7 million) for activities related to the development of India's human spaceflight capabilities. The human spaceflight program envisions the development of a two- or three-person vehicle capable of transporting humans to and from low Earth orbit, although other options are also being considered at this early phase of development. ISRO has outlined a three-phase development path for this program. The FY 2011 budget initiates funding for the first phase, focused on feasibility and design studies for the critical technologies in the crew module and crew escape system.[111] The budget documents do not outline a time frame for completion of this activity.

In keeping with India's traditional focus on direct societal applications of space technology, the combination of space applications and operational satellite telecommunications services receive the second greatest share of the ISRO budget, while space science receives only slightly more funding than administration and management functions. Within space science activities, a main focus is the Chandrayaan-2 lunar spacecraft, slated to launch in 2013, which received estimated funding of 800 million rupees (US$17.9 million) in FY 2011.[112]



VENµS, (Vegetation and Environment monitoring on a New Micro-Satellite) is a cooperative venture between Israel and France that will enable monitoring, analysis, and modeling of land surface functioning under the influences of environmental factors as well as human activities. *Credit: IAI*

2.3.7 Israel

Israel's civil space budget remains small, estimated at 50 million New Israeli Shekels (NIS) (US$14.7 million) in 2011.[113] This accounts for roughly 0.02% of the country's 2011 national budget of 271.2 billion NIS (US$79.3 billion).[114] In late 2011, the Israeli Space Agency and the Ministry of Finance reached an agreement, in principle, to notably increase the agency's funding. Under the agreement, the funding for civil space activities will total 165 million NIS (US$48.5 million) per year in 2012 and 2013, and may increase to as much as 300 million NIS (US$88.2 million) in the years beyond that.[115] Israel has agreed to participate in satellite development projects with other nations, including the VENµS Project with CNES and the Spaceborne Hyperspectral Applicative Land and Ocean Mission (SHALOM) with ASI.[116] The increased funding will help ensure Israel's ability to keep its commitments to these programs. The funding is also intended to help Israel commercialize its space-related technology expertise, developed though military space programs, in manufacturing communications satellites and microsatellites.[117] The majority of Israel's space spending is for military purposes.

The Advanced Land Observing Satellite-2 is addressing social needs such as disaster monitoring, continuous updating of data archives related to land and infrastructure information, observation of cultivated areas, and global assessment of tropical rain forests to identify carbon sinks. *Credit: JAXA*

2.3.8 Japan

In FY 2011, Japan allocated ¥309.4 billion (US$3.8 billion) for space programs across the government, a decrease of approximately 9% from the previous year's total of ¥339 billion.[118] This represents approximately 0.32% of the country's ¥95.9 trillion (US$1.19 trillion) national budget.[119] Japanese space spending is allocated among several government ministries, coordinated through the Strategic Headquarters for Space Policy. In FY 2011, which ran from April 2011 until March 2012, the Japan Aerospace Exploration Agency (JAXA), funded through the Ministry of Education, Culture, Sports, Science and Technology, operated with a budget of ¥172.6 billion (US$2.14 billion), representing approximately 55.8% of Japan's space spending.[120]

The March 2011 earthquake and tsunami placed pressure on most government agency budgets as resources were shifted to aid in response and recovery efforts. While the overall Japanese space budget did decrease in 2011, officials maintained investment in most top space activities such as the Global Change Observation Mission (GCOM) satellite, the Advanced Land Observing Satellite 2 (ALOS-2), and upgrades to the country's fleet of space launch vehicles, including the H-IIA, H-IIB, and Epsilon rockets.[121]

The ALOS-2 mission, funded at ¥6.14 billion (US$76.3 million) in FY 2011, is an Earth observing synthetic aperture radar satellite due to launch in 2013.[122] Aimed at applications in disaster monitoring and response, ALOS-2 is a replacement for the ALOS-1 satellite, which suffered a fatal power failure while conducting an observation campaign to map the effects of the March 2011 earthquake.[123]

During 2011, JAXA began improving and upgrading the H-IIA and H-IIB rockets, with the intention of increasing their performance and attractiveness on the international commercial launch market. The first phase of the upgrade project, funded at approximately $100 million in 2011, focuses on improving the capabilities of the vehicles' upper stages to increase their performance in the delivery of satellites to geostationary orbit. Future phases of the improvement, not yet funded, will focus on upgrades to the engines that power the vehicles.[124] Japan is also investing in the development of a smaller launch vehicle, known as Epsilon. The Epsilon program received ¥3.8 billion (US$47.1 million) in FY 2011, a 90% increase over the preceding year.[125]

Japan is expected to increase investment in FY 2012 in the ongoing development of its Quasi-Zenith satellite navigation system, which is intended to provide Japan with an independent GPS-like capability over the Asia-Pacific region. The utility of GPS capabilities was demonstrated during the 2011 earthquake, where GPS signals were used in early warning systems and post-disaster impact mapping.[126] The Prime Minister's office will request ¥4.1 billion (US$50.8 million) in the FY 2012 budget for the development of three additional Quasi-Zenith satellites to add to the one already in orbit. The Quasi-Zenith system requires a minimum of four satellites to provide a stable operational service. Japan ultimately aims to expand the system to seven satellites.[127]

EXHIBIT 2bb. Japanese Space Spending by Agency, 2011

Agency	FY 2011 (Yen)	FY 2011 (U.S. Dollars)	Percent Change* from FY 2010
Ministry of Education, Culture, Sports, Science and Technology	¥177.000 B	$2,194.48 M	-4.517%
Japan Aerospace Exploration Agency	¥172.600 B	$2,139.92 M	-4.111%
Cabinet Secretariat	¥67.200 B	$833.16 M	5.597%
Ministry of Defense	¥41.300 B	$512.04 M	-32.221%
Ministry of Land, Infrastructure, Transport, and Tourism	¥11.200 B	$138.86 M	2.246%
Ministry of Economy, Trade, and Industry	¥4.800 B	$59.51 M	-47.426%
Ministry of Internal Affairs and Communication	¥4.400 B	$54.55 M	0.640%
Ministry of the Environment	¥1.100 B	$13.64 M	-34.602%
Ministry of Agriculture, Forestry, and Fisheries	¥0.900 B	$11.16 M	-18.919%
National Police Agency	¥0.800 B	$9.92 M	2.302%
Cabinet Office	¥0.500 B	$6.20 M	-37.578%
Ministry of Foreign Affairs	¥0.200 B	$2.48 M	5.263%
Total	**¥309.400 B**	**$3,836.00 M**	**-8.722%**

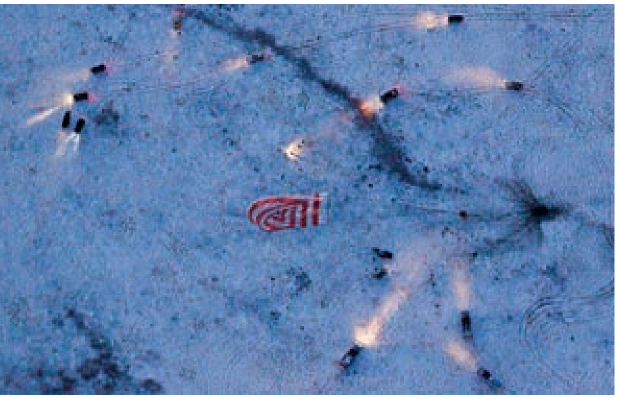
**Change from FY 2010 is calculated in yen to provide an accurate comparison from year to year.*
Source: Government of Japan, Strategic Headquarters for Space Policy

2.3.9 Russia

In calendar year 2011, the estimated planned budget for Roscosmos, the Russian Federal Space Agency, was 115 billion rubles (US$4.12 billion).[128] This is an increase of 21% from the previous year's budget of 94.9 billion rubles (US$3.04 billion) and represents approximately 1.07% of Russia's 10.7 trillion ruble (US$383.8 billion) planned 2011 federal spending.[129] Roscosmos officials said they expect a budget of 150 billion rubles (US$5.38 billion) in 2012, and that funding may increase to as much as 200 billion rubles (US$7.17 billion) by 2015.[130]

Russia's space program suffered a series of high-profile mishaps in 2011, including the launch failure of a Rokot vehicle carrying the military satellite Geo-IK-2 in February, the loss of the Express-AM4 communications satellite after launch in August, a malfunction of a Soyuz-U rocket in August that resulted in the loss of an uncrewed Progress ISS resupply spacecraft, and the failure of the Phobos-Grunt Mars spacecraft in November.[131] Russian officials have blamed these failures, in part, on low workmanship quality within the Russian space industry and have initiated a reorganization of the country's space enterprise, both government and industry.[132] The failure of Phobos-Grunt in particular has caused Russian officials to consider closer cooperation with other nations' Mars exploration projects, most notably an ESA offer to Russia to participate in the ExoMars project.[133] NASA and ESA's interest in working with Russia on the ExoMars project is largely rooted in an effort to overcome expected funding shortfalls in the project, especially those related to launch vehicle costs.[134]

The failures suffered in 2011 have not delayed Russia's increased investment in its space infrastructure, including construction of an upgraded space launch complex at Vostochny in the Russian Far East.[135] In November 2011, Russia announced that it will allocate approximately 250 billion rubles (US$8.97 billion) over a period of several years for the construction of the Vostochny space center. Construction began in 2011, and is scheduled to conclude in 2016. The first launch from Vostochny is intended for 2016, with the first crewed flight planned for 2018.[136] Ultimately, Vostochny will replace the Baikonur Cosmodrome as the center of Russia's space launch infrastructure.



Russian support personnel arrive shortly after the Soyuz TMA-02M spacecraft landed in November 2011 in a remote area outside of the town of Arkalyk, Kazakhstan. Until another human-rated spacecraft is ready, crews will travel to and from the ISS exclusively aboard the Russian Soyuz. *Credit: Roscosmos*

As it reevaluates its space program, Russia is increasing its emphasis on Earth monitoring, weather, and communication satellites. By 2015, the country aims to have 20 operational Earth observation satellites, 30 operational GLONASS navigation satellites, and 48 operational communications and Cospas-Sarsat search and rescue satellites.[137] From 2001 to 2011, Russia spent 98.7 billion rubles (US$3.54 billion) on GLONASS and plans spending of 330.5 billion rubles (US$11.9 billion) between 2012 and 2020.[138]

Russia is also evaluating future options for its human spaceflight programs, including the ISS and exploration beyond Earth orbit. Roscosmos has initiated the initial design phases of a potential six-person crewed spacecraft—the Prospective Piloted Transport System—to replace the current Soyuz capsule.[139] If this project proceeds through full development, it may cost up to 10 billion rubles (US$358.7 million) and see its first flights around 2020.[140] The head of Roscosmos has also established a working group to define Russia's strategy for space development and exploration beyond 2015.

2.3.10 South Korea

In calendar year 2011, South Korea spent an estimated 229 billion won (US$214.5 million) on civil space, a 13% decrease from the 2010 budget of 262 billion won (US$214.4 million).[141] South Korea's 2011 civil space spending constituted approximately 0.07% of the country's 309.6 trillion won (US$290.1 billion) national budget.[142] Civil space activities in South Korea are carried out primarily by the Korea Aerospace Research Institute (KARI).

While investments in Earth observation, meteorology, and satellite communications programs continue, a major area of KARI emphasis is the development of space launch vehicles. Since 2002, South Korea has been working on the development of a small launch vehicle, the KSLV-1, with Russian technical assistance. The KSLV-1 would be South Korea's first space launch vehicle. The vehicle has conducted two flights, in 2009 and 2010, both of which ended in failure. Although a joint Korean-Russian investigation board has failed to agree on the root cause of the most recent failure, South Korea is pressing forward with a third KSLV-1 launch attempt, expected in early 2012. As of October 2011, South Korea had spent an estimated 502.5 billion won (US$470.8 million) on the KSLV-1 program.[143] KARI also began developing a second space launch vehicle, the KSLV-2. This vehicle will be a larger rocket, capable of lofting satellites weighing up to 1.5 tons, and will be developed without foreign technical assistance. The South Korean government expects to invest 1.5 trillion won (US$1.4 billion) in the development of the KSLV-2, which is not expected to fly until at least 2021.[144]

KARI continued to develop the Earth observation satellites KOMPSAT 3 and 3A, scheduled for launch in 2012 and 2013, respectively. The agency also awaited the launch of the KOMPSAT-5 Earth observation satellite aboard a Russian Dnepr vehicle, which has been delayed from 2011 to 2012.

2.3.11 South Africa and Other Emerging Space Countries

Around the globe, many smaller nations—in terms of economy or population size—are investing in space projects or programs. Exhibit 2cc shows the most recent available yearly budget for civil space activities in a number of selected emerging spacefaring nations. Typically, the programs of such countries feature targeted investment in space applications linked to specific national development and economic goals. Although care must be taken in generalizing the activities of this set of countries, South Africa's space program provides a good example of the types of space-related investments governments of emerging nations are making.

Space activities in South Africa are funded through the Department of Science and Technology (DST). In FY 2011, which ran from April 2011 to March 2012, the DST planned to spend 209.9 million rand (US$31.1 million) on space activities executed through two programs: the South African National Space Agency (SANSA) and the Space Science Research, Development and Innovation subprogram.[145] SANSA, established in 2008, planned an FY 2011 budget of 93.5 million rand (US$13.8 million).[146] The agency focuses its activities in three major areas: environment and resource management; health, safety, and security; and innovation, economic growth, and social development. A major focus for SANSA in recent years has been the Sumbandila Earth observation satellite. Launched in 2009, Sumbandila was manufactured in South Africa at a cost of 11 million rand (US$1.4 million) and is South Africa's only satellite. In July 2011, SANSA lost contact with the satellite as a result of what is believed to be damage caused by a blast of solar radiation. The agency will attempt to recover control of Sumbandila in the summer of 2012, when solar exposure for the satellite's power generating solar panel is at a maximum. Regardless of the outcome, Sumbandila is viewed as a success, and South Africa is considering follow-on programs.[147] Earth observation satellites are a common investment among emerging countries. Argentina, Nigeria, Thailand, and Ukraine are among the many countries that currently operate Earth observation satellites.[148]

EXHIBIT 2cc. Space Budgets of Selected Emerging Countries

Country	Agency Name	2011 Budget (U.S. Dollars)	Description	Source
Argentina	Comisión Nacional de Actividades Espaciales (CONAE)	$0.1541 B	Calendar Year 2011 Planned Spending	Government of Argentina
Australia	Space Policy Unit	$0.3293 B	Fiscal Year 2011/ 2012 Appropriation	Government of Australia
Chile	Agencia Chilena del Espacio (ACE)	$0.0044 B	Calendar Year 2011 Appropriation	Government of Chile
Indonesia	Lembaga Penerbangan Dan Antariksa Nasional (LAPAN)	$0.0260 B	Calendar Year 2011 Estimated Spending	Futron
Malaysia	Agensi Angkasa Negara (ANGKASA)	$0.0046 B	Calendar Year 2011 Estimated Spending	Futron
Nigeria	National Space Research and Development Agency (NASRDA)	$0.0157 B	Calendar Year 2011 Planned Spending	Government of Nigeria
South Africa	South African National Space Agency (SANSA)	$0.0311 B	Fiscal Year 2011 Planned Spending	Republic of South Africa, National Treasury
Turkey	Türkiye Bilimsel ve Teknolojik Araştırma Kurumu (TÜBİTAK)	$0.0069 B	Calendar Year 2011 Estimated Spending	Futron
Kazakhstan	Kazcosmos	$0.1877 B	Calendar Year 2011 Estimated Spending	Futron
Ukraine	National Space Agency of Ukraine	$0.0420 B	Calendar Year 2011 Estimated Spending	Futron
Total		**$0.8018 B**		

South Africa is also investing in space science. In FY 2011, DST planned investment of 116.3 million rand (US$17.2 million) in its Space Science Research, Development and Innovation subprogram.[149] The majority of South Africa's activities in space science are focused on competing to host the Square Kilometer Array (SKA) project, which will be the world's largest and most sensitive radio telescope. South Africa and Australia are on the short-list to host the facility, and a final decision is to be announced in 2012. Australia has pledged AU$40.2 million (US$43.1 million) over a four-year period to support its bid to host the SKA. In South Africa, DST plans to invest 904 million rand (US$133.8 million) in the Space Science Research, Development and Innovation subprogram from FY 2011 to FY 2013, 63% of which will go to the SKA. South Africa is investing in the development of an SKA precursor radio telescope array which will provide the country with a radio astronomy capability even if it is not selected to host the SKA.[150] Although competition for the SKA is now limited to South Africa and Australia, other areas of space science are a target of investment for other nations. Vietnam, for example, has committed to a US$600 million project to build a space center focused on space science and applications by 2018.[151]

South Africa has also committed funding to space-related communications applications, although it has not invested in a national communications satellite. Several South African entities were partners in the financing of Intelsat's

New Dawn satellite, which launched in April 2011. New Dawn is targeted at providing satellite communications services to African nations.[152] Elsewhere, many smaller nations are choosing to invest in dedicated national communications satellites. For example, in August 2011, Pakistan's first national communications satellite, PakSat 1-R, was launched aboard a rocket in China, where the satellite was manufactured.[153] In July 2011, Kazakhstan launched the US$115 million KazSat-2 communications satellite, and has already committed US$164 million over the period from 2012 to 2014 to build the KazSat-3 satellite.[154]

Intelsat's New Dawn satellite, launched in April 2011, serves the African continent and delivers wireless backhaul services, broadband, and television programming. Intelsat is a leading video provider in Africa, offering more than 800 television channels to the continent. *Credit: Orbital Sciences*

2.3.12 Military Space Budgets

Military space spending is significant but difficult to quantify because most nations do not publish budget and program information about space-related national security and intelligence activity. Additionally, space capabilities have become an integral part of modern warfare, and space programs therefore often receive supportive funding from secondary sources not clearly defined as space-related. Also, many missions labeled primarily as civil assets serve dual-purpose military objectives. For all of these reasons, the estimation of military space spending is uncertain.

Given these challenges, this analysis uses a detailed methodology that combines available data, publicly cited sources, and estimates to evaluate military space spending. It is calculated that global military space spending was $27.85 billion in 2011. The United States spends the greatest amount on military space, estimated at $26.46 billion in 2011.[155] This estimate remains flat compared to 2010 spending due to the U.S. government's failure to pass a new defense budget; therefore, the U.S. funding estimate generally reflects 2010 levels. The United States represents an estimated 95% of global military space spending. Combined military spending by the rest of world is calculated as $1.39 billion.[156]

2.4 Summary of Data

Space industry revenue and government budgets associated with global space activity based on collected data and estimates are compiled in Exhibit 2dd. *The Space Report 2012* separates industry revenue and government budgets to eliminate double-counting. All figures included were selected to provide the most complete and consistent figures possible. However, in a continual effort to improve the fidelity of estimates and consistency of year-to-year collection, some methodological changes have been made in the organization and collection of certain elements. First, NRO and NGA budgets are no longer estimated separately within the U.S. government budget, as it became apparent that the funding for these agencies is likely included in the overall number for DoD. Second, the number of emerging space nations for which budget data has been collected may vary from previous years, depending on data availability. Third, funding for EUMETSAT by its contributing nations is now included in the report. Due to rounding, some percentages may not add up to 100%.

2.5 Space Investment Outlook

Throughout 2011, space industry companies made strategic use of abundant capital for transactions. During a dynamic period of transition, mergers and acquisitions (M&A) provided a tool for the space industry to reshape itself. The number of transactions rose 14% above 2010 levels, with a total of 33 deals in 2011. M&A activity during the year also reflected a significant increase in individual transaction size, with a median space-related deal size of nearly $80 million, 60% higher than 2010. Most of these acquisitions featured strategic buyers who used existing cash reserves and other assets to fund transactions. The space industry's use of capital is likely to increase again in 2012, given the industry's

EXHIBIT 2dd. **Global Space Activity Revenues and Budgets, 2011**

Type	2009 ($B)	2010 ($B)	2011 ($B)	Growth*	2011 Source	Description
Commercial Infrastructure and Support Industries	**$77.11**	**$87.61**	**$106.46**	**21.52%**		
Launch Industry (Commercial)	$2.41	$2.45	$1.93	-21.22%	FAA	2011 estimated value of commercial launches
Satellite Manufacturing (Commercial)	$4.03	$3.41	$4.24	24.34%	SIA/Futron analysis	2011 revenue from production of commercial satellites
Ground Stations and Equipment	$69.53	$80.70	$99.24	22.97%	SIA/GSA/Futron analysis	2011 revenue from production of telecommunications and PNT ground equipment
Independent Research and Development (IR&D)	$0.18	$0.17	$0.19	11.76%	Futron	2011 estimate of space industry IR&D
Insurance	$0.96	$0.88	$0.86	-2.27%	AON/ISB	2011 satellite insurance premiums
Commercial Space Products and Services	**$93.44**	**$101.73**	**$110.53**	**8.65%**		
Direct-to-Home Television (DTH)	$71.82	$79.12	$86.42	9.23%	SIA/Futron analysis	2011 direct-to-home TV revenue
Satellite Radio	$2.54	$2.83	$3.02	6.71%	SIA/Futron analysis	2011 revenue from Sirius XM
Satellite Services (FSS & MSS)	$17.07	$17.67	$18.85	6.68%	SIA/Futron analysis	2011 revenue from FSS and MSS satellite communications
Earth Observation	$2.01	$2.11	$2.24	6.16%	Northern Sky Research	2011 Earth observation data sales and value-added services
Commercial Space Transportation Services	**$0.09**	**$0.01**	**$0.01**	**0.00%**		
Orbital	$0.08	$0.00	$0.00	0.00%	Space Adventures	2011 revenue from commercial orbital flights
Suborbital (Deposits)	$0.01	$0.01	$0.01	0.00%	Virgin Galactic, XCOR	2011 deposits for suborbital flights
U.S. Government Space Budgets	**$46.48**	**$47.44**	**$47.25**	**-0.40%**		
Department of Defense (DoD) Space	$25.60	$26.46	$26.46	0.00%	Futron Estimate	FY 2011
National Aeronautics and Space Administration (NASA)	$18.78	$18.72	$18.49	-1.23%	Public Law 112-10	FY 2011 enacted
National Oceanic and Atmospheric Administration (NOAA)	$1.25	$1.40	$1.44	2.86%	NOAA	FY 2011 enacted
Department of Energy (DOE)	$0.04	$0.04	$0.04	0.00%	DOE	FY 2011 enacted
Federal Aviation Administration (FAA)	$0.01	$0.02	$0.02	0.00%	FAA	FY 2011 enacted
National Science Foundation (NSF)	$0.80	$0.64	$0.64	0.00%	NSF	FY 2011 enacted
Federal Communications Commission (FCC)	–	$0.01	$0.01	0.00%	Futron	FY 2011 estimated spending
United States Geological Survey (USGS)	–	$0.15	$0.15	0.00%	USGS	FY 2011 enacted
Non-U.S. Government Space Budgets**	**$21.13**	**$21.42**	**$25.52**	**19.14%**		
European Space Agency (ESA)	$5.16	$4.60	$5.80	26.09%	ESA	2011 appropriation
European Union	$1.56	$1.63	$1.06	-34.97%	European Union	2011 appropriation
EUMETSAT	$0.23	$0.25	$0.32	28.00%	EUMETSAT	2011 estimated spending
Brazil	$0.19	$0.18	$0.32	77.78%	Government of Brazil	2012 authorization
Canada	$0.30	$0.32	$0.38	18.75%	CSA	FY 2011 appropriation, excluding planned ESA contributions
China	$1.79	$2.25	$3.08	36.89%	Futron	2011 estimated budget
France	$1.06	$0.90	$1.11	23.33%	Government of France	2011 appropriation, excluding ESA
Germany	$0.77	$0.64	$0.79	23.44%	Government of Germany	2011 appropriation, excluding ESA
India	$1.06	$1.05	$1.49	41.90%	Government of India	2011–12 budget estimate
Israel	$0.01	$0.01	$0.01	0.00%	*The Marker*	2011 appropriation
Italy	$0.47	$0.44	$0.63	43.18%	ASI	2011 planned spending
Japan	$3.72	$3.83	$3.84	0.26%	JAXA	FY 2011 appropriation
Russia	$2.90	$3.04	$4.12	35.53%	Roscosmos	2011 planned spending
South Korea	$0.23	$0.21	$0.21	0.00%	KARI	2011 appropriation
Spain	$0.06	$0.05	$0.06	20.00%	Government of Spain	2011 appropriation, excluding ESA
United Kingdom	$0.10	$0.10	$0.11	10.00%	Futron	FY 2011 estimated spending
Non-U.S. Military Space	$1.35	$1.39	$1.39	0.00%	Futron	Estimated non-U.S. military space spending, assuming U.S. spending is 95% of global total
Selected Emerging Countries***	$0.17	$0.53	$0.80	–	Various	See Exhibit 2cc
TOTAL	**$238.25**	**$258.21**	**$289.77**	**12.22%**		

*Growth estimates include new data sources available in 2011 but not available in 2010.
**Non-U.S. budget growth rates may vary from text due to currency exchange
*** For budgets of included emerging contries see Exhibit 2cc: Space Budgets of Selected Emerging Space Countries

EXHIBIT 2ee. Space-Related Transactions in 2011, Chronological Order

Acquirer	Primary Business	Target	Primary Business	Deal Value
Moog	Precision motion and fluid controls	Bradford Engineering	Spaceflight components and systems	$13 M
MBDA	Missile and weapon systems	Northrop Grumman Viper Strike Munitions Business	Precision-guided weapons for manned and unmanned aircraft	NA
Thales Communications	Software-defined radio equipment	Tampa Microwave	Satellite communications equipment	NA
API Technologies	Electronic systems, subsystems, RF, and secure systems	Commercial Microwave Technology	Radio frequency microwave filter products	$8.2 M
Altus Capital Partners	Private equity investment firm	MT Acquisitions (also known as Models & Tools)	Assembly tooling systems for commercial, space, defense, and military aircraft manufacturers	NA
TransDigm Group	Engineered aircraft components	Harco Laboratories	Thermocouple cable assemblies, air data systems and sensors	$84 M
Parsons Corporation	Engineering, construction, technical, and management support services	Sparta (now known as Cobham Analytic Solutions)	Weapon, tactical, and space systems, missile, and network-centric warfare	$350 M
Curtiss-Wright	Mechanical, hydraulic, and electromechanical control and actuation systems	South Bend Controls	Fluid control components	$10 M
Thales	Integrated solutions and security equipment	Omnisys Engenharia	Systems and equipment for air traffic control, electronic warfare, tracking radars	NA
Cobham	Aerospace and defense technology and systems	Trivec-Avant	Sophisticated UHF SATCOM antenna systems	$144 M
Embraer Defense and Security	Technology management and systems integration	AEL Sistemas	Design and manufacture satellite equipment	NA
Greenbriar Equity Group	Private equity investment firm	Anixter International, Aerospace Hardware Division	Aerospace hardware and related components	$185 M
EADS Astrium	Space satellite systems' orbital infrastructures and launchers	Vizada	Mobile satellite communications solutions	$969 M
Saab	Products and services for aerospace and defense market	Sensis	Air traffic management solutions and surveillance technologies	$195 M
Plasan Sasa	Lightweight survivability solutions for protection on a variety of platforms	KaZaK Composites	Composite structures and low-cost automated composite manufacturing	NA
OHB	Space technology and security, telematics, and satellite services	Svenska Rymdaktiebolaget, Space Systems Division	Designs, launches, tests, and operates space and aerospace systems	NA
PRV Aerospace	Components, subassemblies, assemblies, and repair and overhaul services	Quality Forming	Metal forming and cutting processes and technologies	NA
World Surveillance Group	Unmanned aerial vehicles	Global Telesat	Satellite airtime and tracking services; airtime and equipment	$4.8 M
Kratos Defense & Security Solutions	Engineering, information technology services, and warfighter solutions	Integral Systems	Products, systems and services for satellite command and control, telemetry and digital signal processing, data communications	$254.1 M
Telematic Solutions	Telematic systems and solutions	Rheinmetall Italia, Satellite Business	Satellite and mini-satellite systems	NA
Aero-Instruments Company	Air data sensors for aircraft applications	SpaceAge Control, Air Data Product Line	Air data sensors	NA
Microsemi	Analog and mixed-signal integrated circuits and semiconductors	AML Communications	Radio frequency and microwave, low noise, and medium and high power amplifiers and subsystems	$33 M
Ducommun	Engineers and manufactures aerostructure and electromechanical components and subassemblies	LaBarge	Electronic and electromechanical systems and devices, and interconnect systems	$340 M
Goodrich Actuation Systems Limited	Supplier of fault-tolerant flight controls	Microtecnica	Flight critical precision mechanics products	$462 M
Embraer Defense and Security	Technology management and systems integration	OrbiSat da Amazonia, Radar Division	Radar technology for air, sea and land remote sensoring and aerial surveillance	$17 M
Agregat	Hydraulic, pneumatic, and fueling equipment	OAO Voskhod Pavlovo Machine-Building Plan	Electro-hydraulic drives and control systems for aircraft industry	NA
Elbit Systems	Defense systems and products	Elisra Electronic Systems Aviospace	Airborne, naval and ground EW, intelligence, communication, and microwave components	$67.5 M
EchoStar Satellite Services	Satellites, uplink facilities, and fiber network access for backhaul and distribution of video, audio, and data	Hughes Communications	Broadband satellite technologies and services	$1,941.5 M
GigOptix	Electronic and electro-optic components	Endwave	High frequency radio frequency solutions and semiconductor products	$25 M
Curtiss-Wright	Engineered valves, pumps, and electronics and related products	BASF, Surface Technologies business	Metallic and ceramic thermal spray coatings	NA
Mercury Computer Systems	High-performance embedded, real-time digital signal and image processing systems and software	LNX	Microwave and millimeter wave components systems for satellite communications	$31 M
Pragmatics	Software engineering and systems integration services	Innovative Solutions International	Aviation satellite technologies	NA
Telespazio	Satellite management services, Earth observation and satellite navigation, integrated communications	VEGA Space	Technical solutions to space agencies, satellite operators manufacturers	NA

strong balance sheets, even in the face of budget pressures and uncertainties that are expected to continue for the next several years. With better-defined policy decisions taking shape, the space industry has entered an important period of transition that provides the private sector with ample and diverse opportunities for investment and growth.

2.5.1 Mergers and Acquisitions

Companies of all shapes and sizes have used M&A to accelerate their growth and execute their business strategies. What was notable about 2011 was the volume and relative valuation sustained by a wide array of buyers pursuing high-demand targets.

Strategic buyers executed the two largest transactions in 2011. EchoStar's acquisition of Hughes Communications represents a consolidation of two leading providers of satellite communications services. EADS Astrium's acquisition of Vizada offers evidence of the growing demand for commercial satellite communications technologies, which EADS is using to rebalance its portfolio of businesses.

In other 2011 transactions, Cobham divested its Analytic Solutions business, which provides a range of scientific and engineering services to the U.S. missile defense and national security markets, to Parsons due to changes in U.S. organizational conflict of interest rules. Kratos Defense & Security Solutions acquired Integral Systems to add expertise in secure satellite and terrestrial communications networks.

These transactions underscore significant trends in the space industry's M&A activity. First, the market shows strong faith in satellite communications technologies and services as a sector with promising growth prospects. Second, the rapidly expanding satellite communications market is experiencing strong consolidation as satellite providers realize extraordinary synergies from mergers. Third, aerospace and defense companies are active acquirers as they seek to reposition themselves in the face of pending military spending cuts. M&A is seen as a rapid and effective way to offset declining growth rates in risky business areas and programs by rebalancing product and service offerings to emphasize priorities.

Buyers are using M&A as a rapid way to fill gaps, strengthen offerings, and incorporate differentiated technical or market niche capabilities. The median size of space acquisitions in 2011 was nearly $80 million, representing a 60% increase from the 2010 median value of more than $50 million. The number of space-related M&A transactions surpassed that of 2010 by 14%, but the total value of M&A transactions declined 8% since only one deal exceeded $1 billion in value as compared with two deals in 2010. The 2011 median space industry deal size is lower than the $84 million median for acquisitions in the aerospace, defense, and government industries, which experienced a 7% decline in the median value and a 9% drop in the number of transactions compared to 2010.

As in 2010, more private equity sellers participated in the industry than buyers. Private equity-backed space-related assets sold during the year included: Bradford Engineering of Heerle, the Netherlands; Vizada of Paris, France; Microtecnica of Turin, Italy; and Hughes Communications of Germantown, Maryland. In each case, private equity sellers decided to exit their investment in order to optimize financial returns.

2.5.2 Near-Term Investment Outlook

Global economic and political uncertainty has risen over the course of 2011 and will continue to affect the space industry's financial support and activity heading into 2012. Near-term progress will be dictated by critical issues including satellite interference both unintended and targeted, human space exploration, commercial and government satellite-based imagery and remote sensing services, and commercially operated space transportation systems. With flat growth anticipated for the NASA budget in 2013 and beyond, industry participants are seeking to diversify their customer base to include more commercial space activities and international growth opportunities, subject to export control laws. U.S. military space programs have seen a rise in competitiveness and cost effectiveness as companies try to maintain funding levels.

The continued internationalization of the space industry, such as the significant milestones achieved by China's space program during 2011, could lead to public support for the United States to resume its leadership position in space. Increasing competition and international security threats place strong pressure on the U.S. Department of Defense to continue to work with allies in partnerships and investments aimed at advancing technological capabilities to defend networks, operational capabilities, and resiliency in space. Despite near-term budget uncertainties and fiscal constraints, investment in space programs is a long-range wealth creator that may be at less of a risk of funding cuts than other discretionary programs.

Several factors suggest M&A activity will continue to flourish, including the financial strength of the space industry's participants and opportunities for further consolidation of a strong, but fragmented industry second tier. After strengthening cash reserves since 2001 during a period of rising military spending, defense contractors are now emboldened to increase leverage levels through debt financings in order to pursue share repurchases, dividend increases, or acquisitions. M&A activity, especially by large prime contractors, will be sustained by the strategic imperative for defense-oriented companies to fill gaps in their portfolios as government defense spending slows.

Other companies or assets will be sold by investors who see that as the best option for realizing financial returns on their investment. Owners, whether private equity or individuals, are likely to look to sell in advance of impending increases in long-term capital gains tax rates. Finally, large defense firms will continue to voluntarily break themselves apart to exhibit better strategic focus and enhance shareholder returns. Stock market valuations will reflect the ability of space industry participants to communicate to customers and investors the potential for productivity and profit.

In 2011, NASA focused more on affordability and mission-critical important projects, a trend that is expected to continue. Looking ahead, NASA will bolster human space flight activities by emphasizing scientific research and technology development, and other real-world applications, including research testing in life sciences, human health, material sciences, and Earth sciences. At a time when government resources are tightening, the commercial sector's ability to demonstrate improved long-term cost savings and growth prospects will be key to attracting investors.

EXHIBIT 2ff. Space Foundation Index vs. Other Market Indexes

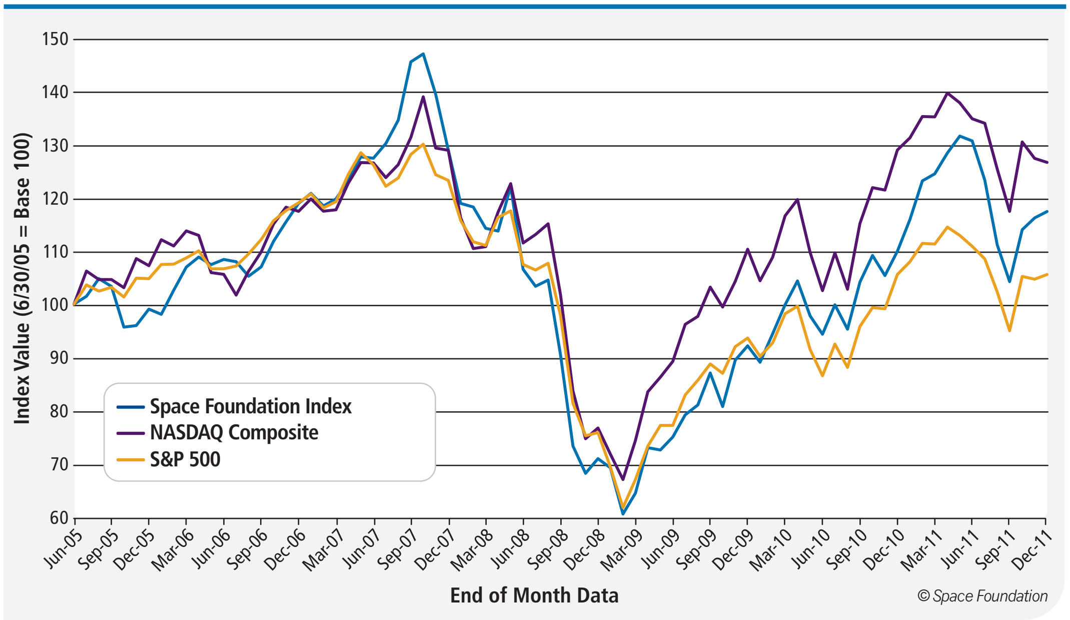
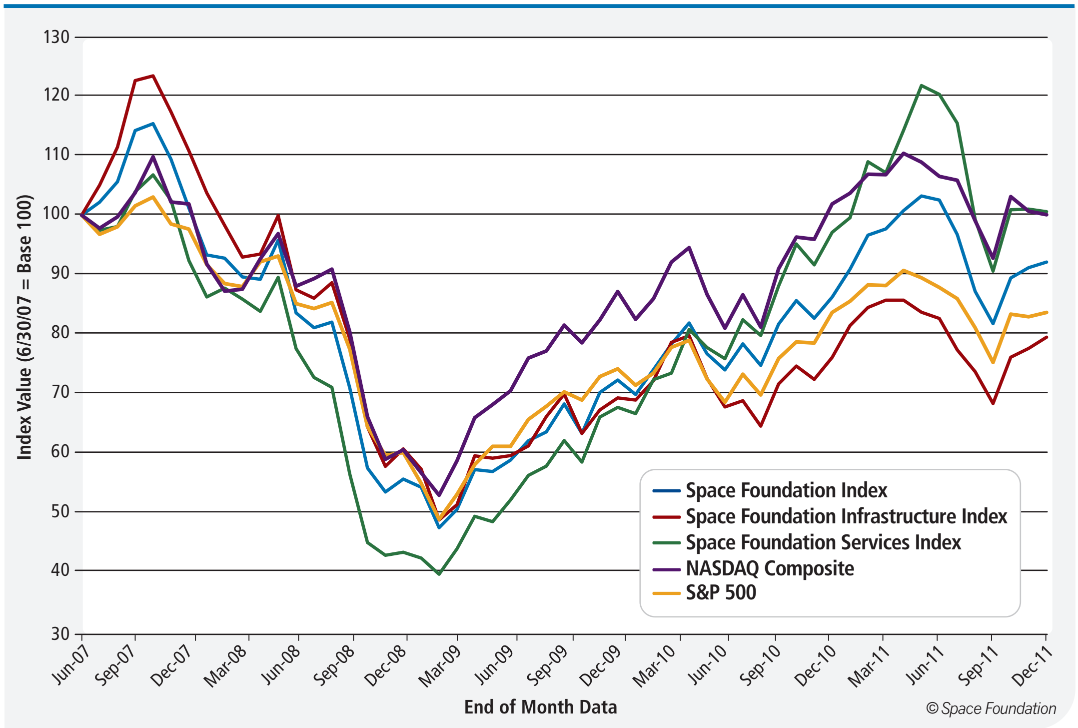


EXHIBIT 2gg. **Space Foundation Indexes vs. Other Market Indexes**



2.6 Space Foundation Indexes

The *Space Foundation Indexes* consist of three weighted indexes that track the performance of the overall space industry as well as space infrastructure and services segments in the U.S. public markets. In 2011, the *Space Foundation Indexes* exhibited annual gains of 3.6% to 6.8%, outperforming both the NASDAQ Composite and the S&P 500 for the year.

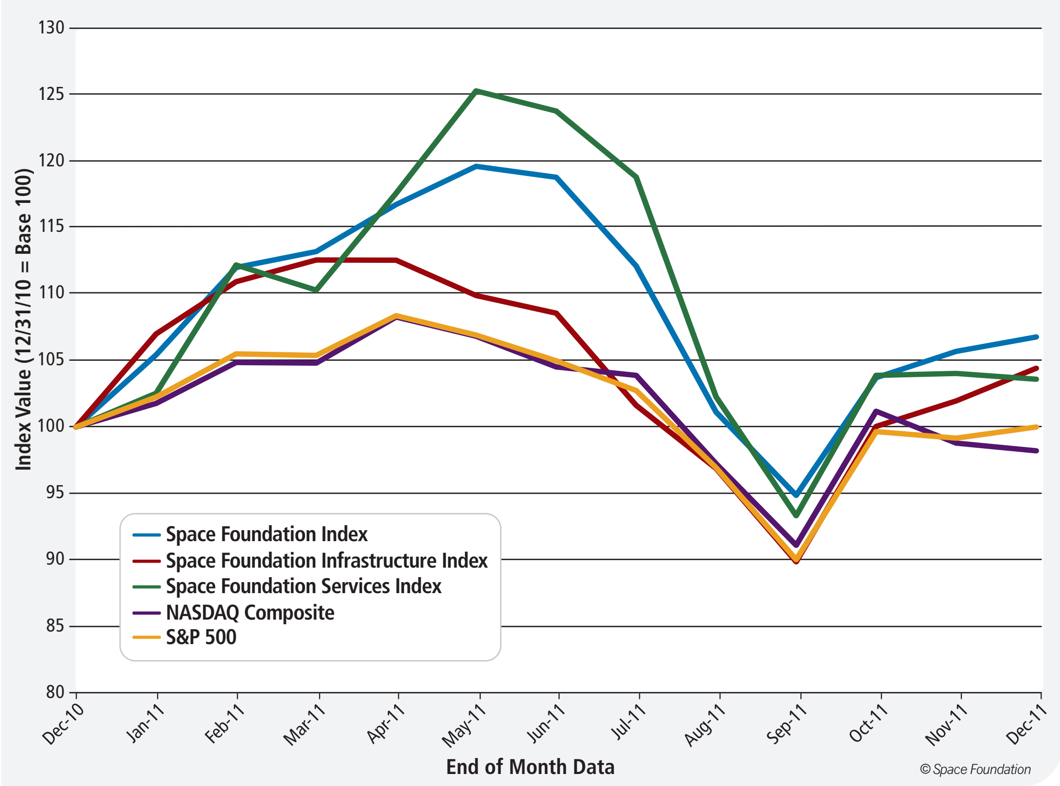
The Space Foundation Index (SFI), now in its seventh year, tracks the market performance of 28 publicly held companies that derive a significant portion of their revenue from a broad range of space-related assets and activities. The SFI was initiated on June 30, 2005, at a level of 100, enabling a quick determination of the percentage change in value.

The Space Foundation Infrastructure Index (SFII) tracks companies in the U.S. public markets that derive significant revenues from the sale of space-related infrastructure, including hardware, software, and integration services for space-related applications such as the manufacturing of satellites and launch vehicles or ground-based items such as terminals and chipsets. It was initiated with a level of 100 as of June 30, 2007.

The Space Foundation Services Index (SFSI) tracks companies in the U.S. public markets that derive significant revenues from space services and depend heavily on space assets for collection, transmission, or provisioning, including satellite broadcast, communications, and remote sensing. It was initiated with a level of 100 as of June 30, 2007.

All three of the *Space Foundation Indexes* are available and updated daily on the Space Foundation's website, www.SpaceFoundation.org/spaceindex. New graphing capabilities added in 2012 allow users to view the performance of the Indexes as compared to each other or indexes such as the NASDAQ and S&P 500 over any time interval. The indexes are updated each business day shortly after the U.S. markets close.

EXHIBIT 2hh. **Space Foundation Indexes vs. Other Market Indexes, 2011**



2.6.1 Index Performance

The *Space Foundation Index* recorded its third straight year of gains, finishing 2011 with a 6.81% increase in value. The SFI significantly outperformed both the S&P 500, which finished flat for the year, and the NASDAQ Composite which closed 2011 in negative territory. The index exceeded the growth of the S&P 500 by 6.82 percentage points and the NASDAQ by 8.61 percentage points, as can be seen in Exhibit 2ii. The SFI performed well throughout the year, except during the market downturn in the third quarter.

EXHIBIT 2ii. **Space Foundation Index Returns vs. Benchmarks**

Returns Period	SFI	S&P 500	Difference in Returns	NASDAQ Composite	Difference in Returns
Since SFI Inception	17.39%	5.56%	**11.83%**	26.65%	**-9.26%**
CY 2006	20.08%	13.62%	**6.46%**	9.52%	**10.56%**
CY 2007	8.43%	3.53%	**4.90%**	9.81%	**-1.38%**
CY 2008	-45.02%	-38.49%	**-6.54%**	-40.54%	**-4.48%**
CY 2009	29.94%	23.45%	**6.49%**	43.89%	**-13.94%**
CY 2010	19.28%	12.78%	**6.50%**	16.91%	**2.37%**
1Q 2011	13.28%	5.42%	**7.85%**	4.83%	**8.44%**
2Q 2011	4.96%	-0.39%	**5.36%**	-0.27%	**5.24%**
3Q 2011	-20.25%	-14.33%	**-5.92%**	-12.91%	**-7.34%**
4Q 2011	12.64%	11.15%	**1.49%**	7.86%	**4.79%**
CY 2011	6.81%	0.00%	**6.82%**	-1.80%	**8.61%**

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During 2011, several component companies of the Space Foundation Indexes were acquired. Due to the following transactions, the acquired companies, which are no longer traded separately, have been removed from the *Space Foundation Indexes*:

- In June 2011, EchoStar completed an acquisition of Hughes Communications. At that time, Hughes was up 50% since the start of the year.
- In July 2011, Integral Systems was acquired by Kratos Defense & Security Solutions. Integral was up almost 15% for the year at the time of the acquisition.
- Honeywell acquired EMS Technologies in August 2011 for $497 million. EMS's acquisition price represented a 67% premium from the share price at the end of 2010.

In addition to the component companies that were acquired in 2011, there are two further index composition changes in 2012:

- A former index component, ITT, announced the spinoff of its Defense and Information Solutions segment into a new publicly-listed company known as ITT Exelis. ITT Exelis includes the bulk of ITT's former space-related business activity and has a substantially higher proportion of space revenues to its overall revenues than ITT had before the spinoff. ITT Exelis has been added to the Space Foundation Index and the Space Foundation Infrastructure Index for 2012.
- During 2011, Pendrell Corporation, formerly known as ICO Global Communications (Holdings) Limited, sold its DBSD North America subsidiary to DISH Network and subsequently announced that it would be divesting itself of its remaining satellite assets in order to fund an intellectual property investment and advisory firm. As a result of the company's change in industry focus, the company will no longer be included in the Space Foundation Indexes in 2012.

EXHIBIT 2jj. Space Foundation Services Index Returns vs. Benchmarks

Returns Period	SFSI	S&P 500	Difference in Returns	NASDAQ Composite	Difference in Returns
Since SFSI Inception	0.61%	-16.35%	**16.96%**	0.07%	**0.53%**
CY 2008	-53.07%	-38.49%	**-14.59%**	-40.54%	**-12.53%**
CY 2009	56.13%	23.45%	**32.68%**	43.89%	**12.25%**
CY 2010	43.43%	12.78%	**30.65%**	16.91%	**26.52%**
1Q 2011	10.35%	5.42%	**4.93%**	4.83%	**5.52%**
2Q 2011	12.28%	-0.39%	**12.67%**	-0.27%	**12.55%**
3Q 2011	-24.70%	-14.33%	**-10.38%**	-12.91%	**-11.79%**
4Q 2011	11.06%	11.15%	**-0.10%**	7.86%	**3.20%**
CY 2011	3.61%	0.00%	**3.61%**	-1.80%	**5.41%**

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In 2011, the *Space Foundation Services Index* (Exhibit 2jj) outperformed the NASDAQ and the S&P 500 for the third year in a row, despite its relatively low growth of 3.61%. Results were mixed as some companies benefited in the stock market from earnings or from acquisition strategies, while others declined due to market weakness or company-specific challenges:

- ICO Global/Pendrell led all gainers with an 86% growth in market capitalization during 2011. Most of this can be attributed to the successful sale of its bankrupt DBSD North America subsidiary to DISH Network at a higher price than expected due to a bankruptcy court decree. As previously mentioned, with Pendrell's pending exit from satellite services, Pendrell was removed from the Indexes at the end of 2011.
- DISH Network experienced the second-largest gain of nearly 50% for the year as it acquired DBSD, Blockbuster, and former Space Foundation Index component, Terrestar Networks, from bankruptcy during 2011. DISH has subsequently filed with the FCC to combine the MSS spectrum of TerreStar and DBSD in order to create a "hybrid satellite and terrestrial mobile and fixed broadband network."

- Other significant gainers include: Orbcomm, which beat growth forecasts and gained 26% in market capitalization and Globecomm, which gained 38% in value based upon strong earnings and bookings.
- Other DTH broadcast companies were not as fortunate. BSkyB was only up by 5% as News Corporation announced that it would no longer attempt to acquire the balance of BSkyB that it does not already own. DIRECTV lost more than 8% during the year.
- Both GeoEye and DigitalGlobe lost almost half their market capitalization as the enthusiasm seen in 2010 for the satellite imaging sector waned due to imminent defense budget cuts and significant doubts surrounding the strength of the commercial imaging market. Early in the year, DigitalGlobe was forced to lower its growth forecasts in response to commercial demand that was lower than expected, while later in the year GeoEye also had to lower its revenue forecasts. It is also expected that the EnhancedView contract between the two companies and the National Geospatial-Intelligence Agency will be reduced in upcoming federal budgets.
- Globalstar declined 64% as difficulties multiplied in 2011 for the LEO communications satellite operator. The first two deployments of its second-generation satellites have exhibited problems with their momentum wheels, and the company is in a dispute with the manufacturer, Thales Alenia. Amidst these challenges, Globalstar has delayed the next launch, its CFO has resigned, and eight more first-generation satellites are beginning to fail due to the same radiation problems that prematurely incapacitated significant portions of that constellation.

EXHIBIT 2kk. Space Foundation Infrastructure Index Returns vs. Benchmarks

Returns Period	SFII	S&P 500	Difference in Returns	NASDAQ Composite	Difference in Returns
Since SFII Inception	-20.51%	-16.35%	**-4.16%**	0.07%	**-20.58%**
CY 2008	-45.23%	-38.49%	**-6.74%**	-40.54%	**-4.69%**
CY 2009	14.15%	23.45%	**-9.31%**	43.89%	**-29.74%**
CY 2010	9.83%	12.78%	**-2.95%**	16.91%	**-7.08%**
1Q 2011	12.63%	5.42%	**7.21%**	4.83%	**7.80%**
2Q 2011	-3.57%	-0.39%	**-3.18%**	-0.27%	**-3.30%**
3Q 2011	-17.32%	-14.33%	**-2.99%**	-12.91%	**-4.41%**
4Q 2011	16.32%	11.15%	**5.16%**	7.86%	**8.46%**
CY 2011	4.45%	0.00%	**4.45%**	-1.80%	**6.25%**

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The *Space Foundation Infrastructure Index* (Exhibit 2kk) outperformed the *Space Foundation Services Index* for the first time since 2008, experiencing 4.45% growth during 2011 despite federal budget tightening and ongoing uncertainty surrounding government space markets:

- The GPS sector performed well in 2011, with Garmin leading all infrastructure companies with a growth in market capitalization of 39%, while Trimble achieved a respectable 15% growth rate.
- Overall, the ground-infrastructure segment of the space industry performed fairly well. The acquisitions of Hughes Communications, EMS Technologies, and Integral Systems, led the way, all coming in significantly higher than their 2010 closing values. ViaSat (which successfully launched its ViaSat-1 Ka-band satellite), Globecomm, Orbcomm, and the GPS companies all finished the year with 11% to 39% growth. Only Gilat, Comtech, and L-3 finished the year in negative territory.
- With a growth in value of almost 15%, Boeing outperformed most of its large space industry manufacturing peers for the second year in a row. Other space segment manufacturers and system integrators did not fare as well, with Computer Sciences Corporation down by more than 45% and Northrop Grumman, ATK, Loral, L-3, and Harris all declining between 15% and 27% in 2011. Many of these companies missed Wall Street sales and earnings estimates amidst federal budget spending reductions and related uncertainty.

2.6.2 Index Composition

The *Space Foundation Indexes* are modified market capitalization-weighted indexes of representative space companies listed on U.S. market exchanges. Component companies are selected based upon an evaluation of several criteria, including proportion of revenues attributable to space-related products and services, market capitalization, and trading volume.

Consideration is given to providing diverse representation across various space-related markets. Space revenues include the manufacture of launch vehicle, satellite, and ground segment systems and components; satellite communications services and capacity leasing; space-related positioning and remote sensing data and services, and related equipment (including GPS chipsets); and space-related software, operations, and support services.

Space revenue estimates were based upon a review of multiple sources, including *Space News'* Top 50 lists, company websites, SEC filings, and internal experience.

EXHIBIT 2II. Composition of the Space Foundation Indexes for 2012

Infrastructure Companies—Space Foundation Infrastructure Index			
Space Segment Manufacturers and System Integrators		**Ground Segment Manufacturers**	
Ticker	**Company**	**Ticker**	**Company**
ATK	Alliant Techsystems Inc.	CMTL	Comtech Telecommunications Corp.
BA	The Boeing Co.	SATS*	EchoStar Corp.
CSC	Computer Sciences Corp.	GRMN	Garmin Ltd.
XLS	Exelis, Inc.	GILT*	Gilat Satellite Networks Ltd.
GY	GenCorp Inc.	GCOM*	Globecomm Systems Inc.
HRS	Harris Corp.	LLL*	L-3 Communications Holdings, Inc.
LLL*	L-3 Communications Holdings, Inc.	TRMB	Trimble Navigation Ltd.
LMT	Lockheed Martin Corp.	VSAT*	ViaSat, Inc.
LORL*	Loral Space & Communications Inc.		
NOC	Northrop Grumman Corp.		
ORB	Orbital Sciences Corp.		
RTN	Raytheon Co.		

Satellite Services Companies—Space Foundation Services Index			
Consumer/Retail Services		**Enterprise/Government Services**	
Ticker	**Company**	**Ticker**	**Company**
BSY	British Sky Broadcasting Group plc	DGI	DigitalGlobe, Inc.
DTV	The DIRECTV Group, Inc.	SATS*	EchoStar Corp.
DISH	DISH Network Corp.	GEOY	GeoEye, Inc.
SIRI	Sirius XM Radio Inc.	GILT*	Gilat Satellite Networks Ltd.
		GSAT	Globalstar, Inc.
		GCOM*	Globecomm Systems Inc.
		IRDM	Iridium Communications Inc.
		LORL*	Loral Space & Communications Inc.
		ORBC	Orbcomm Inc.
		VSAT*	ViaSat, Inc.

**Company has major operations in more than one industry segment*

© Space Foundation

Index Composition: The *Space Foundation Index* is composed of all the companies represented in the *Space Foundation Infrastructure Index* and the *Space Foundation Services Index*.

The *Space Foundation Indexes* were prepared by ISDR Consulting, LLC on behalf of the Space Foundation. Changes in the index values are driven by changes in the market capitalization of the component companies (share price multiplied by number of shares outstanding of each company). The contributions of certain component companies' market capitalization to a given index have been discounted to adjust for lower percentage of revenues attributable to the space-related products and services that are the focus of a given index. Certain component companies' market capitalization contributions to a given index have also been adjusted to discount for size. The levels of the indexes are not directly altered by stock splits, stock dividends, or trading halts, nor are they affected by new listings, additional issuances, delistings, or suspensions.

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A GPS receiver embedded in the SINCGARS tactical radio, manufactured by ITT Exelis, provides U.S. troops with positioning, navigation, and timing information without the need for additional equipment. *Credit: ITT Exelis*

SPACE INFRASTRUCTURE

A Japanese H-IIB launch vehicle lifts off from Tanegashima Space Center in January 2011, carrying the second H-II Transfer Vehicle (HTV) to the International Space Station. It docked with the ISS, providing supplies such as spare parts and drinking water before de-orbiting and burning up in the atmosphere in March. *Credit: JAXA*

EXHIBIT 3a. Topics Covered in Space Infrastructure

3.0 Introduction

Space activities are performed for purposes such as national security, revenue creation, or scientific inquiry. Just as an architect requires the infrastructure of the construction industry—building materials, tools, and other specialized equipment—to turn plans for a building into an actual structure, space-related organizations require infrastructure to implement their plans. This infrastructure includes both well-known elements such as launch vehicles and spacecraft and less-known items such as ground stations and spaceports. Technology development is also critical to space infrastructure, providing capabilities that can enhance existing systems and enable new ones.

3.1 Launch Vehicles

As the sole means of access to space, launch vehicles are the indispensable foundation of space activity. Orbital launch vehicles propel a payload with enough energy to send it into orbit or beyond the Earth's gravitational pull. Suborbital launch vehicles can send a payload into space but do not have enough energy to prevent it from returning to the Earth's surface. Both orbital and suborbital launch vehicles require relatively complex infrastructure to support space launches. The ability to make and use reliable, safe, and cost-effective launch vehicles is a key measure of national space capability.

The Juno spacecraft is launched by an Atlas V rocket from Cape Canaveral Air Force Station, Florida. Juno will take five years to reach Jupiter, where the spacecraft will orbit the planet, probe its internal structure and gravitational field, analyze its atmosphere, map its powerful magnetic field, and observe its intense auroras. *Credit: NASA/Bill Ingalls*

3.1.1 Orbital Launch Vehicles

Orbital launch vehicles are defined as rockets capable of placing a spacecraft or other payload into Earth orbit or into trajectories beyond Earth orbit. A country's ability to develop and build a vehicle and then launch it into orbit is an indicator of the sophistication of its space capabilities and is an essential foundation of a national space effort.

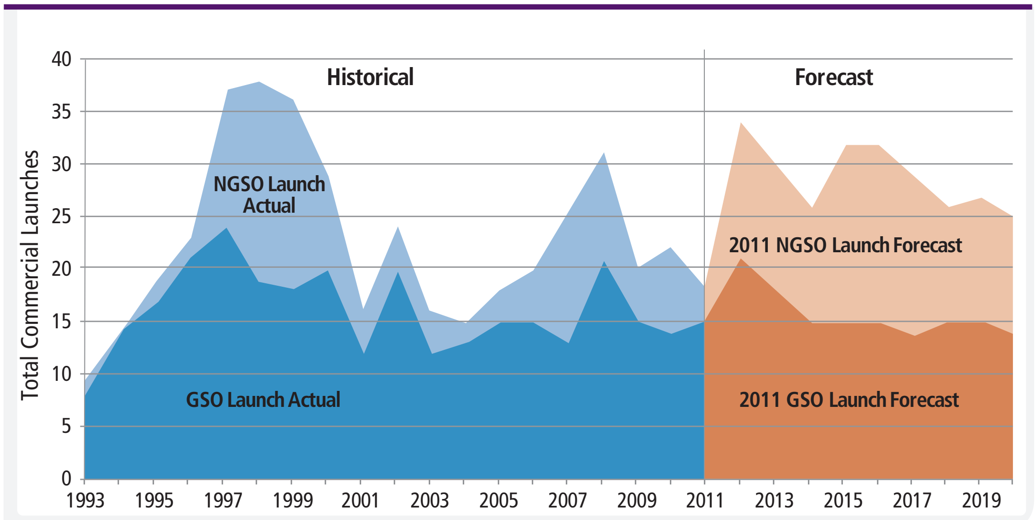
Since space exploration first began with the 1957 launch of Sputnik 1, all orbital launch vehicles have been chemical rockets, which burn a mixture of fuel and oxidizer in a combustion chamber in order to produce thrust and lift its payload into orbit. Competing concepts such as nuclear rockets and single-stage-to-orbit vehicles have been proposed over the years, but these technologies are not currently feasible.

Orbital launch activity increased by 14% in 2011, rising to 84 launches from a total of 74 in 2010. Continuing a trend that began in 2004, Russia was the nation that conducted the most launches, with a total of 31. China followed with a total of 19 launches, conducting one more launch than the United States. According to forecasts from the Federal Aviation Administration (FAA) in May 2011, commercial satellite and launch activity is likely to increase in 2012, as shown in Exhibits 3b and 3c. Subsequent years are likely to see slightly lower levels of activity. These forecasts do not include government launches, so the overall launch trend may ultimately be somewhat different.

3.1.1.1 U.S. Orbital Launch Vehicles

The United States continued to operate the world's most diverse fleet of orbital launch vehicles in 2011. While its total of 18 successful launches was not the world's highest, it led in terms of diversity, with eight different types of orbital rockets launched throughout the year. In addition, 2011 saw progress toward the introduction of a new rocket system, the Antares (known prior to December 2011 as the Taurus II) and the announcement of three new launch systems, the Falcon Heavy, the Space Launch System, and the as-yet unnamed vehicle under development by Stratolaunch Systems. The Antares and Falcon Heavy are both commercially developed vehicles that will be used by commercial and government clients to launch satellites, cargo, and possibly even crew. The Space Launch System is a NASA-developed rocket that will be used primarily for human space exploration beyond low Earth orbit (LEO).

EXHIBIT 3b. Commercial Geosynchronous Orbit (GSO) and Non-geosynchronous Orbit (NGSO) Historical Launches and Launch Forecast, 2011



Source: FAA Format modified

The Evolved Expendable Launch Vehicle (EELV) systems, consisting of the Atlas and Delta family of launch vehicles operated by United Launch Alliance (ULA), successfully completed 11 missions in 2011.[1] From 2006 to 2011, ULA successfully launched 56 missions, of which 30 were national security missions, 17 were for NASA, and nine were for commercial customers. In the field of human spaceflight, ULA is positioning its Atlas V vehicle to support commercial missions to the International Space Station (ISS). Atlas V is currently the launch vehicle of choice for three of four teams receiving funding from NASA to develop a commercial crew transportation capability to the ISS.

The Antares rocket was scheduled to make its first launch in late 2011 but has been delayed to 2012 because of development setbacks as well as construction delays at its launch site at Wallops Island, Virginia. Using funds from NASA's Commercial Orbital Transportation Services (COTS) program, Orbital Sciences developed the Antares to launch its Cygnus cargo spacecraft and traditional satellite payloads. The COTS program is helping fund the development of the rocket and its first two test launches. Following those, the Antares is scheduled to fly eight cargo delivery missions to the ISS under NASA's Commercial Resupply Services (CRS) contract. Orbital Sciences is also marketing the Antares to other customers in need of medium-lift capability, such as the Department of Defense (DoD) and the National Oceanic and Atmospheric Administration (NOAA).[2]

EXHIBIT 3c. Commercial Satellite and Launch Forecasts, 2012–2020

Satellites	2012	2013	2014	2015	2016	2017	2018	2019	2020	Total	Average
GSO Forecast (COMSTAC)	26	23	20	20	20	19	20	20	19	**187**	**20.8**
NGSO Forecast (FAA)	31	22	15	45	41	39	15	16	15	**239**	**26.6**
Total Satellites	**57**	**45**	**35**	**65**	**61**	**58**	**35**	**36**	**34**	**426**	**47.4**
Launch Demand											
GSO Medium-to-Heavy	21	18	15	15	15	14	15	15	14	**142**	**15.8**
NGSO Medium-to-Heavy	11	9	9	15	15	13	9	10	9	**100**	**11.1**
NGSO Small	2	3	2	2	2	2	2	2	2	**19**	**2.1**
Total Launches	**34**	**30**	**26**	**32**	**32**	**29**	**26**	**27**	**25**	**261**	**29.0**

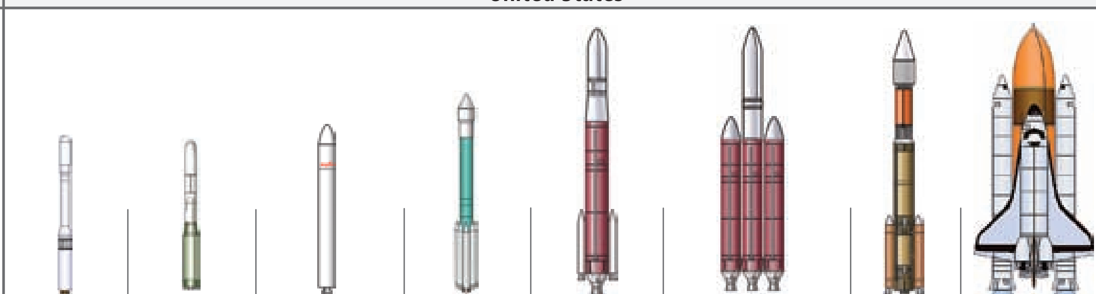
Note: GSO – geosynchronous orbit, NGSO – non-geosynchronous orbit, COMSTAC – Commercial Space Transportation Advisory Committee; FAA-Federal Aviation Administration
Source: FAA

Space Exploration Technologies (SpaceX) formally announced, in April 2011, that the company was developing the Falcon Heavy rocket, a powerful addition to the U.S. fleet which the company claims will drastically reduce the cost of placing payloads into orbit. The Falcon Heavy is a variation on the company's Falcon 9, which made its first two launches in 2010 and was developed using NASA COTS funds with the eventual goal of delivering cargo to the ISS through the CRS contract. The Falcon Heavy differs from the Falcon 9 in that it will have two additional first stages attached to its sides, resulting in more than three times the total thrust on liftoff and the ability to carry almost five times the amount of payload into LEO. SpaceX expects the Falcon Heavy to place 53,000 kilograms (117,000 pounds) into LEO for a price of $80 million to $125 million. This cost equates to prices as low as $1,500 per kilogram ($700 per pound), approximately 10 times less expensive than existing vehicles.[3] SpaceX expects the Falcon Heavy's first market to be the U.S. intelligence community, whose reconnaissance satellites are some of the largest payloads currently launched into space. With this in mind, ground was broken on a launch facility for the Falcon Heavy at Vandenberg Air Force Base, California, in July 2011. The first Falcon Heavy is anticipated to arrive at the site by 2012 for ground tests, followed by a first flight in 2013.[4]

This rendering of the Stratolaunch Systems launch vehicle shows a multi-stage booster attached to the center of its carrier aircraft. The system is designed to deliver payloads of up to 4,500 kilograms (10,000 pounds) into low Earth orbit. *Credit: Stratolaunch Systems*

In December 2011, Microsoft co-founder Paul Allen announced that he was funding the development of an entirely new launch vehicle, to be built by a new company called Stratolaunch Systems. Launches would be conducted by a novel aircraft with a wingspan nearly twice that of a Boeing 747 which would carry a rocket designed by SpaceX into the stratosphere and launch it while airborne. Scaled Composites, the company that collaborated with Allen to produce SpaceShipOne, will be responsible for the design and construction of the carrier aircraft. The rocket built by SpaceX will be a smaller, modified version

EXHIBIT 3d. U.S. Orbital Launches, 2011



	United States							
Vehicle	Taurus XL	Minotaur	Minotaur IV	Delta II	Delta IV	Delta IV Heavy	Atlas V	Shuttle
Total Launches, 2011	1	2	1	3	2	1	5	3
Launch Reliability, 2011	0/1 0%	2/2 100%	1/1 100%	3/3 100%	2/2 100%	1/1 100%	5/5 100%	3/3 100%
Launch Reliability, 2001–2011	1/4 25%	8/8 100%	3/3 100%	57/57 100%	12/12 100%	5/5 100%	28/28 100%	34/34 100%
Year of First Launch	1994	2000	2010	1990	2002	2004	2002	1981
Active Launch Sites	VAFB	VAFB, WFF	VAFB, WFF	CCAFS, VAFB	CCAFS, VAFB	CCAFS, VAFB	CCAFS, VAFB	KSC
Payload to LEO in kilograms (pounds)	1,590 (3,505)	640 (1,410)	1,735 (3,825)	6,100 (13,440)	9,150 (20,170)	22,560 (49,740)	20,520 (45,240)	23,435 (51,557)
Payload to GTO in kilograms (pounds)	–	–	–	2,170 (4,790)	4,300 (9,480)	12,980 (28,620)	8,670 (19,110)	5,663 (12,459)

LEO - Low Earth Orbit, GTO - Geosynchronous Transfer Orbit. CCAFS - Cape Canaveral Air Force Station, KSC - Kennedy Space Center, VAFB - Vandenberg Air Force Base, WFF - Wallops Flight Facility.
Note: Launch reliability is determined by analyzing the number of successful and failed launches of a particular vehicle; mission outcome (success or failure) is not used in the calculation of launch vehicle reliability. Images of rockets not to scale.
Source: FAA. Format modified.


Blue Origin's second test vehicle flew twice in 2011. The first flight consisted of a successful short hop, seen here. *Credit: Blue Origin*

of the Falcon 9. Benefits of air launching include the ability to launch in almost any trajectory and through a broader range of weather conditions, since the use of an airplane to launch means flying away from land and above any turbulent weather. The aircraft is scheduled to make its first flight as early as 2015, with the first launch planned at least a year later.[5]

3.1.1.2 U.S. Orbital Human Spaceflight Systems

The events of 2011 marked a transition in the U.S. human spaceflight program with the retirement of the Space Shuttle. In the near term, NASA will rely on Russia to transport its astronauts to the ISS. However, the United States is pursuing development of several human spaceflight systems that are expected to take over U.S. crew transportation duties to the ISS and allow U.S. astronauts to travel beyond Earth orbit to explore destinations throughout the Solar System.

The current gap in U.S. human spaceflight access began when the Space Shuttle landed for the final time on July 21, 2011, ending the program after 135 flights over 30 years. All three of the remaining shuttles—*Discovery*, *Endeavour*, and *Atlantis*—flew in 2011, delivering the final core ISS elements into orbit.[6] The three orbiters are being decommissioned as all the components are cleaned and potentially hazardous substances are removed in preparation for museum display. After a competition to host the shuttles, NASA Administrator Charles Bolden announced that the oldest flying orbiter, *Discovery*, will be given to the Smithsonian National Air and Space Museum. *Atlantis* will go to the Kennedy Space Center's Visitor Complex, and *Endeavour* will be displayed at the California Science Center in Los Angeles. *Enterprise*, an atmospheric test vehicle that did not fly in space, will be moved from its current place at the Smithsonian to make room for *Discovery* and will be given to the Intrepid Sea, Air & Space Museum in New York. The *Enterprise* was completed before the operational shuttles and lacks working engines or a functional heat shield, but it has essentially the same size, mass, and shape as the orbiters.[7]


The Space Launch System (SLS) is designed to meet the budget of the U.S. space program by addressing high-cost development activities early in the development process. It will also use a modular architecture to achieve the most efficient configuration for each mission. *Credit: NASA*

After an extended period of uncertainty, the United States' next human spaceflight system was formally announced in September 2011. The new rocket, dubbed the Space Launch System (SLS), will be the core of NASA's architecture for sending astronauts farther into space than ever before. With a projected development cost of $10 billion, the SLS shares some notable similarities with its predecessor, the Ares V, which was cancelled along with the Constellation program in 2010. It will be powered by a liquid-fueled core based on the shuttle's external tank and will use Space Shuttle Main Engines in addition to two five-segment solid rocket boosters. The SLS will also use much of the technology originally developed for the shuttle and modified in anticipation of the Ares launches. NASA officials said that a first flight could come as early as 2017, with crewed launches of the Orion Multi-Purpose Crew Vehicle (MPCV) slated to begin in 2021, although the vehicle is expected to continue to evolve through 2030.[8] A final variant of the SLS could have a lift capacity and vehicle height similar to the original Saturn V Moon rocket. The MPCV could also be launched to the ISS using existing U.S. launch vehicles such as the Delta IV or Atlas V to provide services similar to those being developed by commercial human spaceflight companies.

In addition to retiring the Space Shuttle and building the SLS and MPCV, NASA also devoted funding toward other efforts to develop human space transportation systems in cooperation with commercial providers. In April 2011, NASA announced the second round of Commercial Crew Development (CCDev) grants.[9] The CCDev program is intended to stimulate commercial ventures looking to provide low-cost human access to LEO. The second round of the CCDev program awarded $270 million to four companies: Boeing, Sierra Nevada, SpaceX and Blue Origin. NASA will continue to use Space Act Agreements to advance development of commercial human spaceflight capabilities in 2012. In February 2012, NASA announced that it intends to provide $300 million to $500 million to at least two companies under the new Commercial Crew Integrated Capability (CCiCap) initiative. Awards will be announced in mid-2012 and are intended to cover development activities through May 2014 for private vehicles to carry crew to and from the ISS.

3.1.1.3 Russian Orbital Launch Vehicles

Russia entered 2011 in the midst of an investigation into the loss of a Proton rocket carrying three Russian government navigation satellites in December 2010. Russian space officials scrambled to determine the cause of the loss, which was eventually determined to be the over-fueling of an upper stage. Problems continued to arise in 2011, leading to the loss of four launch vehicles and the Phobos-Grunt mission to Mars. Nevertheless, Russia maintained its place as the world's most-frequent launch provider with 31 launches.

EXHIBIT 3e. Russian Orbital Launches, 2011

	Russia						
Vehicle	**Dnepr**	**Rockot**	**Soyuz**	**Soyuz 2**	**Zenit 3F**	**Zenit 2F**	**Proton M**
Total Launches, 2011	1	1	10	7	2	1	9
Launch Reliability, 2011	1/1 100%	0/1 0%	9/10 90%	6/7 86%	2/2 100%	1/1 100%	8/9 89%
Launch Reliability, 2001–2011	14/15 93%	11/13 85%	99/101 98%	15/16 94%	2/2 100%	1/1 100%	51/56 91%
Year of First Launch	1999	1994	1963	2004	2011	2011	2000
Active Launch Sites	Baikonur, Dombarovskiy	Baikonur, Plesetsk	Baikonur, Plesetsk	Baikonur, Plesetsk, Kourou	Baikonur	Baikonur	Baikonur
Payload to LEO in kilograms (pounds)	3,700 (8,150)	1,850 (4,075)	6,708 (14,758)	7,800 (17,100)	–	12,000 (26,500)	21,000 (46,305)
Payload to GTO in kilograms (pounds)	–	–	1,350 (2,975)	1,700 (3,800)	3,300 (7,300)	–	5,500 (12,125)

LEO - Low Earth Orbit, GTO - Geosynchronous Transfer Orbit. Note: Launch reliability is determined by analyzing the number of successful and failed launches of a particular vehicle; mission outcome (success or failure) is not used in the calculation of launch vehicle reliability. Images of rockets not to scale.
Source: FAA. Format modified.

In early 2011, a fault in the Rokot's upper stage placed its payload, an Earth observation satellite for the Russian military, into the wrong orbit. The satellite became unusable and was subsequently abandoned.[10] Russia suffered two more launch failures in August. The first took place when the upper stage of a Proton rocket failed and did not place a Russian communications satellite into the proper orbit.[11] The second was the first-ever failure of an ISS cargo launch. Due to foreign matter in a fuel line, the upper stage engine of the Soyuz rocket carrying the Progress 44P cargo spacecraft unexpectedly shut down, causing the vehicle and its payload to crash in eastern Siberia. The Soyuz rocket fleet was temporarily grounded while the problem was addressed. An extensive delay could have forced the ISS partners to temporarily abandon the station since replacement crews could not be launched, which could have jeopardized the entire station. However, Russian engineers identified the cause of the failure and addressed it quickly; and the launch of a replacement crew to the ISS was delayed only two months to mid-November.[12]

Russia suffered yet another setback in November, when the long-delayed launch of its Phobos-Grunt probe to Mars began well, only to leave the probe stranded in Earth orbit after the spacecraft's transfer stage failed to ignite. Russian mission controllers worked for days to contact the probe and manually reboot the probe's guidance system, but no progress was made. The spacecraft broke up during re-entry in January 2012.

Russia experienced its fourth launch failure in December 2011, when a Soyuz rocket carrying a military communications satellite failed shortly after liftoff. The cause was not conclusively determined by the end of the year, but it is thought that a fault in the vehicle's third stage was to blame. The incident intensified the Russian space industry's internal debate regarding quality control and oversight.[13]

A bright spot for Russia's space program was the inaugural launch of the Soyuz rocket in October and a second in December from the newly built Soyuz launch facility in Kourou, French Guiana. The launch facility is jointly operated by European and Russian technicians, though the Soyuz rocket assembly and launch integration are controlled exclusively by Russia. The launch marks the beginning of an arrangement intended to benefit both the European and Russian space programs. By launching from Kourou, which is only five degrees north of the Equator, the Soyuz can loft almost twice as much payload into orbit as it can from the much more northerly Russian launch facilities. This has the potential for halving the price per kilogram of payloads sent to orbit, making the Soyuz more competitive on the global market. For the Europeans, having the Soyuz launch at their facility gives them a medium-class rocket that they can offer to customers who do not need the larger capacity of the Ariane 5.[14]

Russia's ambitious plans to develop a new human-rated rocket system to eventually replace the Soyuz came to an official halt in October when Roscosmos, the Russian space agency, announced its decision to cancel the development of the Rus-M rocket. Originally planned to have its first flight in 2015, the rocket was to launch primarily from the new Russian launch facility of Vostochny in eastern Siberia. Launching from Vostochny would have relieved Russia of the need to rely on its Baikonur spaceport, which is leased to Russia by Kazakhstan and currently provides the only launch facilities for crewed Soyuz rockets.[15]

Development of Russia's other new rocket system, the Angara, continued in 2011. Designed to be a modular system, the Angara will range from lightweight to super-heavyweight capacity rockets, depending on its configuration. Funding shortfalls have delayed the program by several years, but the Russian government announced its commitment to make the first flight of the Angara system by the end of 2013. This flight will use the smallest and simplest version of the Angara vehicle and will take place at the Plesetsk Cosmodrome in northeast Russia. With the end of the Rus-M's development, it is likely that the Angara will take on the role of Russia's next human-rated space vehicle.[16]

The first Soyuz flight from Europe's spaceport in French Guiana sits ready for liftoff. The rocket successfully carried the first two satellites of Europe's Galileo navigation system into orbit. *Credit: ESA/S. Corvaja*

Russia's main human spaceflight launch system, the Soyuz, is the only operational human spaceflight vehicle that is currently transporting astronauts to and from the ISS following the end of the Space Shuttle Program. Russia continues to pursue development of the Prospective Piloted Transport System (PPTS), a replacement for the Soyuz crew capsule. However, funding priorities in Russia may shift attention away from human spaceflight toward development of other types of space infrastructure, as detailed in Section 5.1, *Trends That Are Shaping Space Activity*.

3.1.1.4 Chinese Orbital Launch Vehicles

China's annual total of 19 flights surpassed its previous record of 15 launches set in 2010. Additionally, 2011 marked the first year that China conducted more orbital launches than the United States, which performed 18 launches in 2011. China's increased launch rate over the last two years was mainly attributable to launches that placed satellites for China's Beidou navigation system into orbit. A Chinese space official indicated that the country intends to maintain an average annual launch rate of 20 orbital launches.[17]

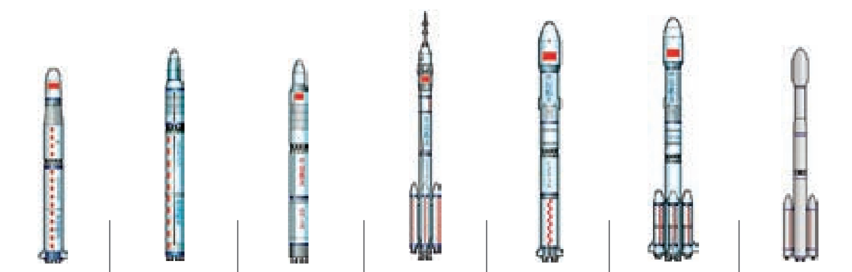
In August, a Chinese Long March 2C rocket failed in midflight, sending its payload, a Chinese government technology development satellite, plummeting back to Earth. This was the first Chinese launch failure since 2009, when a faulty upper stage placed an Indonesian communication satellite in the wrong orbit. An investigation determined that a defective mechanical component was the reason for the failure. In light of the accident, the launch of China's first space laboratory module was delayed by about a month.[18]

China is the only nation other than Russia to currently operate a human spaceflight system. In 2011, China placed its first modular space laboratory into orbit with the launch of the Tiangong-1 laboratory in September. The Tiangong module, whose name means "heavenly palace" in Mandarin, is about the size of a city bus. Following Tiangong-1, China launched an uncrewed Shenzhou-8 spacecraft. Following two days of maneuvers as Shenzhou-8 adjusted its orbit to meet up with Tiangong-1, the spacecraft conducted a successful, and technically challenging, automated docking procedure. This successful rendezvous and docking is a major milestone toward China's long-term goal of establishing a permanent modular space station by the end of the decade.[19]

The Shenzhou-8 is the same type of spacecraft that took China's first astronaut, or "taikonaut," into space in 2003, and has launched two times since then with taikonauts aboard. Although still relatively low, China's rate of human spaceflight launches indicates confidence in the program's technology demonstration missions and future plans.

EXHIBIT 3f. Chinese Orbital Launches, 2011

China



Vehicle	Long March 4B	Long March 2D	Long March 2C	Long March 2F	Long March 3A	Long March 3B	Long March 3C
Total Launches, 2011	3	1	4	2	3	5	1
Launch Reliability, 2011	3/3 100%	1/1 100%	3/4 75%	2/2 100%	3/3 100%	5/5 100%	1/1 100%
Launch Reliability, 2001–2011	15/15 100%	11/11 100%	14/15 93%	8/8 100%	16/16 100%	13/13 100%	7/7 100%
Year of First Launch	1999	1992	1975	1999	1994	1996	2008
Active Launch Sites	Taiyuan	Jiuquan	Jiuquan, Taiyuan, Xichang	Jiuquan	Taiyuan, Xichang	Xichang	Xichang
Payload to LEO in kilograms (pounds)	2,800 (6,170)	3,500 (7,700)	3,200 (7,048)	9,500 (20,900)	6,000 (13,225)	13,562 (29,900)	3,700 (8,200)
Payload to GTO in kilograms (pounds)	–	1,250 (2,750)	1,000 (2,203)	3,500 (7,700)	2,600 (5,700)	4,491 (9,900)	–

LEO - Low Earth Orbit, GTO - Geosynchronous Transfer Orbit. Note: Launch reliability is determined by analyzing the number of successful and failed launches of a particular vehicle; mission outcome (success or failure) is not used in the calculation of launch vehicle reliability. Images of rockets not to scale.
Source: FAA. Format modified.

In October 2011, China conducted its first commercial launch of a western-owned satellite since 1999. Eutelsat W3C is a communications satellite owned and operated by Eutelsat, a European company that is one of the world's largest operators of commercial communications satellites. The satellite is an "ITAR-free" craft, built without any components banned from export by the U.S. International Traffic in Arms Regulations (ITAR). Previously, many commercial communication satellites could not be launched using China's lower-cost rockets due to ITAR regulations preventing satellites with U.S.-built components from launching aboard Chinese vehicles.[20]

3.1.1.5 European Orbital Launch Vehicles

Europe made progress in 2011 toward expanding its range of launch options. Europe conducted five launches of its workhorse Ariane 5 rocket. Four of those were standard dual-payload commercial launches, each lifting two communications satellites into orbit for commercial clients. The first Ariane 5 launch of 2011, conducted in February,

The European Space Agency's first Vega rocket sits in the mobile gantry at the Centre Spatial Guyanais, in French Guiana. In February 2012, the vehicle conducted its first successful flight, launching nine satellites into orbit. *Credit: ESA/S. Corvaja*

was the exception and placed an Automated Transfer Vehicle (ATV) into orbit to rendezvous and dock with the ISS. The vehicle, named the *Johannes Kepler*, was the second ATV sent to the ISS. Carrying almost 1,600 kilograms (3,500 pounds) of dry cargo in addition to fuel and water, the *Kepler* docked with the ISS, transferred its cargo, and received garbage from the ISS. The *Kepler* then detached from the station and burned up in the atmosphere over the Pacific Ocean in June. The third ATV, named the *Edoardo Amaldi*, is scheduled to be launched in the first half of 2012.[21] NASA has formally asked the European Space Agency (ESA) to explore the feasibility of using the experience gained through the ATV program to collaborate with the United States to develop a service module that could attach to the Orion MPCV.

ESA also prepared for the first flight of the new Vega rocket, which successfully took place in February 2012. The Vega is a new solid-fuel rocket developed by Europe to launch payloads that are too small to be economically launched by the Soyuz or the Ariane 5. With the addition of the Vega to its fleet, Europe has three launch options to offer potential customers and is able to launch almost any conventionally-sized payload into any orbit.[22]

3.1.1.6 Japanese Orbital Launch Vehicles

The Japanese space program continued operations at its usual pace with three launches in 2011. The first launch occurred in January and sent the second H-II Transfer Vehicle (HTV) to its rendezvous and docking with the ISS. Much like the European ATV, the HTV is an uncrewed cargo vehicle designed to dock with the ISS and transfer dry cargo, fuel, and water to the station, before being loaded with the station's garbage and sent back to Earth to burn up in the atmosphere.[23] The second launch of the year took place in September, placing a reconnaissance satellite into orbit for the Japanese government.[24] Japan's third launch took place in December and also deployed a reconnaissance satellite. All three launches used versions of Japan's H-II rocket. The September and December launches used the standard H-IIA version while the January launch of the HTV used the more powerful H-IIB version.[25]

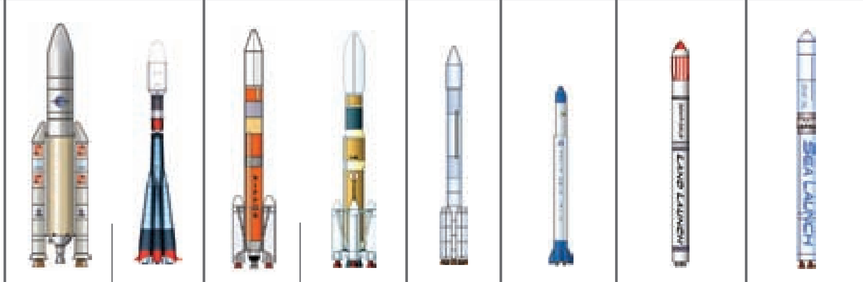
Japan has discussed plans to leverage experience gained from development and operation of the HTV to incrementally develop toward a crewed capability. A plan has not yet been submitted to decisionmakers for formal government approval.

3.1.1.7 Indian Orbital Launch Vehicles

India had a successful year in 2011, launching three rockets without any of the failures that plagued its 2010 launch season. All three launches used the Polar Satellite Launch Vehicle (PSLV). While the rocket's nomenclature hints at its original purpose to place satellites into polar orbit, over time it has launched medium-weight satellites into a variety of orbits. The first launch took place in April and placed an Indian Earth observation satellite into orbit. The second took place in July and placed into geosynchronous orbit (GEO) an Indian communications satellite with the specific purpose of providing better connectivity to rural communities in India.[26] The third launch took place in October and carried a French environmental monitoring satellite.[27]

An Indian Polar Satellite Launch Vehicle is transported from the vertical integration building to the launch site. It successfully launched GSAT-12, an Indian communications satellite that will increase capacity for tele-education, telemedicine, and Village Resource Centres. *Credit: ISRO*

EXHIBIT 3g. Other Orbital Launches, 2011



	Europe		Japan		India	Iran	Land Launch	Sea Launch
Vehicle	**Ariane 5**	**Soyuz 2**	**H-IIA**	**H-IIB**	**PSLV**	**Safir**	**Zenit-3SLB**	**Zenit-3SL**
Total Launches, 2011	5	2	2	1	3	1	1	1
Launch Reliability, 2011	5/5 100%	2/2 100%	2/2 100%	1/1 100%	3/3 100%	1/1 100%	1/1 100%	1/1 100%
Launch Reliability, 2001–2011	51/52 98%	2/2 100%	19/20 95%	2/2 100%	16/16 100%	2/3 67%	5/5 100%	24/26 92%
Year of First Launch	1996	2011	2001	2009	1993	2008	2007	1999
Active Launch Sites	Kourou		Tanegashima		Satish Dhawan	Iran Space Center	Baikonur Cosmodrome	Odyssey Pacific Ocean Platform
Payload to LEO in kilograms (pounds)	17,250 (37,950)	–	11,730 (25,860)	19,000 (42,000)	3,700 (8,150)	N/A	13,920 (30,624)	15,246 (33,541)
Payload to GTO in kilograms (pounds)	10,500 (23,127)	3,060 (6,750)	5,800 (12,800)	8,000 (17,600)	800 (1,760)	N/A	4,120 (9,060)	6,100 (13,440)

LEO - Low Earth Orbit, GTO - Geosynchronous Transfer Orbit. Note: Launch reliability is determined by analyzing the number of successful and failed launches of a particular vehicle; mission outcome (success or failure) is not used in the calculation of launch vehicle reliability. Images of rockets not to scale.
Source: FAA. Format modified.

India did not fly its larger Geosynchronous Satellite Launch Vehicle (GSLV) in 2011. Having suffered two GSLV launch failures in 2010, the Indian space program decided to focus its attention on continuing development of the next Indian heavy launch vehicle, the GSLV Mk. III. The Mk. III model will be an almost entirely new vehicle when compared to the Mk. I and II models, and testing proceeded successfully through 2011. The first flight of the GSLV Mk. III is scheduled for 2012. When the vehicle becomes operational, it will have a performance double that of the GSLV Mk. I and II and will be able to loft around 10,000 kilograms (22,000 pounds) into LEO.[28]

India is considering a variety of options for transporting Indian astronauts into orbit, including the possibility of launching aboard a vehicle operated by another nation, developing a crewed capsule that would launch on a foreign launch vehicle, or building a complete launch system featuring a launch vehicle and capsule. Indian leaders believe it is possible to develop an Indian human spaceflight capability by the end of the decade.[29]

3.1.1.8 Other Orbital Launch Vehicles

Two other space programs made news in 2011, as space newcomer Iran successfully conducted its second launch and the multinational commercial venture Sea Launch resumed operations after a hiatus of nearly two and a half years.

A Zenit-3SL rocket carrying the ATLANTC BIRD 7 satellite lifts off from Sea Launch's ocean-based Odyssesy Launch Platform in September 2011. The satellite is operated by Eutelsat and provides digital broadcasts to markets across the Middle East and North Africa. *Credit: Sea Launch*

Iran's 2011 launch was its third orbital launch attempt and the second successful one. Although its first launch in 2008 was unsuccessful, Iran successfully placed a small satellite into orbit in 2009. Its most recent launch took place in June 2011, placing the Iranian Rasad 1 Earth observation satellite into LEO. The achievement was widely hailed in Iran but was seen by many in the West as an indication of the growing sophistication of Iran's missile technology.[30]

Sea Launch resumed launch operations in 2011 after completing a restructuring of the company. Following the company's Chapter 11 bankruptcy in June 2009, Boeing divested itself of its 40% stake in Sea Launch and Russian aerospace company Energia increased its share from 25% to 85%. Previous shareholders, including Boeing, the

Norwegian company Aker, and the Ukrainian company Yuznoye/Yuzhmash gave up their shares in the company, leaving the remaining 15% of shares in the hands of smaller investors. Sea Launch's first launch since completing restructuring took place in September 2011 from the Pacific Ocean aboard the mobile Odyssey platform. A Zenit-3SL rocket successfully placed its payload, Eutelsat's Atlantic Bird satellite, in GEO orbit.[31] Additionally, Land Launch, a wholly Russian-owned subsidiary of Sea Launch, made its first flight in almost two years in October using a Zenit-3SLB rocket.[32]

Other human spaceflight systems in development include Excalibur Almaz (EA), a private venture that plans to refurbish flight-proven Russian Almaz reusable space capsules and modules to transport astronauts and space tourists into orbit. In October 2011, NASA signed an unfunded agreement with EA to allow exchange of technical details, a move that formally acknowledges EA as an element of NASA's overall effort to develop the U.S. commercial spaceflight industry.

3.1.1.9 Orbital Launch Trends

One common measure of space infrastructure is the number of launches a country or service provider executes each year. Given the variety in launch vehicle capabilities, a more telling metric would be to compare the number of launches alongside the amount of payload mass delivered into orbit by each nation or launch entity. A five-year view of these trends in orbital launch is found in Exhibit 3h.

EXHIBIT 3h. Number of Launches Attempted and Payload Mass Intended for Orbit by Country, 2007–2011

	2007		2008		2009		2010		2011		Total	
	Launches	Mass (kg)	Launches	Mass (kg)	Launches	Mass (kg)	Launches	Mass (kg)	Launches	Mass (kg)	Launches	Mass (kg)
China	10	26,007	11	30,613	6	16,388	15	37,990	19	63,911	61	174,909
Europe	6	25,156	6	40,384	7	35,220	6	24,442	7	43,810	32	169,012
India	3	3,185	3	2,294	2	1,336	3	4,187	3	3,576	14	14,578
Iran	0	0	1	45	1	26	0	0	1	15	3	86
Israel	1	300	0	0	0	0	1	272	0	0	2	572
Japan	2	4,085	1	2,000	3	19,838	2	2,300	3	18,600	11	46,823
North Korea	0	0	0	0	1	500	0	0	0	0	1	500
Russia	26	90,370	26	92,814	29	116,932	31	125,997	31	137,365	143	563,478
Sea Launch/Land Launch	0	0	1	1,370	3	8,913	0	0	2	7,800	6	18,083
South Korea	0	0	0	0	1	100	1	100	0	0	2	200
United States	20	78,665	20	206,186	25	112,136	15	100,383	18	61,299	98	558,668
Total	**68**	**227,768**	**69**	**375,706**	**78**	**311,389**	**74**	**295,671**	**84**	**336,376**	**373**	**1,546,909**

Source: Futron

An examination of the mass of the payloads launched in 2011 demonstrates the disparity in launch capabilities. For example, although China performed nearly three times as many launches as Europe in 2011, Europe placed almost the same amount of mass into orbit as China. This is partly due to the use of the Ariane 5 rocket, which is capable of carrying two large communications satellites with each flight; whereas China uses smaller, single-payload launch vehicles.

3.1.2 Suborbital Launch Vehicles

Not all launches are intended to place spacecraft into orbit, as many payloads are designed to enter space only for a brief period. The most prevalent types of vehicles in this category are sounding rockets and reusable launch vehicles (RLVs).

3.1.2.1 Sounding Rockets

Sounding rockets are vehicles designed to transport a payload to the highest reaches of Earth's atmosphere and beyond and then return it to Earth without entering orbit. Sounding rockets vary in size and capability, and they have a long and well-established history. Some have maximum altitudes of 30 kilometers (18 miles), while the most capable can take a payload up to 1,500 kilometers (930 miles) above the Earth's surface before returning to the ground. Many sounding rockets use engines recycled from surplus military rockets due to their proven capability and relatively low cost compared to custom-built engines. Due to their relative simplicity, they can be launched from small-scale facilities that are not suited for orbital launches. Two active facilities that support only suborbital launches are White Sands Missile Range, New Mexico, and the Esrange Space Center in northern Sweden.

A Brazilian VSB-30 sounding rocket emerges from the Skylark Launcher at the Esrange Space Center in Kiruna, Sweden. The heated, enclosed launchpad protects the rocket's sensitive equipment from the cold weather north of the Arctic Circle. *Credit: DLR/Thilo Kranz*

3.1.2.2 Suborbital Reusable Launch Vehicle Developments

Suborbital RLVs are designed to fly multiple times, with or without human passengers, to serve space tourism, research, and other markets. The best-known of these vehicles is SpaceShipTwo, which is undergoing flight tests and may begin commercial passenger-carrying operations in 2013. SpaceShipTwo uses technology first used on SpaceShipOne, which made the first private human spaceflight in 2004. Officially unveiled at the end of 2009, SpaceShipTwo made its first glide test flight in late 2010. It spent 2011 undergoing a series of test flights to prove its safety and reliability. When testing is complete, SpaceShipTwo will carry six passengers and two pilots on suborbital flights that will allow them to experience approximately five minutes of weightlessness.[33]

Also being developed for suborbital tourism flights is the Lynx, a rocket-powered spaceplane by XCOR Aerospace. Designed to carry a pilot and one passenger, the Lynx will take off from a runway under rocket power on a suborbital trajectory before gliding back to a landing. At the end of 2011, XCOR had completed a series of wind tunnel tests using Lynx models. The first flight of the full-scale vehicle is planned for 2013.[34]

Blue Origin, a secretive company funded by Amazon.com founder Jeff Bezos, revealed in September 2011 that in August it had suffered a failure of one of its New Shepard suborbital test vehicles. The company reported that it lost control of its PM 2 vehicle at an altitude of 13,700 meters (45,000 feet) and a speed of Mach 1.2. The company had carried out a flight of the same vehicle in May and had flown a separate vehicle, Goddard, in 2006 and 2007. Blue Origin announced it is working on a new development vehicle but has not announced a timetable for beginning commercial flights.[35]

Armadillo Aerospace has been working for several years on concepts for suborbital RLVs. In December 2011, it launched a suborbital rocket named STIG-A from Spaceport America, New Mexico. The uncrewed rocket flew to a peak altitude of 41,910 meters (137,000 feet) before landing by parachute at the spaceport. The company said the flight successfully demonstrated a number of technologies it plans to incorporate into its planned crewed suborbital RLV.[36]

One of the purposes of Armadillo Aerospace's STIG-A rocket is to test long-range communications, which will be applicable to the company's other projects. *Credit: Armadillo Aerospace/Ben and Phil Eaton*

3.2 Space Stations

Long before the launch of the world's first space station, Salyut 1, by the Soviet Union in April 1971, humans considered ways to make space a permanent habitat and workplace. Today, the ISS is one of the world's most recognized spacecraft. China is also developing its own modular space station, and Russia is considering plans to build a station designed to serve as a test bed and assembly point for deep-space exploration missions. In the private sector, economic uncertainty and delayed progress in the development of commercial crew transportation vehicles have affected progress in building space stations.

This photo was taken from a departing Soyuz spacecraft during a four-hour maneuver specifically designed to capture the first video and still imagery of a space shuttle docked with the International Space Station. *Credit: ESA/NASA*

3.2.1 International Space Station

The ISS provides a unique platform for humans where long-term scientific research and experiments can occur. The ISS is a project involving the United States, Russia, Japan, Canada, and 11 ESA member states. It is a research facility in LEO that can host a permanent crew of up to six people in its current configuration. In-space assembly of the ISS began in 1998 and continued through 2011, at which point the station was "core complete," featuring modules and other components from all five major partners. The station consists of 15 pressurized modules and an extensive integrated support structure. Full assembly is expected to be complete in 2012 with the addition of the Russian Multipurpose Laboratory Module and the Node Module.[37] NASA and its international partners have agreed to continue operations of the ISS until at least 2020 and potentially to 2028.[38]

The ISS is serviced multiple times a year through resupply missions executed by the major partners' space agencies. As of the end of 2011, there had been 29 Soyuz and 45 Progress missions launched by Roscosmos, two Automated Transfer Vehicle (ATV) launches by ESA, two H-II Transfer Vehicle (HTV) launches by the Japan Aerospace Exploration Agency (JAXA), and 36 shuttle flights to the station by NASA.[39] Soyuz crew rotation flights and Progress resupply flights each visit the station four times every year on average, with the ATV and HTV planned to visit annually from 2012 onward. The shuttle made its final visit to the ISS in July 2011, when *Atlantis* delivered supplies to the station. NASA has selected SpaceX and Orbital Sciences to provide new spacecraft to transport cargo to and from the ISS until at least 2015, and a separate effort is underway to develop commercial crew transportation systems to support the ISS.

Technicians in Europe's spaceport in Kourou load cargo onto Automated Transfer Vehicle 3 for its journey to the International Space Station. The spacecraft carried 6,600 kilograms (14,540 pounds) of cargo, including propellant, oxygen, water, food, clothes, and equipment. *Credit: ESA/CNES/Arianespace/Optique Video du CSG/S. Martin*

3.2.2 OPSEK

In June 2009, Roscosmos informed the United States of its intention to develop an orbital research facility by the time the ISS is retired. This complex would be known as the Orbital Piloted Assembly and Experiment Complex (OPSEK). The Russian Multipurpose Laboratory Module and Node Module are expected to dock with the ISS in 2012, but whenever the decommissioning of the ISS occurs, Roscosmos intends to detach those modules to use as the basis for OPSEK. The main goal of the station would be to support deep space exploration, including missions to the Moon and Mars.[40]

3.2.3 Chinese Space Station

China made great strides in 2011 toward developing its own modular space station, through the successful launch of the Tiangong-1 laboratory and rendezvous and docking with an unmanned Shenzhou-8 space vehicle. Two more Shenzhou missions are expected to dock with the module in 2012, with at least one of the missions carrying a crew. The module is expected to hold up to three crew members. Future Chinese space station plans include the launch of two more Tiangong modules, one in 2013 and the other in 2015. A full-fledged modular station, weighing about 60 metric tons, is planned for assembly around 2020.[41]

3.2.4 Bigelow Space Station

Bigelow Aerospace is developing expandable, or inflatable, modules for commercial applications using technology licensed from NASA. Through the launch of Genesis I in 2006 and Genesis II in 2007, Bigelow has already demonstrated this innovative method of launching modules in compact form and inflating them once in orbit. The next phase for Bigelow is launching the Space Complex Alpha using two Sundancer modules and one larger BA 330 module, as well as a docking node and propulsion bus. In late September 2011, Bigelow announced it was slowing operations and laying off approximately half of its workforce because of delays in the development of crew transportation systems needed to access its planned stations. The company cited a weak economy that has affected the plans of potential customers as an additional reason for this decision.[42]

EXHIBIT 3i. Satellites Launched by Mission Type, 2011

Satellite Mission	Launched in 2011
Communications (Non-military)	41
Military (Reconnaissance, Communications, Early Warning)	24
Scientific Research	12
Remote Sensing and Environmental Monitoring	11
Positioning, Navigation, and Timing	11
Technology Demonstrations	3
Total	**102**

**Only successful missions included in this data*
Source: Futron

3.3 Satellites

Telecommunications technology has made the world a much more intimate place. This is in no small part due to satellites circling the globe providing communications, scientific research, broadcasting, navigation, imagery, and support for national defense efforts. The first satellite, Sputnik, was launched by the Soviet Union in 1957 and served to demonstrate that man-made objects can reach and maintain a simple orbit. This small craft with limited instrumentation did little more than measure the density of the upper atmosphere and provide information on how radio waves propagate through the ionosphere. However, its cultural impact was immense, and it spurred a space race with the United States. Since that time, launches have become commonplace, sending into orbit thousands of highly complex machines that affect our daily lives.

In 2011, there were 102 satellites successfully launched on behalf of 22 different countries and international organizations. The number of satellites launched by mission type is detailed in Exhibit 3i. The consulting firm Euroconsult forecasts that more than 1,100 satellites collectively worth $196 billion will be constructed in the next decade. Approximately 70% of them are for civilian and military communications, Earth observation, weather forecasting, and navigation. The majority of these satellites will be launched for the United States, Russia, Europe, Japan, China, and India.[43]

By the end of 2011, there were an estimated 994 active satellites in various types of orbits around the Earth.[44] Of these, 419 satellites (approximately 42% of the total) were in geosynchronous orbit (GEO). Located at an altitude of 35,800 kilometers (22,245 miles) over the Equator, GEO satellites circle the Earth exactly once per day, thus appearing to be fixed above a single region on the Earth's surface. The satellite is therefore constantly aligned with a stationary antenna on the ground and can view up to one-third of the planet's surface from its location. GEO satellites are generally used for communication purposes, from distributing television programming to cable television providers and direct-to-home (DTH) television customers to providing long-distance relay of phone calls from one continent to another. These satellites also support corporate data networks and military communications. Examples of GEO satellite applications are described in Exhibit 3j.

An additional 471 satellites (47% of the total) operate in low Earth orbit (LEO), most of them flying 600–900 kilometers (372–559 miles) above sea level, circling every 96–102 minutes in a pattern that allows them to view all or most of the Earth's surface as they make several passes around the globe. The lower orbit and the extensive coverage makes LEO ideal for remote sensing satellites, which need the close proximity to the surface to take scientific readings or high-resolution images.

The closer proximity to the Earth also greatly reduces signal delay from a LEO satellite to ground stations and allows for smaller receivers on the ground. While minimizing signal delay is not vital for DTH services or corporate networks, it makes the orbit ideal for voice traffic being sent directly to handheld devices. These lower orbits are challenging since the satellites constantly move in and out of view of individual ground receivers. If it is necessary to maintain a continuous link despite the movement of the satellites, a fleet of spacecraft is required to form a constellation.

EXHIBIT 3j. Applications of Geosynchronous Satellite Systems

Application	Description
Video Distribution and Backhaul	Relaying video content to redistribution sites, such as local cable television providers
Direct-to-Home Television	Direct broadcast of television content to households
Internet Backhaul	Connecting internet service providers to network backbone
Carrier Backhaul	Long haul transport of traffic for telephone networks
Wireless Backhaul	Long haul transport of traffic for wireless/cellular networks
Corporate Networks	Private communications networks for enterprise
Direct Internet Access	Satellite-delivered consumer broadband internet
Military	Applications specific to defense activities: communications, surveillance, early warning
Maritime/Aviation Services	Direct broadcast to ships and airplanes in transit
Meteorology/Earth Science	Weather forecasting, scientific study of the Earth

Source: Futron

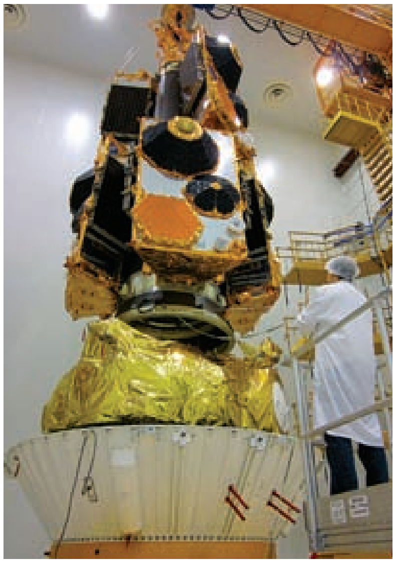
There are 69 satellites (nearly 7% of the total) in medium Earth orbit (MEO), nearly all of them circling at an altitude of 19,000–21,000 kilometers (11,800–13,050 miles). MEO constellations require fewer satellites than their LEO counterparts because their higher altitude gives them line-of-sight access to a larger portion of the Earth. While not ideal for high-throughput applications such as voice or video communications, MEO provides an efficient solution for low-speed data links that still require a global footprint and minimum signal delay. For that reason, the vast majority of satellites in MEO are used to support navigation services, such as the U.S. Global Positioning System (GPS).

Another 35 satellites (nearly 4% of the total) utilize highly elliptical orbits (HEO). The shape of the orbit these satellites use resembles an oval; its highest altitude above the Earth, called the apogee, can be many thousands of miles higher than its lowest altitude, called the perigee. There is no typical HEO orbit, as apogees vary greatly between 4,000 and 470,000 kilometers (2,548 and 292,044 miles). One benefit of these kinds of orbits is their slow speed when travelling near apogee, allowing for hours of dwell time and providing extended views of areas such as the polar regions that are not easily covered by GEO satellites. Another benefit of this orbit is its flexibility. An operator who needs to change the satellite's Earth coverage area can adjust the orbital pattern slightly while the satellite is near its apogee. A similar maneuver on a LEO satellite would use up more fuel and significantly shorten the life of the satellite. These specialized orbits are often used to support military missions such as early warning systems and electronic surveillance, and scientific missions such as astrophysics.

3.3.1 Communications Satellites

Communications satellites have been a crucial part of the global telecommunications infrastructure for decades. They bridge the oceans and connect continents with international telephone calls, bring live video footage of major events to television studios, and connect the major network hubs that extend the reach of the internet. Thanks to international standardization of radio frequencies and encoding technologies, equipment manufacturers and network operators have thrived in providing these services and in developing new ones.

Many commercial operators also lease their capacity to various nations' respective defense agencies for dedicated communications links. The U.S. DoD relies on commercial satellite operators to provide more than 80% of its satellite communications. It is often too difficult for government agencies to quickly provision entire satellites to support their defense agencies' missions around the globe. Commercial operators have assets already in orbit and can quickly allocate capacity over specific regions when unpredictable events occur that require increased communications support for troops in the field. While military reliance on commercial satellite communications is strong, the military consumes only 5% of overall commercial satellite communications supply.[45] In addition to communications services, defense agencies are collaborating with commercial operators to incorporate military-specific communications payloads and other instrumentation on commercial spacecraft as hosted payloads.



A dispenser with six Globalstar satellites is attached to the upper stage of a Soyuz launch vehicle inside the pre-launch facility at the Baikonur Cosmosdrome in Kazakhstan. *Credit: Arianespace*

3.3.1.1 Communications Satellite Characteristics

Communications satellites broadcast signals in specific frequency bands optimized for applications such as mobile communications, fixed broadcast, or high-throughput two-way communications. Predominant communications satellite uses by frequency are listed in Exhibit 3k.

Satellites come in various sizes and perform different missions. Among commercial communications satellites, the number of transponders varies from satellite to satellite, as do the frequency bands and power levels at which those transponders operate. The capacity of each satellite can be measured using a metric called 36 megahertz (MHz) transponder equivalents (TEs), which converts the actual number of transponders on a spacecraft to the equivalent number using an industry-standard bandwidth of 36 MHz. Using TEs allows for a better comparison of the capabilities of individual communications satellites as well as the overall capacity of spacecraft in a given frequency band.

EXHIBIT 3k. Commonly Used Satellite Communications Frequency Bands

Frequency Name	Frequency Range*	Predominant Uses
L-Band	1-2 GHz	Mobile
S-Band	2-4 GHz	Mobile
C-Band	4-8 GHz	Low-throughput Fixed
X-Band	8-12 GHz	Government, Medium-throughput Fixed
Ku-Band	10-18 GHz	Medium-throughput Fixed
Ka-Band	27-40 GHz	High-throughput Fixed

**Specific sub-ranges within these general bandwidth ranges are assigned for satellite uplink and downlink transmissions*
Source: Institute of Electrical and Electronics Engineers (IEEE) Std 521-2002

3.3.1.2 Fixed Satellite Services

GEO satellites provide a wide fixed coverage area, making them ideal for sending one signal to a large number of stationary antennas. There were 294 fixed satellite services (FSS) satellites in orbit during 2011, providing DTH video, satellite radio, broadband internet, broadcast video distribution, and corporate network connectivity. The dominant providers of international FSS are Intelsat (50 satellites), SES (45), Eutelsat (27), and Telesat (13). These four companies collectively own nearly half of all GEO commercial communications satellites (135, or 46% of the total), and represented 49% of the total FSS market revenues in 2010, the latest year for which figures are available.[46] They continue to expand their fleets and collectively plan to launch at least 25 additional satellites by 2014.[47] The remainder of the market is shared by dozens of smaller operators with small fleets focused on specific services, regions, or individual countries.

The number of FSS satellites has increased tremendously over the past five years. A huge driver of demand for capacity is the international growth of high-definition (HD) television. HD signals require approximately twice as much bandwidth as their standard-definition (SD) counterparts and are re-transmitted multiple times on different satellites, further increasing the need for capacity. These channels are also distributed directly to consumers via DTH systems around the globe.

In 2010 and 2011, several highly specialized satellites that utilize a relatively underused frequency range, called the Ka-band, were placed into orbit to support space-based internet broadband delivered directly to homes or small businesses. These FSS operators are looking to tap a market of consumers who are underserved by

EXHIBIT 3l. GEO Commercial Communications Satellite Capacity Launched, 2008–2011

Frequency Band	Capacity measured in 36-MHz transponder equivalents (TEs)			
	2008	2009	2010	2011
C-Band	178	261	102	291
Ku-Band	476	565	443	532
Ka-Band	77	24	259	115
S/L-Band	6	9	15	0
UHF, X, EHF-Band	17	0	0	0
Total	754	859	819	938
Satellites Launched	25	22	19	23

Note: Excludes satellites that failed to reach orbit. Commercial satellites are defined for this chart as systems whose capacity is available on the open market.
Source: Futron

terrestrial broadband, highlighting satellites' inherent advantages in reaching rural communities, underdeveloped countries, or any location where terrestrial options are limited, nonexistent, or expensive. Various governments have also supported the deployment of these platforms through mandated broadband initiatives meant to bridge the digital divide between major cities and less affluent rural areas.

EXHIBIT 3m. Top 25 Fixed Satellite Services Operators by Revenue, 2010

Rank	Company	Country of Origin	2010 Revenue ($ in millions)	FSS Satellites in Orbit, December 2011
1	Intelsat	Luxembourg	2,540	50
2	SES	Luxembourg	2,300	45
3	Eutelsat	France	1,480	27
4	Telesat	Canada	821	13
5	Sky Perfect JSAT	Japan	391	12
6	Star One	Brazil	319	5
7	SingTel Optus	Singapore/Australia	287	4
8	Hispasat	Spain	240	5
9	Russian Satellite Communications Company	Russia	227	10
10	Arabsat	Saudi Arabia	202	6
11	AsiaSat	Hong Kong	187	4
12	Telenor Satellite Broadcasting	Norway	174	3
13	China Satcom	China	155	6
14	Indian Space Research Organisation	India	150	10
15	Nilesat	Egypt	130	3
16	Thaicom	Thailand	128	3
17	Satmex	Mexico	106	3
18	APT Satellite Holdings	Hong Kong	92	2
19	MEASAT Satellite Systems	Malaysia	91	3
20	AMOS-Spacecom	Israel	77	3
21	Gazprom Space Systems	Russia	72	2
22	Intersputnik	Russia	72	0*
23	EchoStar	United States	64	6
24	TELKOM	Indonesia	41	2
25	Indosat	Indonesia	15	2

**Intersputnik is a reseller of capacity aboard satellites owned by other entities.*
Sources: Space News, Union of Concerned Scientists

Broadband via satellite was pioneered in the United States in 1996 by Hughes Network Systems with the HughesNet product. Hughes has operated HughesNet on several traditional Ku-band satellites and on the Spaceway-3 satellite, which was launched in 2007. Hughes' next satellite, Jupiter, is scheduled to launch in 2012 and should provide customers with throughput ranging from 1–5 megabits per second (Mbps). This capability, while faster than traditional satellite internet offerings, still falls short of the average broadband throughput of 12 Mbps provided by U.S. terrestrial services. Hughes was purchased by FSS operator EchoStar in 2011 at a price that represents a 31% premium over the Hughes stock price, indicating the increasing value of satellite-based broadband services to the home or small business.[48]

ViaSat-1 serves more broadband users with faster data rates than any previous satellite. The satellite is a collaborative effort between ViaSat and the top satellite broadband leaders in the market, including Loral, Telesat, and Eutelsat. *Credit: Space Systems/Loral*

3.3.1.3 Mobile Satellite Services

Mobile satellite services (MSS) providers offer satellite-based communications directly to devices such as mobile phones. These satellites provide global coverage for basic voice and data services to places underserved by terrestrial facilities such as isolated rural villages, ships at sea, polar settlements, and other remote sites. MSS satellites can utilize LEO, MEO, or GEO orbits. MSS is particularly vital in the aftermath of natural disasters where terrestrial infrastructure is damaged or overwhelmed with voice and data traffic.

Total MSS revenues in 2010 reached $1.38 billion, an 8.8% increase over the previous year, and are expected to exceed $2.2 billion by 2020.[49] The market is dominated by two players: the United Kingdom's Inmarsat and U.S.-based Iridium. These two firms accounted for 53% and 17% of the market, respectively. Both companies have benefited from contracts with the DoD, which supplements its own military communications satellite networks with commercial capacity. They also are making strides to upgrade their networks with more powerful replacement satellites.

The U.S. Department of Defense employs Distributed Tactical Communications System (DTCS) technology from Iridium to increase military efficacy and provide secure internet service. Unlike most FM radios, the system can support military service members in rough terrain, including the hills of Afghanistan. *Credit: Iridium*

Iridium's LEO constellation of 66 active and 6 spare satellites relay signals to each other directly, unlike other systems that require multiple hops between space and the ground to send signals around the world.[50] In June 2010, the company named France's Thales Alenia Space as prime contractor to construct the communications payload for Iridium's second-generation, 81-satellite constellation Iridium NEXT. The constellation is expected to begin launching in 2015 and be fully deployed by 2017. The upgraded network will be able to support higher data speeds to more types of devices. Orbital Sciences was selected in 2011 to assemble and test the satellites, integrating the Thales payload.[51]

Iridium NEXT will also provide a unique opportunity to host Earth observation payloads for government, military, or scientific organizations. The new network can provide an Earth-facing platform able to host a payload weighing up to 50 kilograms (110 pounds) and an average power requirement of no more than 50 watts. Payloads could be placed on one or many satellites, but due to the time required for design, testing and integration, contracts for hosted payloads must be secured several years before launch. In April 2011, Orbital Sciences committed a $10 million deposit, essentially granting it the right of first refusal for 20% of Iridium NEXT's hosted payload capacity. Several agencies have expressed interest in utilizing Iridium NEXT for hosted payloads, including the DoD and ESA.

The original and still-dominant MSS operator, Inmarsat, uses a fleet of 11 GEO satellites to provide mobile services to land, maritime, and aviation customers. Inmarsat's core business has always been voice and low-rate data transmissions. In 2005, it began rolling out its high-throughput Broadband Global Area Network (BGAN) service, which can provide data at up to 492 kilobits per second, enough to allow users to surf the internet. In 2010, it initiated a program to expand beyond its established mobile and maritime customer base and into the FSS broadband market via a next-generation Ka-band constellation. Inmarsat contracted with Boeing in August 2010 for construction of three Inmarsat-5 Ka-band satellites, as part of a $1.2 billion worldwide, wireless broadband network called Inmarsat Global Xpress, to be deployed between 2013 and 2014. Each Inmarsat-5 will carry a payload of 89 small Ka-band beams that will offer global Ka-band coverage, facilitating service to ships at sea and transoceanic airlines. In addition to its construction role, Boeing will act as a partner in the leasing of capacity to government customers. Inmarsat also helped develop the Alphasat MSS satellite, an ESA-sponsored satellite being built by Astrium for launch in 2012. Alphasat is intended to serve Europe and the Middle East using a frequency range known as the extended L-band.[52]

Alphasat I-XL uses a new deployable dish antenna technology. The Alphasat I-XL dish will be 12 meters (39.4 feet) in diameter and will augment Inmarsat's mobile data and voice services, increasing capacity across Europe, Asia, Africa, and the Middle East. *Credit: Astrium*

To compete with these dominant players, the remaining MSS operators are pursuing new market approaches. One such approach is the enhancement of satellite networks with a terrestrial component that expands system coverage and increases quality of service. In the United States, several of these companies are implementing programs under licenses from the U.S. Federal Communications Commission (FCC) for an ancillary terrestrial component (ATC), a ground-based augmentation system added to their space-based systems. Several ATC licensees faced technical, market, and financial difficulties in 2011.

New operator LightSquared, formerly known as SkyTerra, has been in the process of deploying a satellite and terrestrial network to provide wholesale capacity to mobile telecommunications companies such as Sprint Nextel. The capacity would support a next-generation wireless broadband technology known as 4G-LTE (for Long Term Evolution), integrating satellite coverage with ground-based repeater stations. LightSquared had sought to reach at least 100 million users in the United States by the end of 2012.[53] In November 2010, LightSquared launched SkyTerra-1, which covers North America and the Caribbean in the L-band spectrum. Plans for a follow-on SkyTerra-2 satellite were put on hold indefinitely as the company focused on deploying the terrestrial portion of the network.

EXHIBIT 3n. Mobile Satellite Services Operators, 2011

Operator	Orbit	Coverage	Number of Operational Satellites	Current System	Planned Development
Iridium	LEO	Global	66	Inter-satellite links providing full global coverage from pole to pole	Thales Alenia Space to build 81 satellites (including spares) for the Iridium NEXT system, expected to be fully deployed by 2017
Globalstar	LEO	Near-global	24	Voice service limited due to first-generation satellite anomalies, new satellites refreshing capability	12 satellites deployed in 2011, full second-generation constellation will consist of 24–32 satellites
ORBCOMM	LEO	Near-global	27	Provides global data services similar to two-way paging or email, targeting data applications and machine-to-machine communications	18 ORBCOMM Generation 2 satellites, constructed by Sierra Nevada, scheduled for launch 2012–2014
Inmarsat	GEO	Near-global	11	Provides voice and broadband data, including video	Announced contract with Boeing for three Inmarsat-5 Ka-band satellites planned for launch between 2013 and 2014
LightSquared	GEO	North America, Northern portion of South America	1	Provides low-rate data and voice with push-to-talk	Use its current satellite for a hybrid satellite-terrestrial network
Thuraya	GEO	Asia-Pacific	2	Provides voice and broadband data with services tailored to region	No new satellite plans announced
TerreStar & DBSD North America	GEO	North America	2	Provides voice, data, and video	Companies purchased by DISH Network in 2011, plans to use satellites as part of a hybrid satellite-terrestrial network

Source: Futron

LightSquared faces resistance from those concerned that its system could interfere with signals from the U.S. Global Positioning System (GPS), which provides worldwide positioning, navigation, and timing services. LightSquared planned to deploy 40,000 terrestrial base stations that would emit the same L-band radio frequencies that are used by its satellite. GPS signals use an adjacent section of L-band frequencies, and tests of GPS receivers showed that LightSquared's terrestrial base stations can overpower the comparatively weak GPS signal from space.[54] In February 2012, the FCC, citing a report by the National Telecommunications and Information Administration that concluded there was no practical way to mitigate the interference, announced it would move to suspend indefinitely LightSquared's ATC license.[55]

MSS operator Globalstar is in transition from its original 24-satellite LEO network to a 32-satellite second-generation LEO network. It successfully deployed six replacement satellites in 2010 and 12 satellites in 2011, with another six expected to launch in early 2012. These satellites are particularly important for the company, since problems with the first generation spacecraft have severely degraded its two-way voice and data services, leaving customers with only one-way communication. Globalstar had partnered with a U.S. broadband wireless internet access provider, Open Range Communications, to operate ATC facilities in the L-band. However, in September 2010, the FCC suspended Globalstar's ATC license due to the company's inability to meet certain FCC-mandated milestones. The license had authorized the operator to use ATC to supplement a satellite system providing service to the United States, Puerto Rico, and the U.S. Virgin Islands. Globalstar's degraded LEO constellation was not considered compliant, and the replacement satellites were not to be launched in time to meet the FCC deadline. Since Open Range Communications was no longer able to lease these frequencies from Globalstar, it was forced to shut down operations in 2011, leaving Globalstar with new satellites but without an ATC partner.[56]

Consolidation affected the smaller players in the MSS industry in 2011. DTH video provider DISH Network acquired two MSS companies out of bankruptcy, TerreStar and DBSD North America. Each operator owned an S-band satellite in GEO, and each had plans to launch a second satellite. Upon acquisition, DISH petitioned the FCC for permission to combine the S-band ATC spectrum held by TerreStar with that of DBSD and to remove any requirement to build and launch the additional satellites the bankrupt companies were developing.[57]

In May 2009, the European Commission selected two operators, Inmarsat and Solaris Mobile, a joint venture between SES and Eutelsat, to provide MSS services to all European Union member states. However, both companies are facing technical and financial difficulties. Inmarsat's Europasat was to be built by Thales Alenia Space and launched by 2011, but construction was suspended in late 2009. Inmarsat instead plans to seek external investors to fund the project, and ultimately to spin it off as a separate company.[58] Plans by Solaris Mobile to offer mobile TV and radio services via S-band were disrupted following faulty performance of the particular antenna aboard the Eutelsat W2A satellite that was intended to deliver the company's services.[59] This anomaly has resulted in lower-than-expected signal strength to customers on the ground. SES and Eutelsat are searching for new investors and commercial partners that will help Solaris Mobile acquire more capacity on a new satellite.

3.3.2 Positioning, Navigation, and Timing Satellites

Since the late 1980s, satellites have been used to provide accurate positioning, navigation, and timing (PNT) capabilities to those equipped with appropriate receiving equipment. Receivers determine their location by receiving one-way signals from at least three PNT satellites. Today, receivers are incorporated into everything from spacecraft to dog collars. Virtually all of these devices have been supported by the U.S. GPS system, which has been fully operational since 1995.

The core structure of the GPS III Non-Flight Satellite Testbed (GNST) stands in Lockheed Martin's GPS III Processing Facility. The GNST is a prototype that allows engineers to identify and solve issues prior to manufacturing the first space vehicle, reducing the overall cost of satellite production.
Credit: Lockheed Martin

Although many generically use the term "GPS" to refer to the overall concept of satellite-based navigation, this acronym only refers to one specific network. The U.S. Navigation Signal Timing and Ranging Global Positioning System (NAVSTAR-GPS or GPS) was developed and deployed by the U.S. Air Force and was the first fully operational global satellite-based navigation network. The GPS constellation nominally requires 24 operating satellites but in practice maintains more satellites in orbit.[60] Currently, the network has 31 satellites, with nearly half of them having already exceeded their design lives.

The system is being upgraded with an interim block of satellites called GPS IIF. Since 2010, two of these Boeing-built satellites have been launched, with 10 more spacecraft scheduled for launch starting in 2012. An even more robust upgrade will start as early as 2014. Called GPS III, the new deployments will provide for additional civil signals, greater accuracy, and more power for military users through use of spot beams. This added capability potentially could provide sub-meter accuracy of the civilian GPS signal without the need for augmentation systems. The new satellites will also have a 15-year design life as opposed to the current fleet's 7- to 12-year design life.[61] The U.S. Congressional Budget Office estimates that the United States will spend roughly $22 billion from 2012 to 2025 to modernize GPS.[62] American spending on the GPS system is indicative of the great expenditures required to develop and maintain a global PNT system.

The GPS network is about to be joined by systems in various stages of development belonging to several other nations. These additional navigation systems, providing global or regional coverage, are meant to complement or compete with the U.S. network. Various augmentation systems are being designed to improve the quality of service by transmitting additional signals designed to increase accuracy, integrity, robustness, and signal availability for

EXHIBIT 3o. Positioning, Navigation, and Timing Systems, December 2011

	China	Europe	India	Japan	Russia	United States
Positioning, Navigation, and Timing Systems						
System Name	Beidou/ Compass	Galileo	Indian Regional Navigation Satellite System (IRNSS)	Quasi-Zenith Satellite System (QZSS)	Global Navigation Satellite System (GLONASS)	Global Positioning System (GPS)
Minimum Constellation	35	27 (plus 3 in-orbit spares)	7	3	21 (plus 3 in-orbit spares)	24
Current Constellation	10	2	0	1	24	31
Operational Date	2011	2015	2015	2013	2011	1995
Coverage	China in 2011, global coverage by 2020	Initial capability by 2015, full global system by 2020	South Asia	Japan	Global	Global
Augmentation Systems						
System Name		European Geostationary Navigation Overlay Service (EGNOS)	GPS-Aided Geo Augmented Navigation (GAGAN)	MTSAT (Multi-functional Transport Satellite) Satellite-based Augmentation System (MSAS)	System of Differential Correction and Monitoring (SDCM)	Wide Area Augmentation System (WAAS)
Minimum Constellation		3	3	2	3	3
Current Constellation		3	1	2	1	3
Operational Date		2009	2013	2007	2013	2003
Coverage		Europe	South Asia	Asia/Oceania	Near-Global	North America

Source: Futron

critical applications such as air traffic control. As of late 2011, there were 68 dedicated PNT satellites in either MEO or GEO supporting six operational systems owned by various countries and international organizations.

The United States enhances the GPS system with the Wide Area Augmentation System (WAAS), which uses dozens of ground stations as well as capacity on commercial FSS satellites to increase the accuracy, integrity, and availability of GPS positioning data.[63] These enhancements allow GPS to be used in systems that require high accuracy and integrity, such as air traffic control. Other nations are developing alternatives to GPS in attempts to stimulate innovation of new technologies and to provide new business opportunities for equipment manufacturers.

A launch in October 2011 raised the number of operational satellites in Russia's GLONASS system to 24, enabling full global coverage for the first time since the 1990s. GLONASS was designed to serve both military and civilian populations. The original Soviet system began deployment with the 1982 launch of its first satellite. However, due in part to Russia's economic difficulties in the 1990s, the network fell into disrepair. In 2001, President Vladimir Putin ordered a 10-year, $3 billion modernization program.[64] The GLONASS system design requires 21 active satellites for global coverage, with three in-orbit spares. GLONASS satellites operate in MEO but their orbits are oriented at a higher angle, or inclination, to the Equator than that of their GPS counterparts. This orbital path allows them to cover higher latitudes, more easily reaching devices throughout Russia. Two major phone manufacturers announced plans to produce smartphones that work with both GPS and GLONASS systems—Apple's iPhone 4S and the MTS 945, an Android-based phone manufactured by the Chinese company ZTE and sold through Russia's largest telecommunications provider, Mobile TeleSystems (MTS).[65]

The European Union (EU) is developing a PNT system called Galileo. The Galileo constellation will consist of 27 operational satellites and three in-orbit spares. In October 2011, the first two Galileo in-orbit validation (IOV) satellites were launched, and two more IOV spacecraft were scheduled to launch by mid-2012. The initial Galileo constellation is expected to be in place between 2014 and 2016. However, financing may be a concern. The EU has already approved contracts for 14 additional satellites with OHB of Germany, but the number of additional satellites that can be ordered depends in part on the European Commission's calculation of exactly how much money remains in the seven-year budget, with the next budget commencing in 2014. That budget will determine whether the Galileo constellation will be able to have a full suite of 30 satellites by 2020.[66]

Twin Galileo satellites are attached to their support structure for launch atop the first Soyuz from French Guiana. The two satellites are part of the In-Orbit Validation phase that will test the Galileo system's space, ground, and user segments. *Credit: ESA/S. Corvaja*

Europe also has a space-based GPS augmentation system called the European Geostationary Navigation Overlay Service (EGNOS). The network works in a similar fashion to the U.S. WAAS system. It utilizes transponders aboard three geostationary satellites with European coverage. The satellites connect to a network of 40 ground stations that incorporate signals from the GPS satellites, combining the data and allowing for higher accuracy. EGNOS officially became operational in October 2009.[67] In March 2011, the EGNOS Safety of Life signal was formally declared available to aviation. This new signal increases navigation sensitivity to a level that allows for precision horizontal navigation and enables the high level of sensitivity and reliability required to vertically guide aircraft during landing approaches.[68]

Since 2000, China has also been building its own national PNT system, known as Beidou (the Mandarin name for the constellation otherwise known as the Big Dipper). China launched three satellites in 2011 to join the seven currently in orbit. These satellites will later become part of a global constellation, Compass, which is planned to consist of 30 MEO satellites for global coverage and five GEO satellites that will focus on regional coverage over China. Beidou began operating in December 2011, providing initial PNT services to a swath of the Asia-Pacific region from Australia in the south to Russia in the north with an accuracy of 25 meters (82 feet). The Chinese are planning to launch six Beidou satellites in 2012. The full Compass constellation is expected to become operational by 2020.[69]

Japan is also creating a national PNT system called the Quasi-Zenith Satellite System (QZSS), consisting of three GEO satellites. In September 2010, the first of these, the spacecraft Michibiki (Japanese for "guiding" or "showing the way"), was launched. While these satellites are GEO, they are not fixed over the Equator like typical FSS satellites. The three satellites will regularly move north and south in relation to the Equator, making them easier to be seen from urban and mountainous regions where the terrain often obstructs the line of sight to traditional GEO satellites. Japan also has a GPS augmentation system that is based on two GEO Multi-functional Transport Satellites launched in 2005 and 2006.

The Indian Regional Navigation Satellite System (IRNSS) will include seven satellites providing coverage primarily for South Asia. Like the Japanese system, four of the seven will be in non-Equatorial GEO, while three will be in traditional GEO. India also has a GPS augmentation system called GPS-Aided Geo Augmented Navigation (GAGAN, which is Hindi for "sky"), designed to improve air navigation in India. A payload for GAGAN was added to the communications satellite GSAT-8 that was launched in May 2011. Two more GAGAN-enabled satellites will be launched in the coming years.[70]

3.3.3 Remote Sensing and Environmental Monitoring

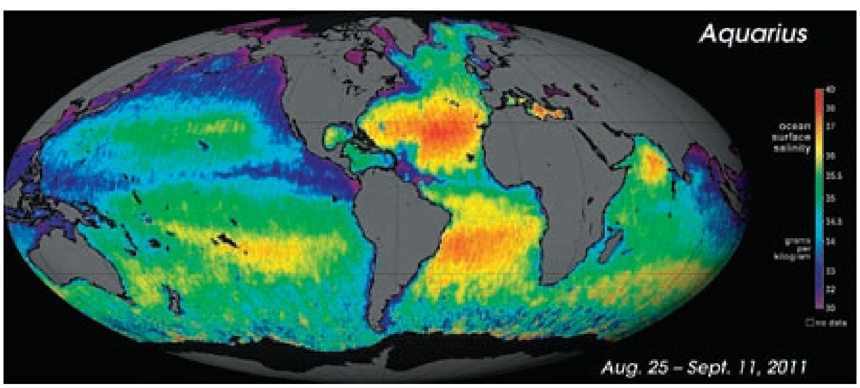
Satellites not only relay signals from location to location, they also carry advanced payloads that observe, measure, and produce data based on what they are able to view from their vantage point. They provide detailed images of the Earth and collect a wide variety of measurements from space, such as ocean temperature, vegetation coverage, or pollution levels. These remote sensing satellites have civil, scientific, and military applications, from providing aerial views on Google Earth to forecasting potential hurricane paths and tracking enemy movements on the battlefield. In 2011, 11 remote sensing or meteorological satellites were launched on behalf of 10 different countries.

Two major players in satellite-based Earth imagery are U.S. companies DigitalGlobe and GeoEye. Both companies provide imagery to widely used applications such as Google Earth. In August 2010, the U.S. National Geospatial-Intelligence Agency (NGA) awarded 10-year contracts to the companies, valued at $3.8 billion for GeoEye and $3.55 billion for DigitalGlobe, under the agency's EnhancedView procurement. The NGA specializes in mapping and imagery intelligence, and played a key role in the raid on Osama bin Laden's compound in May 2011 by providing satellite imagery, geospatial and targeting analysis, and modeling support to plan the successful mission.[71] The new contracts make it possible for both companies to finish the procurement and launch of new and advanced satellites. In 2013, GeoEye plans to launch GeoEye-2, which will be capable of discerning objects on the Earth's surface as small as 25 centimeters (10 inches) in size. DigitalGlobe will launch WorldView-3 in 2014, which will have a 31-centimeter (12-inch) resolution.

This DigitalGlobe satellite image shows Osama bin Laden's compound in Abbottabad, Pakistan, one day before a raid by U.S. Navy SEALs. *Credit: DigitalGlobe*

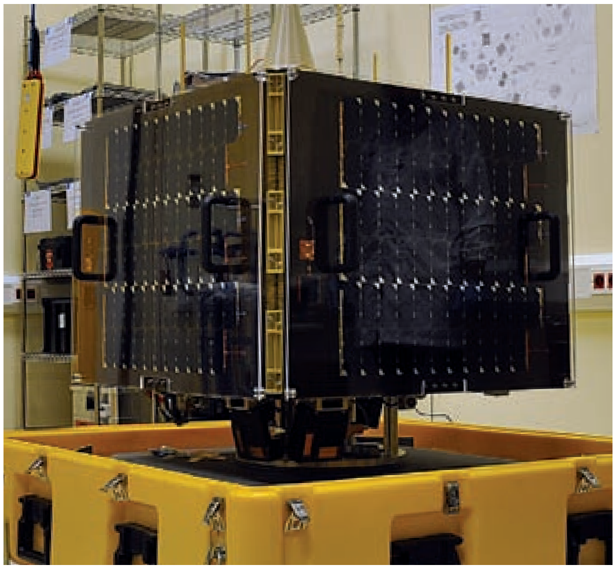
RapidEye Canada owns and operates five small LEO satellites that were launched in 2008 and are expected to remain operational until 2018. These spacecraft provide geospatial imagery with five-meter (16.4-foot) resolution. Formerly a German company, RapidEye did not have the benefit of long-term government contracts and, after disappointing sales in 2009 and 2010, filed for bankruptcy protection in June 2011. The Canadian company Iunctus, a distributor of satellite imagery products, purchased the German-owned operator out of bankruptcy in August 2011 and renamed it RapidEye Canada.[72]

Funding is a serious concern for government-supported remote sensing satellite endeavors. Europe's Global Monitoring for Environment and Security (GMES) program is facing difficulties because of the global economic climate, which is forcing many space programs around the world to cut costs. In November 2011, the European Commission (EC) proposed moving funding for operating the GMES space segment from the 27-member commission to the individual EU member states. The GMES space segment is to consist of five Sentinel satellites that will focus on ocean imaging and temperature measurements, land imaging, emergency services, and atmospheric monitoring.[73] It was to begin launching in 2013. A final decision to shift funding from the EC to individual EU member nations starting in 2014 may have unforeseen consequences for GMES.[74]



In 2011, NASA's Aquarius instrument on the SAC-D satellite produced its first global map of the salinity of the Earth's ocean surface. Red represents areas of high salinity, while purple indicates low levels. Ocean surface salinity affects the cycling of fresh water and influences ocean circulation, a key component of the Earth's climate. *Credit: NASA*

In June 2011, SAC-D, the first joint scientific satellite mission between NASA and the space agency of Argentina, the Comision Nacional De Actividades Espaciales (CONAE), was launched by a Delta II rocket from Vandenberg Air Force Base, California. SAC-D carries nine instruments from six countries. The primary experiment is NASA's Aquarius, which will study the salinity of the Earth's oceans for three years. This information will help researchers better understand global patterns of precipitation, evaporation, and ocean circulation, which are key drivers of the Earth's climate.[75] Five CONAE experiments are also carried aboard the spacecraft, including a microwave radiometer to measure wind, precipitation, and sea ice conditions; the New Infrared Scanner Technology experiment, which will measure temperatures on the surface of the Earth; and a High Sensitivity Camera, which will be used to image aurorae, fires, and city lights. Other instruments will be operated by Italian and French agencies. The Indian space agency, ISRO, launched Megha-Tropiques from the Satish Dhawan Space Centre in October 2011.



Turkey's RASAT is a remote sensing satellite that allows the country to create maps for rural and urban land use and to monitor disasters and environmental changes. Weighing in at just 93 kilograms (205 pounds), it shows that even small satellites can provide significant benefits. *Credit: TÜBİTAK*

Megha-Tropiques is a joint satellite program with the French space agency CNES to conduct research on the contribution of the tropical water cycle to the atmospheric dynamics of the Earth's climate. The mission is expected to last at least three years.[76]

An August launch from Russia carried the payloads of five countries, including several remote sensing missions. Ukraine's Sich-2 satellite is a spacecraft designed to obtain medium-resolution images of Earth. NigeriaSat2 will provide 2.5-meter (8-foot) resolution imagery to monitor Nigerian crops to ensure the security of the nation's food supply. RASAT is the first Earth observation satellite designed and built in Turkey. The 93-kilogram (205-pound) RASAT payload features a camera capable of a peak resolution of about 7.5 meters (25 feet).[77]

3.3.4 Military Satellites

The national defense needs of many countries help to drive demand for satellite capacity. Armed forces and international peacekeeping organizations from across the globe lease capacity from various commercial satellite operators or acquire Earth imagery services from commercial companies. Military forces are also building more of their own dedicated satellites due to increased capacity demands and the need for secure connectivity for deployed troops.

Many military satellites provide similar remote sensing or communications capabilities as their non-military counterparts, but they are operated by national intelligence services or branches of the military and are primarily used by those personnel. Their capabilities are often tailored specifically to the missions they support, and many have features that are not offered on commercial products such as anti-jamming or radiation-hardened features.

Defense-operated satellite systems include the U.S. Defense Meteorological Satellite Program (DMSP), a network of meteorological LEO satellites which monitor weather, oceans, and solar-terrestrial physics environments. The network's data is shared directly with DoD operational centers worldwide.[78] The German Federal Armed Forces operate a five-satellite LEO fleet called SAR-Lupe, which provides radar imagery with one-meter (3-foot) resolution for surveillance purposes.[79] The Russian Ministry of Defense operates a LEO fleet called Parus, currently consisting of 10 active satellites, which provides navigation services specifically for the Russian military. However, the network is expected to be retired since the GLONASS system is fully operational.[80]

In late 2011, there were approximately 173 active military spacecraft, not including PNT satellites. More than half (92) of these satellites belong to the United States. There were 24 military payloads launched in 2011 on behalf of the United States, Japan, China, France, Chile, and Russia. Five of these satellites were for the U.S. National Reconnaissance Office (NRO), which is responsible for designing, building, and launching U.S. reconnaissance satellites. The NRO currently has 37 operational satellites in LEO, GEO, and HEO, and their specific missions, while classified, are presumed to be for communications, surveillance, and reconnaissance.[81]

In March 2011, the U.S. Air Force launched the second test flight of the top secret X-37B space plane. Originally scheduled to land after 270 days, the mission was extended and the spacecraft was still in orbit at the end of 2011. The 2010 maiden flight of the X-37B lasted for 220 days. The military has not divulged specifics about the space plane's cargo or mission, but it is speculated that it carries advanced Air Force experiments, sensors, and other research payloads. Some space technology experts believe the X-37B is a reconnaissance tool, given its ability to land, change payloads, and alter its orbit more rapidly than a LEO satellite.[82]

The ability to rapidly deploy or replace space-based assets has drawn growing interest from military planners. In June 2011, the U.S. Operationally Responsive Space (ORS) office launched its first non-developmental, operationally focused satellite, ORS-1. According to the Joint ORS Office, the purpose of ORS is to address emerging, persistent, or unanticipated needs via timely augmentation, reconstitution, and exploitation of space forces, space control, and space support capabilities. These goals require the quick development and execution of new technologies, as opposed to the slower traditional government and commercial satellite procurement processes. ORS favors smaller, modular "plug-and-play" satellites that can be quickly constructed and launched. The ORS-1 satellite incorporates such characteristics and was developed and launched in less than three years from program approval. ORS-1 provides forces in Afghanistan and the Middle East with field reconnaissance, relaying images from the satellite directly to troops, as opposed to routing them through U.S.-based intelligence analysts and ground controllers.[83]

The need to launch satellites quickly and cheaply has also led the U.S. Defense Advanced Research Projects Agency (DARPA) to investigate unique, lower-cost launch options for small military satellites. In November 2011, DARPA released a broad area announcement, seeking proposals detailing the possibility of launching a 45-kilogram (100-pound) payload from an aircraft as a low-cost alternative to expensive vertical rocket launches. The program is called Airborne Launch Assist Space Access and calls for a range of modified carrier aircraft and custom-built rockets with the goal of making less-expensive launches a routine occurrence.[84]

In 2010, the United States launched the first Space Based Space Surveillance satellite (SBSS-1) for its Space Surveillance Network. From its LEO orbit, SBSS-1 supplements ground-based equipment that tracks more than 20,000 objects 10 centimeters (4 inches) or larger orbiting Earth. Its vantage point in space means that its observations of other objects in space are not affected by weather, lighting, or distortion that can be caused by the Earth's atmosphere. This enables more accurate and timely information regarding objects' orbital paths, thus allowing for earlier warnings of potential spacecraft collisions.

An artist's rendering of DARPA's Airborne Launch Assist Space Access concept. Similar to Orbital Sciences' Pegasus system, the rocket is attached to the belly of an airplane and released at a specified height. *Credit: DARPA*

In nearly all cases, information about national security satellites is much harder to obtain than information about their scientific or commercial counterparts, and this difficulty can become more pronounced when exploring other nations' use of satellites for security purposes. China's utilization of space for military purposes is harder to gauge than its civilian program due to the country's overall lack of transparency. In 2011, China launched the Chinasat 1A communications satellite into GEO. The Xinhua news agency reported that its purpose was for "high-quality voice communication, broadcast, and data transmission services for users across China."[85] However, western space industry analysts believe Chinasat 1A will actually serve the Chinese military. Russia launched two military satellites in 2011, including a LEO communications satellite called Meridian-4, the fourth in a series of spacecraft that are intended to replace the decades-old Molniya satellite system.[86] In some cases, a satellite will serve multiple missions, including military ones. Japan launched two military satellites in 2011, including IGS Optical 4, a classified imagery satellite that carries an optical camera and telescope for intelligence and defense purposes, as well as for civilian remote sensing applications.[87]

3.4 Ground Stations

Ground stations serve as the links between Earth and space, tying together terrestrial and space infrastructure. They track satellites and spacecraft, as well as communicate with and control satellites, probes, crewed space vessels, and space stations.

3.4.1 Earth Remote Sensing Ground Stations and Data Processing Centers

Earth observation satellites produce the largest amounts of data to be transmitted to Earth on a regular basis and thus require dedicated data processing ground stations. While all satellites require ground stations to keep track of them and relay commands, Earth observation satellites are specifically intended to gather large amounts of data through a variety of sensors and then transmit that data back down for interpretation and storage. Specialized facilities stitch together and interpret the data collected by these satellites, enabling people to make use of the imagery and data in a wide range of consumer and scientific applications.

One such receiving station, the Earth Resources Observation and Science (EROS) Center in Sioux Falls, South Dakota, is operated by the U.S. Geological Survey. The center collects and interprets geological information collected by Earth observation satellites. EROS also archives and distributes images of the Earth's surface captured from aircraft and Earth observation satellites, such as the Landsat series.[88]

3.4.2 Space Situational Awareness Stations

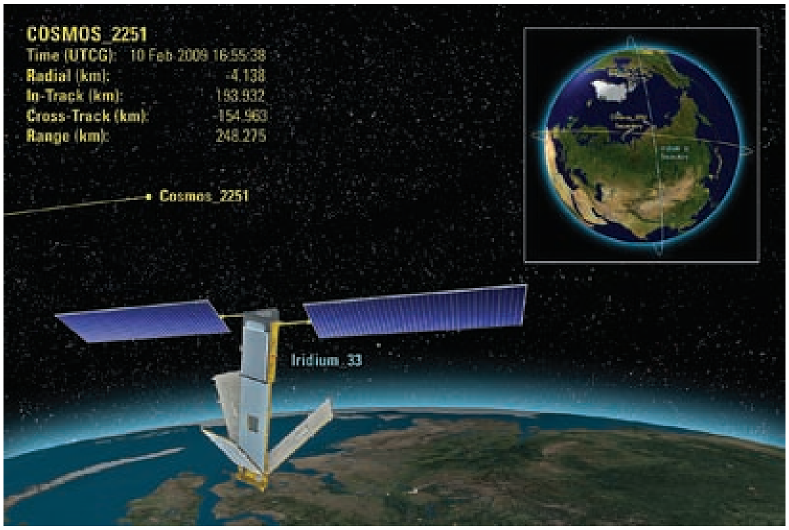
As Earth's orbit becomes increasingly crowded with satellites and debris, preventing further collisions is essential. Space Situational Awareness (SSA) stations are designed to locate and track objects in Earth's orbit and predict potential collisions. Even very small objects moving at orbital velocity possess incredible amounts of kinetic energy that can damage or destroy other objects in a collision. Debris from a collision, still travelling at orbital velocities, can create the potential for even more collisions in the future. For example, in February 2009, a collision between the Iridium 33 and Cosmos 2251 satellites created hundreds of objects which must now be tracked until they fall back to Earth's atmosphere.

The United States currently operates the most capable SSA system, the Space Surveillance Network (SSN). The SSN is composed of stations based around the globe that use a combination of radar and optical information to track objects in orbit. The system has impressive abilities; it is able to detect objects the size of a basketball at an altitude of 36,000 kilometers (23,000 miles), and smaller objects closer to Earth.[89]

A series of SSN upgrades are underway. In 2011, a DARPA-funded space surveillance telescope underwent testing. After nine years of development, the new telescope, located at White Sands Missile Range, New Mexico, is capable of capturing wide-field views of objects in GEO orbit. While the SSN uses radar signals to track objects in LEO, distant objects in GEO orbits are tracked by optical systems such as the DARPA telescope at White Sands and other telescopes in Hawaii; Socorro, New Mexico; and the island of Diego Garcia in the Indian Ocean.[90]

The United States partnered with Australia in late 2010 to cooperate on space situational awareness by placing U.S. radars in Australia to track satellites and debris in LEO. The agreement helps

China's *Yuanwang 2* tracking ship docks in New Zealand's Waitemata Harbor. Unlike nations that have access to a globe-spanning network of ground stations, China uses three Yuanwang-class tracking ships to monitor rocket launches and maintain contact with spacecraft. *Credit: Abri le Roux* clear the way for the United States to install a $3.5 billion upgrade to its Space Fence, extending its reach around the planet. The existing Space Fence tracks objects in orbit by means of three radar transmission sites and six receiver sites located within the continental United States. In addition to the Australian site, the United States may deploy radar facilities on the Kwajalein Atoll in the Pacific Ocean and Ascension Island in the Atlantic Ocean. The upgraded Space Fence is still in design, with the USAF awarding two 18-month contracts in 2011 for second-phase design studies.[91]



This AGI simulation shows the 2009 collision between the Iridium 33 and Kosmos-2251 satellites that resulted in more than 1,000 pieces of debris larger than 10 centimeters (4 inches). *Credit: AGI*

ESA also maintains a space situational awareness program with increasing support from its member nations.[92] Numerous close encounters between orbital debris and Germany's five SAR-Lupe radar reconnaissance satellites and an urgent warning by the U.S. Space Surveillance Network for France's Helios optical reconnaissance satellite in 2009 revealed a vulnerability and provided further reason for Europe to establish its own space situational awareness capacity.[93]

3.5 Spaceports

Spaceports are specialized facilities built to support the integration and launch of space vehicles. The most visible parts of any spaceport are its launch pads, but spaceports contain far more infrastructure. They require fuel storage and distribution systems to service launch vehicles, tracking and communication equipment to stay in touch with rockets, and rocket assembly and integration facilities to prepare rockets and mate them with their payloads. Spaceports range in size and complexity from the streamlined single launch pad at Alaska's Kodiak launch complex to the vast Baikonur spaceport in Kazakhstan, which has been in operation since the mid-1950s and has served as a testing ground and launch pad for almost every type of rocket ever used by the Soviet Union and, later, Russia. Several spaceports saw significant changes in 2011, as established facilities dealt with the end of programs by finding new uses for their existing infrastructure.

The Kennedy Space Center (KSC), Florida, is the only spaceport in the United States that currently supports orbital human spaceflight, and it has been dramatically affected by the end of the Space Shuttle Program. As the home of the shuttle, KSC has seen its workforce decrease significantly as the program ended. More than 6,000 workers at KSC lost their jobs over the past two years.[94] However, there have been some developments that bode well for KSC's health. The new SLS is projected to launch from KSC starting in 2017, and much of the infrastructure previously used by the shuttle fleet will be repurposed to support the testing and flight of the SLS.[95] Other infrastructure formerly used by the shuttle program will be repurposed for private spaceflight initiatives. In October 2011, NASA and Boeing announced an agreement to convert Orbiter Processing Facility 3 into the manufacturing and assembly center for Boeing's CST-100 spacecraft. The facility is expected to support approximately 550 jobs.[96] KSC's newly renovated Visitor Center will be home to recently decommissioned *Atlantis*, which will help attract tourists to the center.[97]

U.S. military spaceports added to their successful launch record and continued to expand and upgrade launch infrastructure in 2011. Vandenberg Air Force Base (VAFB), California, is the home of the 30th Space Wing, which conducted seven launches in 2011 deploying 16 satellites into space. In July, launch vehicle operator SpaceX broke ground at Vandenberg's Space Launch Complex 4 East, marking the beginning of construction of a launch facility for the Falcon Heavy. In Florida, Patrick Air Force Base, home of the 45th Space Wing and the Cape Canaveral Air Force Station (CCAFS), conducted seven launches in 2011, deploying eight satellites. Both VAFB and CCAFS conducted what may be their final launches of the Delta II launch vehicle as no other flights have been procured. However, five Delta II vehicles remain in storage and the system has not been officially retired by its operator, United Launch Alliance.[98]

Workers at the Mid-Atlantic Regional Spaceport (MARS) spent 2011 engaged in construction to allow it to support launches of Orbital's Antares rocket. MARS is a commercially-operated spaceport located at the southern end of NASA's Wallops Flight Facility, Virginia. Funding for MARS is provided by the states of Virginia and Maryland along with fees collected from commercial users. It has previously launched the smaller Minotaur rockets, but the completion of spaceport upgrades in early 2012 will enable it to launch the more powerful Antares. MARS will serve as the home base of the Antares rocket and is expected to host commercial communications satellite launches in the future.[99]

A pressure vessel for Boeing's Crew Space Transportation 100 (CST-100) spacecraft is displayed in Orbiter Processing Facility-3 at Kennedy Space Center, where manufacturing of the CST-100 will take place. Boeing chose to locate operations for the capsule here to benefit from close proximity to the launch site, pre-existing aerospace manufacturing facilities, and the experienced space workforce. *Credit: NASA*

Spaceport America, the New Mexico home base of Virgin Galactic and future launch site of SpaceShipTwo, celebrated the official dedication of its main terminal in an October 2011 ceremony, with Virgin Galactic CEO Sir Richard Branson and New Mexico Governor Susana Martinez in attendance. Final interior work on the terminal building, officially named the Virgin Galactic Gateway to Space, will be completed in early 2012. Completion of the terminal building ends Phase One of the spaceport's development. Phase Two, which will feature development of visitors' centers and related facilities, is scheduled to begin later in 2012.[100]

Also in New Mexico, the U.S. firm Pegasus entered into an agreement with White Sands Missile Range in July 2011 to study the possibility of developing and operating an International Commercial Space Launch Facility. The agreement covers research into technical launch processes, range safety, debris mitigation, logistics, fuel handling, on-site servicing facilities infrastructure, and the various regulatory and legal implications.[101]

After several years of delays and false starts, Russia began construction of the Vostochny Cosmodrome in the Russian Far East in January 2011. During the year, workers completed geological surveys of the site and approved overall site plans. Workers' housing and other preliminary facilities were completed and improvements have been made in the road and rail network connecting them with the site. With infrastructure ready to support a labor force, construction of the Cosmodrome's main infrastructure is expected to begin in early 2012. Launch operations are expected to begin in 2018. Roscosmos then plans to gradually reduce its activity at Baikonur and transfer much of its launch activity to Vostochny.[102]

Construction continued at China's new Wenchang launch facility throughout 2011, and the spaceport's planned completion date has remained fixed for 2013. Little new information was released regarding Wenchang in 2011. Wenchang will be China's fourth launch facility when it begins operations. Unlike China's previous three spaceports, which are located far inland in relatively unpopulated areas, Wenchang sits on the eastern coast of the densely populated island of Hainan, off the southern coast of mainland China. One of the reasons for the coastal location was the need to accommodate the five-meter (16-foot) diameter of China's next generation of rockets. Too wide to move between manufacturing plants and launch centers by railroad, as is currently done with present Chinese rockets, the Long March 5 rockets are being built at a new coastal facility and will travel to Wenchang by barge. While Wenchang is being developed specifically for GEO communications satellites, the potential capabilities of this new center and the Long March 5 system may eventually include human spaceflight.[103]

The Satish Dhawan Space Centre, located on the east coast of India, is expanding to provide greater flexibility and permit a higher launch rate while supporting the launch of India's upcoming GSLV Mk. III heavy-lift vehicle. ISRO completed an upgrade to the center in 2005, adding a second launch pad capable of processing and launching any of India's orbital vehicles. The latest expansion will add a third launch pad to the complex, enabling India to launch more often and with fewer scheduling restrictions. Every launch occupies a launch pad for at least 60 days, meaning that launches much be scheduled very tightly to work around each other as people and equipment are shuffled among pads. Scheduled to host its first launch in 2013, the third pad is being built to handle India's next generation of launch vehicles, which will make extensive use of cryogenic propellants such as liquid hydrogen and liquid oxygen. Cryogenic fuels are more efficient than those stored at room temperature but they require more complicated handling systems. ISRO has not specifically said whether the new launch pad is being built to support human spaceflight but it is likely that the infrastructure for such flights will be included in the design.[104]

After several years of low activity, Brazil pledged in late 2011 to more than double its space budget for the years 2012-2015 with the aim of revitalizing the facilities at its Alcântara spaceport located on the northern coast of the country. Following a launch pad explosion in 2003 that killed 21 people, relatively little progress has been made at Alcântara, and no orbital launch attempts have been made. Brazil's space budget in 2010 totaled approximately $300 million. This is expected to rise to more than $2.1 billion in the 2012–2015 period. Brazil plans to use the funding increase to set up operations for the Ukrainian Tsyklon-4 rocket at Alcântara, develop the first Brazilian GEO satellite, and fly the Brazilian Satellite Launch Vehicle.[105]

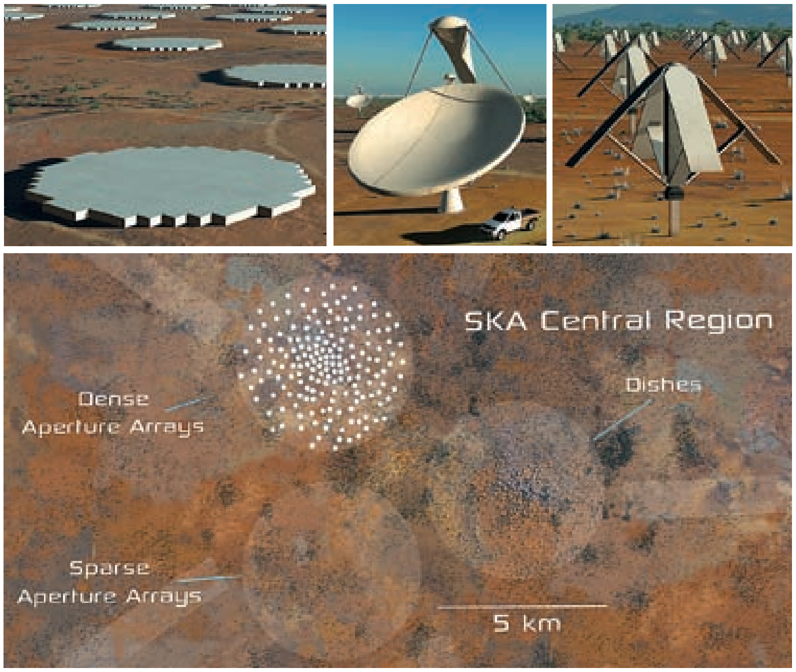
Japan's two launch sites, the Tanegashima Space Center and Uchinoura Space Center, benefited from the lifting of a ban designed to prevent disruptions to the fishing industry. These coastal launch sites in southern Japan previously were only allowed to conduct launches from July 22 to September 30 and from November 1 to February 28. As of April 2011, these facilities can now operate throughout the year.

3.6 Observatories and Robotic Exploration Systems

The infrastructure that scientists use to study and explore our solar system and universe falls into three broad categories: ground-based observatories, spacecraft in orbit around the Earth or other celestial bodies, and rovers and other systems that explore the surfaces of planets, moons, or other bodies.

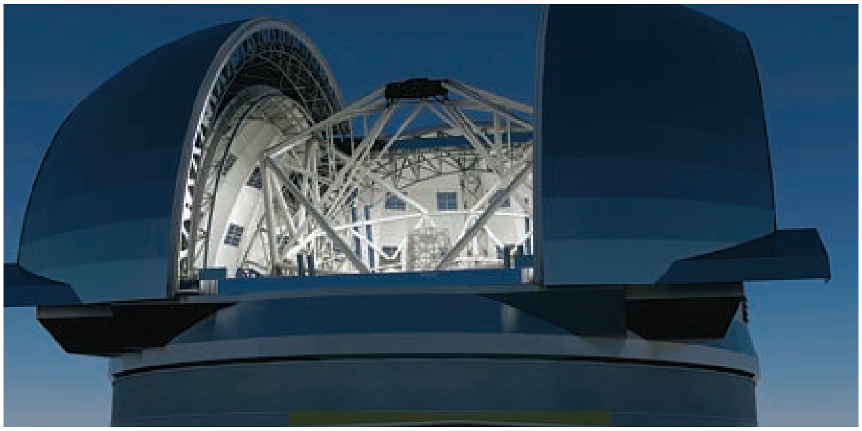
3.6.1 Ground-Based Observatories

To improve the resolution from ground-based observatories and to capture light from distant, dim objects, telescopes are growing larger. Due to the correspondingly large cost of construction and operation, these massive telescopes are often supported financially by multinational consortia.



The Square Kilometer Array will use 3,000 dishes (top, center), each about 15 meters (50 feet) wide. Two other types of receptors, dense (top, left) and sparse (top, right) aperture arrays, will also be used to observe very large areas of the sky simultaneously. The receptors will be arranged in five spiral arms extending from a central core to at least 3,000 kilometers (1,800 miles). *Credit: SPDO/Swinburne Astronomy Productions*

The Square Kilometer Array (SKA) Telescope is a €1.5 billion ($2.16 billion) global effort to build the world's largest and most sensitive radio telescope, whose multiple dishes will have a total collecting area of approximately one square kilometer (247 acres). The SKA is expected to be 50 times more sensitive and have 100 times better resolution than any other radio telescope in use.[106] The SKA will have telescopes spread over thousands of kilometers, allowing it to collect observations 10 times more detailed than the Hubble Space Telescope.[107] However, the two observatories are not directly comparable, as they do not make observations in the same wavelength ranges. In November 2011, seven national governmental and research organizations announced the formation of the SKA Organization: Australia, China, Italy, the Netherlands, New Zealand, South Africa, and the United Kingdom. The purpose of the independent, nonprofit company is to formalize relationships with international partners and centralize the leadership of the SKA telescope project. The organization plans to spend €69 million ($99 million) to fund the project in the period leading up to the construction phase which starts in 2016. The SKA will be built in the southern hemisphere, in either South Africa or Australia, where the view of our own galaxy, the Milky Way, is best and radio interference least. A decision on the site of the SKA is expected in early 2012.[108]



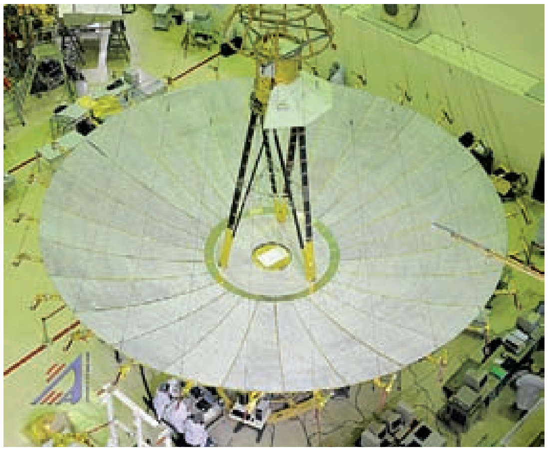
Planned to begin operations early in the next decade, the European Extremely Large Telescope (E-ELT) will search for Earth-like planets around other stars in the "habitable zones" where life could exist. The E-ELT will also make fundamental contributions to cosmology by measuring the properties of the first stars and galaxies and probing the nature of dark matter and dark energy. *Credit: Swinburne Astronomy Productions/ESO*

The Thirty Meter Telescope (TMT) is a planned astronomical observatory with a segmented mirror 30 meters (100 feet) in diameter, capable of observations from the near-ultraviolet to the mid-infrared. The observatory effort is led by a consortium of universities including the California Institute of Technology, the University of California, and the Association of Canadian Universities for Research in Astronomy. The project team also receives support from the National Astronomical Observatory of Japan, the National Astronomical Observatories of the Chinese Academy of Sciences, and the Department of Science and Technology of India. The TMT will be capable of observations with up to 10 times the spatial resolution of Hubble. Construction of the telescope is tentatively scheduled to begin in 2014 atop Mauna Kea, Hawaii, but an official start date had not been announced as of February 2012. The telescope is scheduled to observe first light by 2018.[109]

For the last five years, the European Southern Observatory (ESO) has been working together with its user community of European astronomers and astrophysicists to design an even bigger telescope. This optical to mid-infrared telescope, called the European Extremely Large Telescope (E-ELT), will boast a mirror with a diameter of 39.3 meters (129 feet), which will be the world's largest. The E-ELT's large mirror may be capable of achieving a spatial resolution 18 times better than Hubble.[110] In October 2011, the ESO signed an agreement with the Chilean government to permit the development of the E-ELT. In exchange for 10% of the observing time on the telescope when complete, Chile will donate land for the telescope in Cerro Armazones, as well as a larger protected area in order to diminish light pollution.[111] The start of operations is planned for early in the next decade.[112]

Chile will also be home to the Atacama Large Millimeter/submillimeter Array (ALMA), a radio telescope that will be composed of at least 66 high-precision antennas. At its highest frequencies, with a complement of 80 antennas, the ALMA will have

The Atacama Large Millimeter/submillimeter Array will consist of 64 movable 12-meter (40-foot) antenna dishes that can be arranged in patterns ranging from 150 meters (500 feet) to 16 kilometers (10 miles) wide. The specialized computer that combines the information received by the antennas will perform 16 quadrillion (16 million-billion) operations per second. *Credit: NRAO/AUI and NRAO/AUI/NSF, Carlos Padilla, General Dynamics C4 Systems*



Spektr-R, the first Russian astrophysics spacecraft to go into orbit in the twenty-first century, is seen here with dish segments unfurled. It took several attempts to get the segments to lock in place after reaching orbit, but the Spektr-R mission was successful and is now observing targets of scientific interest. *Credit: Roscosmos*

10 times the resolution of Hubble.[113] The project is a partnership among countries in Europe, North America, and East Asia, in cooperation with Chile. ALMA is the largest and most expensive ground-based astronomical project currently under construction, with an estimated cost of $1.3 billion. Scientific observations started in September 2011, with the array scheduled to be fully operational by 2013. ALMA will have the capability to capture high-resolution images of gases and dust in star-forming regions that are often obscured at optical and infrared wavelengths.[114]

3.6.2 Space-Based Systems

The second category of space and robotic exploration systems involves seeing the Universe through the eyes of a satellite. The advantage is that the satellite is able to capture images unaffected by the Earth's atmosphere, enabling researchers to more accurately decipher the mysteries of the Universe.

After nearly a decade of delays, the Russian Astro Space Center's Spektr-R satellite was successfully deployed into orbit via a Zenit-2SB rocket from Baikonur Cosmodrome in July 2011. The Spektr-R is currently the largest radio telescope in space. Working in conjunction with RadioAstron ground-based observatories and using interferometry techniques, the telescope makes astrophysical observations of extragalactic objects at very high resolution, producing images that are 1,000 times sharper than optical images obtained using the Hubble Space Telescope.[115]

NASA's New Frontiers program is a series of medium-class space exploration missions with the purpose of studying the Solar System. In August 2011, the latest New Frontiers mission, Juno, launched from Cape Canaveral Air Force Station, Florida, on an Atlas V on a mission to the planet Jupiter.[116] Upon arrival in July 2016, Juno will orbit the planet approximately 33 times during one Earth year. Juno uses three solar panels symmetrically arranged around the spacecraft, making it the first Jupiter-bound spacecraft to use solar rather than nuclear power systems. This allows the spacecraft to get around a current shortage of plutonium-238 used for spacecraft nuclear power systems, but limits the lifetime of the spacecraft as its solar panels will degrade in the Jovian radiation environment. The onboard infrared and microwave instruments will allow Juno to measure the thermal radiation emanating from deep within Jupiter's atmosphere and also to investigate other planetary characteristics such as its gravitational field and polar magnetosphere.[117]

Technicians inspect GRAIL-A and GRAIL-B after testing in the vacuum chamber. The twin spacecraft underwent an 11-day-long test at Lockheed Martin Space Systems in Denver, Colorado, that simulated many of the flight activities they will perform during the mission, all while being exposed to extreme conditions that they will encounter in space. *Credit: NASA/JPL-Caltech*

The twin GRAIL satellites are part of NASA's Discovery Program, a series of lower-cost, highly-focused, Solar System exploration missions. The satellites were successfully launched in September 2011 and entered orbit around the Moon on December 31 and January 1. Once in orbit, the satellites began their 90-day mission to determine the Moon's interior structure by using high-quality gravitational field mapping. Each spacecraft transmits and receives telemetry from the other spacecraft and Earth-based facilities. By measuring the change in distance between the two spacecraft, the gravitational field and geological structure of the Moon can be determined.[118]

3.6.3 Landers and Rovers

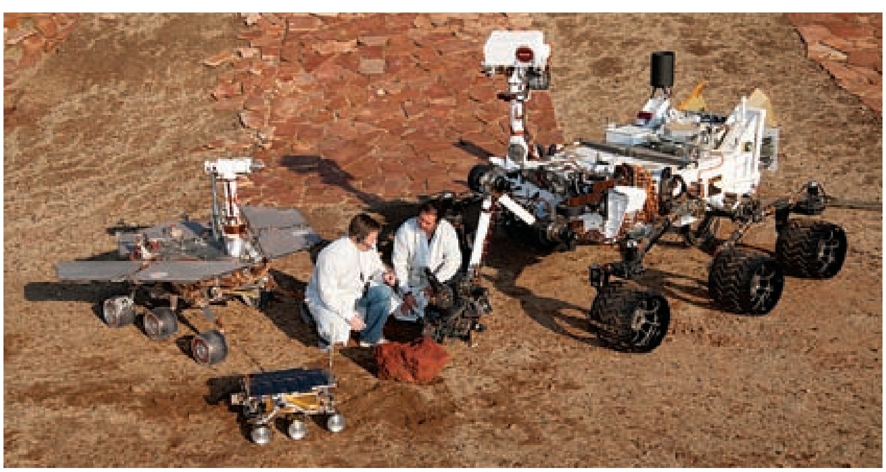
The third type of space and robotic exploration systems involves samples and observations being collected by systems located on the surface of other bodies in the Solar System. Several missions are in development both by government and commercial entities.

Astrobotic Technology is currently field testing lunar rover prototypes. The final rover will be remotely operated from Earth and will capture high-definition video and create a high-resolution terrain map as it explores. *Credit: Astrobotic Technology*

The Google Lunar X PRIZE (GLXP) is a competition featuring teams from nonprofit organizations, university consortia, and established companies. Each team is attempting to construct a spacecraft that will safely land on the surface of the Moon, travel at least 500 meters (1,640 feet) across the lunar surface, and send images and data back to the Earth. The teams have until the end of 2015 to meet the requirements. The winning team will receive $20 million, with $5 million going to the second-place team. There are 26 GLXP teams.[119]

In 2011, the Astrobotic Technology team signed a launch contract with SpaceX for a launch in late 2013 or 2014 that will send Astrobotic's robotic lander and rover to the surface of the Moon. Astrobotic was also selected by NASA to research new methods to explore lava tubes, caves, and recently discovered "skylights"—mysterious holes in the surface that may lead down to these subterranean features on the Moon and Mars. Other GLXP teams also undertook new partnerships and demonstrated progress toward their goals in 2011. In March, Odyssey Moon announced a collaboration with Paragon Space Development Corporation to deliver a biological greenhouse to the lunar surface and a partnership with Moonlink to place a British science instrument on the Moon. The Dynetics-led Rocket City Space Pioneers team successfully hot-fire tested a new rocket engine, which the company expects to use when placing its lander on the Moon.

NASA's Mars Science Laboratory (MSL), also known as Curiosity, follows the Spirit and Opportunity Mars rovers as part of NASA's Mars Exploration Program, a long-term effort managed by NASA's Jet Propulsion Laboratory. Curiosity is equipped with the latest advances in rover technology and the most advanced scientific gear to date, with a science payload more than 10 times as massive as those of earlier Mars rovers. Curiosity has been engineered to roll over obstacles up to 65 centimeters (25 inches) high and to travel up to about 200 meters (660 feet) per day on Martian terrain.[120] The main objective of Curiosity will be to help assess Mars' habitability and whether it was ever able to support microbial life. It will also analyze samples scooped up from the soil and drilled from rocks. MSL launched from Cape Canaveral, Florida, on an Atlas V in November 2011 and is scheduled to land on Mars in August 2012.[121]



Mars rovers built by NASA's Jet Propulsion Laboratory come together for a family portrait along with two spacecraft engineers. From left to right are the Surface System Test Bed rover, a working sibling of Spirit and Opportunity; Marie Curie, the flight spare for the Sojourner rover; and the Vehicle System Test Bed rover, which will be used to test commands before they are sent to Curiosity. *Credit: NASA/JPL-Caltech*

3.7 Technology Development

Many elements of space infrastructure use cutting-edge technologies to maximize performance, minimize mass, and improve reliability and safety. Continued development of new technologies is essential to enable new capabilities and make existing ones more affordable and reliable. Some technological advancements are revolutionary, enabling missions not previously feasible. For example, on-orbit robotic servicing of satellites is a technology receiving considerable attention by government agencies and companies alike, as it holds the potential to extend the life of operational satellites and to repair ailing ones.

3.7.1 On-Orbit Servicing

Once launched, satellites generally cannot be refueled or repaired. Satellites have lifetimes limited by the amount of propellant they can carry on board to maintain their orbits. A failure of a key system on a satellite can partially or totally disable the spacecraft, causing a disruption in service and potentially creating a hazard for other satellites. The Space Shuttle enabled the repair of some satellites, the best-known example being the Hubble Space Telescope, which was repaired and upgraded during five servicing missions between 1993 and 2009. However, the shuttle, which could access satellites in only a limited range of orbits, is no longer available for such missions.

There are a number of commercial and government efforts underway to develop robotic systems for the on-orbit servicing of satellites. In January 2011, ATK and U.S. Space announced the formation of a joint venture called Vivisat to perform on-orbit servicing of GEO satellites. A Mission Extension Vehicle (MEV) developed by ATK would dock to a satellite and serve as its propulsion system, allowing a satellite that was running low on fuel, but otherwise in good condition, to continue operations. Vivisat has not set a date when the MEV would be available to potential customers.[122]

MacDonald, Dettwiler and Associates (MDA), a Canadian company, is developing its Space Infrastructure Servicing (SIS) spacecraft. The SIS is intended to attach itself to satellites and transfer fuel to them. It will also be equipped with a robotic arm that can perform some satellite repairs, such as freeing jammed solar arrays and antennas. In March 2011, MDA announced Intelsat as its first customer, buying half of the 2,000 kilograms (4,400 pounds) of fuel on the first SIS.[123] However, in January 2012, MDA announced that its agreement with Intelsat ceased to be in effect. MDA plans to continue to pursue satellite servicing opportunities and is currently pursuing a space servicing opportunity issued by the U.S. government.[124]

MDA's space infrastructure servicing concept involves a single satellite that would refuel, tow, inspect, and perform simple repairs. The spacecraft would service about a dozen satellites before being restocked in orbit with fuel and other supplies, allowing it to continue operations. *Credit: MacDonald, Dettwiler and Associates*

NASA and DARPA are also studying satellite servicing technology. The Robotic Refueling Mission (RRM), a technology experiment equipped to simulate satellite fuel valves and caps, was bolted to the exterior of the ISS during the final shuttle mission in July. Using the station's Special Purpose Dexterous Manipulator, also known as Dextre, engineers will test techniques to access fuel caps that are screwed into place, secured with wires, and covered in thermal blankets. Those technologies could be used for future robotic servicing vehicles. Tests using Dextre and the RRM are expected to begin in early 2012.[125]

In October 2011, DARPA announced its Phoenix program, an effort to develop satellite servicing technologies using defunct satellites as sources for spare parts. DARPA envisions a robotic vehicle capable of removing solar panels, antennas, or other components from satellites no longer in service and installing them on other satellites. DARPA plans an initial mission under the program in 2015, testing technologies by removing an antenna from one satellite and transferring it to another.[126]

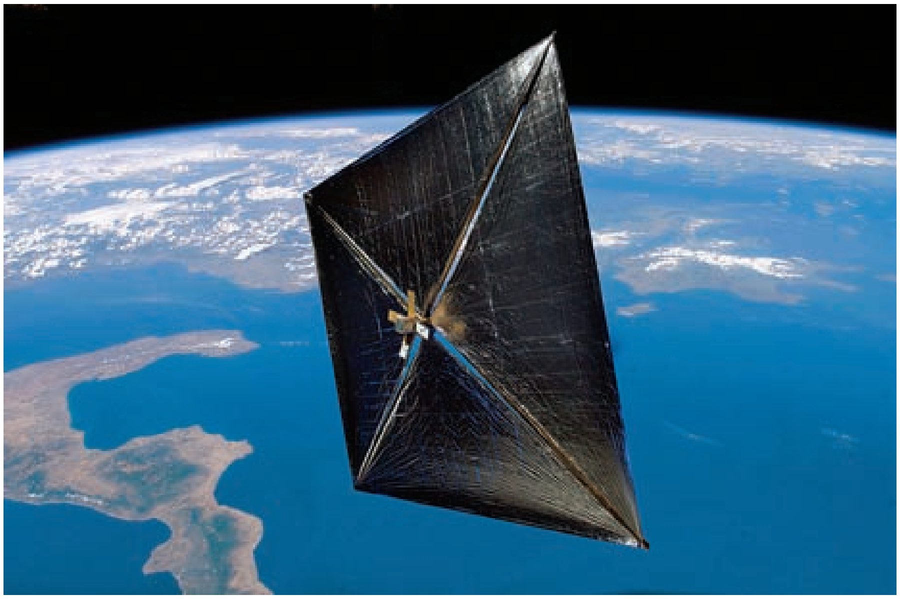
3.7.2 Other Technology Efforts

There is a wide range of technology development in the public and private sectors related to space infrastructure. One of the largest efforts is within NASA's Office of the Chief Technologist (OCT), an office created by NASA in 2010 to centralize and coordinate the agency's technology development efforts. OCT divides its technology development activities into three areas: Early Stage Innovation, where it solicits and evaluates promising ideas for space technologies; Game Changing Technology, where space technology concepts are demonstrated; and Crosscutting Capability Demonstration, where those technologies are matured for operational use.[127]

The OCT is also funding a number of early-stage technology development efforts through its NASA Innovative Advanced Concepts (NIAC) program. In August 2011, NASA awarded 30 grants of approximately $100,000 each for one-year studies of new, potentially revolutionary technologies. The NIAC awards study a wide range of technologies, from orbital debris removal to space-based solar power to advanced propulsion systems.[128]

In August 2011, NASA selected three technology demonstrations for future spaceflights. One experiment will test the use of laser communication relays, which can transfer data with a bandwidth up to 100 times greater than conventional communications systems. This could enable high definition video from even distant planetary missions. A second experiment will test an atomic clock 10 times more precise than existing instruments, which can improve the accuracy of space navigation. A third experiment will deploy a solar sail seven times larger than any previous experiment, allowing for propellant-free transportation that can enable low-cost Solar System exploration as well as missions in Earth orbit that require frequent changes in orbit. The technology demonstration missions are expected to launch in 2015 and 2016.[129]

Other national space agencies are also supporting key technology development efforts. In April 2011, ESA approved the development of Proba-3, a mission to demonstrate autonomous formation flying by spacecraft. Scheduled for launch in 2016, Proba-3 will feature two satellites that will fly in formation, maintaining a positional accuracy of a few millimeters at separation distances of up to 150 meters (500 feet) without any intervention from the ground. Such technology could support future scientific missions, such as arrays of space telescopes.[130] In October 2011, the Canadian Space Agency announced the award of six contracts for technology development studies to support potential future missions. These studies include technologies for removing orbital debris and designing compact scientific instruments for potential use on future Mars missions.[131]



Launched in November 2010, the NanoSail-D initially failed to fully unfurl. To the surprise of its engineers, the sail successfully deployed in January 2011 and became the first solar sail to orbit the Earth. Solar sails harness the minute force of sunlight reflecting off the surface of the sail to slowly accelerate to high speeds without the use of fuel. *Credit: ESA/P. Carril*

WORKFORCE AND EDUCATION

THE SPACE REPORT 2012

Aluminum domes, each created using innovative welding processes, are seen in Marshall Space Flight Center's Advanced Welding and Manufacturing Facility in Huntsville, Alabama. In this cutting-edge facility, a team of NASA and contractor engineers and technicians develops complex manufacturing processes required for next-generation launch vehicles and spacecraft. *Credit: NASA/MSFC/David Higginbotham*

EXHIBIT 4a. Topics Covered in Workforce and Education

4.0 Introduction

The space sector employs hundreds of thousands of professionals around the world. Space workers are attracted to the industry for reasons both practical and visionary. They hail from diverse educational backgrounds and earn salaries well above average while utilizing skills attractive to a variety of employers beyond the space industry. To promote growth in the number of skilled individuals, policymakers and institutions increasingly emphasize the importance of science, technology, engineering, and mathematics (STEM) education at the primary, secondary, and university levels.

In 2011, as the global economy continued to grow slowly, space employment remained relatively resilient. While the United States saw a decline in the number of space jobs, Europe, Japan, and South Korea registered an increase in spite of challenging economic conditions. These and other nations are investing in space-related education and training because they recognize the importance of technical education in sustaining a skilled space workforce and fostering other high-value economic activities.

Technicians at a Lockheed Martin Space Systems facility in Denver, Colorado, inspect the Juno spacecraft after a simulation of the acoustic and vibration environment it will experience during launch. *Credit: Lockheed Martin*

4.1 U.S. Space Workforce

The number of people employed in the U.S. space sector remained fairly stable throughout the first decade of the 21st century, weathering both the substantial industry restructuring that characterized the early 2000s and the economic slowdown that has dominated the past several years. According to data tabulated by the U.S. Bureau of Labor Statistics (BLS), more than a quarter of a million people work in the U.S. civil and commercial space sectors. On average, these workers continue to earn more than double the average private-sector employee, and their salaries have grown in the years following the 2007–2009 financial crisis.[1]

4.1.1 U.S. Space Industry Employment

As an indicator of U.S. space industry employment, the Space Foundation surveyed the 15 U.S. companies (including two joint ventures between Boeing and Lockheed Martin) with space-related sales greater than $1 billion in 2010 as reported by *Space News*. Of these companies, 14 provided workforce data as of the end of 2011. As shown in Exhibit 4b, these 14 companies together employed 87,520 space workers. However, the U.S. space industry comprises many smaller companies as well. For example, more than 80 companies in 28 states are involved in the development of NASA's Multi-Purpose Crew Vehicle (MPCV) as subcontractors for Lockheed Martin.[2]

The BLS addresses the breadth of the U.S. space industry by accounting for both large and small companies. It combines employer surveys with statistical analysis, it measures local, state, and national workforce trends across all American economic sectors, and it offers the most authoritative and representative source of U.S. space industry employment information. Data from the six space-related industry sectors, or North American Industry Classification System (NAICS) codes, shown in Exhibit 4c provides the basis for a detailed assessment of core U.S. space employment and salaries.

These six NAICS codes reflect the labor force involved in developing core space products and services, including manufacturers of navigation instruments; builders of space vehicles; suppliers of space vehicle engines and propulsion units; manufacturers of other space vehicle components; providers of satellite telecommunications; and civilians working for NASA or other government agencies engaged in space research, space exploration, or the development, launch, or operation of U.S. government spacecraft. Due to the methodology used by the U.S. government to define NAICS codes, employees from different industry sectors may be grouped within the same labor category. As a result, some employees within these six space-related categories may work in non-space fields. Conversely, there are also space employees counted in other NAICS codes who are not included in this study because BLS statistics do not provide sufficient detail to isolate the number of space jobs within other NAICS categories. For example, NAICS code 541330, Engineering Services, likely includes some space workers but determining how many from within such a broad category poses a challenge.

EXHIBIT 4b. Number of U.S. Space Employees at Selected Companies, 2011

Company	Number of Space Employees, 2011	Space Revenue, 2010 ($ in billions)
Lockheed Martin	19,600	$11.037
Boeing	9,300	$9.455
United Launch Alliance (ULA)	3,600	Revenue is included in figures for Lockheed Martin and Boeing
United Space Alliance (USA)	2,900	
Northrop Grumman	12,949	$5.319
Raytheon	9,977	$4.463
Garmin	3,344	$2.690
L-3	4,500	$1.800
General Dynamics	Not Disclosed	$1.752
EchoStar	691	$1.470
ATK	4,400	$1.423
Orbital Sciences	3,800	$1.290
ITT Exelis	4,300	$1.188
Space Systems/Loral	3,139	$1.165
United Technologies Corp. (UTC)	3,600	$1.100
Hughes	1,420	$1.038
Total*	**87,520**	**$45.190**

**Workforce total only includes employment numbers from companies that disclosed them.*
Sources: Space Foundation workforce survey, Space News *revenue data*

While the number of states reporting space-related jobs rose slightly, U.S. space employment fell overall in 2010, the most recent year for which BLS employment data is available. The number of U.S. space workers decreased

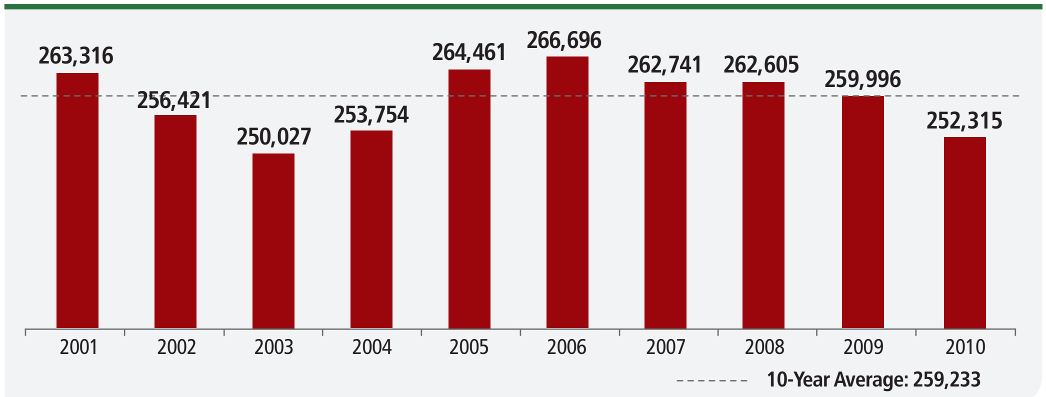
EXHIBIT 4c. U.S. Space Industry Employment by Sector, 2005, 2009, and 2010

Category Name and NAICS* Code	2005	2009	2010	% Change, 2005–2010	% Change, 2009–2010	Definition
Search, Detection, and Navigation Instruments (NAICS Code: 334511)	155,492	150,415	147,519	-5.1%	-1.9%	Includes the manufacturing of search, detection, navigation, guidance, aeronautical, and nautical systems and instruments.
Guided Missile and Space Vehicle Manufacturing (NAICS Code: 336414)	53,316	55,303	53,911	1.1%	-2.5%	Includes the manufacturing of complete guided missiles and space vehicles and/or developing and making prototypes of guided missiles or space vehicles.
Guided Missile and Space Vehicle Propulsion Unit and Propulsion Unit Parts Manufacturing (NAICS Code: 336415)	13,115	14,638	12,673	-3.4%	-13.4%	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.
Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment Manufacturing (NAICS Code: 336419)	7,423	8,033	7,964	7.3%	-0.9%	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.
Satellite Telecommunications (NAICS Code: 517410)	16,349	13,159	11,668	-28.6%	-11.3%	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.
Space Research and Technology (NAICS Code: 927110)	18,766	18,448	18,580	-1.0%	0.7%	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.
Overall Space Industry Employment	**264,461**	**259,996**	**252,315**	**-4.6%**	**-3.0%**	

**North American Industry Classification System*
Source: U.S. Bureau of Labor Statistics

from 259,996 in 2009 to 252,315 in 2010, a net loss of 7,681 jobs. This marked the fourth straight year in which U.S. space jobs shrank. Moreover, the 3% decline represented the most rapid year-on-year contraction of the past decade.

EXHIBIT 4d. U.S. Space Industry Core Employment, 2001–2010



Source: U.S. Bureau of Labor Statistics

Although these BLS statistics do not offer specific company data, precluding an exact attribution of job losses, the 2009–2010 U.S. space workforce reductions likely largely connected with the termination of both NASA's Space Shuttle Program and its planned successor, the Constellation Program. Several prime contractors announced phased layoffs over the course of 2010, and additional layoffs continued in 2011. For example, between 2009 and September 2010, more than 1,500 employees left voluntarily or were laid off from the Magna, Utah, facilities of ATK, which helped manufacture the rocket motor for the Ares vehicle under the Constellation Program.[3] In August 2010, United Space Alliance (USA) notified 1,394 shuttle workers that their positions would be eliminated in October.[4] In September 2010, Northrop Grumman announced plans to cut 500 aerospace jobs, mainly at its El Segundo, Manhattan Beach, and Redondo Beach facilities in California.[5] An additional 175 Constellation contractor positions, most affiliated with Jacobs Technology, were also eliminated in 2010.[6]

Technicians with ATK Aerospace Systems of Magna, Utah, make final preparations for testing inside an avionics mounting structure. The avionics system in a launch vehicle is responsible for controlling key guidance, launch, navigation, and recovery hardware. *Credit: ATK*

Despite the drop in employment observed in 2010, a longer view of the past decade shows that U.S. space employment has remained relatively consistent. The number of U.S. space workers has fluctuated between a low of 250,027 workers in 2003, following the collapse of the telecommunications bubble, to a high of 266,696 workers in 2006. This low and high represent a difference of no more than 3.6% from the ten-year average employment level of 259,233 U.S. space workers. The 2010 employment count, despite being the second-lowest of the past decade, is only 5.4% lower than the 2006 high, and only 2.7% below the ten-year average.[7]

U.S. Space Industry Employment by Sector

The loss of 7,681 jobs in 2010 marks the largest annual decline of the past 10 years and accounts for more than half of all U.S. space jobs lost between 2005 and 2010.[8] The extent to which space employment has decreased has varied considerably by industry sector, both from one year to the next and in aggregate over the period from 2005 to 2010. Four of the six sectors showed net job losses between 2005 and 2010. The *Search, Detection, and Navigation Instruments* sector gained 1,730 jobs in 2006 but then shed more than 1,500 jobs each year between 2006 and 2010, leading to an aggregate loss of 7,973 employees, or about 5%, accounting for the largest absolute loss in workers over this period. The largest percentage loss occurred in the *Satellite Telecommunications* sector, which posted significant declines in 2007 and 2010 and a smaller decline in 2008, leading to a net loss of 4,681 employees between 2005 and 2010, a reduction of nearly 29%. During the same period, *Guided Missile and Space Vehicle*

Propulsion Unit and Propulsion Unit Parts Manufacturing lost 442 jobs, about 3%, as sector employment growth from 2005 to 2008 was eclipsed by workforce cuts in 2009 and 2010. Though *Space Research and Technology* employment grew in 2008 and 2010, this did not quite offset losses in 2006, 2007, and 2009, leading to an aggregate loss of 186 jobs, or 1%, between 2005 and 2010. [9]

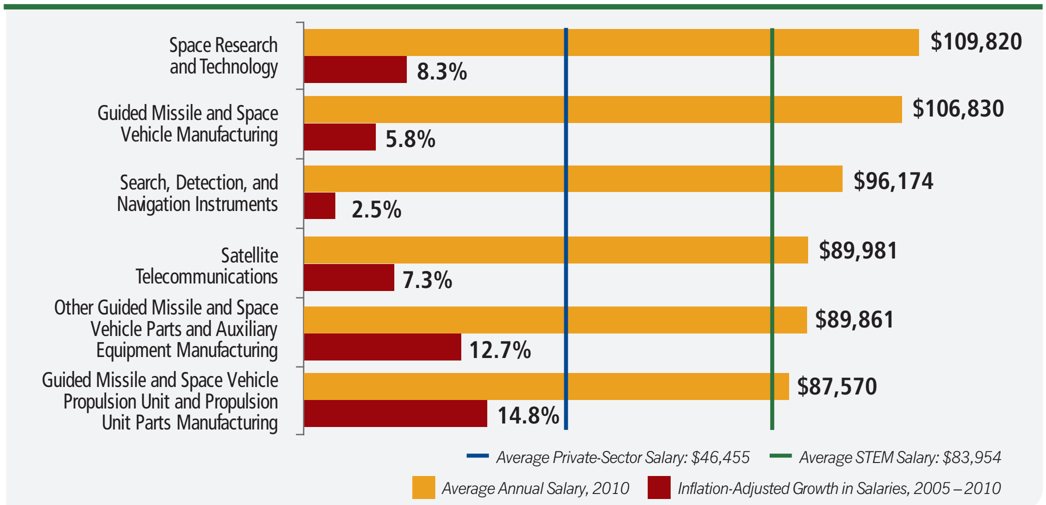
By contrast, two industry sectors showed net job gains between 2005 and 2010. The largest percentage growth occurred in the *Other Guided Missile and Space Vehicle Parts and Auxiliary Equipment Manufacturing* sector. After a decrease of less than 1% in 2006, the sector showed annual workforce increases of more than 2% in 2007, 2008, and 2009 before declining by less than 1% in 2010, leading to a net increase of 541 jobs, more than 7%, overall between 2005 and 2010. The *Guided Missile and Space Vehicle Manufacturing* sector grew by a net 595 jobs, about 1%.[10]

4.1.2 U.S. Space Industry Salaries

Space salaries have increased even as U.S. space employment has declined. In 2010, the combined average salary across the six core U.S. space industry sectors was $96,706. This was more than double the average 2010 U.S. private-sector salary of $46,455, reflecting the tendency of space jobs to require high levels of technical education and training that can generate high-value products and services.[11] The average 2010 U.S. space industry salary was also 15% higher than the average salary for the 10 STEM careers that employ the largest number of Americans. The average salary for these 10 STEM careers, most of which were in computer science fields, was $83,954 in 2010.[12] High salaries benefit the national economy because they provide professionals with more discretionary income to consume goods and services, reinvest in the broader economy, and foster a larger tax base.

The gap between space and general private-sector salaries is even more pronounced within certain industry sectors. In 2010, professionals in two of the six space sectors analyzed earned an average salary in excess of $100,000. As Exhibit 4e shows, the average salary in the *Space Research and Technology* sector was $109,820, or 2.4 times the average private-sector salary.[13] Similarly, *Guided Missile and Space Vehicle Manufacturing* professionals earned an average of $106,830, or 2.3 times the average private-sector salary.[14]

EXHIBIT 4e. Space Industry Salaries and Real Salary Growth by Sector, 2005–2010



Source: U.S. Bureau of Labor Statistics

Equally significant, the growth in average U.S. space salaries has been sustained both before and after the 2007–2009 recession.[15] As Exhibit 4e indicates, all six space industry sectors analyzed showed real wage increases between 2005 and 2010, notwithstanding the recession and the subsequent sluggishness in economic growth. The *Guided Missile and Space Vehicle Propulsion Unit and Propulsion Unit Parts Manufacturing* sector experienced the largest increase, with average salaries growing by 14.8% over five years in real terms. Generally, an increase in average salaries could be caused by either a growth in base salaries or a reduction in the lower end of the labor force or both. The *Search, Detection, and Navigation Instruments* sector experienced the smallest increase but still saw real growth of 2.5% in average salaries over five years. Overall, between 2005 and 2010, the inflation-adjusted average annual U.S. space industry salary rose by 8.2%.[16]

U.S. Space Salaries by State

U.S. space employment is geographically dispersed, with respondents in 42 states plus the District of Columbia reporting employees in at least one of the six space-related BLS labor categories. In 20 states plus the District of Columbia, more than 1,000 people were employed in the space industry. Nine states reported more than 5,000 space-related jobs, while four states exceeded 10,000 space-related jobs in 2010. Exhibit 4f displays the top five states, excluding those with fewer than 1,000 space employees, in terms of average annual salaries in the space industry. In all five of these states, space employees earned an average annual salary exceeding $100,000.

EXHIBIT 4f. Top Five States by Space Industry Average Annual Wages, 2010

State	Space Industry Wage	Private Sector Wage	Wage Differential
Colorado	$125,735	$47,916	162%
Maryland	$113,056	$49,496	128%
Massachusetts	$110,827	$58,359	90%
California	$109,833	$52,553	109%
Virginia	$109,442	$49,138	123%

Source: U.S. Bureau of Labor Statistics

Soldiers set up a Tactical-IP satellite receiver as part of simulated nuclear terrorist attack at the Clarks Hill Training Center in McCormick, South Carolina. *Credit: U.S. Air Force/SSgt Eric Harris*

4.1.3 U.S. Military Space Workforce

The BLS data characterizing the American space workforce does not include U.S. military space personnel, who constitute a dedicated "space cadre" maintained by the U.S. Department of Defense (DoD). Implemented by the U.S. National Security Space Office (NSSO) in 2001 to address a perceived gap in national military space readiness, the DoD space cadre is designed to be a force of highly competent professionals skilled in the operational and tactical demands of the space medium, including the technical requirements of space vehicles, ground systems, and space systems. Its overall objective is to maximize the use of current and emerging space assets to defend the United States, as well as evolving integrated command-and-control systems and doctrines that enhance U.S. security.[17]

To sustain a military space workforce equal to this task, Title 10 of the United States Code requires the U.S. Secretary of Defense, in conjunction with the heads of each of the four branches of the armed forces, to "identify, track, and manage space cadre personnel" to ensure there are sufficient numbers with "the expertise, training, and experience to meet current and future national security space needs." In early 2012, the DoD completed its third *Biennial Report on the Management of Space Cadre within the Department of Defense*. This report provided updated information on the numbers and status of U.S. military space professionals as of December 2011 as well as projections of future staffing requirements.[18] Each branch of the armed forces is empowered to implement the Title 10 directive according to its own organizational, training, and staffing objectives. As a result, there is wide variance in numbers of space professionals by military service. For instance, the U.S. Marine Corps maintains a space cadre of approximately 80, stating that this scope is appropriate to its small-scale, flexible mission doctrine. The U.S. Air Force, by contrast, maintains a cadre of more than 13,000 space professionals. These numbers include personnel that have been assigned to the National Reconaissance Office (NRO).

EXHIBIT 4g. U.S. Military Space Workforce

	Air Force	Army	Navy	Marines	Total*
2009	12,142	276 (+1,854 space enablers)	1,439	80	15,791
2011	13,116	416 (+ 1,760 space enablers)	1,365	82	16,739
Percentage Change, 2009–2011	**8%**	**2%***	**-5%**	**3%**	**6%**

*Includes space enablers.
Source: Biennial Report on the Management of Space Cadre within the Department of Defense, 2011

The internal organization of space cadre groups is also unique to each service. Generally, each space cadre is staffed predominantly by active duty personnel, supplemented by reserve officers and civilian employees. The exception is the U.S. Army, which maintains a core of space professionals bolstered by a much larger number of "space enablers," consisting of civilian staff as well as soldiers whose primary career field is not space but who perform functions that help maintain and utilize military space capabilities.[19]

4.1.4 NASA Workforce Status

In 2011, NASA's Space Shuttle Program came to an end. The shuttle program had been a major source of employment for the U.S. aerospace workforce. Anticipating the retirement of the shuttle, NASA developed strategies and policies for the transition of the government and contractor workforce, expecting that when the shuttle program concluded, many of the associated professionals would transition to the Constellation Program. However, funding for the Constellation Program was cancelled under the U.S. fiscal year (FY) 2011 federal budget.

EXHIBIT 4h. Selected Space Shuttle Contractor Workforce Layoffs, 2011

Number of Employees Laid Off	Location	Company	Month of Layoff Announcement
1,550	Brevard County, Florida	United Space Alliance	June
800	Houston, Texas	United Space Alliance	June
200	Houston, Texas	Boeing	June
100	New Orleans, Louisiana	Lockheed Martin	August
515	Houston, Texas	United Space Alliance	August
560	Utah	ATK	August
54	Houston, Texas	United Space Alliance	September
400	Huntsville, Alabama	Jacobs Engineering	December

Sources: Space News, Space.com, The Texas Tribune, The Huntsville Times, The Ogden Standard-Examiner, NASAWatch

The design for NASA's new proposed follow-on human spaceflight system, the combination of the Space Launch System (SLS) and the Multi-Purpose Crew Vehicle (MPCV), was announced in September 2011. The SLS is in the concept development phase and its workforce requirements are not yet fully defined. NASA intends to leverage, to the extent possible, existing shuttle and Constellation contracts to develop the SLS.[20] From a cost standpoint, the combined SLS and MPCV system is intended to be a leaner program than either the shuttle or Constellation, and it is reasonable to expect that the number of contractor jobs associated with it will be smaller than that associated with the shuttle.

As of July 2011, the number of employees associated with the shuttle program nationwide had dropped to approximately 5,000 contractors and 1,000 civil servants for a total of 6,000 employees, compared to a high of 32,000 during the 1990s. NASA workforce planners estimate that the number of shuttle contractors will be reduced to 1,000 by the close of FY 2012, and from there to 400 contractors during FY 2013.[21] The remaining shuttle contractors are working in activities related to the closeout and termination of the program, including property disposal, knowledge capture, and orbiter decommissioning.

The contractor layoffs associated with this workforce reduction have affected many communities across the United States. In July 2011, the Space Shuttle *Atlantis* made its final landing at the Kennedy Space Center (KSC) in Florida, ending its 30-year career of flight. Following this event, approximately 1,550 employees of United Space Alliance (USA), the company with responsibility for shuttle vehicle operations and maintenance, were laid off.[22] By the time the shuttle program closeout activities are completed in FY 2013, more than 8,000 employees in the area surrounding KSC will have lost their jobs.[23] Not all of these job losses are permanent. In October 2011, Boeing announced it had leased one of three NASA buildings previously used to process shuttle orbiters for use in preparing its planned Crew Space Transportation 100 (CST-100) vehicle for launch. This vehicle program is expected to create positions for up to 550 people.[24]

With the final shuttle flight, USA also laid off approximately 800 employees at NASA's Johnson Space Center (JSC) in Houston.[25] Boeing downsized approximately 200 workers in the area at the same time.[26] As is the case in Florida, Texas is looking to the emerging commercial space industry, in addition to NASA's SLS program, to restore some of the lost jobs. The Texas legislature has adopted policies to encourage commercial space transportation companies to establish operations in the state.

At the Michoud Assembly Facility (MAF) in New Orleans, Louisiana, which manufactured the external fuel tanks for the shuttle, Lockheed Martin had approximately 400 employees at the time of the last flight of the shuttle. In August 2011, subsequent to the final launch, the company laid off 100 of those employees and transferred about 200 to work on the development of the MPCV, which will continue under NASA's current plans. The remaining 100 are expected to be working on shuttle closeout activities over the next year.[27]

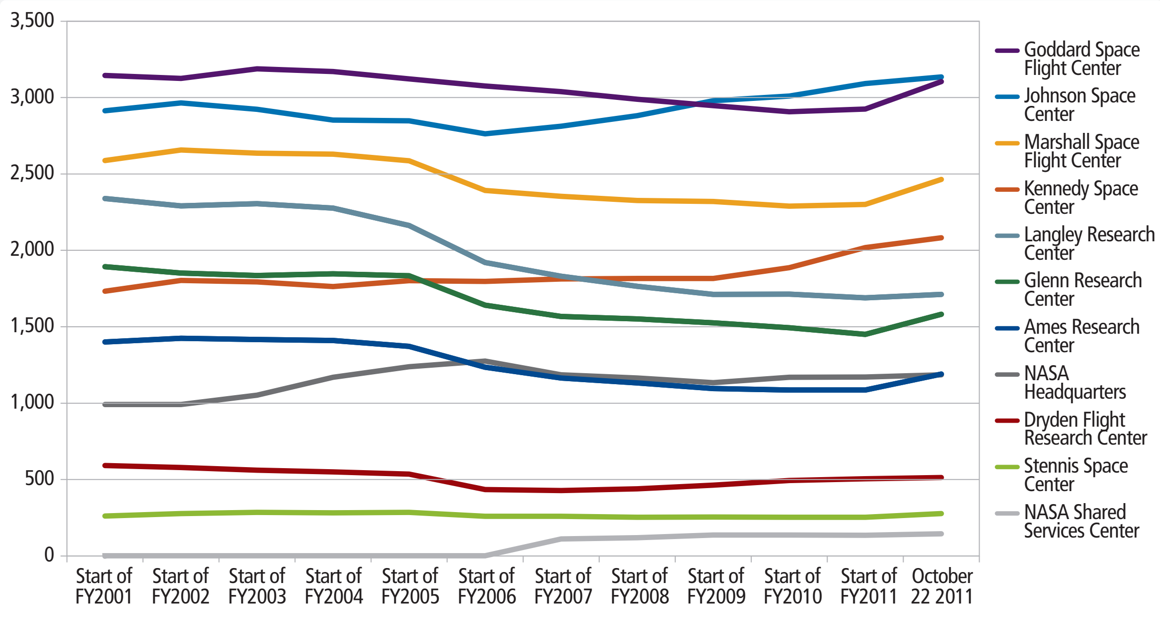
The Orion spacecraft's parachute system undergoes testing at Texas A&M's Wind Tunnel Complex. NASA intends to leverage existing shuttle and Constellation contracts, to the extent possible, to develop the Space Launch System. *Credit: NASA*

In 2010, more than 800 contractors located at NASA's Marshall Space Flight Center (MSFC) in Huntsville, Alabama, lost their jobs. As many as 400 additional positions associated with MSFC were set to be downsized by the end of 2011, many of these associated with Jacobs Engineering.[28] MSFC officials expect activity under the SLS program to stabilize job reductions at the center but not to result in the recovery of lost jobs.[29]

In contrast to the contractor workforce associated with U.S. human spaceflight programs, NASA's civil servant workforce has not been affected by layoffs. The size of the NASA civil servant workforce and its geographic deployment across NASA's centers have been relatively stable over the past 10 years, as shown in Exhibit 4i. NASA does not currently have authority to reduce the size of its civil servant workforce by means other than voluntary attrition and through the use of buyouts. A buyout is a financial incentive of up to $25,000 offered to select employees to encourage voluntary early retirement.[30] NASA uses buyouts to aid in workforce restructuring actions, including post-shuttle reorganizations. For example, NASA offered buyouts to 120 civil servants at MSFC in September 2011.[31] Buyouts have also been offered at JSC, KSC, Ames Research Center in Mountain View, California, and NASA headquarters in Washington, D.C.[32]

Like NASA civil servant jobs, NASA contractor jobs are high-skill, high-salary positions. When these jobs are lost, communities often have difficulty replacing them, and the employees encounter difficulty in finding similar positions

EXHIBIT 4i. NASA Civil Servant Workforce by Center, FY 2001–2011



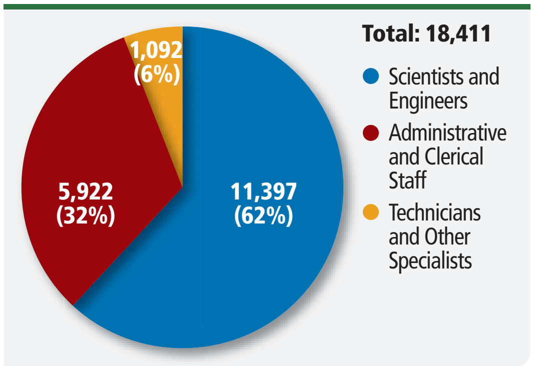
Source: NASA Cognos Workforce Database, November 16, 2011

Dwarfed by the immense Vehicle Assembly Building, thousands of Kennedy Space Center employees stand side-by-side to form a full-scale outline of a Space Shuttle Orbiter. The event was organized to honor the Space Shuttle Program's 30-year legacy and the people who contributed to safely processing, launching, and landing the vehicle. *Credit: NASA/Kim Shiflett*

in the local area. In order to keep the skilled technical workforce associated with the shuttle program from relocating elsewhere, many local communities affected by NASA layoffs have invested in job-transition assistance and worker retraining programs in alternative skill sets.

The significance of the shuttle retirement goes beyond the immediate impact of job reductions associated with NASA programs. The local communities around many NASA centers, in particular the Kennedy Space Center, have traditionally received economic benefit from tourism associated with shuttle flights and launch facilities. With the end of the shuttle program, there is concern that NASA-related tourism will decline.[33] Some communities hope to protect tourism activities by displaying retired space shuttle orbiters. In June 2011, NASA announced that four museums were selected to receive the retired shuttle vehicles: the Kennedy Space Center in Florida; the National Air and Space Museum in Washington, D.C.; the Intrepid Sea, Air & Space Museum in New York City; and the California Science Center in Los Angeles.[34]

EXHIBIT 4j. NASA Workforce by Job Type, 2011



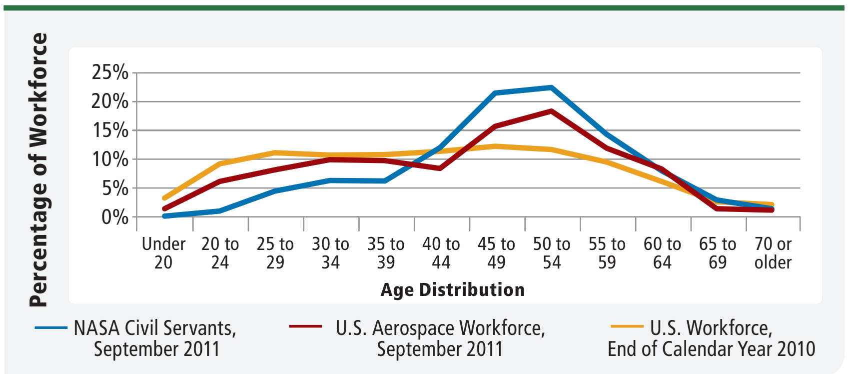
Source: NASA Cognos Workforce Database, February 21, 2012

4.1.5 U.S. Space Workforce Outlook

The ongoing impacts of the economic slowdown and the reductions in NASA's contractor workforce are not the only issues affecting U.S. space industry employees. The American aerospace workforce is aging. As shown in Exhibit 4k, the ages of both the NASA workforce and the broader aerospace workforce are clustered in the 40- to 60-year age range.[35] More than 70% of the NASA workforce is between 40 and 60 years old. By contrast, the overall U.S. workforce shows a more evenly distributed age profile, with less than 45% of the workforce in this range.[36] The NASA workforce also has a smaller cohort of younger professionals, with less than 12% of its workforce under age 35. In the broader U.S. workforce this age group makes up 34% of the workforce.[37]

As the older generation of aerospace employees retires, companies are hiring young professionals to take their place. The 2011 edition of the annual *Aviation Week Workforce Study* finds that 22% of the aerospace workforce in U.S. aerospace and defense companies is 35 years or younger, a percentage that nearly matches those 56 or older.[38] The *Aviation Week* study included a targeted survey of the young professional aerospace and defense workforce. The survey indicates that young professionals are concerned that the U.S. aerospace industry and government appear to be cutting back research and development expenditures, potentially resulting in less exciting and challenging work. Although young professionals surveyed by *Aviation Week* place a high priority on education benefits, the industry also appears to be decreasing investment in continuing education support. Taken together, these two trends have caused concern over the retention of younger workers—a theme expected to come into greater focus as the U.S. space industry adapts to an increasingly multi-generational workforce.[39]

EXHIBIT 4k. U.S. Workforce Age Profiles

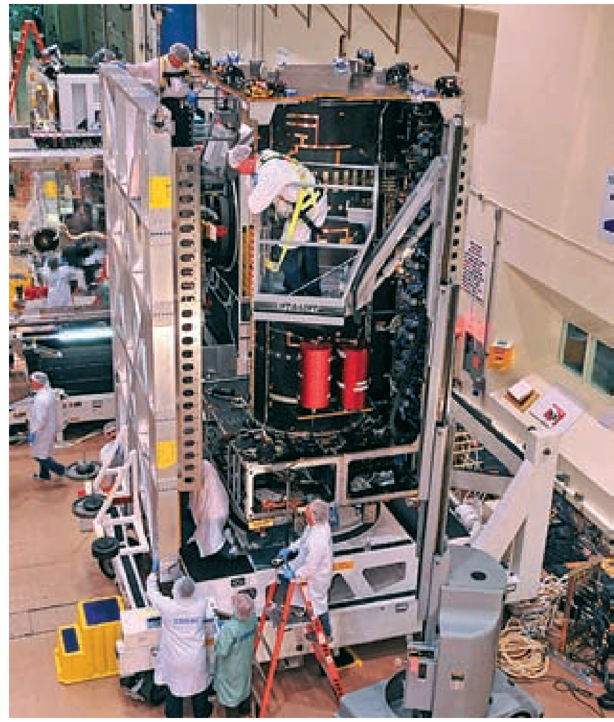


Source: NASA, U.S. Bureau of Labor Statistics, and U.S. Census Bureau

4.2 European Space Workforce

The nonprofit European space industry association Eurospace tracks European space employment through annual surveys of European space-related companies, as well as multinational space companies employing personnel in Europe. In 2010, the Eurospace methodology evolved to include more European companies, reclassify some companies formerly counted in one space industry sector to another, and reflect movement of some European space employees from one country to another. As a result, although European space employment posted growth between 2009 and 2010, some of the increase was due to the expanded number of companies surveyed. Similarly, some of the changes in European space employment by sector or country are attributable to differences between the new accounting and the old.[40]

Despite substantial macroeconomic pressures faced by some European nations in the form of sovereign debt crises and fiscal austerity reforms, the number of European space employees grew by 10% between 2009 and 2010, corresponding to a robust increase in space industry sales. According to data collected for 16 European countries by Eurospace, European space sales grew by more than €507 million (US$623 million) in 2010, amounting to €6.14 billion (US$7.55 billion), a 9% increase.[41]



QuetzSat-1, shown under construction, was launched in September 2011 from the Baikonur Cosmodrome in Kazakhstan. Operated by European satellite communications company SES, QuetzSat-1 was built by Space Systems/Loral. It provides coverage for Mexico, the United States, and Central America. *Credit: SES*

A closer view of 2010 European space industry data reveals that more than half of revenues were generated by the satellite sector, with an additional 16% attributed to scientific systems, many of which are included as payloads aboard spacecraft. Launch systems comprised approximately 17% of sales, with the remaining revenues, about 15%, derived from ground or other systems. These figures mirror to some extent the proportions of European employees working in each of the three main European space industry sectors: spacecraft, launch, and ground equipment.[42]

EXHIBIT 4l. European Space Industry Employment by Sector, 2005–2010

Employment Sector	2005	2006	2007	2008	2009	2010	% Change, 2005–2010	% Change, 2009–2010
Spacecraft	18,788	19,310	19,838	20,561	21,721	22,754	21%	5%
Launch	6,716	6,436	6,412	6,336	6,571	4,913	-27%	-25%
Ground	3,080	3,126	3,256	3,404	3,077	6,668	116%	117%
Total Workforce	28,584	28,872	29,506	30,301	31,369	34,334*	20%	9%

**2010 figures do not add up to the total due to rounding.*
Source: Eurospace

European Space Industry Employment by Sector

The number of European space workers counted has expanded by 20% over five years, from 28,584 full-time equivalent (FTE) employees at the end of 2005 to 34,334 FTE employees in 2010. While some of the changes in European space workforce by sector reflected in Exhibit 4l are attributable to Eurospace methodology changes, they also underscore the shifting composition of the European space workforce. Spacecraft and ground segment employment have increased over time, while the number of launch jobs has steadily declined. This has resulted in a changing proportion of the European space workforce share by segment. Whereas in 2005, the share of European space workers employed in the launch segment was 23%, by 2010 it had shrunk to 14%. The share of European space employees in the ground segment grew, from 11% in 2005 to 20% in 2010. Although the spacecraft manufacturing sector added 3,966 jobs between 2005 and 2010, its proportion of the European space workforce remained unchanged at 66%.[43]

European Space Employment by Country

France continued to have the largest number of European space workers in 2010, accounting for 12,082 FTE space jobs, more than one-third of the European total. Germany, Italy, the United Kingdom, and Spain rounded out the top five European nations for space jobs, reflecting their status with France as the largest European nations in terms of population, GDP, and European Space Agency (ESA) contributions. Together, these five nations account for 29,369 space employees, 85% of Europe's total.[44]

EXHIBIT 4m. European Space Industry Employment by Country, 2005–2010

National Workforce	2005	2006	2007	2008	2009	2010	% Change, 2005–2010	% Change, 2009–2010
France	11,157	11,145	11,453	11,641	11,225	12,082	8%	8%
Germany	4,415	4,481	4,812	4,962	5,270	6,112	38%	16%
Italy	3,814	3,738	3,963	3,985	4,490	5,095	34%	13%
United Kingdom	3,287	3,576	3,242	3,437	3,429	3,554	8%	4%
Spain	1,896	1,901	1,915	2,095	2,231	2,526	33%	13%
Belgium	1,189	1,187	1,288	1,284	1,523	1,446	22%	-5%
Switzerland	670	671	707	743	783	796	19%	2%
Netherlands	505	559	491	460	610	794	57%	30%
Sweden	699	686	689	641	664	760	9%	15%
Austria	294	279	290	301	318	320	9%	1%
Norway	247	223	205	254	276	293	19%	6%
Denmark	175	180	200	167	216	231	32%	7%
Finland	136	131	129	153	172	150	10%	-13%
Portugal	55	73	53	109	101	118	115%	17%
Luxembourg	—	—	27	27	31	31	—	0%
Ireland	45	42	42	42	30	26	-42%	-13%
Total Workforce	**28,584**	**28,872**	**29,506**	**30,301**	**31,369**	**34,334**	**20%**	**9%**

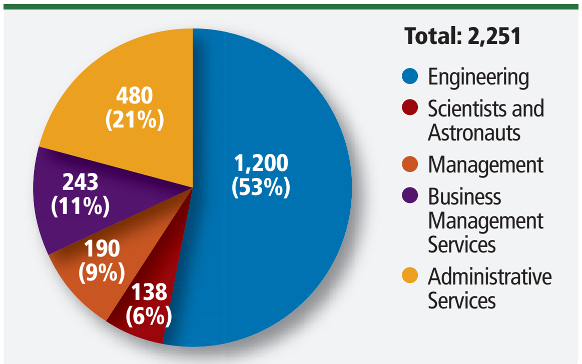
Source: Eurospace

The countries with the fastest-growing European space employment centers tend to be those with smaller space workforces. Although German, Italian, and Spanish space employment showed double-digit expansion rates of between 13% and 16%, the Netherlands saw the highest growth rate between 2009 and 2010. Dutch space employment expanded by 30%, from 610 to 794 jobs, part of a larger five-year growth trend of 57%. Portugal and Sweden were also notable for their space workforce expansions. Although building from a small base, Portugal added 17 space positions in 2010, growing from 101 to 118 space employees. Portuguese space employment has more than doubled over five years, up from 55 positions in 2005. Meanwhile, Sweden added 96 space employees, growing from 664 positions in 2009 to 760 in 2010.[45]

European Space Agency Demographics

As of June 2011, the European Space Agency (ESA) directly employed 2,251 people, and another 2,000 people worked on-site as contractors. More than half of ESA's employees were engineers and an additional 138 were astronauts and scientists. The remaining 913 employees, comprising about 41% of the total ESA workforce, held administrative or managerial roles.[46] This roughly 60–40 ratio of technical to administrative personnel is fairly similar to NASA's workforce, which as an approximately 70-30 ratio.[47]

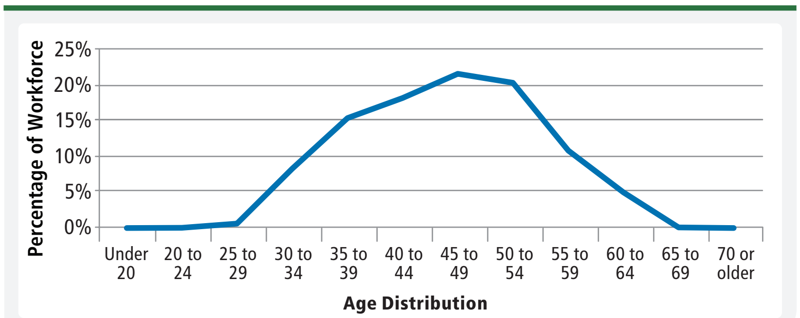
EXHIBIT 4n. ESA Workforce by Job Type, 2011



Source: ESA, June 2011

As shown in Exhibit 4o, the age profile of ESA's employees correlates closely with that of the NASA workforce, with just over 70% of its workforce between the ages of 40 and 60. However, a larger proportion of ESA's workforce, more than 24% compared to NASA's 12%, is made up of young professionals under the age of 35. To replace its workers nearing retirement with younger workers, ESA now recruits about 130 new staff and 100 trainees per year. This recruiting places particular emphasis on increasing the number of female students in science and engineering through job fairs, promotional tours, and trainee networking programs.

EXHIBIT 4o. ESA Workforce Age Profile, 2011



Source: ESA, June 2011

JAXA engineers examine the results of a test using the High Enthalpy Shock Tunnel, which simulates the environment experienced by spacecraft re-entering the atmosphere. During re-entry, vehicles can be exposed to temperatures higher than 10,000 degrees Celsius (180,000 degrees Fahrenheit). *Credit: JAXA*

Additionally, to ensure knowledge transfer from one generation of managers to the next, ESA has introduced a specialized project management course. The 15-day course enrolls between 10 and 20 participants per year and intersperses lectures with simulation exercises across ESA's administrative functions.[48]

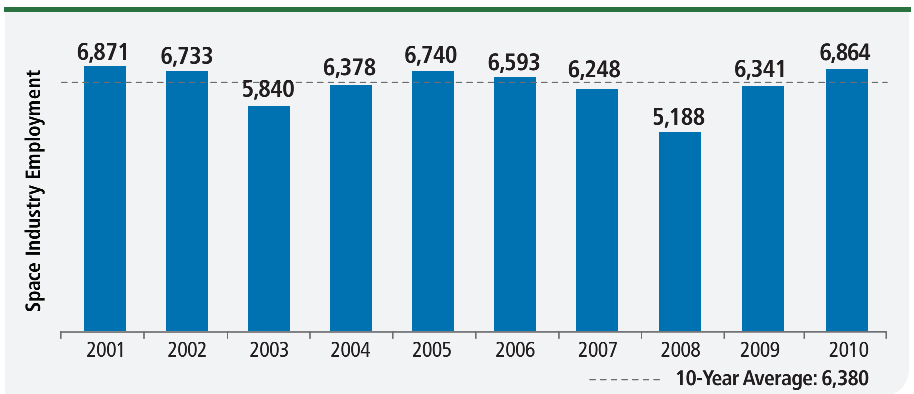
4.3 Japanese Space Workforce

As of 2011, approximately 8,400 people were employed in the Japanese space sector. These included 1,547 employees who worked at the Japan Aerospace Exploration Agency (JAXA), along with an estimated 6,864 private-sector employees.[49]

Japanese Space Industry Employment

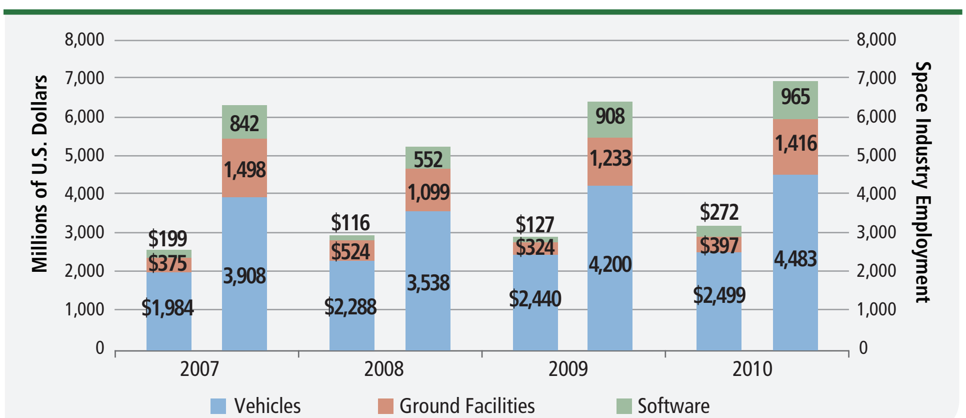
According to the Society of Japanese Aerospace Companies (SJAC), Japanese private-sector space employment has averaged 6,380 jobs over the past decade. The number of Japanese private-sector space jobs was highest in FY 2001, at 6,871 jobs, and has oscillated up or down from the ten-year average by no more than 8% in each of the following years, with the exception of FY 2008. In FY 2008, Japanese space employment dropped to a low of 5,188 jobs, representing a 19% drop from the ten-year average. The SJAC estimate relies on surveys, so some of this decline was attributable to lower survey response rates in that year. However, the worldwide economic slowdown was also a factor, as reflected in Japanese private-sector space revenues from the year prior, FY 2007, shown in Exhibit 4q. Since FY 2008, Japanese space employment has increased sharply, reaching 6,864 jobs in FY 2010, almost equal to the FY 2001 peak.[50]

EXHIBIT 4p. Japanese Space Industry Employment, 2001–2010



Source: Society of Japanese Aerospace Companies (SJAC)

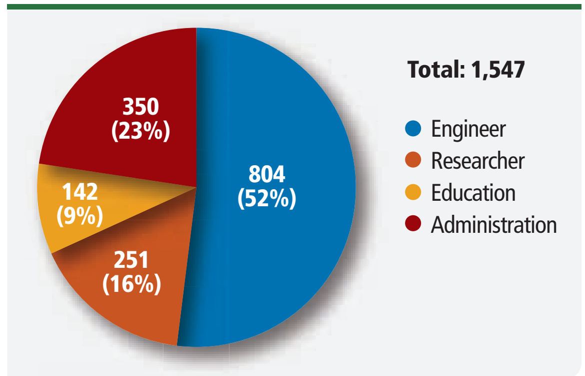
EXHIBIT 4q. Japanese Space Industry Revenue and Employment by Sector, 2007–2010



Source: Society of Japanese Aerospace Companies (SJAC)

Japanese space employment by industry sector has roughly correlated to revenues by sector. As Exhibit 4q shows, the largest sector by far is space vehicles, which includes both launch systems and spacecraft. The vehicles sector accounted for about US$2.5 billion, or 78.9%, of Japanese private-sector space revenues in FY 2010, and employed 4,483 professionals, or 67% of the Japanese private-sector space workforce. Revenues from space-related ground facilities and equipment totaled US$397 million in FY 2010, 12.5% of the total, and the ground facilities sector employed 20% of Japanese private-sector space workers. The space software sector generated US$272 million, accounting for 8.6% of Japanese private-sector space revenues and 14.1% of the Japanese space workforce.[51]

EXHIBIT 4r. JAXA Workforce by Job Type, 2011

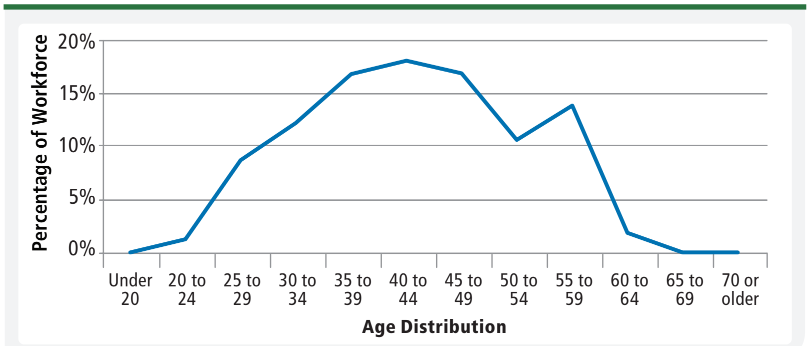


Source: JAXA, April 2011

Japan Aerospace Exploration Agency Demographics

Within JAXA, 77% of employees were in technical positions as of April 2011. These included 804 engineers who comprised 52% of the JAXA workforce, along with 251 researchers and 142 education specialists. The remaining 350 JAXA employees worked in administration.[52] The age profile of the JAXA workforce shows a more evenly distributed age profile than those of the NASA and ESA workforces, with slightly less than 60% of its workforce between 40 and 60 years old, and nearly 38% under 35.[53]

EXHIBIT 4s. JAXA Workforce Age Profile, 2011



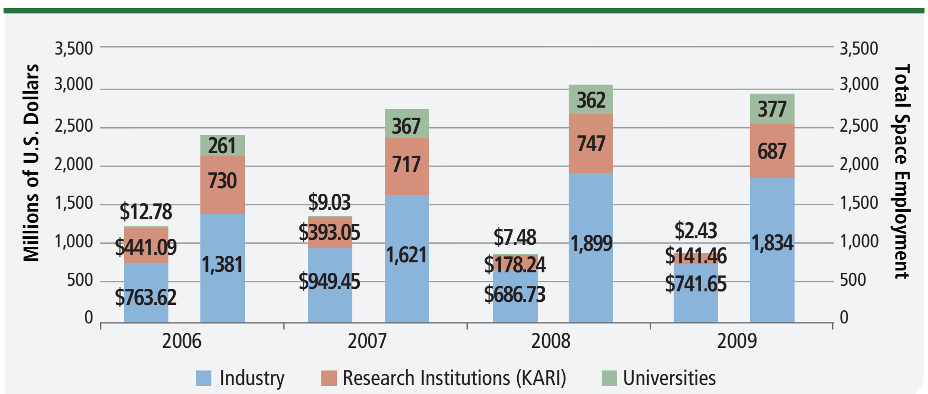
Source: JAXA, December 2011

4.4. South Korean Space Workforce

One of the most important stated goals of the South Korean space program is to develop domestic aerospace capabilities, specifically the capacity to manufacture and launch satellites. South Korea hopes to do this by investing in aerospace research and development and by strategically leveraging international partnerships.

While South Korea has made progress toward its space goals, the failures of the first two Korea Space Launch Vehicle (KSLV) launches have been significant setbacks in achieving these objectives. Nevertheless, South Korea continues to invest in its space workforce.[54] The following data, gathered by the Korea Aerospace Research Institute (KARI), reflects South Korea's space workforce as of 2009. This information was published by South Korea's Ministry of Education, Science, and Technology (MEST) in an October 2010 report, the *Aerospace Industry Survey 2010*. According to the report, the number of South Korean space-related companies has tripled from 19 in the year 2000 to 57 in 2009. In the shorter term, South Korea's private industry space revenues grew by 8% from 2008 to 2009, from US$687 million to US$742 million.[55]

EXHIBIT 4t. South Korean Space Revenue and Workforce, 2006–2009



Source: MEST, *Aerospace Industry Survey 2010*

The South Korean space workforce is divided among three sectors: private industry, government research, and universities. The industry sector accounts for the largest share of Korean space activity by revenues. Government research is dominated almost entirely by KARI, according to the MEST report.

The South Korean space workforce consisted of 2,898 people in 2009. While this represents a 3.8% drop from the 3,008 Korean space workers recorded in 2008, 526 employees were added over the period from 2006 to 2009, representing a 22% increase in the overall workforce during that time frame. The vast majority of these new employees, 453 workers, were added by the private sector.[56]

EXHIBIT 4u. South Korean Space Industry Workforce by Gender, 2009

	Male		Female		Total
	Personnel	Ratio (%)	Personnel	Ratio (%)	Personnel
Enterprise	1,651	90	183	10	1,834
Research Institutions (KARI)	597	86.9	90	13.1	687
Universities	346	91.8	31	8.2	377
Total	2,594	89.5	304	10.5	2,898

Source: MEST, Aerospace Industry Survey 2010

The two main activities of the Korean space workforce are space equipment manufacturing and space utilization. Approximately two-thirds of Korean space workers, 1,877 employees, are involved in the manufacture of space equipment, subdivided into almost-even thirds among satellite, vehicle, and ground equipment production. The remaining 1,021 Korean space workers manage Korean space assets and space-derived data, including the Kompsat-2 satellite as well as remote sensing, satellite navigation, and space science activities.[57]

The gender composition of the South Korean space industry force showed a 9-to-1 male/female ratio, which is fairly consistent with prior years, according to the *Aerospace Industry Survey 2010*.[58] The male/female ratio was highest at KARI, where men outnumbered women 13-to-1, and lowest among universities, which had an 8-to-1 ratio in the space sector.[59]

Russian space workers prepare a Proton rocket for the launch of a Telstar telecommunications satellite. The satellite, built by Space Systems/Loral, was successfully delivered to orbit in May 2011. *Credit: Roscosmos PAO*

Within KARI, 95% of employees were dedicated to research and technical activities as of 2009. These 651 technical workers were complemented by a small staff of 19 directorate-level staff, and 17 administrative and other employees.[60]

4.5 Other Space Employment

Consistent statistics on space employment for other major space countries are less available and the definition of what constitutes a space worker varies.

In December 2011, Reuters reported that the Russian space workforce numbered 250,000 professionals, 90% of whom are older than 60 or younger than 30. Demographically, Russia faces a very different situation than the United States, where these two age groups make up less than 20% of the workforce.[61]

The Organization for Economic Cooperation and Development (OECD) estimates that as of 2009, about 48,000 Chinese workers were directly employed by 40 Chinese spacecraft manufacturing companies, including both private and state-owned enterprises. It estimates that about 500,000 Chinese workers are employed in China's larger aerospace sector, of which civil space is a small subset.[62] Heritage Foundation analyst Dean Cheng assesses China's space professionals as young compared to the American and Russian workforce.[63]

While estimates of the overall Indian space workforce vary widely, the number of employees at the Indian Space Research Organisation (ISRO) is approximately 17,000.[64]

4.6 Global Space Education

The worldwide space sector employs hundreds of thousands of skilled workers who require high levels of education and competency. To maintain this workforce over time, space employers require a steady supply of trained workers capable of performing tasks in key scientific and engineering disciplines. A number of degree programs focus on skills directly pertaining to space, such as aerospace engineering, astronomy, astrophysics, and space science.

However, the precise number of students completing these degree programs is often not available, particularly in countries outside of the United States. U.S. and international data is more consistently available for STEM education as a whole. While not all STEM students work in space fields, STEM education produces students trained in space-relevant areas. STEM education is therefore an important indicator of national ability to sustain a space-skilled workforce, and countries around the world are making efforts to support growth of STEM educational programs.

4.6.1 U.S. Space-Related Education Trends

There is a broad consensus that high-quality STEM education is critical to producing a workforce capable of maintaining a competitive edge in numerous technological areas, including space.[65] However, space leaders, elected officials, and government agencies in the United States have frequently expressed concerns that the supply of potential new STEM workers is not adequate to meet future demands.[66]

To encourage students to take an interest in space-related fields, the "Space in the Classroom" event at the Advanced Maui Optical and Space Surveillance Technologies Conference in Hawaii features a chance for students to interact with an astronaut, conduct hands-on science experiments, and attend full-day workshops. *Credit: Space Foundation*

4.6.1.1 U.S. Space Sector Demand for STEM-Educated Professionals

Both the government and industry space sectors in the United States show a high demand for STEM-educated professionals. As of December 2011, 11,606 of NASA's 18,851 employees—62% of its civil servant workforce—worked in STEM-related fields, mainly as professionals working in engineering, mathematics, biological and physical sciences, or medicine. Of these, 99.7% had at least a bachelor's degree and 52.7% also held an advanced (master's or doctoral) degree. A similar distribution was evident among NASA employees hired in the past five years.[67]

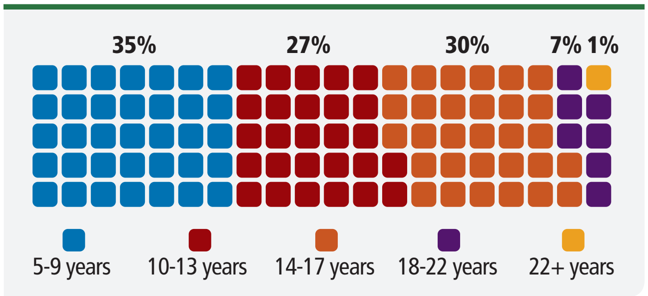
The BLS predicts that the number of professionals in several space-related occupations in the United States will grow. Nearly all these positions will require at least some college education, so trends in degree attainment will be important in determining whether this demand can be met. Exhibit 4v shows the expected growth in the number of professionals for four space-related career fields, as well as the educational requirements typically associated with each job type. While the job type with the largest number of professionals, aerospace engineers, is expected to grow at close

EXHIBIT 4v. U.S. Space-Related Occupations, Projected Growth Rates, and Education Requirements

Specialty	Description	2008 U.S. Workforce	2018 U.S. Workforce	10-year Growth Rate	Education
Aerospace Engineers	Aerospace engineers develop aircraft, spacecraft, and missiles	71,600	79,100	10%	Bachelor's degree for entry-level, Master's for advancement, Ph.D. required for teaching positions at universities
Aerospace Engineering and Operations Technicians	Install, calibrate, and operate systems used to launch, track, and evaluate air and space vehicles	8,700	8,900	2%	2-year associate or postsecondary training for entry-level, Bachelor's or Master's for advancement
Astronomers	Astronomers study the fundamental nature of the universe and its components	1,500	1,700	13%	Bachelor's degree for technician positions, Master's for jobs requiring a physics background, Ph.D. required for teaching and independent research
Atmospheric Scientists	Atmospheric scientists study the atmosphere's characteristics, motions, and processes and the way these factors affect the rest of our environment using ground, air, and space-based measurements	9,400	10,800	15%	Bachelor's degree for entry-level, Master's for advancement, Ph.D. required for teaching and research positions at universities

Source: U.S. Bureau of Labor Statistics, Occupational Outlook Handbook to the average growth rate for all occupations, demand for astronomers and atmospheric scientists is expected to grow at above-average rates. Almost all of these positions require some college education. At minimum, a two-year associate's degree or other postsecondary training in engineering technology is required for entry-level aerospace engineering and operations technicians. All other space occupations listed here generally require a bachelor's degree for entry-level positions, a master's degree for advancement, and a Ph.D. to conduct basic research or to teach at a university.[68]

EXHIBIT 4w. Age of First Interest in Aerospace



Source: MIT Survey of Aerospace Attitudes, 2009

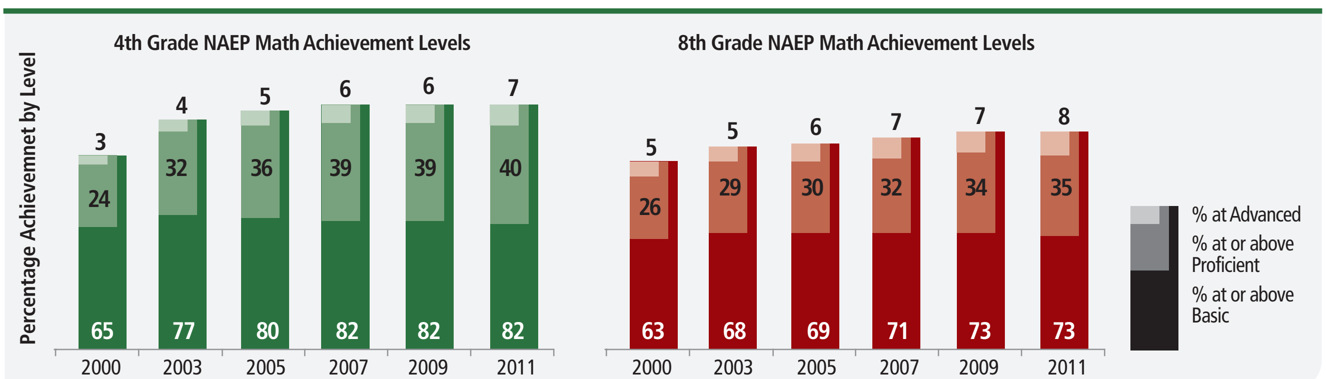
Demand for STEM-educated professionals is also reflected in surveys of major aerospace firms. In August 2011, *Aviation Week & Space Technology* released its annual U.S. aerospace workforce study, developed in association with the Aerospace Industries Association, the American Institute of Aeronautics and Astronautics, and the National Defense Industries Association. The study focused entirely on private-sector employees and was conducted via surveys of U.S. aerospace and defense contractors. Although the term "aerospace" encompasses more than space, the skills of the employees analyzed were mainly in aerospace engineering, related engineering categories, and space-related research and development activities. The study found that despite the lackluster economic climate and the fact that many veteran aerospace employees have opted to postpone retirement, U.S. aerospace companies still collectively expected to fill about 32,000 positions in 2011 and an additional 22,000 in 2012.[69] As a subset of this data, respondents also identified five critical talent fields for which skills were in high demand: systems engineering, software engineering, mechanical engineering, electrical engineering, and aerospace engineering.

Though predictions of the share of space jobs as a proportion of STEM employment are not available, STEM occupations overall are expected to comprise an increasing share of U.S. job openings. A 2011 Georgetown University Center on Education and the Workforce study projects that between 2011 and 2018, the overall number of U.S. STEM jobs will rise from 6.8 million to nearly 8 million, expanding from 4.4% of all U.S. jobs to nearly 5%. The growth rate in STEM jobs is expected to be second only to that of health care positions. Of these new STEM jobs, 90% are expected to require at least some postsecondary training by 2018, with 65% requiring at least a bachelor's degree.[70]

4.6.1.2 U.S. Supply of STEM-Educated Professionals

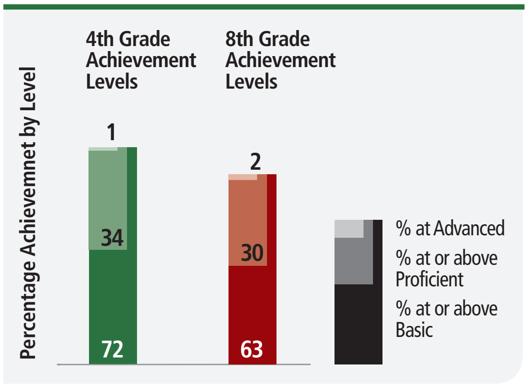
It is helpful to examine current trends in primary and secondary U.S. STEM education because this is when many potential space professionals first become interested in space. Exhibit 4w shows the results of a Massachusetts Institute of Technology (MIT) 2009 Survey of Aerospace Attitudes for approximately 1,200 aerospace engineering

EXHIBIT 4x. National Assessment of Educational Progress (NAEP) Mathematics Proficiency, 2000–2011



Source: National Center for Education Statistics (NCES)

EXHIBIT 4y. NAEP Science Proficiency, 2009



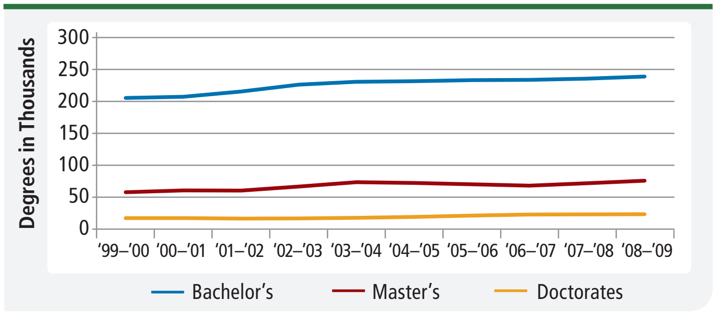
Source: National Center for Education Statistics (NCES)

students at 22 colleges across the United States. More than 90% of respondents indicated they first became interested in aerospace between the ages of 5 and 17.[71]

STEM achievement in primary and secondary schools is an indicator of how well the United States is ensuring that students are later prepared to pursue STEM degrees, enabling them to enter the space workforce. Every two years, the U.S. National Center for Education Statistics (NCES) National Assessment of Educational Progress (NAEP) uses standardized tests to rate the mathematics and science proficiency of fourth- and eighth-grade students. Based on these tests, the NAEP found that 34% of U.S. fourth-grade students and 30% of eighth graders performed at or above the proficient level for the 2009 science assessment—the most recent year for which results have been tabulated.[72] More recent results were available for the math assessment. As of 2011, 40% of fourth graders and 35% of eighth graders scored at proficient-or-higher levels on the math exam.[73] A longer-term view reveals gradual improvement in math proficiency scores at both the fourth- and eighth-grade levels, as shown in Exhibit 4x. The NAEP began to track science performance more recently, and the slight changes that have occurred are not statistically significant.[74]

At the university level, the United States produced approximately 240,000 STEM-trained bachelor's degree graduates, 75,000 master's degree graduates, and 22,000 doctoral graduates in 2009. These graduates earned degrees in physical sciences, science technologies, chemistry, geology, earth sciences, computer and information sciences, biology and microbiology, engineering and engineering technologies, and mathematics and statistics. Biomedical sciences, while a STEM field, was excluded from this analysis to avoid integrating the health care sector into the discussion of space-relevant education. Growth trends in bachelor's and master's degrees in the United States from 1999 to 2009 were similar, with rises leveling off in 2004, a slight dip in 2007, and then steadily increasing into 2009, as indicated in Exhibit 4z. Doctoral degrees over this period remained relatively stable, with small but steady growth. Over the 10-year period, the number of STEM-trained bachelor's, master's, and doctoral degree graduates increased by 16%, 32%, and 39%, respectively.[75] All three growth rates outpaced the 8.7% growth in U.S. population during that time.[76]

EXHIBIT 4z. U.S. STEM Degrees Awarded, 2000–2009



Source: National Center for Education Statistics (NCES)

According to NCES data, the top five STEM bachelor's degree-producing states in 2009 were California, New York, Texas, Pennsylvania, and Florida. Because these states are also among the most populous, this finding is not surprising; however, absolute numbers are more relevant than population-adjusted statistics for space employers interested in setting up new operations. Among the top 10 STEM bachelor's degree-producing states, Florida's production of STEM graduates grew at the fastest rate from 2000 to 2009, followed by Ohio and Massachusetts, while Illinois experienced the slowest growth. Among the top 10 STEM master's degree-producing states, Michigan and Massachusetts grew at the slowest rates, while Florida grew fastest.[77] Though not all STEM graduates will pursue space, or even STEM jobs, the growth in the number of students attaining STEM degrees is an important indicator in determining whether the United States will produce enough skilled professionals to supply its future space industry.[78] The portion of STEM graduates who specialize in space will depend on how the U.S. space industry job market continues to evolve.

EXHIBIT 4aa. Top 10 STEM Degree-Producing States, 2009

Bachelor's		Master's	
State	Degrees	State	Degrees
California	26,510	California	9,084
New York	16,637	New York	7,055
Texas	14,807	Texas	5,473
Pennsylvania	13,994	Illinois	4,751
Florida	10,531	Pennsylvania	3,869
Illinois	9,991	Massachusetts	3,505
Michigan	9,728	Florida	3,320
Ohio	8,495	Michigan	3,265
Massachusetts	7,929	Maryland	2,830
North Carolina	7,195	Virginia	2,684

Source: National Center for Education Statistics (NCES)

4.6.2 Global Space Education Trends

Just as the United States measures progress in early mathematics and science proficiency, other nations also track student progress. Many of these countries, including the United States, participate in the Programme for International Student Assessment (PISA) evaluation process. The PISA study, which is conducted every three years, tests the mathematics and science literacy of 15-year old students from the OECD member nations and several other countries.[79] The PISA test methodology and scoring differ from the NAEP test discussed earlier, which focuses exclusively on the United States. By comparing national scores against an international mean, countries can assess the average relative performance of their 15 year-old students in mathematics and science.[80]

4.6.2.1 PISA 2009 Findings Related to Countries Active in Space

An examination of PISA test scores among 14 countries active in space offers a more focused view of relative math and science literacy, which has implications for the numbers of STEM graduates each country produces and in turn the supply of STEM-skilled workers available for space-related professions. Exhibit 4bb shows national PISA test scores from 2009 for major space countries in mathematics and science.

At the University of Colorado, the field of Bioastronautics encompasses biological, behavioral, and medical aspects governing humans and other living organisms in a space flight environment. *Credit: University of Colorado*

Although China scored highest in both subject areas, these scores reflect only Chinese students from Shanghai. While these scores may be representative to some extent, they are not suitable for direct comparison to average national scores, especially since urban students tend to fare better than others on the PISA exam.[81]

Japan, South Korea, Canada, Australia, and Germany followed, with all scoring above the international mean score of 500 in both science and math in 2009. Of the 14 nations analyzed here, the United States ranked eighth in science and ninth in math.

EXHIBIT 4bb. PISA Mathematics and Science Scores for Selected Space Actors, 2009

Mathematics	Average	Science	Average
China-Shanghai	600	China-Shanghai	575
South Korea	546	Japan	539
Japan	529	South Korea	538
Canada	527	Canada	529
Australia	514	Australia	527
Germany	513	Germany	520
France	497	Spain	514
Spain	492	United States	502
United States	487	France	498
United Kingdom	483	Italy	489
Italy	483	United Kingdom	488
Russia	468	Russia	478
Israel	447	Israel	455
Brazil	386	Brazil	405

Source: PISA 2009 Profiles by Country/Economy Database

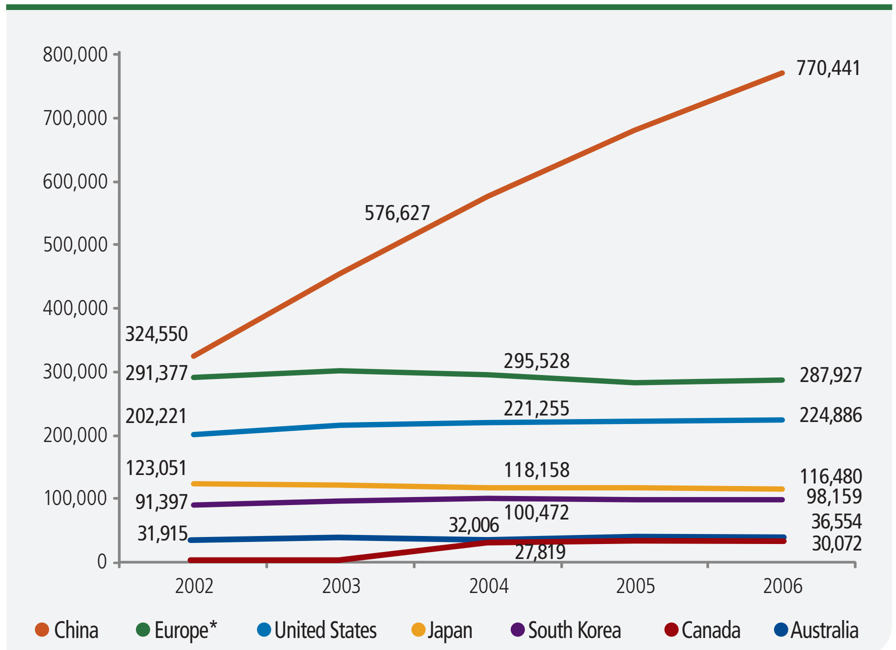
The remaining space countries all scored below the PISA average in 2009 in at least one subject. Russia achieved a score of 468 in math and 478 in science. Israel achieved a score or 447 in math and 445 in science. Brazil trailed the pack, achieving scores of 386 in math and 405 in science. Although Brazil has improved its mathematics and science scores by 16% and 8%, respectively, between 2000 and 2009, it remains well behind the PISA average.[82]

4.6.2.2 Global Trends in Higher Education

While mechanisms such as the PISA test reveal a cross-national focus on primary and secondary STEM competency, a more direct measure of the potential international space workforce is offered through a comparative analysis of STEM university graduates by country. Exhibits 4cc and 4dd show the number of STEM first-degree (bachelor's degree-equivalent) and STEM doctoral graduates, as provided by the National Science Foundation (NSF) for eight selected space countries and regions: Australia, Canada, China, Europe, India, Japan, South Korea, and the United States. Because Europe constitutes a multi-national area, the European space education metrics reflect STEM graduates of the five most populous European nations: France, Germany, Italy, Spain, and the United Kingdom. Although all eight areas reported data between 2002 and 2006, not all nations provided data for both first-degree and doctoral graduates.[83]

The number of STEM first-degree graduates among the seven regions reporting this data grew from 1,064,511 in 2002 to 1,564,519 in 2006. Of the six regions that provided data on doctoral degrees, the reported number grew from 66,004 to 87,692. The actual 2006 number was certainly higher, as India provided no data during that year.[84]

EXHIBIT 4cc. STEM First-Degree Graduates by Country, 2002–2006

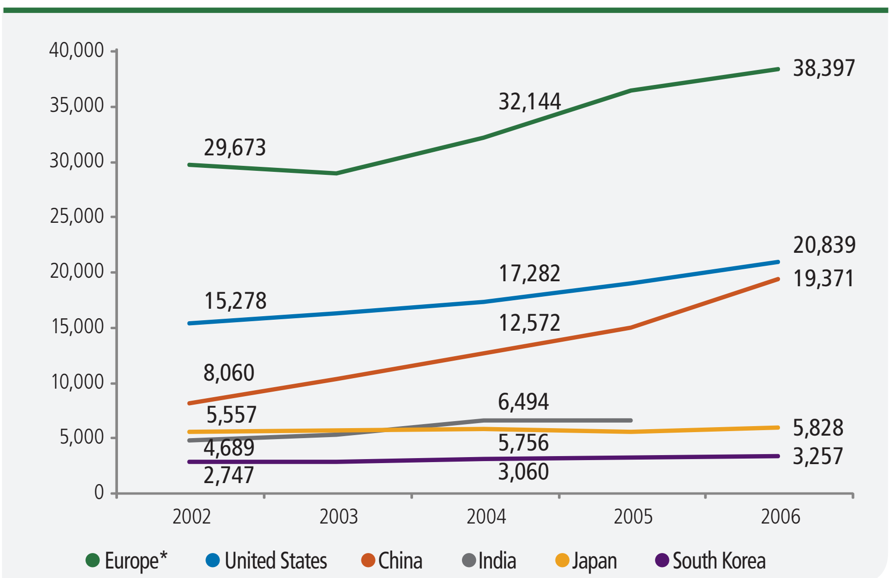


*Europe reflects graduates of five most populous European nations: France, Germany, Italy, Spain, and the United Kingdom
Note: For this analysis, First-Degree STEM Graduates include graduates at bachelor's degree or equivalent level specializing in physical or biological sciences, mathematics, computer science, and engineering.
Source: National Science Foundation Science and Engineering Indicators 2010

Between 2002 and 2006, China more than doubled its number of first-degree STEM graduates, from about 325,000 to 770,000. China also increased its rate of STEM doctoral degree production, raising its number of degrees from 8,060 in 2002 to 11,311 in 2006, a 40% increase. China's share of first-degree STEM graduates rose from 30% in 2002 to 49% in 2006, and its share of doctoral STEM graduates rose from 12% to 22%.

The United States, Canada, and Europe together comprised about 35% of first-degree STEM graduates. Japan and South Korea comprised 8% and 6%, respectively, while Australia comprised 2%. Europe led in STEM doctoral degree production, comprising 44% of the total as of 2006 and experiencing growth of 29% between 2002 and 2006. The United States comprised about 24% of the STEM doctoral degree total, having grown by 36% during the same period. Japan and South Korea accounted for the remaining 6% and 4%, respectively.[85]

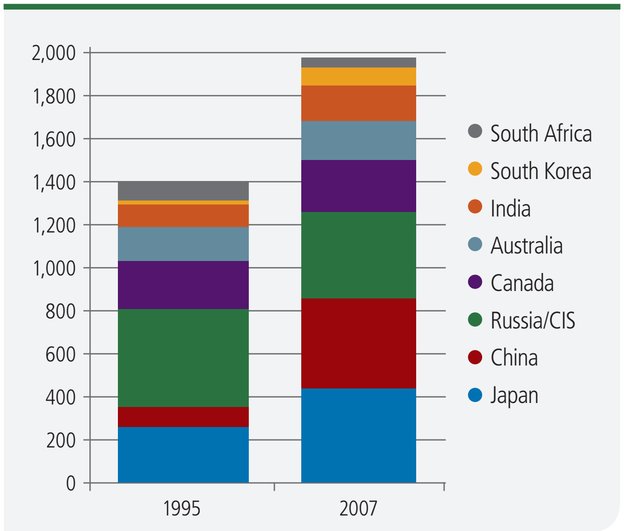
EXHIBIT 4dd. STEM Doctoral Graduates by Country, 2002–2006



*Europe reflects graduates of five most populous European nations: France, Germany, Italy, Spain, and the United Kingdom
Note: For this analysis, First-Degree STEM Graduates include graduates at bachelor's degree or equivalent level specializing in physical or biological sciences, mathematics, computer science, and engineering.
Source: National Science Foundation Science and Engineering Indicators 2010

The most important conclusions to draw from these NSF international STEM degree statistics are not specific to one country. Instead, they show that the global pool of newly minted STEM graduates trained in space-relevant disciplines and possessing first-degree levels or higher exceeded 1.6 million people as of 2006, and that this base of potential space workers could be found across different countries and regions of the world. The space job market in each country will determine the extent to which this global STEM human capital base enters the space workforce. However, the large number of STEM graduates being produced each year suggests that a shortage of technically skilled workers will not be a limiting factor in future space activity.

EXHIBIT 4ee. Publication of Academic Astronomy Articles by Selected Country or Region, 1995 and 2007



Source: National Science Foundation Science and Engineering Indicators 2010

A similar trend toward newer space countries increasing their share of global space activity is apparent in the number of scholarly astronomy articles published worldwide, which surged by 40% between 1995 and 2007, from 6,706 to 9,415. Although Canada, Europe, and the United States accounted for more than three-quarters of the total in 2007, proportionally the fastest growth came from emerging nations and regions. The number of astronomy articles published in China more than quadrupled, from 91 in 1995 to 420 in 2007, while the number of Indian scholarly astronomy articles grew by 64%, from 104 to 171.[86]

4.7 Conclusion

In 2010, the global space workforce continued to weather the effects of the global financial crisis, recession, and ongoing economic uncertainty with relative resiliency. Declines in American space employment caused hardship but were relatively small compared to the overall global space workforce. Continued increases in average U.S. space salaries suggested an ongoing demand for highly skilled workers through the immediate recession and its aftermath. Similarly, job growth in other leading space nations suggested that space retains an ability to withstand global economic slowdowns.

The number of jobs requiring STEM education is expected to grow in coming years, and BLS projections suggest that space-related occupations, which require at least some college education, are likely to grow as fast or faster than the U.S. average. The number of U.S. STEM graduates has also grown over the past 10 years, with more than 200,000 STEM graduates earning bachelor's, master's, or doctoral degrees in 2009. International education statistics show that the number of STEM-related first degrees and doctorates awarded is increasing even more rapidly in other parts of the world, particularly in China. The growing number of STEM-educated professionals around the world represents a pool of talent essential to the global space industry, enabling the industry to continue to grow as the first generation of space employees retires and new professionals enter the space workforce.

During a Space Foundation student workshop, students learn the principles of aerodynamics. Using a pressurized launch mechanism, they design, test, redesign, and launch air rockets.
Credit: Space Foundation

OUTLOOK

THE SPACE REPORT 2012

This star-forming region, called Sharpless 2-106, looks like a soaring, celestial snow angel. Twin lobes of super-hot gas, glowing blue, stretch outward from the central star. This hot gas creates the "wings" of the angel. A ring of dark dust and gas orbiting the star helps to create the hourglass shape. *Credit: NASA/ESA/Hubble Heritage Team (STScI/AURA)*

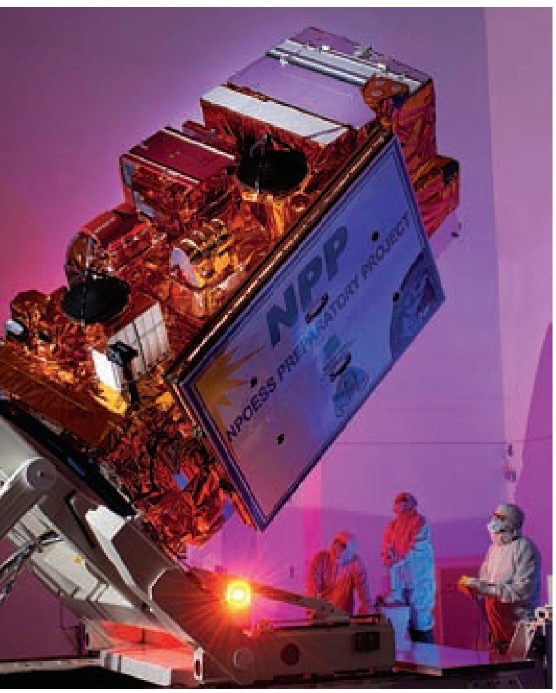
EXHIBIT 5a. Topics Covered in Outlook

5.0 Introduction

For half a century, human beings have been traveling to and from Earth's orbit. Since the April 12, 1961 flight of Yuri Gagarin, 523 spacefarers from 34 countries have flown in space.[1] The applications and services generated by space activities have become an integral aspect of life on Earth. They connect individuals, governments, and businesses. Satellites bring television and internet access to homes and offices in the most remote locations on the planet, help drivers and hikers navigate their routes, and enable emergency first responders to communicate with each other and those needing help.

Space science and discovery drive innovation and investigation at the very frontier of human understanding. From its beginning as a competition between the United States and the Soviet Union, today's space industry has evolved into a global community with a variety of multidisciplinary activities that cross national boundaries and include novel partnerships between governments and commercial entities.

In the face of increased scrutiny of government spending, governmental space activities must demonstrate both cost-effectiveness and positive societal return. Governments around the world are re-evaluating budgets devoted to space programs and making difficult investment decisions with limited funds. Times of difficulty also prompt new ways of tackling challenges. Partly in response to fiscal austerity, a host of public-private, private-private, and international partnerships are emerging in the major spacefaring nations.



The Suomi National Polar-orbiting Partnership (NPP), a 2,100-kilogram (4,600-pound) spacecraft about the size of a small school bus, was launched in October 2011. The spacecraft carries five instruments that will contribute important information for weather forecasting. *Credit: Ball Aerospace*

The potential for partnerships to drive costs down, stimulate innovation, and allocate resources efficiently is beginning to be tapped. In many respects, the promise of space exploration has never been greater in the history of humanity. Technological advancements underway allow us to monitor the Earth's health at a critical time of climatic changes, make key advancements in human health, communication and living standards, and answer fundamental questions such as how the Universe began and whether there is life elsewhere. In the first 50 years of spaceflight, civil, national security, and commercial space activities have become foundational capabilities that support and enable societal and economic good. In the next fifty years, space activities will continue to support humanity's progress and perhaps enable its greatest discoveries.

5.1 Trends That Are Shaping Space Activity

The outlook for space activity is largely positive, in spite of the challenges facing many of the governments and agencies most active in space. In many ways, 2011 was a pivotal year as governments re-evaluated their human spaceflight plans and examined their portfolio of space activities in light of fiscal constraints. On the commercial side, the relationship with government customers continued to grow and evolve, and companies partnered with each other in new and innovative ways. These trends played a significant role in 2011 and their implications are likely to affect space activity for years to come.

5.1.1 Evaluating the Future Of Human Spaceflight

In the predawn hours of July 21, 2011, the Space Shuttle *Atlantis* rolled to a stop on the Kennedy Space Center runway for the last time, marking the end of the shuttle era in U.S. human spaceflight. After 135 flights over 30 years, the vehicles—*Atlantis, Challenger, Columbia, Discovery,* and *Endeavour*—had logged approximately 1,323 days in space, completing more than 21,000 orbits of the Earth. In all, 355 astronauts from 17 different countries flew on the shuttle.[2] The program leaves a legacy of significant technical and scientific achievements and innovations, including the construction of the International Space Station (ISS), the Hubble Space Telescope, and the deployment of multiple satellites and hundreds of experiments.[3]

EXHIBIT 5b. Topics Related to Human Spaceflight

Section	Topic
1.2.7	Science, Biotechnology, and Health Care
2.1.3	Space Stations
2.2.5	Commercial Space Transportation Services
2.3	Government Space Budgets
3.1.1	Orbital Launch Vehicles
3.2	Space Stations
4.1.4	NASA Workforce Status

With the completion of core ISS facilities in 2011, more ISS crew time will be available to conduct experiments and research.[4] Accordingly, the ISS partner nations are actively identifying research topics and technology demonstrations, including Earth observation, robotic satellite servicing, solar energy, small satellite deployment, space life sciences, and space habitability technologies.[5] The U.S. laboratory module aboard the ISS, Destiny, has been designated as a National Laboratory with the purpose of ensuring that use of the ISS for experiments is expanded to a broad cross-section of the U.S. scientific and academic communities.[6]

Russian spacecraft docked at the ISS are illuminated by the Aurora Australis, seen at a point over the southeast Tasman Sea near southern New Zealand. *Credit: NASA*

Even as ISS participants conduct research, efforts to address transportation vulnerabilities continue, centering on NASA's spacecraft development programs. Following the retirement of the shuttle, the primary way to transport cargo to the ISS is now the Russian Progress vehicle, which is supplemented by Japanese and European spacecraft. However, for transporting crew to and from the ISS, the only currently viable option is the Russian Soyuz system. ISS management officials have expressed concern over the vulnerability of being dependent upon a single crew transportation system.[7] ISS access concerns were amplified due to a failure in August 2011 while launching an uncrewed Progress cargo spacecraft, which uses a version of the rocket used for human Soyuz flights. This event focused additional attention on the reliance upon Russian launch systems to sustain ISS operations.[8]

NASA has three major programs underway to reach the ISS in both the near- and long-term. In the near-term, NASA's Commercial Orbital Transportation Services (COTS) and Commercial Resupply Services (CRS) activities are expected to result in two U.S. commercial spacecraft with the ability to transport cargo to the ISS. The first delivery of cargo to the ISS via one of these spacecraft is expected to occur in 2012. These spacecraft will supplement existing ISS cargo capacity provided by Russia, Europe, and Japan. NASA is also supporting a program to develop a U.S. commercial crew space transportation capability intended to reach the ISS and other destinations in low Earth orbit (LEO). The Commercial Crew Development (CCDev) program includes a variety of partners and currently is expected to lead to a U.S. crewed space transportation vehicle in 2015 or 2016.[9] Until that time, crewed access to the ISS will likely remain dependent upon Russian systems.

NASA's third ongoing effort consists of the Space Launch System (SLS) and the Multi-Purpose Crew Vehicle (MPCV). Combined, the SLS and the MPCV are intended to be the core of NASA's next generation space exploration system, capable of servicing the ISS but primarily designed to enable crewed exploration of destinations beyond LEO. Both the SLS and MPCV build upon systems and expertise developed during the Space Shuttle Program, as well as the cancelled Constellation Program.[10] Potential destinations for crewed exploration using the combined MPCV/SLS system include near-Earth asteroids, the Moon, special gravitational points in the Earth-Moon system known as Lagrange points, and Mars.

Outlook | 5.0

EXHIBIT 5c. The Legacy of the Space Shuttle Program

Space Shuttle Atlantis final landing » STS-135 » July 21, 2011 » 9:57 a.m. UTC

THE SPACE SHUTTLE

30 YEARS | **135** FLIGHTS | **1,323** DAYS IN FLIGHT | **21,000** ORBITS OF EARTH

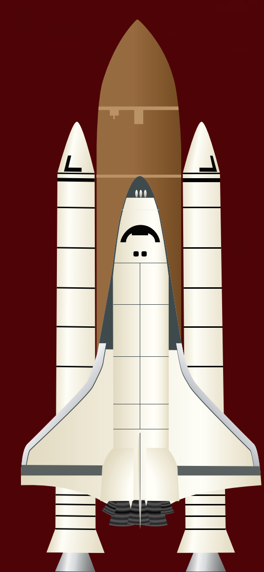
These charts illustrate the emergence of an international cadre of spacefarers who followed in the footsteps of Yuri Gagarin, whose flight on April 12, 1961, made him the first human in space. Launched from Baikonur Cosmodrome, Gagarin completed a single orbit of Earth lasting 108 minutes from launch to landing.

Of the 525 humans who orbited Earth by the end of 2011, 355 were launched aboard a U.S. Space Shuttle in the 30 years since the inaugural flight of Space Shuttle *Columbia* on April 12, 1981. Of the 355* shuttle astronauts, 306 were men and 49 were women. U.S. citizens constituted 312 of the shuttle astronauts, joined on missions by 43 spacefarers representing an additional 16 nations. The first woman to fly on the shuttle was Sally Ride in 1983, the youngest shuttle astronaut was Sultan bin Salman bin Abdul-Aziz Al Saud (28) in 1985, and the oldest was John Glenn (77) in 1998. Glenn's shuttle flight took place 36 years after his Mercury flight put a U.S. citizen in Earth orbit for the first time, just 10 months after Gagarin. Story Musgrave is the only astronaut to fly on all five Space Shuttle orbiters: *Atlantis, Challenger, Columbia, Discovery,* and *Endeavour.*

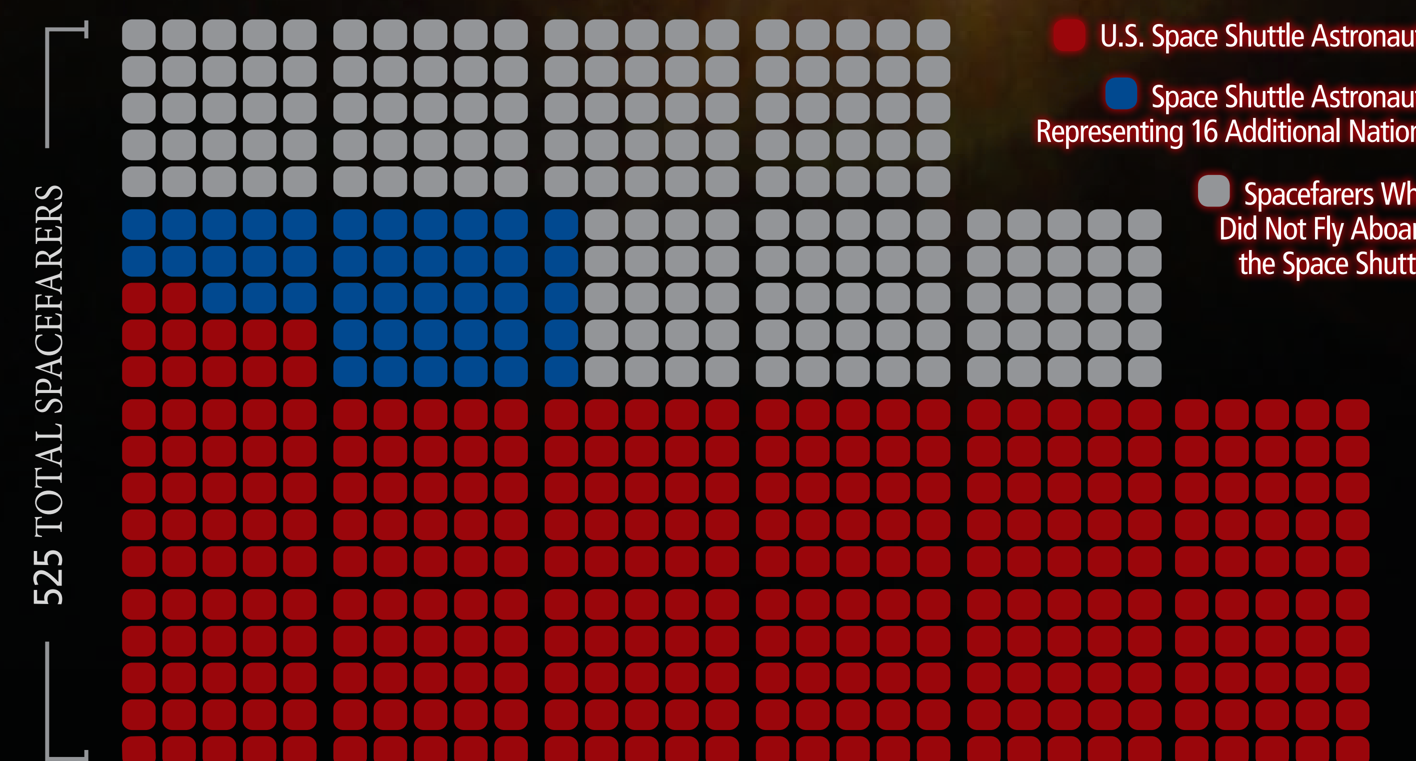
Of 36 Spacefaring Nations, 17 Flew on the Space Shuttle

● = Nations whose citizens have flown on the U.S. Space Shuttle

- Afghanistan
- Austria
- Belgium ●
- Brazil ●
- Bulgaria
- Canada ●
- China
- Cuba
- Czech Republic
- France ●
- Germany ●
- Hungary
- India
- Israel ●
- Italy ●
- Japan ●
- Kazakhstan
- Malaysia
- ● Mexico
- Mongolia
- Netherlands
- Poland
- Romania
- ● Russia
- ● Saudi Arabia
- Slovakia
- South Africa
- South Korea
- ● Spain
- ● Sweden
- ● Switzerland
- Syria
- ● Ukraine
- ● United Kingdom
- ● United States
- Vietnam



525 TOTAL SPACEFARERS 1961-2011 » 355 FLEW ON THE SPACE SHUTTLE



*The 355 shuttle astronauts collectively undertook 852 trips to space, as some individuals flew multiple missions.
Sources: CBSNews.com; NASA

With the retirement of the shuttle, China and Russia are the only countries with a current capability to launch crews into space. Although China conducted no crewed launches in 2010 or 2011, its human spaceflight program continued its ambitious but incremental development process, with significant activities expected over the coming years. In September 2011, China launched the unmanned Tiangong-1 space module, essentially a rudimentary space station.[11] In October 2011, China launched the Shenzhou 8 spacecraft, an uncrewed version of the country's human spaceflight system. Shenzhou 8 docked with Tiangong-1 in November 2011.[12] This mission provided data and a demonstration of China's rendezvous and docking systems, an important step in the overall progression of China's human spaceflight program.[13] Launches of additional Tiangong modules are expected, followed by two crewed Shenzhou launches and dockings in 2012.[14] China currently has 21 trained astronauts and is expected to begin assembly of a space station around 2020.[15]


Technicians install Dragon's solar array panels at the SpaceX hangar in Cape Canaveral, Florida. The Dragon spacecraft will rely on solar arrays to provide power for running sensors, driving heating and cooling systems, and communicating with SpaceX's Mission Control Center and the International Space Station. *Credit: SpaceX*

In India, policymakers are evaluating several options for continuing with the country's human spaceflight plans. Previously, officials from the Indian Space Research Organisation (ISRO) had indicated that the launch of an Indian astronaut on an Indian vehicle could occur before the end of the current decade. However, setbacks in India's Geosynchronous Satellite Launch Vehicle (GLSV) rocket development program may extend that timeline.

ISRO is now considering three options to advance its human spaceflight program. The first option would entail flying an Indian astronaut aboard a vehicle operated by another nation, most likely Russia. This would provide practical experience on a potential short-term time frame but would reduce the immediate technical gains India would receive from the activity. A second option is to develop a crewed spacecraft or capsule, but seek to launch it aboard a human-rated launch vehicle operated by a foreign country. The third option is the development of a complete human spaceflight system, including crew spacecraft, launch vehicle, and all associated systems.[16] The government is considering the process for human-rating one of its launch vehicles and has invested funds in studies of flight suits, life support systems, and crew escape systems.[17] The country is also planning to build a third launch pad at its space launch facility to support increasing numbers of space launches, including potential human flights in the future.[18] The ISRO chairman estimates that a formal human spaceflight development program would take seven years to complete if adequately funded, making Indian capacity for crewed spaceflight a possibility by the end of the decade.[19] India is likely to continue to invest in human spaceflight development as it also studies concepts for a reusable human-rated spacecraft, although such technology appears to be decades off.[20]


Construction begins with the first weld on the Orion Multi-Purpose Crew Vehicle (MPCV) at the Michoud Assembly Facility in September 2011. This is the first Orion capsule that will undergo a test flight in space. *Credit: NASA*

In Japan, plans to develop human spaceflight capability have been drawn up, but government support for them is less clear than for the similar activities in India. The Japan Aerospace Exploration Agency (JAXA) has developed a concept for a human mission to be carried out in 2025. The mission would use a spacecraft based upon the Japanese HTV capsule, which is currently used for ISS cargo flights. In an incremental development process, the HTV would be upgraded to be capable of returning cargo from the ISS to Earth and subsequently upgraded to support crew transportation. As of the end of 2011, the plan had not been submitted to government decision-makers for formal approval.[21]

The Prospective Piloted Transport System, currently in development, is intended to replace the existing Soyuz capsule. A concept model of the new command capsule is shown here. *Credit: Rocket & Space Corporation Energia (RSC Energia)*

In contrast to Chinese, Indian, and Japanese plans to scale up human spaceflight programs, European and Russian space agencies plan to maintain the status quo, or even scale back their involvement in human spaceflight activities. The newly installed chief of Roscosmos, Vladimir Popovkin, has stated that Russia should pursue a more balanced space program which no longer sees human spaceflight as its sole top priority. While Russia expects to maintain its commitments to ISS transportation and utilization requirements, Roscosmos will likely give more attention to technology development programs in satellite communications, navigation, and Earth observation.[22] Russia has cancelled development of its Rus-M rocket program, which was planned to carry a next-generation human spaceflight vehicle with crewed flights starting as soon as 2018. With the cancellation of Rus-M, the Soyuz family of launch vehicles will continue to support Russia's crewed flights in the near future.[23] Human spaceflight consumes nearly 50% of the Roscosmos budget, leaving fewer funds for other programs. Despite budgetary concerns, design work will continue for Russia's Prospective Piloted Transport System (PPTS), a planned replacement for the Soyuz crew capsule. The PPTS is intended to be a six-seat vehicle capable of supporting multiple mission types.[24]

Excalibur Almaz plans to use a reusable return vehicle to provide cargo and human transportation services. Customers are expected to include private enterprises, educational organizations, and governments. *Credit: Excalibur Almaz*

In Europe the situation is similar. Due in part to budget pressures and competing priorities, ESA Director General Jean-Jacques Dordain has said Europe does not have an interest in pursuing independent human spaceflight capabilities. Industry officials in Europe have echoed this sentiment. Nonetheless, ESA will maintain an astronaut corps and may contribute to international efforts to develop new crewed systems.[25] The U.S. MPCV project may provide a venue for such contribution. European officials have suggested that ESA may leverage technical knowledge developed for the ATV, Europe's ISS supply ship, to develop a service module for attachment to the MPCV. The proposed service module would supplement the existing capabilities of the MPCV to enhance the vehicle's deep space exploration capabilities.[26] NASA has formally asked ESA to explore the feasibility of this concept and is also working with other ISS partners, including JAXA and the Canadian Space Agency, to identify any similar approaches that may be used to leverage unique national capabilities. Collectively, these efforts represent an effort to extend the use of barter relationships developed during the ISS partnership to further human space exploration.[27]

In the coming years, government ventures in human spaceflight may be complemented by private sector efforts as ambitious commercial orbital spaceflight plans come to fruition. Space Adventures, the U.S. firm that has brokered eight private flights to the ISS, announced in August 2011 that it had sold two tickets for a flight around the Moon in 2016 or 2017. Space Adventures plans to utilize a Soyuz craft, and negotiations with Russia's Energia Corporation on project timing and cost are underway.[28] Excalibur Almaz, a U.S.-owned company based in the Isle of Man, is a private venture that plans to refurbish flight-proven Russian reusable Almaz space capsules and modules for flights of up to five days. The company plans uncrewed test flights beginning in late 2013, with the first crewed flights in 2014.[29]

EXHIBIT 5d. Topics Related to National Budget Austerity

Section	Topic
2.3	Government Space Budgets
4.1	U.S. Space Workforce
4.2	European Space Workforce
4.3	Japanese Space Workforce
5.2	Space Policy: Programs and Progress
5.3	Cosmic Discovery

5.1.2 National Budget Austerity is Leading to Programmatic Uncertainty

During times of economic pressure, space programs are frequently subject to budget austerity measures. As funding is evaluated, space priorities are balanced against other programs, and many space projects face programmatic uncertainty. This trend is not as visible in Brazil, China, and India, partly because their economies have not slowed as much as those of Europe and the United States.

The SLS will use a liquid hydrogen and liquid oxygen propulsion system, with Space Shuttle Main Engines already in stock providing the core propulsion and the J-2X engine, now in testing, planned for use in the upper stage. This architecture enables NASA to leverage existing capabilities and keep development costs down. *Credit: NASA*

In the midst of the current economic climate and uncertain prospects for future growth, governments are cutting spending to control their total budgets. As these cuts begin to take effect, programs and agencies are being asked to run their projects and activities with fewer resources. This requires a rethinking of programmatic approaches, which may place more emphasis on effective partnerships. This may also force policymakers to choose between competing programs. Outside of government, austerity programs affect industry plans and profits, as many companies rely upon government customers. At the same time, these budget cuts may also stimulate innovative new approaches in government-industry relations.

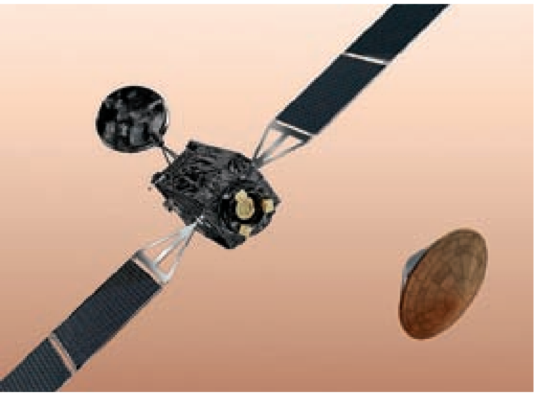
The U.S. civilian space program is directly affected by budget reductions, as policymakers evaluate which programs to cut.[30] Four high-profile programs—the SLS, the Commercial Crew Program (CCP), the James Webb Space Telescope, and the joint NASA/ESA ExoMars project—are under scrutiny, along with other less-visible activities, as policymakers develop budget plans for fiscal year (FY) 2013 and beyond. Overall, NASA expects a slight budget reduction in 2013 and future years.[31]

NASA's external safety advisory group, the Aerospace Safety Advisory Panel (ASAP), has expressed concerns that underfunding the agency may undermine its ability to replace the shuttle in a safe and efficient manner.[32] The ASAP's concern is that funding shortfalls may cause NASA to delay development or focus resources on a single commercial crew provider, thereby undermining the reliability and cost-effectiveness of the human space transportation vehicles being developed under the CCDev activity. Adding to the uncertainty surrounding funding for the CCP is concern that NASA's projected requirement of two human flights to the ISS per year might not be sufficient to support multiple commercial crew transport providers. There is also concern that funding for the SLS may compete with the funding available for CCDev and related initiatives.[33]

ASAP expects Congress to provide a flat annual budget of $3 billion to support the development of the SLS.[34] Developing a complex rocket program within a flat budgetary environment poses challenges to the agency. NASA cannot advance the development time frame for certain components of the system because funding levels cannot be shifted forward. Consequently, the agency cannot identify when it expects to start development on these components, such as a specific rocket engine, because that development requires funding which only becomes available if other components achieve development milestones ahead of schedule. This in turn leads to uncertainty for contractors and subcontractors and may pose difficulties in their ability to adequately plan for and maintain required staffing and capabilities.[35]

Technicians working on the James Webb Space Telescope inspect the prototype of a primary mirror segment. The telescope has a mirror more than twice the diameter of the one on the Hubble Space Telescope, allowing it to look further back in time to when galaxies were very young. *Credit: NASA/Chris Gunn*

A tight fiscal environment is complicated by high-profile programs which have not met their budgets. The James Webb Space Telescope (JWST) program is placing both itself and other programs in jeopardy through its significant cost and schedule overruns.[36] JWST is an infrared telescope that is the successor to the Hubble Space Telescope. When operational, it will look further back in time than any other telescope to date and will potentially make fundamental discoveries about the origin of the Universe.[37] In 2001, JWST was estimated to cost $1 billion with a 2011 launch date. In 2006, the cost estimate was $2.4 billion with a 2014 launch date. JWST is currently estimated to cost $8.7 billion by the time it launches in late 2018. Whether JWST should be considered a priority has been a subject of some debate within the space community and Congress. With approximately 75% of the spacecraft (by weight) finished or in



The ExoMars Trace Gas Orbiter, along with an Entry, Descent and Landing Demonstrator Module, were to form the first mission in the ESA-NASA ExoMars Programme and were scheduled to arrive at Mars in 2016. NASA indicated its plan to end participation in the program in its fiscal year 2013 budget request. *Credit: ESA-AOES Medialab*

production as of July 2011, driving the program to completion will arguably be the most effective use of funding, despite the cost overruns.[38] While Congress is expected to fund the completion of JWST, legislators have asked NASA to provide a list of projects that could be cut to offset the continued costs of JWST. Other programs from the NASA's Planetary Sciences Division, such as robotic Mars missions and various space probes, are now expected to pay for these overruns. NASA has already canceled the LISA gravitational wave probe and delayed the Wide-Field Infrared Survey Telescope (WFIRST) mission, which would study dark energy.[39]

A fourth high-profile program, the joint NASA/ESA ExoMars, is at risk due to funding shortfalls. For a number of years NASA and ESA have been planning an ambitious joint Mars exploration program, intended to feature missions to the planet in both 2016 and 2018. Funding challenges on both sides of the Atlantic have caused the agencies to re-evaluate their participation.[40] As of late 2011, NASA had reduced its planned $2.2 billion contribution to the 2018 ExoMars mission by approximately $700 million.[41] In NASA's FY 2013 budget request, all funding for ExoMars was removed, ending NASA's involvement in the project.[42] Meanwhile, ESA has only been able to secure €850 million ($1.2 billion) of its planned €1 billion ($1.45 billion) contribution to the project.[43] ESA is now investigating ways to further pursue the ExoMars program together with alternative partners such as Russia.[44] For reasons of orbital mechanics, missions to Mars can only be launched in certain years, meaning that disruptions to programs can cause missions to miss their targeted launch windows and have to wait for the next one.

A JAXA technician inspects the Global Change Observation Mission Water (GCOM-W1) satellite after a vibration test. NOAA has negotiated a data-sharing partnership with JAXA to use information from the satellite for weather forecasting. *Credit: JAXA*

The challenges faced by NASA are also evident in other U.S. agencies involved in space activities. Lower budget levels are contributing to the increasing likelihood of a gap in coverage in one of the core U.S. weather monitoring satellite programs. Developmental and schedule delays in the U.S. next-generation weather satellite program, the Joint Polar Satellite System (JPSS), are being exacerbated by a second consecutive year of reduced budgets.[45] Reduced funding has contributed to delays in the development of the first satellite in the JPSS series, pushing back the expected launch date to 2017. This delay means that the National Oceanic and Atmospheric Administration (NOAA) will have to rely upon data collected by a satellite that was originally designed only to test instruments to be used in the JPSS series. This satellite, the Suomi National Polar-orbiting Project (NPP), previously known as the National Polar-orbiting Operational Environmental Satellite System (NPOESS) Preparatory Project, was launched in October 2011 and has an expected lifetime of five years. NPP is expected to cease operations before the first JPSS satellite is launched, leading NOAA to believe that a data collection gap is likely.[46]

Impacts of a gap could be significant. The gap would reduce, although not eliminate, NOAA's ability to forecast severe weather events beyond three days in the future, information that the agency estimates impacts one-third of the U.S. economy.[47] NOAA is also working to demonstrate to policymakers the critical role JPSS will play in providing citizens with the most accurate forecasts, specifically linking weather satellite data with the central role of forecasting natural disasters. To demonstrate the potential impact of this data gap, NOAA recalculated forecasts for the large-scale February 2010 blizzard that resulted in up to 60 centimeters (2 feet) of snowfall across the major cities of the northeast coast of the United States. Without access to the type of data that would have been collected by an NPP or JPSS satellite, the accuracy of the snowfall forecast was reduced by approximately 50%, resulting in a forecast of a much less severe storm and likely decreasing preparation levels for the storm.[48] To mitigate this gap, NOAA will have to rely more heavily on international partnerships and data-sharing. For example, NOAA has negotiated with JAXA to secure access to data from the first Japanese Global Change Observation Mission (GCOM) satellite, which is due to launch in 2012. Data from this satellite will partially replace data that would have been collected by the technically challenging Microwave Imager Sounder instrument intended to be part of the NPOESS satellites.[49]

The military space budget in the United States is also coming under increased pressure. Prospects for the U.S. Air Force's next-generation weather satellite program, similar to JPSS, are uncertain. In September 2011, the Senate Appropriations Committee called for the cancellation of the Defense Weather Satellite System (DWSS). This follows action in 2010 in which appropriators denied the Pentagon's full DWSS funding request, arguing that the program was not a priority. However, despite moves to terminate DWSS, the Department of Defense (DoD) has been directed to develop a follow-on weather satellite program, and funding has been provided to continue some sensor and instrument development intended for DWSS. The DoD also has a fully complete satellite of the current generation ready for launch when necessary. Although the future looks hazy for DWSS, the risk of a gap in military weather forecasting capabilities is not as acute as in the JPSS program.[50]

This satellite image provided by the DigitalGlobe Analysis Center shows China's first aircraft carrier, Shi Lang, sailing in the Yellow Sea. The U.S. National Geospatial-Intelligence Agency (NGA) has contracted with DigitalGlobe and GeoEye to provide imagery as part of the EnhancedView program. *Credit: DigitalGlobe*

The National Geospatial-Intelligence Agency (NGA) is expecting to face increased cost scrutiny for its Earth observation activities in coming years. The NGA has contracted with two commercial companies, GeoEye and DigitalGlobe, to purchase Earth observation imagery for 10 years. The NGA's EnhancedView program is structured as a $7.3 billion one-year budget followed by nine one-year renewals. NGA seeks stable 10-year funding to create program certainty, but its budget is likely to be reduced in FY 2013.[51]

Pressure to reduce government spending has created significant uncertainty for one of Europe's flagship space utilization programs. In July 2011, the European Commission (EC) proposed removal of the satellite-based environmental monitoring program Global Monitoring for Environment and Security (GMES) from the EC's 2014–2020 budget. The proposal was rooted in a belief, challenged by ESA, that the project is behind schedule and at risk of significantly overrunning its planned budget.[52] In September 2011, 44 members of the European Parliament submitted a petition urging the EC to reinstate funding for the program.[53] The GMES funding situation in future years remains uncertain. It is expected it will take up to two years of negotiations among the Parliament, the EC, and national governments before the issue will be settled.[54]

Russia is considering restructuring the organization of its space program to include stronger defense ministry involvement in a bid to increase funding stability. Roscosmos has linked the need for steady financing to efforts to improve the reliability of launch and space activities, following several launch failures. It is further believed that such a move would improve discipline and oversight in manufacturing and quality control within Russian space projects.[55]

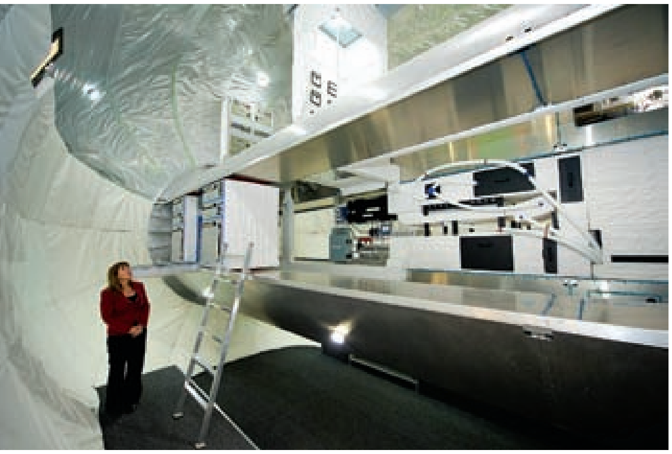
Long-term funding stability is also a concern for Canada's space community. Canada expects to see government space funding slashed over the next two years, with a 34% drop from the all-time high level of funding received in 2011. This is part of a complete overhaul and restructuring of the Canadian Space Agency's (CSA) program activity portfolio and is linked to the uncertainty facing NASA's strategy for the years ahead, as many Canadian projects are tied to NASA programs. Canada's space community fears that the remaining uncertainty in future U.S. space activities could bring severe cutbacks in space research.[56]

EXHIBIT 5e. Topics Related to Government and Commercial Space

Section	Topic
1.1	The Development of a Space Spinoff Product
2.1	Commercial Infrastructure and Support Industries
2.2.5	Commercial Space Transportation Services
2.3	Government Space Budgets
3.1	Launch Vehicles
3.3.1	Communications Satellites
3.3.2	Positioning, Navigation, and Timing Satellites
3.3.3	Remote Sensing and Environmental Monitoring

These budget-cutting trends do not uniformly affect all spacefaring countries. For example, ISRO has seen its 2011–2012 budget increased by 36% after the Indian government allotted it approximately 66 billion rupees (US$1.49 billion). The money will help finance current programs, although no significant new projects will be initiated. The funding will allow India to maintain its momentum in space since 800 million (US$17.9 million) of the 66 billion rupees is allocated to Chandrayaan-2, the lunar exploration mission being developed jointly with Russia and planned to be launched in 2013, and 660 million (US$14.8 million) for development activities related to India's human spaceflight ambitions.[57] This funding returns Indian space spending to levels close to or above those that were present before a 2010–2011 revised Indian budget resulted in significant cuts to ISRO.

Brazil is also contemplating significant increases in its space investment as it plans to overhaul its space effort. The Brazilian Space Agency (AEB) and other space projects in Brazil will be the beneficiary of an increased government investment totaling US$2.1 billion in a four-year period from 2012 through 2015.[58] In the coming year, the AEB will also pursue a merger with the National Institute for Space Research (INPE), creating a single space entity. Brazil also aims to increase funding levels in science, technology, engineering, and mathematics education. The goal of this revamping is to give Brazil its own national space launch system by the end of the decade.[59]



A visitor stands inside a full-scale mockup of Bigelow Aerospace's Space Station Alpha on display at the company's facilities in Las Vegas. NASA has been discussing potential partnership opportunities with Bigelow for its inflatable habitat. *Credit: NASA/Bill Ingalls*

The worldwide trend of budget austerity is causing concern for commercial space companies as budget pressure translates to a reduction of funding available for the government space contracts that were intended to provide core funding for a number of companies. For example, the uncertainty in NASA's crew transport development timeline and funding contributed to Bigelow Aerospace's decision to lay off 40 workers, half its workforce, in late September 2011. Bigelow's business model is dependent on commercial crew transportation services to carry astronauts to and from Bigelow's expandable space habitation module. Without the presence of a cost-effective means to send people to orbit, Bigelow Aerospace will be unable to carry out its business plan.[60]

Larger aerospace firms see impacts as well. Major commercial satellite manufactures do not expect any new large-scale government satellite programs to start in the coming years, especially in the United States and Europe. With fewer orders on the horizon, companies are looking to optimize efficiency in existing activities and to develop alternate revenue streams. These efforts include broadening activities to component and equipment manufacturing, in addition to complete system manufacturing.[61]

EXHIBIT 5f. Interactions Between Government and Commercial Space

Government Operated Spacecraft for Government Use Only	Government Operated Spacecraft for Government Use Primary Commercial Use Secondary	Commercial Operated Spacecraft for Government Use Primary Commercial Use Secondary	Commercial Operated Spacecraft for Commercial Use Primarily Government Use Secondary

5.1.3 The Maturing Relationship Between Government and Commercial Space

In an environment where budgets are stagnant or decreasing, the trend toward government use of commercial space assets and markets is growing. Various new legal and financial structures have been used by private and public entities to support national and commercial goals simultaneously. A representation of these methods of interplay between government and commercial space is shown in Exhibit 5f.

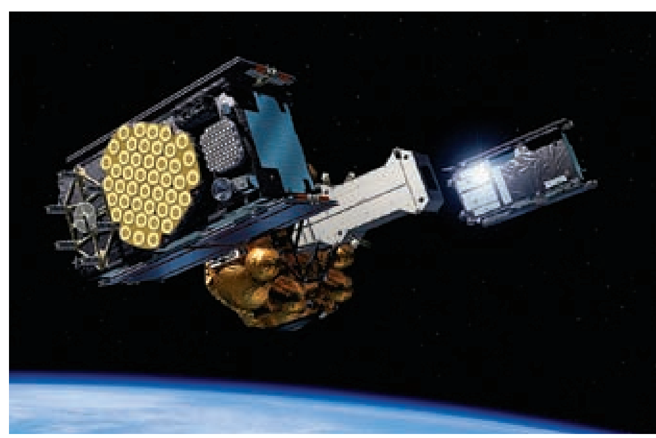
Before-and-after imagery from the GeoEye-1 satellite shows the damage at Rikuzentakata, on the Northeast coast of Japan, following the earthquake and tsunami in March 2011. According to police, every building less than three stories high was completely flooded. *Credit: Images ©GeoEye Inc. Distributed by e-GEOS.*

Where governments must operate the spacecraft for government-only or primarily government applications, they are leveraging lean manufacturing practices and multi-supplier procurement strategies for hardware. They are also augmenting budgets with revenues generated by sales of services on the commercial market.

In situations where a government is the primary customer but secondary markets exist, nations can choose to procure services from commercially operated spacecraft in order to allow commercial operators to design systems that can serve the needs of government and commercial markets. Allowing commercial providers to serve secondary markets increases the overall market size, enabling economies of scale and attracting multiple suppliers that will compete, driving down cost and promoting innovation. Additionally, governments increasingly rely on services provided by commercial suppliers. These services are often more cost-effective than government-only systems because commercial operators can attain greater operational efficiencies by selling satellite services to the commercial market when a government is not using a satellite.

For government-operated spacecraft, nations are generating revenue to support these programs by selling products and services on the open market. An example is e-GEOS, an Italian company that sells high-resolution imagery collected by government-operated satellites, such as the COSMO-SkyMed system of radar satellites. Other examples of national imaging programs using this model include Germany's TerraSAR data sold through Astrium Services, India's remote sensing satellites data sold through the Antrix Corporation, and South Korea's KOMPSAT data sold through KAI Image.

Satellite navigation is an example of a government-provided utility that has resulted in the creation of a strong market for innovative commercial products and services. The decision by the United States to regard its global positioning, navigation, and timing (PNT) systems as a global utility created a large market for commercial suppliers to develop products and services. In a virtuous cycle, innovation driven by the commercial market benefits both government and private users of satellite navigation products and services. The broad reliance on PNT systems makes their development a national priority, as evidenced by robust planned spending on global systems by the United States, Europe, China, and Russia, as well as smaller planned spending on regional systems by India and Japan.



Launched in October 2011, two Galileo In-Orbit Validation satellites are simultaneously ejected from the upper stage of the Soyuz launcher. When complete, the global navigation system will consist of 30 satellites. The European Commission has worked to contain program costs by procuring satellites from two different providers. *Credit: ESA/P. Carril*

Europe is using a competitive multi-provider procurement strategy to drive down the cost of deploying its Galileo satellite navigation system. Galileo is currently estimated to cost approximately 40% more than its original planned budget.[62] In November 2011, the EC announced its intention to procure eight more Galileo navigation satellites for approximately $270 million.[63] This procurement was only possible due to the EC's decision earlier in the Galileo program to procure satellites from two different providers. The companies competing for the contract will have an incentive to offer lower prices in order to be successful.

NASA is attempting to stimulate development of a cargo transportation system to the ISS by using a multi-provider procurement strategy featuring carefully selected, high-level performance requirements that encourage commercial industry to create solutions that can serve NASA as well as other related markets. An example of this approach is the multi-phased COTS demonstration mission. The COTS program is unique in that it leverages the flexible NASA Space Act Agreement, which can be used to stimulate development of new services but not to directly purchase them. NASA invested approximately $500 million from 2006 through 2011 toward cargo space transportation flight demonstrations.[64] The program required developers to provide a certain level of their own financing in addition to the COTS funding. Developers of the transportation systems plan to use the launch vehicles to serve adjacent markets. For example, SpaceX currently has a manifest that includes 20 launches for non-NASA customers through 2017 using the same launch vehicle developed in part through COTS.[65]

The Cygnus spacecraft is being developed by Orbital Sciences to demonstrate cargo delivery services under the Commercial Orbital Transportation Services program and to carry out ISS resupply flights. *Credit: Orbital Sciences*

NASA's strategy to stimulate development of crew transportation capability via the Commercial Crew Development Round 1 and Round 2 initiatives (CCDev1 and CCDev2) uses a multi-provider approach. Like COTS, these initiatives seek to stimulate development of technologies that could be used by a commercial operator to supply passenger services to NASA and others. In addition to NASA providing funding for some candidate CCDev1 and 2 proposals, it has also signed non-funded Space Act Agreements with suppliers that grant access to NASA knowledge and facilities to support development of capabilities that could serve NASA or other clients.

In lieu of a CCDev3, in September 2011, NASA announced the Integrated Design Contract (IDC), a procurement that will award up to $1.61 billion in funding to multiple companies to provide a complete end-to-end design, including spacecraft, launch vehicles, launch services, ground and mission operations, and recovery.[66] Although the IDC will use a modified form of the Federal Acquisition Regulations used for procurement throughout much of the government, rather than the more flexible Space Act Agreement, NASA is trying to adopt the best features of the successful Space Act Agreement approach. NASA will not own the vehicle designs. Instead, industry will be able to develop designs that not only meet NASA's basic requirements but can be designed with other commercial customer requirements in mind. The Space Shuttle Program complied with roughly 10,000 requirements that had to be validated through six levels, down to the nuts and bolts. The new procurement will be managed using approximately 600 requirements, with NASA overseeing the top two requirement levels.[67] Levels three to six will be managed by the contractors. In addition, NASA will waive the requirement to provide certified cost and pricing data, allowing new, innovative companies that may not have a certified accounting system to compete. IDC will also use commercial-like performance-based funding milestones. This strategy will ideally allow flexibility to create innovative, cost-effective solutions that will be viable for NASA's needs as well as viable in the commercial market.

The U.S. military is also considering a range of commercially focused practices aimed to enhance the affordability of its government-operated satellite architectures. In January 2011, the U.S. Air Force Space and Missile Systems Center (SMC) announced the award of four contracts totaling $3.7 million for MILSATCOM Commercial Architecture Options. With the first phase beginning in 2011, these studies will determine the feasibility of using commercial satellites for MILSATCOM requirements within military frequencies.

Perhaps the most striking example of the growth of government dependence on the private sector is the strong reliance of the United States and some European and Middle Eastern militaries on commercial satellite communications to support military operations around the world. In times of conflict, military users can access the commercial networks to supply communications where there may not be adequate military operated capacity available. Commercial communications satellites encircle the globe, serving a total market demand of

7,500 transponders of capacity or an estimated 325 gigabits per second of throughput. Military demand for unsecured capacity is estimated to compose only about 6% of total demand.[68] This relatively small percentage, however, supports the majority of the throughput requirement of military satellite communications. Increased use of remotely piloted aircraft and other intelligence, surveillance, and reconnaissance assets, as well as increased sensor sophistication, could drive reliance on commercial capacity for as much as 90% of military requirements.[69] To better support government usage of commercial satellite communications and to increase competition among commercial providers, the U.S. Defense Information Systems Agency (DISA) and the General Services Administration (GSA) consolidated multiple procurement paths into one. In 2011, military users of commercial services continued transition to the new vehicle, called the Future COMSATCOM Services Acquisitions (FCSA) program. FCSA features three levels of competition in order to promote competition among the various types of providers.[70]

EXHIBIT 5g. Planned Entrepreneurial Space Milestones

Company	Year	Description
Orbital Sciences	2012	First launch of Antares on Commercial Orbital Transportation Services demonstration mission
Orbital Sciences	2012	First Cygnus cargo-carrying mission to the ISS
Sierra Nevada	2012	Dream Chaser drop flight testing begins
SpaceX	2012	First docking of Dragon spacecraft with the ISS
SpaceX	2012	First launch of Falcon Heavy
Virgin Galactic	2012	First flight of SpaceShipTwo in space
XCOR	2012	Flight tests of Lynx begin
Excalibur Almaz	2013	First commercial flight
Google Lunar X PRIZE	2015	Google Lunar X PRIZE expires

A mix of emerging companies in the United States and other nations, collectively referred to as the "entrepreneurial space" sector, are creating new commercially developed products and services for government and commercial users. These companies are developing products such as innovative spacecraft components, vertical takeoff and landing technologies, new vehicles for suborbital spaceflight, inflatable space structures and habitats, and new orbital cargo and crew launch systems. The companies often employ relatively small workforces, maintain minimal overhead costs, and feature a culture focused on as much hands-on prototyping and testing as possible. As with any developing industry, some of these companies will be successful while others will fail. However, those that can deliver solid products and services have the potential to foster innovation in the space industry. A list of entrepreneurial development milestones is shown in Exhibit 5g.

While a maturing interplay of government and commercial space exists, the pendulum may swing back toward traditional government operated systems if commercial providers fail to deliver adequate products, accidents occur, or the fiscal environment loosens and governments choose to spend more money on space. In the United States, political battling has already led to significant cuts in funding for NASA's commercial crew development program based in part on the belief that multiple competing providers are not necessary. Ironically, in a fiscal environment where many U.S. military space programs have received large budget cuts, funding has remained strong for new government operated communications systems that, in many ways, provide capabilities similar to those available on the commercial market

EXHIBIT 5h. Topics Related to Partnership Models

Section	Topic
2.1	Commercial Infrastructure and Support Industries
2.2.5	Commercial Space Transportation Services
2.3	Government Space Budgets
3.1	Launch Vehicles
3.3.2	Positioning, Navigation, and Timing Satellites
3.3.3	Remote Sensing and Environmental Monitoring
3.6	Observatories and Robotic Exploration Systems

5.1.4 Diverse Partnership Models Increase in Prevalence

Partnership and cooperation are becoming more prevalent as standard elements of successful space activities. The boundaries that separate space companies, national space programs, and space-related economic sectors are blurring as collaboration becomes a key aspect of success. This evolution is driven by a combination of factors, including budgetary pressures forcing an emphasis on creativity and efficiency; an increasingly diverse set of actors in the global space community; and the ever-growing technical capabilities distributed throughout the government, industry, and academic sectors. Building from activities in prior years, 2011 saw a number of space community partnerships result in operational and programmatic success, even as new activities emerged.

One partnership that continued to grow successfully in 2011 was the Space Data Association (SDA). Founded in 2010, the SDA is a nonprofit partnership of the world's largest commercial communications satellite operators. The organization's purpose is to coordinate satellite maneuvers and reduce the likelihood of collision and signal interference through the sharing of satellite location data. In September 2011, the SDA announced it had achieved full operational capability.[71] The organization also expanded its membership from the initial three founding members by adding seven member companies in 2011.[72] The SDA now provides collision and interference risk calculations for more than 65% of the operational satellites in geosynchronous orbit.[73]

Building from its early operational successes, the SDA is looking to expand its role in the global space community. The organization is working to establish data-sharing agreements with governments and space companies.[74] Membership in the SDA is open to all government and commercial satellite operators who agree to an unusual structure which includes a legally binding data-sharing requirement as a condition of membership.[75] This data sharing entails exchange of information that could be used to competitive advantage—satellite position and maneuvering information. The SDA takes this sensitive data and, as a neutral broker, provides value to all participants. In its current form, the SDA represents a novel partnership model in which companies that are competitors in many activities are collaborating for the common good. The SDA is also notable because it provides a paradigm-shifting supplement to the more traditional approach to space debris, which relies on data supplied by governments.

EXHIBIT 5i. Space Data Association Members, 2011

Company	Headquarters Country	Sector
Executive Members		
Eutelsat	France	Satellite Telecommunications
Inmarsat *	United Kingdom	Satellite Telecommunications
Intelsat *	Luxembourg	Satellite Telecommunications
SES *	Luxembourg	Satellite Telecommunications
Members		
AMOS-SPACECOM	Israel	Satellite Telecommunications
Avanti Communications	United Kingdom	Satellite Telecommunications
EchoStar Satellite Services	United States	Satellite Telecommunications
GE - Satellite	United States	Satellite Telecommunications
GeoEye	United States	Earth Observation
Paradigm	United Kingdom	Satellite Telecommunications
Space Systems/Loral	United States	Satellite Manfacturing
Star One	Brazil	Satellite Telecommunications
Chief Technology Adviser		
Analytical Graphics, Inc. (AGI)	United States	Software
Corporate Administrator		
ManSat	Isle of Man	Financial Services

** Indicates founding member*
Source: Space Data Association

Another area for cooperation is in industry efforts to advance the use of hosted payloads, or the use of excess capacity on satellites for additional instruments or payloads.[76] Typically, a hosted payload arrangement features a secondary payload operated by someone other than the operator of the satellite's primary payload. Use of hosted payloads represents a departure from the traditional mission architecture of a dedicated satellite or a grouping of similar instruments on a single satellite platform. Hoping to take advantage of a growing momentum behind the hosted payload model, in March 2011 a group of seven U.S. satellite companies formed the Hosted Payload Alliance (HPA) to increase awareness within U.S. government and industry of the potential benefits of the hosted payload concept.[77] Many of the members of the HPA are competitors. As in the case of the SDA, by working together through the HPA, the companies hope to advance the cause of an operational model that benefits them all by providing an additional revenue source. For government customers using hosted payload opportunities, the primary benefits are increased cost effectiveness and more flexible flight opportunities.[78]

Interest in hosted payloads is also expanding within the DoD. In 2011, the U.S. Air Force established a dedicated office to explore the increased use of hosted payload opportunities on commercial satellites for DoD programs.[79] The mission of the Hosted Payload Office (HPO), within the Air Force's SMC, is to match Air Force programs with hosted payload opportunities.[80] The SMC hopes to build on experience gained through its Commercially Hosted Infrared Payload (CHIRP), launched in September 2011 aboard the SES-2 communications satellite operated by Dutch satellite communications provider SES World Skies.[81] CHIRP is a flight-demonstration program providing in-space testing of a new sensor technology.[82] Importantly, the project also tests new partnership models and

In addition to its commercial payload, the SES-2 communications satellite also includes the Commercially Hosted Infrared Payload (CHIRP) for the U.S. Air Force. Benefits of hosted payloads include increased cost effectiveness and more flexible flight opportunities. *Credit: Orbital Sciences*

operating practices for the Air Force, providing SMC with insight into the nature of operating a hosted payload. Air Force officials see hosted payloads eventually replacing some of the functions currently provided by free-flying satellites, such as missile-launch detection and communications.

Interest in hosted payload partnerships extends far beyond the U.S. government. Motivated by the same cost efficiency that drives potential government users of hosted payloads, private-sector space organizations are expressing interest in using the same model. Commercial satellite communications companies, in particular, are coming to view the utilization of hosted payloads as a means to broaden service offerings.[83] The scientific research community is also interested in the approach. In October 2011 the Johns Hopkins University Applied Physics Lab announced that it had applied for NASA grant funding to support the placement of a network of 66 scientific instruments as hosted payloads aboard the commercial Iridium NEXT constellation of mobile communications satellites.[84]

Government agencies outside the United States are also interested in hosted payload utilization. One member of the HPA, U.S. satellite manufacturer Space Systems/Loral, sees foreign governments as more willing than U.S. government agencies to use hosted payloads. Space Systems/Loral has built commercial satellites that include hosted payloads for government customers in Japan, Australia, and Spain. The company is manufacturing a communications satellite for SES, due to launch in 2012, that will carry a hosted navigation payload as part of the European Geostationary Navigation Overlay Service (EGNOS). Space Systems/Loral is also manufacturing a satellite which includes a hosted communications payload for the government of Qatar.[85] International hosted payload arrangements of the types undertaken by Space Systems/Loral and its customers not only cross commercial and national boundaries, but also provide a vector for non-traditional spacefaring nations, such as Qatar, to acquire space capabilities in a cost-effective manner. As hosted payload support becomes a more common feature offered by satellite operators and manufacturers, the range of customers operating hosted payloads is likely to expand. International collaborations similar to the SDA and HPA are increasingly becoming commonplace in commercial space operations and manufacturing.

The space launch services sector is another prime example of the cross-border relationships in the space

EXHIBIT 5j. Selected Current and Planned Hosted Payload Relationships

Hosted Payload			Host Satellite	
Hosted Payload Operator	Payload Name/Type	Country	Host Satellite Operator	Country
U.S. Federal Aviation Administration	Wide Area Augmentation System (WAAS)	United States	Intelsat	Luxembourg
U.S. Federal Aviation Administration	WAAS	United States	Telesat	Canada
U.S. Coast Guard	Nationwide Automatic Identification System (NAIS)	United States	Orbcomm	United States
U.S. Department of Defense	Internet Router In Space (IRIS)	United States	Intelsat	Luxembourg
U.S. Air Force	Commercially Hosted Infrared Payload (CHIRP) Flight Demonstration Program	United States	SES	Luxembourg
NASA	Global-scale Observations of the Limb and Disk (GOLD)	United States	SES	Luxembourg
NASA	Multispectral Imaging System for the Thermosphere and Ionosphere (MISTI)	United States	Intelsat	Luxembourg
NASA	Thermosphere Ionosphere Global and Regional Imaging System (TIGRIS)	United States	Intelsat	Luxembourg
Australian Defence Force	Specialized UHF communications payload	Australia	Intelsat	Luxembourg
European GNSS Supervisory Authority	European Geostationary Navigation Overlay Service (EGNOS)	Europe	SES	Luxembourg
ictQATAR	Ku-band Communications Payload	Qatar	Eutelsat	France

Sources: U.S. Department of Commerce, Space Systems/Loral

EXHIBIT 5k. International Partners in NASA Commercial Space Transportation Programs

NASA Initiative	Lead Company	Major International Partners	Use of Atlas V*
CCDev (Unfunded)	ATK	Europe – EADS-Astrium	
CCDev (Funded)	Blue Origin	None	✓
CCDev (Funded)	Boeing	None	✓
CCDev (Unfunded)	Excalibur Almaz	Europe – EADS-Astrium Japan – Japan Manned Space Systems Russia NPO – Mashinostroyenia (NPOM)	
COTS/CRS	Orbital Sciences	Ukraine – KB Yuzhnoye and PA Yuzhmash Italy – Thales Alenia Japan – Mitsubishi Electric Corporation	
CCDev (Funded)	Sierra Nevada	None	✓
COTS/CRS/CCDev	SpaceX	None	
CCDev (Unfunded)	United Launch Alliance	Russia – NPO Energomash	✓

**The Atlas V launch vehicle relies upon RD-180 engines supplied by Russian firm NPO Energomash. The engines are modified for use in the Atlas family by a joint venture of Energomash and Pratt & Whitney Rocketdyne known as RD AMROSS.*
Sources: Satellite Spotlight, NASASpaceflight.com, Excalibur Almaz.

industry. The supply chains and service relationships that support the launch industry have long been international in nature. For instance, the Atlas V rocket—a mainstay of the U.S. satellite launch sector since 2002—uses a Russian-built rocket engine in its first stage and a payload fairing manufactured by a Swiss company.[86] A number of developments underway in global launch vehicle programs in 2011, and moving into 2012 and beyond, emphasize the global partnerships that support this critical element of space activities.

NASA is currently supporting many commercial partnerships aimed at developing new space launch or transportation systems. These partnerships take a number of forms, but a key facet is international participation at the subcontractor level. U.S. spacecraft and launch vehicle manufacturer Orbital Sciences is one of two private firms developing systems to provide cargo services to the ISS. Orbital's system, with a planned first demonstration launch in 2012, consists of a launch vehicle known as Antares (formerly Taurus II) and a pressurized cargo spacecraft known as the Cygnus.[87] Key parts of both the rocket and the spacecraft come from suppliers in four countries. The Antares launch vehicle will use a Russian first-stage engine and fuel tanks supplied by Ukrainian firms KB Yuzhnoye and PA Yuzhmash. The Cygnus spacecraft will carry cargo modules manufactured by Thales Alenia Space of Italy and rely on a proximity detection system built by Japanese company Mitsubishi Electric Corporation. Although use of this diverse international supply chain can pose a challenge in system integration and assembly, it also allows Orbital to source components with the highest degree of technical pedigree and heritage.[88]

Representing a collaborative effort between ATK, the U.S. manufacturer of the Space Shuttle's Solid Rocket Boosters, and EADS, the European manufacturer of the Ariane 5 launcher core, the Liberty launch vehicle is designed to serve various markets, including crew, cargo, and satellite launch. *Credit: ATK*

International partnerships are also evident in many of the CCDev efforts supported by NASA. One of the program participants, U.S. solid rocket booster manufacturer ATK, is hoping to increase interest in its Liberty launch vehicle. Aiming for a first launch in 2015, the Liberty vehicle is targeted for NASA and DoD use. Liberty would feature a first stage developed by ATK and would use the core stage of the European Ariane 5 launch vehicle as its upper stage. In its nascent stage of development, the Liberty project represents a collaboration between NASA, a U.S. firm, and a European firm.[89] Four of the other CCDev partners propose use of the Atlas V launch vehicle, which relies upon Russian manufactured engines.[90]

Activities at two launch facilities in South America demonstrate similar dynamics. In October 2011, a Russian-built Soyuz vehicle launched from the Centre Spatial Guyanais (CSG), Europe's launch site in French Guiana. The launch was the first of a Soyuz vehicle from a non-Russian facility and represented the maturation of a 15-year partnership between the French company Arianespace, the Russian space agency Roscosmos, the French space agency CNES, and ESA.[91] While managing the international supply lines and relationships inherent in the project was difficult and the program suffered delays, the ability to launch Soyuz from

CSG provides a host of advantages to the partners. For Arianespace, the ability to offer Soyuz in international commercial satellite launch markets provides increased flexibility and an expansion of potential customers. For ESA and CNES, the addition of Soyuz as a launch option provides Europe with a mid-class launch vehicle between Ariane 5 and the small Vega vehicle, saving costs associated with development of a mid-class vehicle.[92] For Roscosmos, the ability to launch Soyuz from CSG gives it the option to launch significantly larger payloads, due to substantial geophysical advantages offered by CSG's proximity to the Equator.

The first flight of the new Vega launch vehicle took place in February 2012 from French Guiana. Vega is designed to place satellites weighing 300–2,000 kilograms (660–4,400 pounds) into the polar and low Earth orbits used for many scientific and Earth observation missions. Vega can be configured to launch payloads ranging from a single satellite up to one main satellite plus six microsatellites. *Credit: ESA/S. Corvaja*

In Brazil, another launch vehicle partnership is maturing. Since 2003, Brazil and Ukraine have been jointly working on the development of a medium-class launch vehicle. The Cyclone-4 will use Ukrainian technology and launch from Brazil's Alcântara launch center. The program is now entering the final phases of development with the first launch expected in 2013.[93] In 2011, the Ukrainian government backed a $260 million loan to complete physical modifications to the Alcântara site, and Brazilian officials have granted permission to use the facility.[94] The first launch of the Cyclone-4 will carry the NANO-JASMINE satellite, built by a Japanese university.[95] Cyclone-4 project officials expect up to six launches per year once the program is operational.[96]

The Cyclone-4 project is not the only investment Brazil is making in its launch programs. Brazil's space agency, AEB, is collaborating with Russia on the potential development of a collection of launch vehicles known as the Southern Cross family. The project begins with an effort to improve upon Brazil's Satellite Launch Vehicle-1, which was put on hold following a fatal vehicle explosion in 2003. The Southern Cross program, which is not expected to see a launch before 2022, is tied to new efforts to expand the size and scope of Brazil's space program and boost commercial returns from space investment.[97]

The U.S. portions of the International Space Station were officially designated a National Laboratory in the 2005 NASA Authorization Act. The nonprofit organization CASIS is working on plans to encourage station utilization. *Credit: NASA*

Innovative partnerships will continue to expand into areas whose outcomes and benefits cannot be easily predicted. In September 2011, NASA entered into a partnership with a nonprofit organization, the Center for the Advancement of Science in Space (CASIS), which will be responsible for managing the portion of the ISS that functions as a U.S. National Laboratory. CASIS will be responsible for managing at least 50% of U.S. research activities on the ISS, with the goal of fostering basic and applied research in a range of fields.[98]

Global space activities are now characterized by technical and organizational partnerships that reach across national and commercial boundaries and between the public and private sectors to achieve programmatic and commercial goals. Driven by funding pressures, the increased number of capable actors, and ever-advancing technical capabilities, such collaborations continue to mature and diversify across the realm of space activities. In many cases, commercial and international engagement is seen as a key element of ensuring program success. Such engagement, while often increasing overall project complexity and total project cost, allows participants to share both the burdens and benefits. At the individual participant level, partnerships can reduce both costs and technical complexity, allowing the pursuit of space programs or projects that may be unworkable on an individual basis.

5.2 Space Policy: Programs and Progress

As space activities across the globe become more dynamic—blending commercial, government, and cross-border activities—governments increasingly see a need for a formal space policy to provide a framework for coordination and integration of activities. Effective space policy can foster public interest in space activities, establish guidance for development of industrial capability, and set the stage for effective international cooperation. In the absence of clear and effective space policy, government space activities are likely to develop in a manner that may present long-term sustainability challenges.[99]

5.2.1 Trends in National Space Policies

National space policy sets the strategies and objectives that define a government space program. In general, a space policy provides direction and a conceptual framework for the creation of laws and budgets, but is binding neither in statute nor budget.[100] In some cases, elements of the guidance provided by a space policy can be embedded in statute, as is the case in Japan's Basic Space Law or the U.S. National Aeronautics and Space Act of 1958. A space policy describes the context in which a government sees the international and domestic space environment, placing its own activities in relation to the activities of others. It can set goals for how government space projects and activities are to be developed in light of that environment and how those programs relate to other issues. National space policies, which can pertain to both civil and military programs, often share common thematic elements across different countries.

EXHIBIT 5I. Selected Major National Space Policy Documents, 2009–2011

Country	Document Name	Month of Release
Australia	Principles for a National Space Industry Policy	September 2011
China	China's Space Activities in 2011	December 2011
Europe	Towards a Space Strategy for the European Union that Benefits Its Citizens	April 2011
Germany	German Space Strategy	November 2010
Italy	Italian Space Agency Strategic Vision 2010–2020	October 2010
Japan	Basic Plan for Space Policy	June 2009
South Africa	National Space Policy	March 2009
Sweden	The Swedish National Space Board's Long-term Strategy Focused on 2011–2015	November 2010
United States	National Space Policy	June 2010
United States	National Security Space Strategy	January 2011

In Europe, space policy is a complex issue that not only involves multiple agencies within a given nation, but involves coordination across multiple nations, intergovernmental organizations such as ESA and the European Organisation for the Exploitation of Meteorological Satellites (EUMETSAT), and EU governance institutions. In April 2011, the EC published a strategy document which aims to provide coordination of themes for space policy development across all levels of European space activity. The document defines why the EU is involved in space, what its main space priorities are, and how its space activities will benefit citizens of EU countries. Priority areas include satellite navigation, climate change and environmental monitoring, satellite communications, protecting space infrastructure, space exploration, space research and development, and industrial competitiveness. The document also discusses the international cooperation element of Europe's space strategy.[101]

A major theme discussed in the strategy document is governance and coordination of European space activities across the various nations and organizations involved. The document notes that the fragmented space program management in Europe is not conducive to effective decision making and financial investment for large projects. To address this problem, the EC is developing a more formal legal framework to govern European space activities and coordinate the efforts of the EU, ESA, EUMETSAT, and national governments. The framework would be established under the auspices of the Lisbon Treaty, which governs the EU.[102]

The issues discussed in the EU document are commonly addressed in many space policy documents worldwide. The *National Space Policy of the United States of America*, released in June 2010, also makes specific mention of satellite navigation, industrial competitiveness, protecting in-space infrastructure, and environmental monitoring and Earth observation.[103] In Australia, the Department of Innovation, Industry, Science and Research released its *Principles for a National Space Industry Policy* in September 2011. The Australian policy also includes discussion of these space applications. As with both the EU and U.S. documents, Australia's policy includes discussion of the importance of international cooperation in executing space strategy.[104]

Military space activities are often the focus of their own dedicated policy statements. In January 2011, the United States released the *National Security Space Strategy* (NSSS). The strategy defines the overarching approach for military and national security activities for the next decade. The central theme of the NSSS is maintaining active U.S. leadership in space. To that end, the document defines principles for protecting U.S. space infrastructure, developing the space industrial base, and promoting the peaceful use of space. The NSSS also gives significant attention to the role of international cooperation in maintaining a beneficial space environment. The document defines a DoD concept of the space environment that is increasingly congested, contested, and competitive. "Congested" refers to the large number of man-made objects in Earth's orbit, as well as to radiofrequency utilization, both driven by the increased number of space actors. "Contested" refers to the increasing military utilization of space by countries around the world, and the potential adversarial environment which may result. "Competitive" refers to increasing technical competencies of space actors outside the United States, as well as the ever-narrowing technological gap between the United States and other spacefaring nations.[105]

5.2.2 Trends in Transnational Space Policies

Aside from governments, many international organizations are starting to introduce space policies, strategies, and programs. The increasingly competitive global space environment is also giving way to space utilization that supports strategies and goals developed at a multinational level. The ways in which space strategies are developed at the transnational level takes several forms.

Many international organizations have established specific subunits or divisions responsible for space activities. Examples include the Space Programme within the World Meteorological Organization (WMO), the Space Applications Section within the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP), and the Sub-Committee on Space Technology and Applications within the Association of Southeast Asian Nations (ASEAN). These groups serve to develop goals and strategies to facilitate the use of space applications and resources within their parent organizations.

Multinational space strategies are also emerging at a regional level in the form of multilateral coordination bodies. In Asia, a regional group known as the Asia-Pacific Space Cooperation Organization (APSCO), headquartered in Beijing, exists to coordinate the activities of its member states. APSCO's membership consists of China and several smaller nations with less advanced space capabilities: Bangladesh, Iran, Mongolia, Pakistan, Peru, and Thailand. APSCO provides its member nations with an opportunity to pool technical resources, including limited shared funds, and allows the smaller nations an opportunity to access technical training and participate in larger-scale programs.[106] For China, leadership in the organization offers diplomatic and international relations benefits. The other regional space cooperation organization in Asia, the Asia-Pacific Regional Space Agency Forum (APRSAF), is led by Japan. Since APRSAF's founding in 1993, 33 Asian countries and 22 international organizations have participated in the organization's activities.[107] The participants in APRSAF include a number of nations which have relatively advanced space capabilities, allowing it to conduct programs that go beyond the technical mentoring activities of APSCO. These activities include an initiative to develop small satellites, development of a geographic information system for regional natural disaster response, and annual technical meetings.

Several African nations are exploring broad cooperation in space activities through two different regional organizational models. In October 2011, South Africa began initial development of a satellite that will be part of a planned constellation of Earth observation satellites focused on the African continent known as the African Resource Management Constellation (ARMC). The ARMC is a partnership between South Africa, Algeria, Nigeria, and Kenya. It aims to put into orbit three African-built satellites with shared data access. The ARMC is expected to provide participants with valuable environmental data for resource management, as well as advance technical capabilities in satellite manufacturing.[108] Beyond the ARMC, the African Union is studying the feasibility of a pan-African space agency modeled after ESA.

International space strategy coordination is also commonly built around topical areas through working groups on technical or programmatic areas of interest. The International Space Exploration Coordination Group (ISECG) is an effort of 14 space agencies to coordinate space exploration. In September 2011, the group released the *Global Exploration Strategy: The Framework for Coordination*. The document is an effort to define feasible destinations for human space exploration and strategies for reaching them over the next 25 years. Destinations include asteroids, the Moon, and Mars. It was written though a broad consultative process with the intent that the document serve as a tool to guide exploration, not as an end result in itself. It is expected that participants will use it to inform their own policy and programmatic processes. The document will be updated over time as policies and capabilities develop, ultimately evolving into a consensus on a coordinated international plan for space exploration.[109]

An initiative is also underway to coordinate global activities in solar monitoring and space weather forecasting. Driven by the significant adverse effects that solar storms can have on satellites and terrestrial electrical power grids, NASA, JAXA and the United Nations have established the International Space Weather Initiative (ISWI). The ISWI aims to close gaps in global space weather monitoring capabilities through the development of an international network of ground-based space weather monitoring stations. Cooperation is seen as essential in advancing global capabilities to monitor and forecast space weather. The ISWI held its first meeting in 2010, its second in 2011, and will continue to meet in the coming years.[110]

A possible new function of Hayabusa 2 would be to send an impactor to create a crater on an asteroid. This would enable the collection of samples that have not been exposed to the space environment to the same degree as the asteroid's surface. *Credit: Akihiro Ikeshita*

5.3 Cosmic Discovery

Observatories, space probes, and the scientists that operate them push humanity's frontiers further out into the Universe. A range of exciting space science missions are in development that will expand humanity's knowledge of the Sun, the planets and other bodies in the Solar System, the composition and physics of the Universe, and the prospects for life in places other than Earth.

5.3.1 Planning Space Science missions

Space science missions are often costly, take a long time to develop, and produce data that can be analyzed by the scientific community for many years. With so many research options available due to the vastness of space, choosing the most productive mission can be a challenge. In the United States, the government determines which space science missions to fund by utilizing the decadal surveys conducted by the Space Studies Board (SSB) of the U.S. National Academy of Sciences. Once a decadal survey is requested, the SSB draws upon the scientific community in a specific field of study to develop a consensus about which missions, capable of being conducted in the next ten years, will provide the greatest scientific returns. Ultimately, these surveys result in a prioritized list of research topics and missions. An astronomy and astrophysics decadal was completed in 2010, a planetary science decadal was completed in 2011, and a heliophysics decadal is in development.[111]

ESA also draws upon the broad scientific community to set Europe's goals for space science. In 2004, ESA worked with the astronomical community to produce its *Cosmic Vision 2015–2025* plan. The plan identified four scientific questions that missions should help answer: what are the conditions required for planetary formation and the emergence of life; how does the Solar System work; what are the fundamental physical laws of the Universe; and how did the Universe originate and what is it made of? In 2007, ESA issued a call for missions supporting these themes. In October 2011, ESA selected two medium-class missions, the first of this kind, to support the Cosmic Vision.[112]

JAXA outlined its basic strategy for cosmic discovery efforts in its Vision 2025 study released in 2005. JAXA states that the two important goals for its scientific space missions are: determining the origin and composition of the Universe and the nature of spacetime, and studying the possibility of life elsewhere in the Universe.[113]

Technicians install spacecraft electronics and payloads on the Lunar Atmosphere and Dust Environment Explorer (LADEE) spacecraft at NASA's Ames Research Center, California. LADEE has passed the Mission Critical Design Review, which means that development can continue on the flight hardware necessary to meet all science and engineering requirements for its 2013 mission to the Moon. *Credit: NASA/Ames Research Center*

Although the recommendations from the scientific community are considered during the mission selection process, ultimately it is national space agencies and governments that decide which missions will receive funding. Therefore, in a world of changing political and scientific priorities, the missions that will ultimately receive funding may be different than current long-term plans indicate.

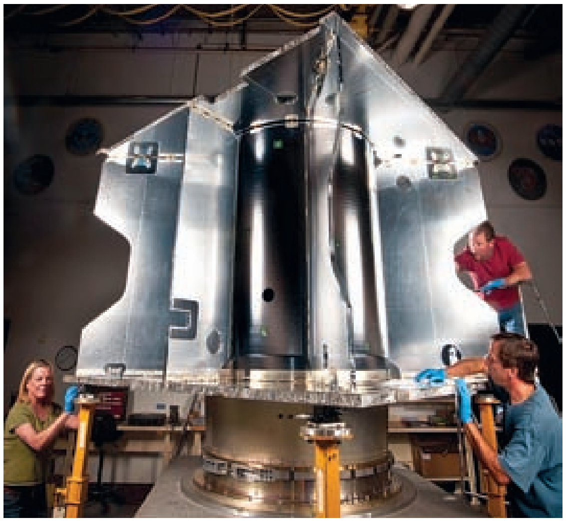
5.3.2 Future Space Science Missions

Heliophysics

Researchers are deploying ever more sophisticated instruments to provide insight into the behavior of the Sun, which supplies our planet with the basic energy needed for life. In October 2011, ESA selected the Solar Orbiter as one of its two medium-class missions. The Solar Orbiter mission, targeted for launch in 2017, will produce images of the Sun at the highest resolution ever obtained and will perform the closest-ever measurements of phenomena near the Sun.[114] These measurements are intended to help better understand how solar wind is propelled, predict solar eruptions, and make long-term forecasts of solar activity. During its seven-year mission, the orbiter will at times enter into a unique stationary position relative to the Sun's surface, allowing it to study the lifecycle of solar storms.

Planetary Science

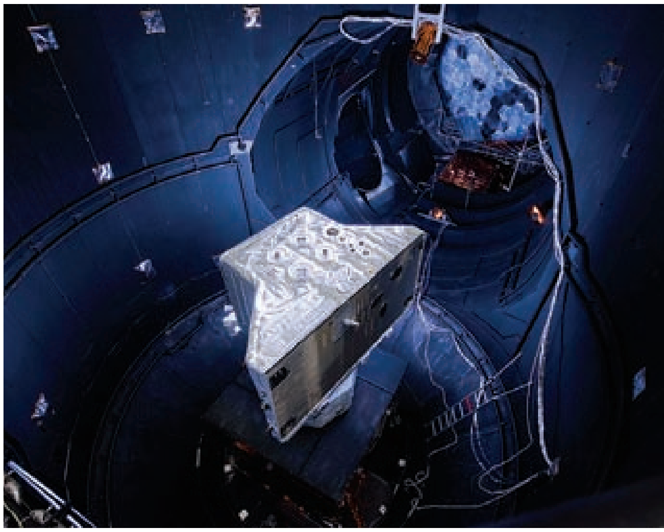
Planetary science missions provide insight into how planets are formed—the processes that shape their internal structure, land forms, and atmospheres. NASA's Lunar Atmosphere and Dust Environment Explorer (LADEE), planned for launch in 2013, will fly to the Moon and spend 100 days analyzing the tenuous lunar atmosphere and dust environment.[115] LADEE will increase our knowledge of the lunar atmosphere as it exists prior to an expected increase of human activity on the Moon in coming decades. An understanding of the amount of dust in the lunar atmosphere will also affect how we would conduct lunar-based astronomy and how future human missions could deal with this aspect of the lunar system.



This image shows the core structure of the Mars Atmosphere and Volatile Evolution Mission (MAVEN) spacecraft under construction by Lockheed Martin. The primary structure is built out of composite panels, so the total weight is a mere 125 kilograms (275 pounds). *Credit: Lockheed Martin*

The Mars Atmospheric and Volatile EvolutioN (MAVEN) mission is scheduled for launch in 2013. MAVEN will measure the current rate of Martian atmospheric escape into space to help determine how the loss of Mars' atmosphere over time has affected its climate. Understanding how much of the Martian atmosphere was lost to space can provide insight into the geologic and geochemical conditions over time, which will help us understand if Mars ever had an environment capable of supporting life.[116]

Following Japan's successful Hayabusa asteroid sample return mission, the nation is developing a follow-on mission called Hayabusa 2. The Hayabusa 2 mission, proposed to launch in 2014, would target a C-type asteroid, an older, more basic body than the S-type asteroid visited by the first mission. The exploration of primitive bodies such as a C-type asteroid will provide researchers with clues about how the Solar System was formed and has grown, and how the primary organic materials of life on Earth were composed and evolved. According to mission planners, this knowledge is also important for understanding the formation and evolution of planets being discovered around other stars.[117]



The Structural and Thermal Model of the BepiColombo Mercury Planetary Orbiter is shown here in the Large Space Simulator at ESA's Test Centre in Noordwijk, the Netherlands. Some of the tests involve exposing the spacecraft to high radiation levels to ensure that it will perform correctly while orbiting the planet closest to the Sun. *Credit: ESA*

Japan and Europe are collaborating to develop the BepiColombo mission to explore Mercury. The mission will consist of two orbiting spacecraft, one by JAXA and one by ESA, that are slated to be launched together on a single European Ariane 5 rocket in 2014. JAXA's orbiter will focus on studying the magnetic fields and space environment around Mercury. This area of study is of particular interest because Earth and Mercury are the only planets in the inner Solar System to have magnetic fields, and studying Mercury's magnetic field could provide insights that help us better understand the one on Earth. ESA's orbiter will focus on understanding the interior and surface of Mercury and how its position so close to the Sun affects its structure. It will also attempt to verify the existence of water ice in Mercury's polar region.[118]

A variety of other destinations have been proposed as high priorities for planetary science missions. In the United States, some of the top priorities include a large mission to Jupiter's moon Europa to study its ice-covered ocean and to determine if life could exist there, and sending the first orbiter to Uranus to investigate its interior structure, atmosphere, and composition. The full list of priority missions can be seen in Exhibit 5m.

EXHIBIT 5m. Candidate Missions Identified in the Planetary Science Decadal Study

NASA Class	Name	Mission Description
Large	Mars Astrobiology Explorer-Cacher	A rover to collect and analyze samples on Mars to look for evidence of ancient life or pre-biotic chemistry. The rover would collect, document, and package samples for future return to Earth
Large	Jupiter Europa Orbiter	Explore Europa, one of Jupiter's moons, to investigate its ability to support life
Large	Uranus Orbiter and Probe	Investigate the interior structure, atmosphere, and composition of Uranus and observe the ring systems around its moons
Medium (New Frontiers)	Comet Surface Sample Return	Collect and return a sample from a comet nucleus to determine contents including complex organics that may be present
Medium (New Frontiers)	Io Observer	Determine internal structure and mechanisms causing volcanism on Io, one of Jupiter's moons
Medium (New Frontiers)	Lunar Geophysical Network	Increase understanding of the lunar interior
Medium (New Frontiers)	Lunar South Pole-Aitken Basin Sample Return	Gather samples from the Moon's South Pole-Aitken Basin and return them to Earth for study
Medium (New Frontiers)	Saturn Probe	A probe that would descend through Saturn's atmosphere to determine the composition and atmospheric structure
Medium (New Frontiers)	Trojan Tour and Rendezvous	Visit, observe, and classify a number of Trojan asteroids
Medium (New Frontiers)	Venus In Situ Explorer	A space probe to land on the surface of Venus and perform experiments
N/A (special case)	ESA/NASA Mars Trace Gas Orbiter	A Mars orbiter that would study the atmosphere for specific gases, including those emitted by life

Source: The National Academies

Astronomy and Astrophysics

Astronomy and astrophysics missions help us determine the composition of the Universe, how it works, and how it developed. In the United States, the SSB completed an astronomy and astrophysics decadal survey in 2010 and released an overview of findings in 2011.[119]

Workers at Orbital Sciences in Dulles, Virginia, prepare the integrated NuSTAR observatory, including the instrument and spacecraft, for environmental testing. This includes testing in a thermal vacuum chamber, ensuring the spacecraft can withstand the stresses of the space environment. *Credit: NASA*

Scheduled to launch in February 2012, the Nuclear Spectroscopic Telescope Array (NuSTAR), will image the sky in the high-energy X-ray region of the electromagnetic spectrum. During its two-year mission, NuSTAR will map selected regions of the sky to take a census of the collapsed stars and black holes surrounding the center of our own Milky Way Galaxy. NuSTAR will observe the material created in young supernova remnants to understand how stars explode and create elements, and it will study particle jets emitted from supermassive black holes.[120]

Currently in development, the James Webb Space Telescope is a large space-based telescope that will help us observe the first galaxies that formed in the early Universe. This powerful infrared telescope will be able to see through dusty clouds to view the formation of stars and planetary systems within nebulae. It will also study the physical and chemical properties of solar systems to understand where the building blocks of life may be present. Although hampered by problems with funding and delays in development, the program is currently working toward a launch in 2018.[121]

The SSB astronomy and astrophysics decadal identified development of the Wide-Field Infrared Survey Telescope (WFIRST) as the top priority for new missions. However, the WFIRST mission is amongst the projects threatened by the JWST cost overruns. This observatory would map the distribution of 2 billion galaxies and seek to understand the structure of the Universe. The telescope would also measure 2,000 supernovae to map the expansion of the Universe and study one of the great mysteries of the Universe, dark energy. Exoplanets around other stars would also be detectable with WFIRST.[122]

ESA's Gaia mission, planned for launch in 2013, will create a three-dimensional map of our galaxy. Gaia will measure the movement of about one billion stars, or roughly 1% of the galactic stellar population. The observatory will be able to detect tens of thousands of extrasolar planetary systems. Based on its measurements, Gaia will also be able to provide stringent new tests of general relativity and cosmology.[123]

In October 2011, ESA selected Euclid as one of two medium-class missions. The Euclid mission, targeting launch in 2019, will help explore the origin of the Universe. Euclid will achieve this by mapping the geometry of the dark Universe—those parts of the Universe consisting of dark matter and dark energy that cannot be observed with traditional telescopes. Euclid will measure the growth of the structure of the dark Universe by using two complementary dark energy probing methods.[124]

Technicians from Astrium, the Gaia mission's prime contractor, carefully construct one element of the spacecraft's imaging equipment at the company's facility in Toulouse, France. Each image captured by the camera will have around one billion pixels, the largest of any space mission to date. *Credit: Astrium*

Japan's ASTRO-G mission is a radio astronomy satellite that builds upon previous Japanese radio astronomy missions. It will use a very large, approximately 10-meter (30-foot) antenna, to conduct some of the highest-resolution observations into the extreme regions of the Universe. Objectives of the mission include studying the accretion disks around black holes and the magnetic fields around protostars.[125]

The ASTRO-H mission proposed by Japan would make observations in a wide swath of the high-energy end of the spectrum, from X-rays to gamma rays. ASTRO-H would be able to map various sources of X-rays which are created at sources with very high temperatures. Such sources include supernova explosions, black holes, active galactic nuclei, and high-temperature plasma between galaxies. Because X-rays are blocked by the Earth's atmosphere, ASTRO-H's location outside the atmosphere enables observations that would otherwise be impossible.[126]

EXHIBIT 5n. Planetary Science Missions, 1957–2011

Destination	Missions Completed	Missions in Progress	Missions in Development	Orbiter/ Flyby	Lander/ Other	Primary Nations
Mercury	1	1	1	3	0	European Space Agency (ESA), Japan, United States
Venus	21	2	1	16	15	ESA, Japan, Russia, United States
The Moon	61	4	1	48	18	China, ESA, India, Japan, Russia, United States
Mars	20	5	3	21	11	ESA, Japan, Russia, United States
Asteroids	3	1	1	5	2	Japan, United States
Jupiter	6	3	0	9	1	ESA, United States
Saturn	4	1	0	5	0	United States
Titan (Saturn Moon)	1	0	0	0	1	ESA
Uranus	1	0	0	1	0	United States
Neptune	1	0	0	1	0	United States
Pluto	0	1	0	1	0	United States
Comets/Kuiper Belt	5	3	0	7	2	ESA, Japan, United States
Extrasolar Planets (Observations from Earth Orbit)	0	4	2	6	0	Canada, ESA, France, United States

Note: Data excludes failed mission attempts. Some missions include multiple types of spacecraft, such as an Orbiter and a Lander. "Lander/Other" includes rovers, impactors, and probes. Extrasolar planet-hunting missions classified as "Orbiter/Flyby." Primary nations are responsible for spacecraft construction and operations. Other non-primary nations may providing funding or instruments. Does not include spacecraft observing the Earth, Sun, other stars, or other types of astrophysical phenomena. Excludes Google Lunar X PRIZE competitors.
Source: NASA and Planetary Society

5.3.3 International Cooperation in Space Science

The space science community has strongly embraced data sharing throughout its history. Even during the height of the Cold War, the scientific exchange between the United States and the Soviet Union continued. Today, an immense body of data is produced by space science missions, and while nations funding the mission generally have the first opportunity to study the data, the research community continues to share space science data liberally. Missions to planets and other bodies in the Solar System are highlighted in Exhibit 5n.

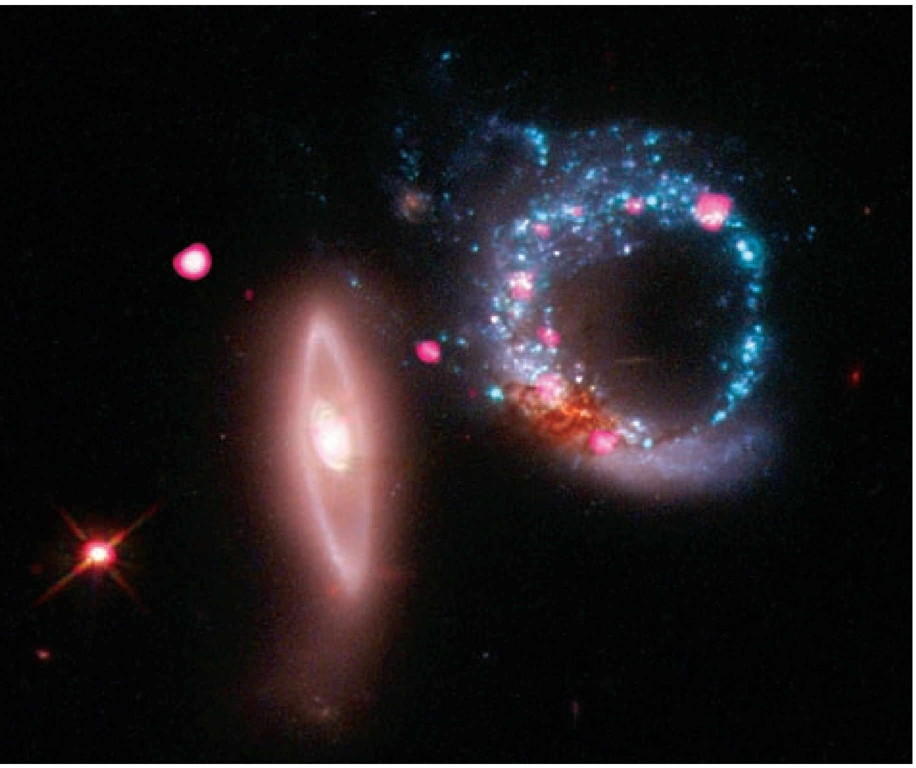
Space science missions that send probes to other worlds are challenging and have only been conducted so far by a handful of space agencies, including those of the United States, Europe, Japan, Russia, China, and India. In addition to their own missions, these nations collaborate on missions to meet common scientific objectives and to spread the cost of missions between partners. However, collaboration is not without risk, as evidenced by recent funding problems and changing support for joint ESA-NASA exploration of Mars. In a report based on the 2011 planetary science decadal, researchers outlined eight essential ingredients for effective international collaborations. The recommendations include clearly defining responsibilities and roles for partners, along with shared objectives that incorporate the interests of all pertinent parties, including scientists, engineers, and mission managers.[127] Despite the recent setbacks in collaboration, the decadal authors emphasized the importance of partnerships and recommended continued use of large-scale collaboration and the flexible procurement vehicles necessary to enable quick development of instruments that can ride along on spacecraft developed by partner countries.

5.4 Conclusion

Space activity has always been a challenging undertaking. The technology is complex, there are considerable risks, and projects typically develop over the course of years rather than weeks or months. Nevertheless, the rewards of engaging in space activity make it a very worthwhile pursuit. The products and services derived from space enhance our lives in ways that are difficult to truly comprehend. The simple act of using a smartphone to display a satellite image of the surrounding area requires the prior investment of billions of dollars in both Earth observation satellites and a constellation of positioning, navigation, and timing satellites. Providing the smartphone owner with this easy-to-use feature required the efforts of a skilled and dedicated workforce that was capable of overcoming the challenges inherent in space activity.

The value of this ability to achieve difficult goals is readily apparent in the size of the space economy. In purely financial terms, the expanding global demand for the services that the space industry provides has brought about rapid growth in commercial revenues, vastly outpacing increases in government spending. Space companies will continue to innovate, to create new goods, and to address needs on Earth by expanding the boundaries of what is possible in space. The grand total of nearly $290 billion in 2011 reflects only a part of the impact that space has on the global economy. As NASA's recent study of spinoff technologies indicated, the value of space can also be measured in thousands of jobs created and lives saved.

The expansion of space-related economic activity is accompanied by an ever-growing understanding of the Universe. As each generation of scientists uses telescopes and probes more powerful than those available to their predecessors, the knowledge they acquire helps us to appreciate our home planet and better ensure its safety. Robotic and human missions to other celestial bodies serve to increase our reach as a species, as well as generating new technologies that have applications on Earth. In a less technical context, the dazzling beauty of space serves to inspire a sense of awe and wonder that motivates young and old to learn more about the intricacies of the natural world.



A collision of two galaxies some 430 million light years from Earth has triggered a wave of star and black hole formation. This composite image includes data from the Chandra X-Ray Observatory which shows black holes formed during the collision as pink spots. *Credit: X-ray: NASA/CXC/MIT/S. Rappaport et al., Optical: NASA/STScI*

Considering all of these positive factors, it is clear that the setbacks experienced in 2011 in some fields of endeavor will not severely dampen the human enthusiasm for space. New programs and solutions will emerge, and the space community will press onward as it always has, ever in search of new challenges to overcome.

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Appendix

Section 1.0 | Space Products and Services

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Section 2.0 | The Space Economy

1 Data and analysis into the space economy offer insight by providing revenue and budget figures as well as the growth drivers and underlying trends for space infrastructure, space products and services, and government space budgets. Data is derived from publicly available commercial revenue reports and government budget sources. Where possible, multiple sources of data are reported and documented. Forecasts and projections from industry research firms and other open sources are included in order to provide a forward-looking view of the global space industry. The methodology to measure the space economy uses several valuation techniques that combine data collection, estimates, internal analysis, and external citations. The sources include public information as well as analysis by a number of third parties such as the media, market analysts, and researchers. The sources are cited throughout the document to ensure consistency, transparency, and traceability. Data is reported in then-year dollars, and international space agency budgets are reported in their respective domestic currencies. Unless otherwise stated, all currency conversion into U.S. dollars use exchange rates as of June 30 of the appropriate year.

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  by American Outdoor Products, Inc.
- **Autonomous Modular Power System (AMPS)**
  by Deeya Energy
- **Chiropractic Screening — Insight Subluxation Station**
  by Chiropractic Leadership Alliance
- **Comfort Phase Change Materials**
  by Outlast Technologies, Inc.
- **CRI Seal of Approval Program**
  by Carpet and Rug Institute
- **DentaPure**
  by DentaPure
- **Engine Treatment and Lubricants**
  by The X-1R Corporation
- **EVOQUE Skin Care**
  by Regenetech
- **Fishing Tackle Lubricants**
  by PENN Fishing Tackle
- **GPS Tracking Services**
  by Rocky Mountain Tracking, Inc.
- **Handheld Vacuum Enhanced X-Ray Fluorescence Analyzer**
  by Bruker Handheld
- **HazNet — All Hazards Network**
  by NVision Solutions, Inc.
- **HEATSHEETS and Thermoflect**
  by AFM Inc.
- **Hyperspectral and Imaging Systems, Hardware, Software, Design, and Services**
  by Themis Vision Systems
- **InsightArthroVR**
  by GMV USA
- **Internet Controlled Intelligent Ovens**
  by TMIO
- **Intrifuge and CellXpansion**
  by Regenetech
- **Joysticks**
  by Immersion
- **Lightning Switch, PulseStar Lightning System**
  by PulseSwitch Systems
- **Optotraffic DLS-10 Automated Red Light & Speed Enforcer**
  by Sigma Space Corporation
- **Panoptic Anterior Segment and Retinal Camera Attachment**
  by Provizion
- **Petroleum Remediation Product (PRP)**
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- **Polarized Lens Technology**
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- **Pressure Relieving Sleep Surfaces**
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- **Systems Tool Kit — Technology**
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  by Quilts of Denmark
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- **Play Attention**
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Certified Imagination Products

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- **5th Edition Beer Drinker's Guide to Colorado**
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- **NORAD Tracks Santa**
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- **Sputnik's Child**
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- **The Space Store**
  by The Space Store

ES | Executive Summary

1.0 | Space Products and Services

2.0 | The Space Economy

3.0 | Space Infrastructure

Acronym List

AEB	Agência Espacial Brasileira/Brazilian Space Agency
AGI	Analytical Graphics, Inc.
ASI	Agenzia Spaziale Italiana/Italian Space Agency
ATC	Ancillary Terrestrial Component
ATK	Alliant Techsystems
ATV	Automated Transfer Vehicle
BLS	Bureau of Labor Statistics (United States)
CBERS	China-Brazil Earth Resources Satellite
CCDev	Commercial Crew Development
CCP	Commercial Crew Program
CNES	Centre National d'Études Spatiales/French Space Agency
CNSA	China National Space Administration
COMSTAC	Commercial Space Transportation Advisory Committee
CONAE	Comisión Nacional De Actividades Espaciales/Argentine Space Agency
COTS	Commercial Orbital Transportation Services
CRS	Commercial Resupply Services
CSA	Canadian Space Agency
DARPA	Defense Advanced Research Projects Agency (United States)
DLR	Deutsches Zentrum für Luft- und Raumfahrt/German Space Agency
DoD	Department of Defense (United States)
DOE	Department of Energy (United States)
DOI	Department of the Interior (United States)
DOS	Department of Space (India)
DST	Department of Science and Technology (South Africa)
DTH	Direct-to-Home
EADS	European Aeronautic Defense and Space Company
EC	European Commission
EELV	Evolved Expendable Launch Vehicle
EIAST	Emirates Institute for Advanced Science and Technology
EGNOS	European Geostationary Navigational Overlay Service
ESA	European Space Agency
EU	European Union
EUMETSAT	European Organization for the Exploitation of Meteorological Satellites
FAA	Federal Aviation Administration (United States)
FCC	Federal Communications Commission (United States)
FSS	Fixed Satellite Services
FY	Fiscal Year
GAGAN	GPS-Aided GEO Augmented Navigation
GCOM	Global Change Observation Mission
GDP	Gross Domestic Product
GEO	Geosynchronous Orbit
GLONASS	Global Navigation Satellite System
GMES	Global Monitoring for Environment and Security
GNSS	Global Navigation Satellite System
GPS	Global Positioning System
GSA	European GNSS Agency
GSLV	Geostationary Satellite Launch Vehicle
GSO	Geosynchronous Orbit
GTO	Geosynchronous Transfer Orbit
HD	High-Definition
HEO	Highly Elliptical Orbit
HPA	Hosted Payload Alliance
HTV	H-II Transfer Vehicle
INPE	National Institute for Space Research (Brazil)
INTA	Instituto Nacional de Técnica Aeroespacial/Spanish Space Agency
IR&D	Independent Research and Development
IRNSS	Indian Regional Navigation Satellite System
ISDR	Investment & Strategic Development Resources
ISRO	Indian Space Research Organisation
ISS	International Space Station
JAXA	Japan Aerospace Exploration Agency
JWST	James Webb Space Telescope
KARI	Korean Aerospace Research Institute
KSC	Kennedy Space Center
KSLV	Korea Space Launch Vehicle
LEO	Low Earth Orbit
M&A	Mergers and Acquisitions
MARS	Mid-Atlantic Regional Spaceport
MEO	Medium Earth Orbit
MEST	Ministry of Education, Science, and Technology (South Korea)
MPCV	Multi-Purpose Crew Vehicle
MSFC	Marshall Space Flight Center
MSL	Mars Science Laboratory
MSS	Mobile Satellite Services
NAEP	National Assessment of Educational Progress
NAICS	North American Industry Classification System
NASA	National Aeronautics and Space Administration (United States)
NCES	National Center for Education Statistics (United States)
NGA	National Geospatial-Intelligence Agency (United States)
NGSO	Non-Geosynchronous Orbit
NOAA	National Oceanic and Atmospheric Administration (United States)
NRO	National Reconnaissance Office (United States)
NSF	National Science Foundation (United States)
NSSO	National Security Space Office (United States)
OECD	Organisation for Economic Co-operation and Development
OODT	Object Oriented Data Technology
OPSEK	Orbital Piloted Assembly and Experiment Complex
ORS	Operationally Responsive Space
PISA	Program for International Student Assessment
PNT	Positioning, Navigation, and Timing
PPTS	Prospective Piloted Transport System
PSLV	Polar Satellite Launch Vehicle
QZSS	Quasi-Zenith Satellite System
R&D	Research and Development
RLV	Reusable Launch Vehicle
SANSA	South African National Space Agency
SBIRS	Space Based Infrared System
SBSS	Space Based Space Surveillance
SDA	Space Data Association
SFI	Space Foundation Index
SFII	Space Foundation Infrastructure Index
SFSI	Space Foundation Services Index
SIA	Satellite Industry Association
SJAC	Society of Japanese Aerospace Companies
SKA	Square Kilometer Array
SLS	Space Launch System
SMC	U.S. Air Force Space and Missile Systems Center
SSB	Space Studies Board
SXC	Space Experience Curaçao
UK	United Kingdom
UKSA	United Kingdom Space Agency
ULA	United Launch Alliance
U.N.	United Nations
U.S.	United States
USA	United Space Alliance
USAF	United States Air Force
USGS	United States Geological Survey
VAFB	Vandenberg Air Force Base
VSAT	Very Small Aperture Terminal
WAAS	Wide Area Augmentation System
WFF	Wallops Flight Facility

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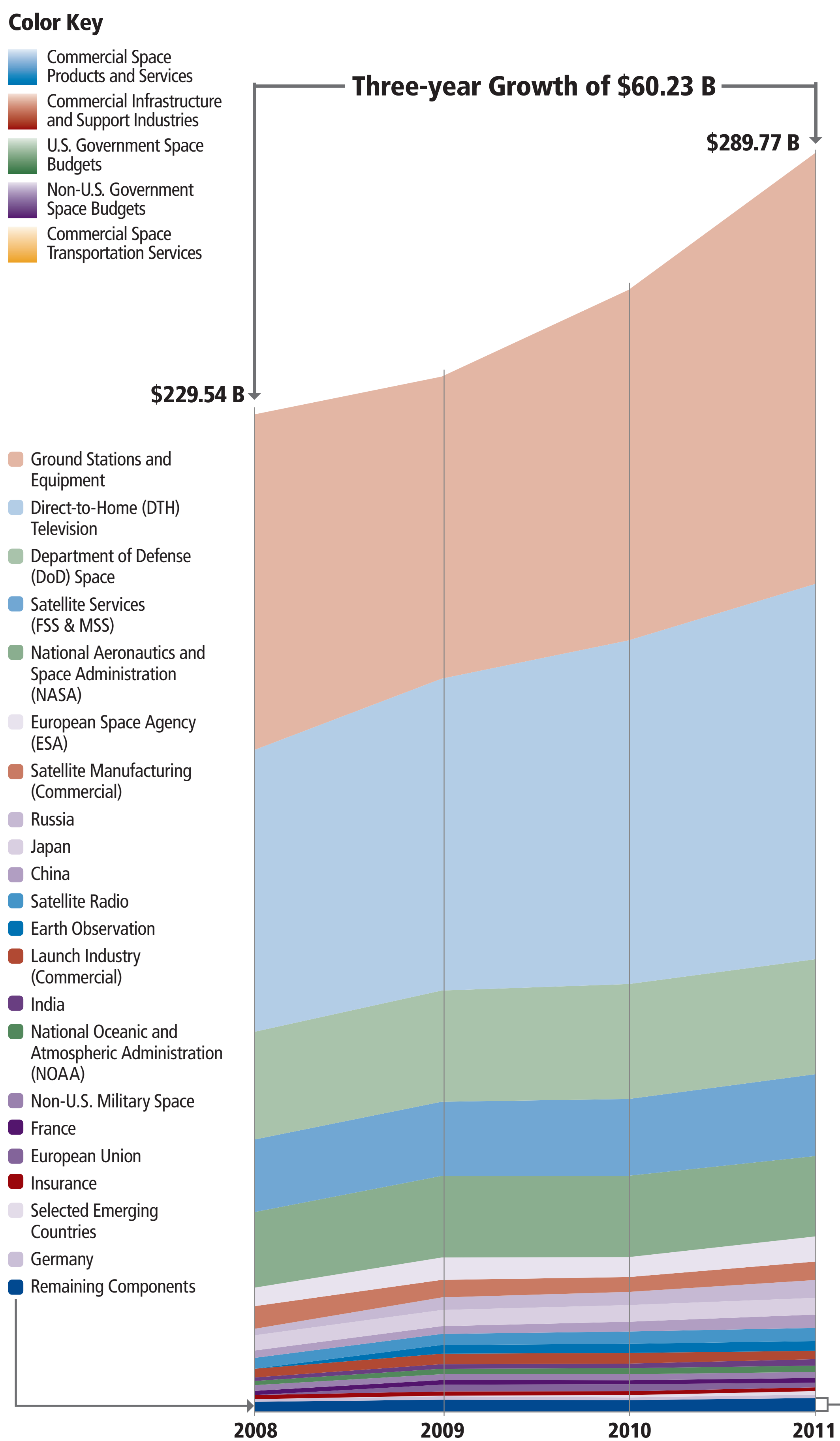
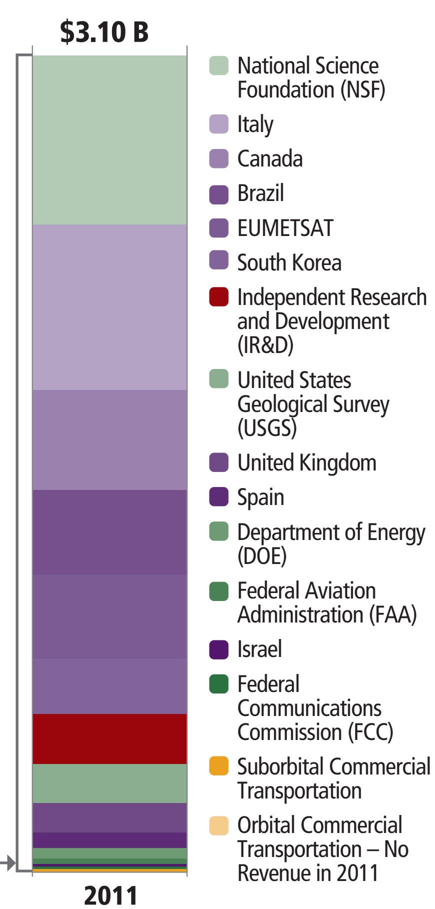


A Snapshot: Four Years of Space Activity

This visualization provides an at-a-glance view of the global space economy's development from 2008 to 2011. Segments are color-coded according to the top-level economic sectors detailed in Section 2.0 and are arranged in descending order of size. All components less than $0.75 billion in 2011 have been consolidated into a single segment on the main graphic. The 2011 breakout of these components can be seen in the lower-right corner.

Remaining Components
(Less than $0.75 B each in 2011)



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