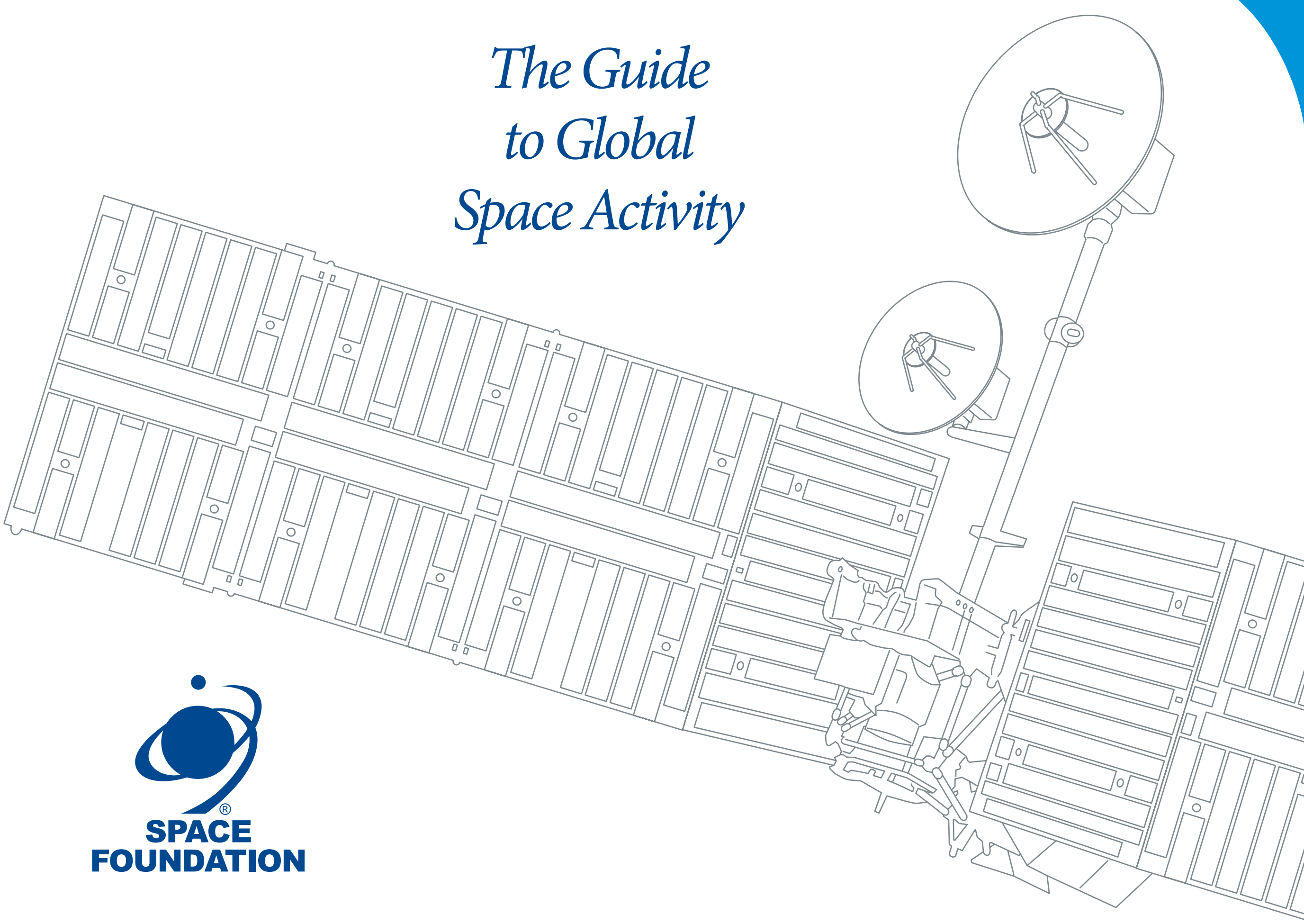
2006

THE SPACE REPORT

The Guide to Global Space Activity



SPACE FOUNDATION

2006

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Foreword

October 2006

The Space Report: The Guide to Global Space Activity is the fruition of a longtime goal of the Space Foundation to provide a definitive, timely, and comprehensive reference document about the global space industry in all its abundant diversity.

The seeds of this fruit were first planted in 1983, when a small group of visionary leaders incorporated the United States Space Foundation as an IRS 501(c)(3) not-for-profit operating foundation with a charter *"to foster, develop, and promote, among the citizens of the United States of America and among other people of the world ... a greater understanding and awareness ... of the practical and theoretical utilization of space ... for the benefit of civilization and the fostering of a peaceful and prosperous world."*

Since that time, the space community has grown larger, more diverse, more international, and more complex. In our dealings with students, teachers, policy makers, elected officials, the news media, community leaders, and others, it has become clear that few people (especially outside our industry) understand the depth, breadth, and importance of the space economy. Despite the many excellent reports that have been published concerning various sectors of the space economy, an unbiased, statistically sound, comprehensive, and definitive reference document has been needed.

The need for such a report has been confirmed repeatedly during the past decade. When the venture capital firm SpaceVest published its landmark *State of the Space Industry* report in 1997, it never anticipated that requests for the 1996 data would continue through 2005. Sensing a larger need, SpaceVest in 2005 donated the relevant economic models, data, and other intellectual property to the nonpartisan, nonprofit Space Foundation. In turn, we have teamed with The Tauri Group, an analytical consulting firm we selected for its objectivity and depth of knowledge in this field. We have spent the past 14 months working with analysts and researchers from trade associations, think tanks, government agencies, university researchers, and executive leaders and interns from across the global space community. Together, the Space Foundation and The Tauri Group have produced *The Space Report: The Guide to Global Space Activity.*

The publication of *The Space Report* is an important milestone, and we hope that everyone who consults this report will find value in its contents. But the journey is just beginning. We look forward to working with our colleagues in the years ahead to broaden the scope of the report, delve deeper into the data with more original research and analysis, and respond to your feedback to ensure the report remains as relevant and dynamic as the space economy itself.

The Honorable Robert S. Walker
Chairman of the Board of Directors

Elliot G. Pulham
President and Chief Executive Officer

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2006

THE SPACE REPORT

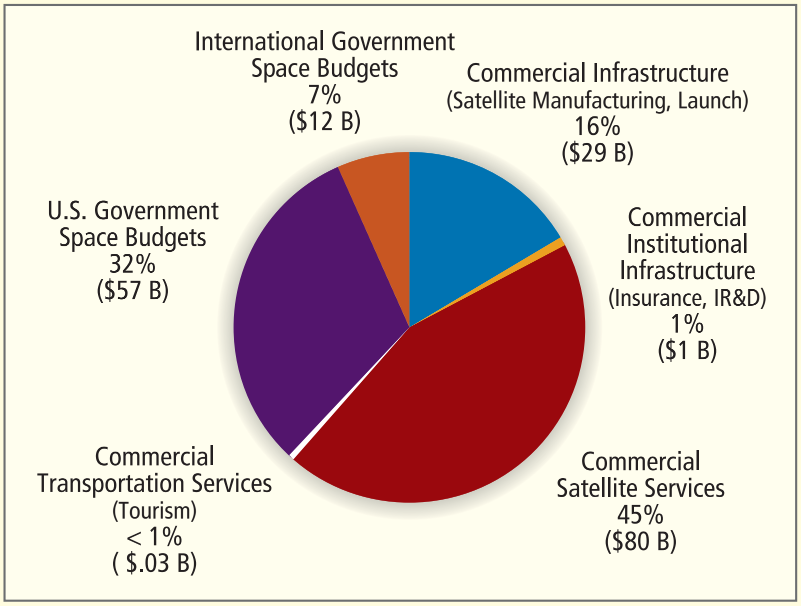
EXECUTIVE SUMMARY

Executive Summary
Introduction | 1.0

The Space Report: The Guide to Global Space Activity presents, for the first time in a single document, comprehensive data and analysis authoritatively characterizing global space activities. With detailed references and its sources fully annotated, this report describes the full range of space activities around 2005: space infrastructure, space products and services, space revenues and government budgets, how space products and services are used, their impact, and the outlook for the future. For easy reference, a two-page graphic overview (Exhibit 5c, pages 114-115) supplements the numerous charts, tables, photographs, and illustrations liberally included throughout the document. In addition, Exhibit ES1 summarizes the available information on 2005 space revenues and budgets.

EXHIBIT ES1. **Percentage Breakdown of Global Space Budgets and Revenues 2005**

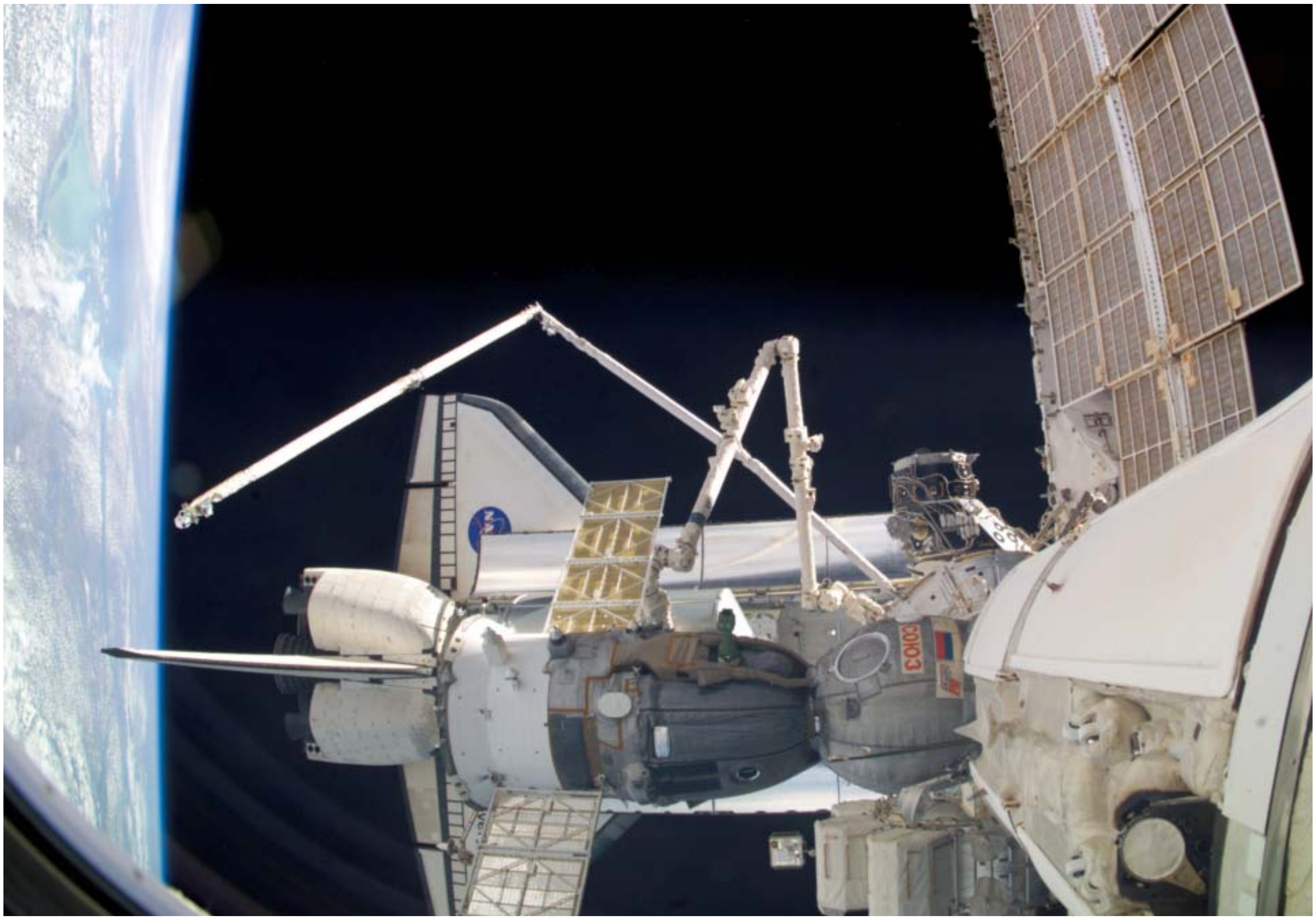
Space revenues and government budgets for space totaled $179.65 billion in 2005. Satellite-based products and services (including consumer equipment and chipsets) represented the greatest portion of commercial revenue and were 45% of the total; this figure excludes most government spending, which is captured under government budgets. The U.S. government's expenditures on space were the second largest portion overall, with 32% of total. The pie chart shows space activities divided into infrastructure, products and services, and government budgets, which includes spending in each of the other categories.



Estimates are based on available information. (Rounded values)

While *The Space Report* is comprehensive, it is not entirely definitive. Compiled from independently sourced existing data, it cannot shed light where original research does not yet exist. Nonetheless, the conclusions of this broad look at all space activities—civil, commercial, and national security—are sweeping. *At minimum,* space activities accounted for about $180 billion in government budgets and industry revenues worldwide in 2005. United States publically-traded space businesses, as evidenced by the performance of the newly created Space Foundation Space Index, out-performed both the NASDAQ and S&P 500.

The Space Report was synthesized from carefully scrutinized public and private information sources and interviews with industry leaders. Quantitative information comes from many sources and reflects published data. These data were compiled from various sources using different methodologies, so care has been taken to describe methods and potential conflicts, disconnects, double-counting, or missing data. The objective in producing *The Space Report* has been to establish a credible baseline of data that fills the previous void, is reliable and (to the extent possible, given available data) internally consistent, and keeps pace with rapidly evolving products and services. The result is more than 170 pages of authoritative content, rich with tables, charts, graphs, photographs, and more than 450 detailed citations and endnotes.



Space Shuttle *Discovery* is seen docked at the International Space Station alongside a *Soyuz* spacecraft on its Return to Flight mission 907 days after the loss of *Columbia*. *Image credit: NASA*

This is the global space industry.

Among its many interesting facts, *The Space Report* explores:

Fei Junlong and Nie Haisheng, the two Taikonauts on Shenzhou VI, were launched into orbit in China's second manned space flight on October 12, 2005. *Image credit: The Chinese University of Hong Kong*

The Boeing Company's Delta IV rocket roars off the launch pad at Cape Canaveral Air Force Station to lift the GOES-N satellite, one of the Earth-monitoring series of Geostationary Operational Environmental Satellites developed by NASA and National Oceanic and Atmospheric Administration (NOAA), into orbit. *Image credit: The Boeing Company/ Carleton Bailie*

Space Infrastructure | 2.0

- **Orbital Launches**

There were 55 orbital launches using 26 different launch vehicles in 2005. Two leaders in this sector, Lockheed Martin and The Boeing Company, announced plans to form a joint venture, United Launch Alliance, merging Delta IV and Atlas V manufacturing, operations, and sales. The Space Shuttle *Discovery* returned to flight, ending a two-year hiatus after the loss of *Columbia*. National Aeronatics and Space Administration (NASA)'s shuttles are scheduled for retirement in 2010. China's *Shenzhou* VI ("Divine Vessel") placed two taikonauts into orbit in 2005, their mission lasting more than 115 hours. The country's second human launch, it followed the flight of a single taikonaut in October 2003. China's next human mission is expected in 2007. Also in 2005, a Russian *Soyuz* capsule took the third orbital "space tourist," Gregory Olsen, to the International Space Station (ISS). Currently, the *Soyuz* vehicle is used to rotate the crew of the ISS, visiting the station twice in 2005. Looking forward, NASA is soliciting private companies to provide crew and cargo services to the ISS through its Commercial Orbital Transportation Services (COTS) program. The selection process had narrowed to two finalists—Space Exploration Technologies (SpaceX) and Rocketplane Kistler—as *The Space Report* went to press. Also in 2005, the last Titan IV launch took place, marking the 44th consecutive successful launch by the United States Air Force.

A Titan IVB is seen lifting off at Vandenberg Air Force Base. This was the final launch of the Titan program, whose first launch was in 1959. *Image credit: 30th Space Wing, VAFB*

- **Suborbital flight**

The Federal Aviation Administration (FAA) noted in February 2005 "a resurgence of interest in commercial suborbital spaceflight, stimulated by the emergence of new markets, notably space tourism, and new vehicles developed by entrepreneurs." The agency identified 18 commercial suborbital vehicles under development. Most are being engineered to serve markets for suborbital tourism but could serve customers for memorabilia, microsatellite delivery, and various science payloads. Ten states and commercial entities are proposing to build commercial spaceports. Additionally, U.S.-based Space Adventures has announced plans to build spaceports in Singapore and the United Arab Emirates.

Astronaut Mike Melvill after his September 29, 2004, spaceflight in SpaceShipOne, the first of two successful flights for the Ansari X PRIZE which SpaceShipOne won on October 4, 2004. This achievement continues to provide momentum, having demonstrated a space economy beyond standard government and commercial launch. (See 7.2.1.2 in section 7.0 of this report.) *Image credit: Scaled Composites*

- **Long-Range Strategic Missiles**

Three major Intercontinental Ballistic Missile (ICBM) systems were decommissioned in 2005: the land-based Peacekeeper MX and submarine-launched Trident

IC4 by the United States and the rail-launched SS-24 M1 by Russia. These vehicles fly a ballistic trajectory, optimized to carry a nuclear warhead payload. While they do not orbit Earth, their flight path carries them well into space.

In this abstract view of a satellite feedhorn, we are peering down the brace. The feedhorn selects the polarity of the waves to be received, which helps to attenuate unwanted signals from adjacent channels and transponders, and from other communications satellites at nearby orbital positions. On a satellite dish, the feedhorn is what is mounted at the end of a mast from the center of the dish, or on tripod legs mounted to the edge of the dish.

- **Satellites and Ground Stations**

The Satellite Database maintained by Analytical Graphics, Inc. (AGI) currently lists 536 active communications satellites in orbit. Of these, 298 are in a geosynchronous orbit. The American Society for Photogrammetry and Remote Sensing (ASPRS) identifies 102 civil and commercial land imaging satellites with resolutions finer than 39 meters in orbit as of February 2006. Satellite navigation constellations (such as the U.S. NavStar Global Positioning System, or GPS) are operated by the United States, Russia, and China, with others being developed by Europe and Japan. Some 102 scientific satellites currently orbit Earth—19 of them launched in 2005. Probes journey beyond Earth orbit, typically on a science mission. There are 13 active probes in space. Four were launched in 2005 and early 2006.

Because satellite communications require line-of-sight, satellite radio providers employ ground-based repeater stations and signal buffering to ensure uninterrupted coverage around large buildings and under tunnels. *Image credit: Sirius Satellite Radio*

Space Products and Services | 3.0

Space products and services rely upon space infrastructure, are in the space environment, or operate in it or through it, and include satellite-related products and services as well as in-space activities.

- **Communications**

The variety and selection of mobile satellite services grew in 2005, as did the number of customers subscribing to these services. New offerings by satellite radio providers and mobile television services operators in Japan and South Korea are broadening the definition of satellite services—including television programming beamed from space to cell phone-sized mobile handsets in these markets. Similar services are being considered in India and other countries. In the United States, DIRECTV now offers its Total Choice Mobile Package for in-vehicle entertainment systems.

Inmarsat began offering new services through its satellite-based Broadband Global Access Network (BGAN)—the first global, mobile broadband network. Meanwhile, the Federal Communications Commission (FCC) gave a boost to this sector of the industry by allowing mobile satellite services providers to obtain licenses to reuse spectra for complementary terrestrial services through Ancillary Terrestrial Component (ATC) licenses. The U.S. market for satellite radio services continued to grow—with XM Satellite Radio, Sirius Satellite Radio, and the much smaller WorldSpace reaching a combined audience of nearly 10 million subscribers.

- **Remote sensing**

  Remote sensing firms have yet to unlock the secrets of mass marketing to a commercial audience and continue to rely heavily on government customers to augment commercial revenues. DigitalGlobe's non-government revenues grew 40 percent in 2004, and Space Imaging (bought by ORBIMAGE and now GeoEye) saw commercial business growing by 15 to 20 percent per year in 2004—yet it still only represented 10 percent of the company's total revenue of $200 million.

FedEx Freight drivers use PDAs to input shipping data and keep information up to date, which, when combined with GPS information is vital to their tracking efforts. *Image credit: FedEx*

- **Positioning**

  GPS chipsets are becoming smaller, more affordable, and increasingly versatile. More and more, GPS technology is being integrated into other products (such as cell phones) and new products use GPS receivers for in-vehicle navigation, inventory tracking, emergency vehicle dispatch, precision agriculture and mining, and more. New GPS applications continue to emerge with no apparent limit.

- **Satellite Service Integration and New Markets**

  Satellite functions are increasingly blended with terrestrial services, and the distinctions between them are blurred. Data is carried over phone and cable television lines, voice traffic is carried over the Internet, satellite video is pushed to cell phones, and navigation data is integrated with communications capabilities and imagery. Precision timing signals from GPS satellites power the networks that enable it all.

New terms continually are being coined for emerging space applications. Among the more useful are (a) **converged media**, encompassing satellite services such as video, voice, data communication, and radio, and (b) **geoinformatics**, encompassing imagery and positioning, navigation, and timing (PNT). Even within these categories, there is crossover —navigation data integrated with communications capabilities, for example.

Satellite converged media applications evolved rapidly in 2005, particularly for satellite services end users and mobile users. For example:

- Satellite television provider DIRECTV now offers up to 25 channels of satellite radio programming from XM at no additional cost to subscribers. EchoStar (DISH Network) has a similar arrangement with Sirius.
- Satellite-delivered television is available on cell phones in Korea and Japan. Japan's Mobile Broadcasting Corporation (MBC) delivers CD-quality audio, MPEG-4 video, and data to mobile devices in Japan.
- Mobile Satellite Ventures (MSV) plans a two-way wireless phone and broadband service. This hybrid satellite/terrestrial system uses terrestrial L-band, the cellular network, and high-powered digital L-band satellites. MSV technology could add two-way voice and high-speed data services to DIRECTV and DISH Network.

WildBlue uses Ka-band "spot beam" satellites to allow multiple re-use of the same frequency, providing higher capacity at lower cost. WildBlue launched its service aboard the U.S. capacity of Telesat's Anik F2 satellite launched in July 2004. The WildBlue service primarily targets customers living in small towns and rural America. *Image credit: WildBlue*

- DISH Network and DIRECTV recently signed five-year agreements with WildBlue Communications to provide satellite broadband Internet service. The service targets rural consumers and offers satellite Internet speeds up to 1.5 megabits per second.

Geoinformatics activities represent the convergence of space-based remote sensing and space-based PNT applications. For example:

- Precision agriculture combines multi-spectral remote sensing data, which reveals crop conditions with GPS-enabled farm equipment to precisely irrigate, fertilize, and harvest crops. Precision mining uses terrestrially augmented GPS signals to automate mining operations. Both techniques improve results while reducing labor costs and removing humans from some hazardous situations.
- Google Earth uses satellite images, maps, and geographic information to allow Internet users to search the globe. With Google Earth Plus and other similar applications, users can import data from GPS devices.
- Satellite enterprise services integrate GPS receivers with telecommunications and Geographic Information System (GIS) databases to provide real-time management and tracking of mobile objects including people, pets, and property.

Google Earth allows users to import 3D models into the program, bringing a new dimension, literally, to remote sensing information. *Image credit: Google*

■ In-Space Activities

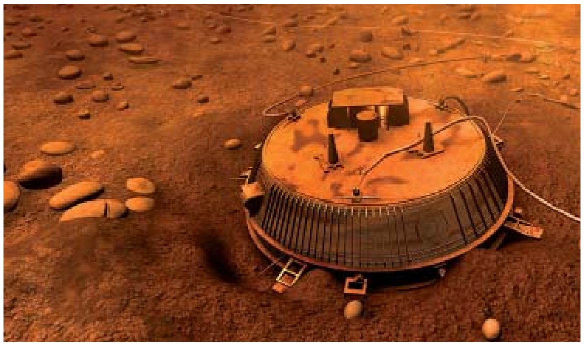
The Mars Reconnaissance Orbiter (MRO) and Venus Express launched in 2005 to explore the inner solar system. The Huygens probe landed on Titan, Saturn's largest moon—the first such landing in the outer solar system—while its carrier spacecraft Cassini continues its science excursion of the Saturnian system.

Venus Express, the European Space Agency (ESA)'s first mission to Earth's nearest planetary neighbor, was launched from Baikonur atop a *Soyuz*-Fregat vehicle on November 9, 2005, and arrived in orbit around the planet on April 11, 2006. The mission (to study the atmosphere, plasma environment, and surface of Venus) is due to last for two Venusian days (about 500 Earth days). *Image credit: ESA, J.L. Atteleyn*

In orbital space tourism, Space Adventures has brokered deals with five individuals to fly on Russian *Soyuz* capsules for one-week stays aboard the ISS. The price for these flights is $20 million. In July 2006, Bigelow Aerospace began in-orbit tests of its commercial space station module, which is a prototype for an eventual in-orbit hotel.

The market for suborbital space travel already is generating revenue, even though there has not yet been a commercial suborbital tourist flight. More than 150 people have placed deposits with Sir Richard Branson's Virgin Galactic for future suborbital flights. The advertised price of $200,000 compares favorably to Antarctic or Himalayan adventure travel, making the suborbital space tourism product accessible to a larger market than current *Soyuz* excursions.

Shown here is an artist's interpretation of the area surrounding the Huygens landing site, based on images and data returned on January 14, 2005. The probe records data on Titan's surface and atmosphere. *Image credit: ESA*

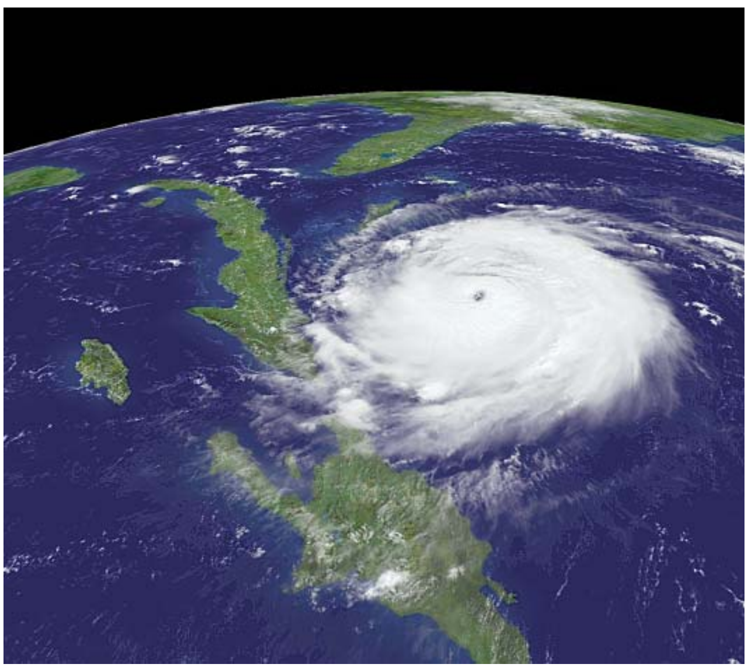


Budgets and Revenues | 4.0

The Space Report draws upon multiple sources of quantitative data on global space activity and its associated revenues and fully documents these sources to enable the reader to perform his or her own analysis and evaluation. In addition, these multiple sources have been synthesized to derive an estimate of overall total dollar value for space activity—about $180 billion for calendar year 2005. The revenue data used were chosen based on the extent of research, reliability of data, and/or strength of methodology to provide the most complete and reliable overall estimates possible. However, some incompatibilities and inconsistencies remain and cannot be resolved without additional original research. These issues are highlighted in the text so readers can make their own judgments.

How Space Products and Services Are Used | 5.0

Space products and services have become ubiquitous and are used in all aspects of daily life, often in unexpected ways.



- **Accommodations**
  Hotels on the ground rely on satellite technology and networks to track bookings, manage capacity, and provide and enhance guest services.

- **Energy and Earth Resources**
  In 2005, the importance of weather forecasting—heavily dependent upon satellites—was evident almost daily as remote sensing satellites beamed images of hurricane after hurricane during one of the most disastrous seasons ever. Response teams relied on satellite communications and remote sensing products and services, both in the United States in 2005 and in Southeast Asia after the December 26, 2004, tsunami.

- **Governance and the Public Good**
  Space products and services enable remote voting, e-governance portals and services, search and rescue missions, fleet management, and emergency communications. After Hurricane Katrina struck the Gulf Coast, Globalstar and Iridium deployed more than 10,000 satellite phones each to provide essential communication services via satellite when land-based systems had been wiped out. With landmarks eradicated, GPS became the only reliable means of navigation and positioning. Commercial remote sensing imagery was widely distributed to aid hurricane recovery and clean up efforts.

- **Healthcare and Biotechnology**
  Telemedicine, tracking of the movements of disease, and biotechnology research are all enabled or reliant upon space assets.

- **Homeland Security, Defense, and Intelligence**
  In today's armed services, "space warriors" operate the satellites and networks that are now vital to all military operations. Remote sensing satellites provide pictures of the battlefield, weather satellites provide up-to-the-second battlefield information and forecasts, and still other satellites gather signals intelligence or detect missile launches and troop movements. The GPS constellation provides precise positioning and targeting information and enables combat search and rescue operations. Meanwhile, military communications satellites provide up-to-the minute digital data to cockpits, ground vehicles, and even individual soldiers on the battlefield.

DRS's Handheld Terminal Unit (HTU) provides the soldier a small, lightweight, rugged, fully-sealed computing device. Highlighted by GPS and TCIM (Tactical Communications Interface Modem), the HTU is based solely on commercial off-the-shelf technology. *Image credit: DRS Technologies, Inc.*

- **Lifestyle Media**
  Space products provide or enable an ever-expanding array of lifestyle media, including high-speed Internet, satellite television and radio services, telephony, and other advanced communications.

- **Retail, Finance, and Management**
  ATMs rely on GPS for financial time-stamping accuracy of 10 nanoseconds, and even outwardly "simple" businesses like gas stations and convenience stores rely on Very Small Aperture Terminal (VSAT) satellite systems for banking and ATM transactions and inventory control. Satellites support sophisticated and integrated inventory management, digital signage, and other uses of space in retail, finance, and management.

- **Science and Academia**
  Space infrastructure, products, and services increase the opportunities for scientific research using telescopes, spacecraft, extra-terrestrial rovers, science aboard the ISS, and satellite-enabled research. Space systems also connect remote classrooms and scientific outposts and enable distance learning.

Carbon nanotubes exhibit extraordinary strength and unique electrical properties and are efficient conductors of heat. Shown here is nanotube grass grown on a flat substrate, obtained by heating at about 600 °C in the presence of oxygen, making the vascular bundles in the stem and nervation become dehydrated and turn into carbon nanotubes, between 30 and 50 nm in diameter. *Image credit: Rensselaer Polytechnic Institute, Carbon Nanomaterials Technology Group*

- **Transportation, Warehousing, and Manufacturing**
  Logistics enhanced by GPS tracking and navigation systems and space-enabled communication systems improve the efficiency and management of transportation, warehousing, manufacturing, and even personal navigation.

Impacts | 6.0

The impacts of space activities frequently are characterized by documenting specific instances of technology transfer or analyzing the economic benefits of space spending (which, after all, is done on Earth). Technology has been transferred from the space industry to nearly every other industry. NASA and the European Space Agency (ESA) both attempt to track technology transfer. In 2005, they reported nearly 70 specific examples of successful technology transfer from space. The Space Foundation's Space Technology Hall of Fame™ program annually recognizes a handful of stellar technologies that have come "from space to Earth" to the benefit of humankind.

Headgear protecting the head and face, and a suit covering the rest of the body, both filtering out 100% UV-light from the sun, is designed to help people suffering from xeroderma pigmentosum, a genetic disorder causing extreme sensitivity to UV rays.The materials used were originally designed for Europe's space programs. *Image credit: ESA*

Recent studies have been conducted on the economic impact of seven of NASA's ten field centers; two proposed U.S. spaceports; space-related military facilities in Nebraska, Florida, California, and Colorado; and the commercial space transportation industry. In addition, two major research efforts seek to understand better how space activities have affected the course of history and how they will help shape the future.

Outlook | 7.0

In addition to reporting on the "state of the industry" around 2005, *The Space Report* provides insight into the future of space activities through interviews with key leaders, summaries of selected forecasts and projections, and a new stock index that will be publicly available and routinely updated on the Space Foundation's Web site (www.SpaceFoundation.org).

The goal of the Aeronomy of Ice in the Mesosphere (AIM) experiment is to resolve why Polar Mesospheric Clouds (PMCs) form and why they vary. PMCs are of special interest as they are sensitive to both global change and solar/terrestrial influences. These data can be obtained only by a complement of instruments on an orbiting spacecraft because of the need for global coverage and because extinction and foreground emissions compromise optical sensing from the ground. *Image credit: Orbital Sciences Corporation*

- **Interviews with Leaders**
  There was generally wide agreement about the most significant policy initiatives of the past year and what needs must be addressed in the near future. Dominating these discussions were the challenges facing NASA and the urgent need to update the International Traffic in Arms Regulation (ITAR) to remove common space products from the so-called "munitions list." Prominently mentioned were initiatives to address national security space acquisition challenges, while a number of leaders also highlighted the need for a coherent national approach to the space initiatives of other nations, such as China.

- **Selected References, Forecasts, and Projections**
  There are few open sources for reliable data on future space activities, revenues, and budgets. *The Space Report* summarizes key forecasts and projections, and in future years hopes to incorporate original research to augment these published forecasts:

▸ The FAA forecasts 236 commercial satellite launches through 2010.

▸ Teal Group Corporation predicts 176 commercial geosynchronous satellites, worth $28.3 billion, will be built and launched between 2006 and 2015.

▸ A study by The Futron Corporation predicts a total suborbital launch market of 852 flights through 2020.

▸ Forecast International projects a $46 billion expendable launch vehicle market through 2015.

▸ Forecast International also projects that 118 dedicated military satellites are earmarked for production during the next ten years, with an associated revenue of $41 billion.

▸ In-Stat estimates the direct-to-home television market will reach $80 billion in revenue and 100 million subscribers by 2009.

▸ The worldwide market for GPS equipment and devices is predicted to reach $30 billion by 2008.

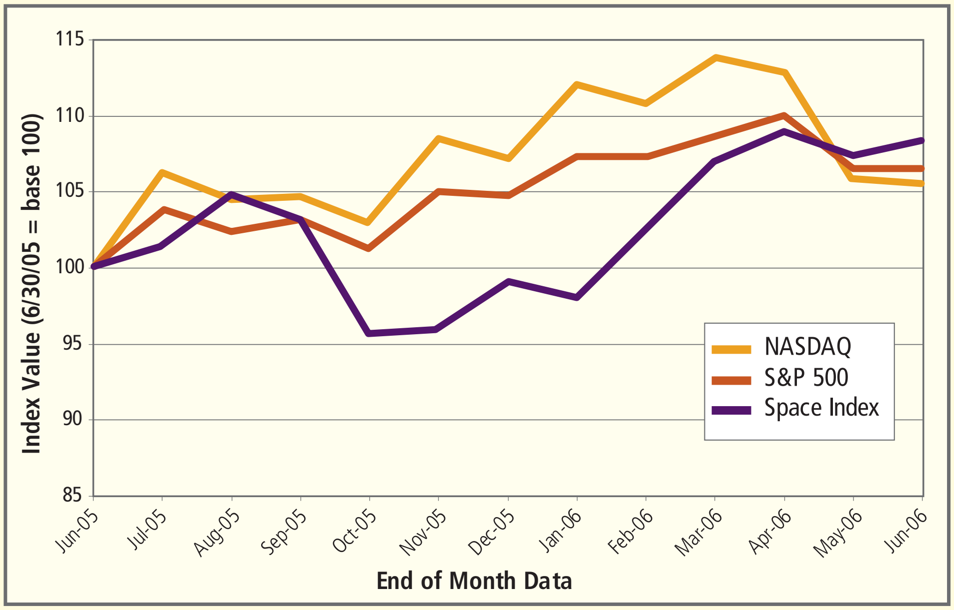
To date, there have been only three commercial, paying "space tourists" visiting the International Space Station, with Anousheh Ansari (the first female space tourist) scheduled to fly on September 2006—all space flights developed and executed through Space Adventures, using the *Soyuz-FG* launch vehicle. Space Adventures will also provide suborbital flights to 62 miles above the Earth's atmosphere. These vehicles will reach space and follow a parabolic arc, but do not achieve orbital velocity. *Image credit: Space Adventures*

Launch vehicle reusability and the ability to be called up on short notice enables satellite operators to keep spares on the ground rather than in the sky. This replenishment strategy, embodied by the K-1 launcher from Kistler Aerospace, can extend the life of satellites and reduce the cost and number of satellites and required launches. Additionally, the U.S. government has long sought launch-on-demand capability for quick call-up for military satellites and cargo resupply and recovery missions for the International Space Station. *Image credit: Rocketplane Kistler*

TomTom's navigation solutions are used by nearly a million customers in 16 countries and 18 languages. They offer GPS navigation on PDAs, mobile phones, and stand-alone vehicle devices. *Image credit: TomTom*

Exhibit 7b, and 7c, shown here, are fully described in section 7.3 of this report. Additional information, including the composition of the Space Foundation Space Index, is also provided there.

EXHIBIT 7b. Space Foundation Space Index vs. Other Market Indices



Finally, *The Space Report* introduces the Space Foundation Space Index as a tool for tracking the performance of the space industry in the U.S. public equity markets. The index currently follows 30 companies that derive a significant portion of their revenue from infrastructure and service activities related to the space industry. During the 12-month period beginning June 30, 2005, the Space Foundation Space Index increased by more than eight percent and outperformed the NASDAQ and S&P 500 indices by approximately two to three percent.

EXHIBIT 7c. Space Foundation Space Index Data

CHART INPUT DATA	COMPARATIVE DATA			ACTUAL INDEX VALUES	
	NASDAQ	S&P 500	SPACE INDEX	NASDAQ	S&P 500
Jun-05	100.00	100.00	100.00	2056.96	1191.33
Jul-05	106.22	103.60	101.44	2184.83	1234.18
Aug-05	104.62	102.43	104.78	2152.09	1220.33
Sep-05	104.61	103.15	103.30	2151.69	1228.81
Oct-05	103.08	101.32	95.66	2120.3	1207.01
Nov-05	108.55	104.88	95.95	2232.82	1249.48
Dec-05	107.21	104.78	99.05	2205.32	1248.29
Jan-06	112.10	107.45	98.09	2305.82	1280.08
Feb-06	110.91	107.50	102.62	2281.39	1280.66
Mar-06	113.75	108.69	106.97	2339.79	1294.87
Apr-06	112.91	110.01	108.85	2322.57	1310.61
May-06	105.93	106.61	107.44	2178.88	1270.09
Jun-06	105.60	106.62	108.38	2172.09	1270.2

INTRODUCTION

1.0

1.0

Introduction | 1.0

The Space Report: The Guide to Global Space Activity brings together, for the first time in a single reference document, comprehensive data and authoritative analysis on the global space economy (Exhibit 1a). For this inaugural publication, *The Space Report* includes information gathered, analyzed, and synthesized from numerous existing sources. References and sources are cited throughout in more than 450 endnotes as well as contextual citations, documenting information from industry research firms, trade associations, articles in the trade press, and interviews of executives and opinion leaders who lead, manage, or influence the global space economy. Space Foundation and The Tauri Group analysts have synthesized and compiled these data to reflect the state of the global space economy as of the end of calendar year 2005. We also have included selected data from 2006 when it was available; this is noted in the text.

EXHIBIT 1a. Major Topics Covered by *The Space Report*

1.0 Introduction
1.1 Methodology
1.2 Data Sources
2.0 Space Infrastructure
2.1 Vehicles and Launch Sites
2.2 Satellites and Ground Stations
2.3 In-Space Platforms
2.4 Surface Systems
2.5 Institutional Infrastructure
3.0 Space Products and Services
3.1 Satellite-Related Products and Services
3.2 In-Space Activities
4.0 Budgets and Revenues
4.1 Space Infrastructure
4.2 Space Products and Services
4.3 Government Space Budgets
4.4 Summary of Space Products and Services
5.0 How Space Products and Services Are Used
5.1 Accommodations
5.2 Energy and Earth Resources
5.3 Governance and the Public Good
5.4 Healthcare and Biotechnology
5.5 Homeland Security, Defense, and Intelligence
5.6 Lifestyle Media
5.7 Retail, Finance, and Management
5.8 Science and Academia
5.9 Transportation, Warehousing, and Manufacturing
6.0 Impacts
6.1 2005 Technology Transfer
6.2 Recent Estimates of Economic Impact
6.3 Broader Societal Impacts of Space Activities
7.0 Outlook
7.1 Selected References, Forecasts, and Projections
7.2 Trends
7.3 Space Foundation Space Index

This high altitude satellite, part of the Tracking and Data Relay Satellite System (TDRSS) constellation, can maintain near continuous contact with lower orbiting satellites, replacing many of the ground stations once needed for communicatiing with satellites. *Image credit: NASA*

The Space Report describes the full range of space activities in qualitative, and, where information is available, quantitative terms. The report covers:

Space Infrastructure, defined here as 1) enabling hardware infrastructure and supporting processes and organizations, such as launch vehicles, satellites, the space station, probes and rovers, and ground equipment, and 2) supporting institutional infrastructure such as space insurance, institutional investment, venture capital, and others.

Space Products and Services covers the products and services directly enabled by space infrastructure, including satellite-based services, in-space platform-based services, and in-space transportation-based services.

Budgets and Revenues consists of quantitative estimates of manufacturing and service revenues and government budgets for space infrastructure, products, and services. Where they are available, we include multiple estimates from different sources. We have then selected the most appropriate estimates to build an overall summary of total dollar value. We also describe where estimates may not be consistent or compatible with one another, and where data may be missing. Our objective is to provide a clear summary of open-source information that is currently available.

How Space Products and Services are Used describes the extensive everyday purposes to which space products and services are implemented. This section highlights how space products and services are used, sometimes surprisingly, in diverse spheres of human activity.

Impacts brings together information on the indirect effects of space activity. This section describes recent technology transfers and product spinoffs from space research and development, summarizes a dozen studies and reports (which reflect varying degrees of rigor and detail) describing the economic impacts of space-related activity, and also describes two major study efforts that seek to characterize and assess the broader societal impacts of space activity.

In-vehicle GPS navigation units combine satellite signals with built-in mapping software to guide motorists to their destinations. *Image credit: TomTom*

Outlook discusses the challenges of analytically forecasting space markets and activities and provides pointers to sources for selected data. Most importantly, *Outlook* provides the views of more than 50 leaders in the space industry on the most important technology, policy, and business trends shaping the future.

Finally, *The Space Report* contains useful, quick-look features, such as

- *Overview of Space Activity 2005* (Exhibit 5c, pages 114-115) serves as a snapshot of space infrastructure, space products and services, and the wide-ranging uses to which they are put.
- *Global Space Activity Revenues and Budgets, 2005* (Exhibit 4t, page 77) is a compilation of revenue and budget estimates selected to build an overall summary of total dollar value of direct space activities (i.e., space infrastructure and space products and services).
- The *Space Foundation Space Index* (pages 149-150) is a tracking tool that will provide on-going, up-to-date insight into the financial performance of space firms in U.S. public equity markets.

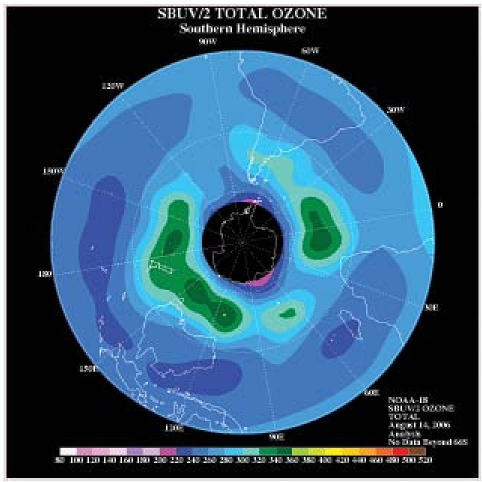
Using a system originally built for the European Space Agency to control space robots, Roboclimber is a new climbing machine designed to prevent landslides without endangering human lives. *Image credit: D'Appolonia/Roboclimber*

We hope that, in combination, these tools can help to fill that persistent, frustrating gap in viewgraph presentations and analyses that calls out for a reliable, shared overview of space activities. *The Space Report* is intended to be a starting point, so when debate and discussion challenges a finding or an estimate or a projection, less time is spent on determining the shared baseline of information, and more time is available to discuss the specific issue at hand. In a way, this compilation of information is designed, fundamentally, to enable users to challenge the information more effectively.

1.1 Methodology

The Space Report was compiled from open source information and from interviews with industry leaders. The leaders interviewed are named and quoted in 7.0, the *Outlook* section of this report, where their views are summarized.

The open source information is fully cited in endnotes and text references. The quantitative information included in *The Space Report* is from many sources and reflects published information. While we believe this to be an extremely thorough compilation of the information available, it does not represent a comprehensive data set for all space activities. For example, while we report in the text an estimate for overall research and development expenditures for commercial tourism vehicles, we do not have an estimate for 2005, or any single recent year to include in Exhibit 4t on page 77; we do not have revenue estimates for some new services such as mobile television. While we discuss new spaceports in the planning or very early development stage, we do not have a 2005 expenditure estimate. We have not found an estimate of the total revenues of space-focused market analysis and finance firms and other supporting industries. The data set does not include the budget for every country with a small space program or offices. Part of our effort in upcoming years will be to fill in these gaps.



The U.S. National Oceanic and Atmospheric Administration (NOAA) satellite observation of total ozone was made using the Solar Backscatter UltraViolet Instrument (SBUV/2). This measures the thickness of the ozone layer which is used in ozone depletion studies. *Image credit: NOAA*

The estimates here reflect a basic differentiation of types of space activities, separating infrastructure from the products and services it enables and addressing products and services in a manner that draws relatively clear distinctions between them. Because the many estimates included come from different sources that used different methodologies, there is no guarantee of internal consistency or compatibility from one estimate to another. Where the information is available, we have described methodologies and potential conflicts, double-counting, or missing data.

Where possible, we have characterized revenues for manufacturing infrastructure hardware, associated institutional infrastructure, end-user products, and end-user services.

Degrees of vertical integration of space manufacturers create challenges. Launch vehicle manufacturing and launch services are generally not differentiable costs as the service delivery firms manufacture their own vehicles. In addition, major manufacturing subcontractors are inconsistently reflected (included in some estimates but not others and not always clearly identified) and lower tier subcontractors are typically not reflected. In practice, this means that some estimates of space infrastructure manufacturing revenue may overstate the value of prime contracts (the end of the manufacturing value chain) and understate the value of total space-specific manufacturing activity (the total of all steps in the manufacturing value chain).

Definitions of space products and services are not hard and fast. We have defined space products and services as those that are directly enabled by space infrastructure. However, it is increasingly difficult to extract the space component from integrated products. Our guideline has been to include the revenues from the sale of a product or service that directly enables or relies on a space asset. Where goods are highly integrated with non-space elements, we have made a judgment as to whether the integrated product or service is primarily space related (for example, direct-to-home satellite television, for which we include all revenues, thereby essentially counting the programming delivered as a space product) or marginally space-related (for example, GPS-enabled cell phones, where we include the cost of the GPS chipset and related services, but not all the revenues associated with use of that cell phone).

This strategy works fairly well, but does run into some difficulties, notably, how to treat lease revenues for satellite transponders and the additional revenue service or subscription revenues generated by the value-added resale or use of that transponder. European direct-to-home television providers typically use leased transponders. Arguably, adding the transponder lease revenues to the direct-to-home television revenues in this case is double counting. American providers own their own satellites; this issue does not arise. On the other hand, it seems arbitrary to exclude European and not American direct-to-home television revenues when the services are highly comparable, solely based on the degree of vertical integration from a characterization of space industry revenues. Similarly, excluding some transponder leasing revenues would understate leasing totals. Our objective here is not to resolve questions like this, because the resolution depends entirely on the question being asked. We have attempted to provide insight into what data and relationships exist and summarize at a gross level the revenue associated with space infrastructure and space products and services, to provide the tools for users to formulate specific estimates and analyses addressing the questions important to them.

Finally, there is the formidable challenge of separating government and commercial revenue. The majority of government space spending is on contractors, so industry revenues and government budgets are not simply additive. Within this framework, we have selected estimates to avoid double counting where feasible, based on the information available. For example, we used a manufacturing estimate for commercial satellite production because the cost of government satellite production is included in government budget estimates. However, there is some duplication. For example, government purchase of commercial services—such as Department of Defense (DoD) leasing of communications satellites—is not fully corrected. That is, those values show both as part of government budget and as revenues to commercial firms.

A concept rendition of the Ares V Cargo Launch Vehicle. It is estimated to have a payload capacity of 130 tons and is expected to be the heavy lifter of the U.S. next generation fleet. *Image credit: NASA*

We have clearly identified what is and is not included (or what is not known) in the text describing these estimates. An objective of the Space Foundation in producing *The Space Report* in the future is to develop a data set that fills in gaps, that is reliably consistent, and that keeps pace with rapidly evolving products and services. We will be aided greatly by feedback from users of this document on high priority areas for improved data.

1.2 Data Sources

The Space Report draws on many sources of publicly available information. Data and information in this report were compiled from published sources of industry trade associations and research firms. Data were also obtained from articles in mainstream business press and industry magazines, journals, and press. We have provided citations for all significant sources to enable the reader to acquire additional information and, as a reflection of the commitment of *The Space Report,* to add clarity, credibility, and completeness.

As depicted in this array of home-based satellite dish receivers, satellites directly impact the lives of humans daily.

SPACE INFRASTRUCTURE

2.0

2.0

Space Infrastructure | 2.0

Space infrastructure is comprised of hardware and facilities unique to the space industry that enable space products and services to be delivered to end-users. Space infrastructure is defined here as the manufacturing and deployment of enabling space hardware infrastructure such as launch vehicles, satellites, the space station, probes and rovers, and ground equipment. This includes supporting processes and organizations within manufacturing organizations and supporting institutional infrastructure, such as space insurance, institutional investment, and venture capital. The section is organized into discussions of vehicles and launch sites, satellites and ground stations, in-space platforms, surface systems, and institutional infrastructure. See Exhibit 2a for detailed categories covered.

EXHIBIT 2a. Topics Covered in Space Infrastructure

2.0 Space Infrastructure
2.1 Vehicles and Launch Sites
2.1.1 Orbital Launch Vehicles
2.1.1.1 Orbital Launch Events
2.1.2 Suborbital Launch Vehicles
2.1.2.1 Commercial Suborbital Vehicles
2.1.2.2 Sounding Rockets
2.1.2.3 Long Range Strategic Missiles
2.1.3 Launch Sites
2.1.4 In-Space Crewed Vehicles
2.2 Satellites and Ground Stations
2.2.1 Communications Satellites
2.2.2 Remote Sensing Satellites
2.2.3 Positioning Satellites
2.2.4 Scientific Satellites
2.2.5 Ground Stations
2.3 In-Space Platforms
2.4 Surface Systems
2.5 Institutional Infrastructure

2.1 Vehicles and Launch Sites

The year 2005 saw NASA's space shuttle return to flight, the second human launch of the Chinese *Shenzhou* ("Divine Vessel"), continued growth and interest in orbital and suborbital tourism, the first launch of a test satellite for the European Space Agency's Galileo constellation, and the last launch of the Titan launch vehicle family.

2.1.1 Orbital Launch Vehicles

The orbital expendable launch vehicle capability currently available in the U.S. is shown in Exhibit 2b.[1] Exhibits 2c through 2e (pages 26-27) show all orbital expendable vehicles launched in 2005. U.S. vehicles are shown in Exhibit 2c, and non-U.S. vehicles in 2d and 2e.[2]

A Zenit-3SL launch vehicle lifts the JCSAT-9, a Japanese communications satellite, to a high perigee geosynchronous transfer orbit. *Image credit: Sea Launch Company, LLC*

The eight vehicles in Exhibit 2b are operated by Lockheed Martin Corporation, The Boeing Company, Orbital Sciences Corporation, and Sea Launch Company, LLC. Orbital has three small launch vehicles: the Minotaur, Pegasus XL, and the Taurus XL. The Boeing Company also has three listed, the Delta II, Delta IV, and the Delta IV Heavy. One Lockheed Martin vehicle, the Atlas V, is listed. Sea Launch, 40 percent owned by The Boeing Company with partners RSC-Energia (Russia), Kvaerner Maritime ASA (Norway), and SDO-Yuzhmash/PO-Yuzhmash (Ukraine), operates the Zenit 3SL.

Lockheed Martin's Atlas V and The Boeing Company's Delta IV line were developed in collaboration with the U.S. Department of Defense (DoD) as part of the Evolved Expendable Launch Vehicle (EELV) program.[3] In 2005, Lockheed Martin and The Boeing Company announced the formation of a joint venture, called the United Launch Alliance, which would merge the Delta IV and Atlas V manufacturing, operations, and sales.[4]

Lockheed Martin and The Boeing Company also collaborated on the space shuttle and are equal owners of the prime contractor for that program, the United Space Alliance.[5]

EXHIBIT 2b. Currently Available Expendable Launch Vehicles, U.S.

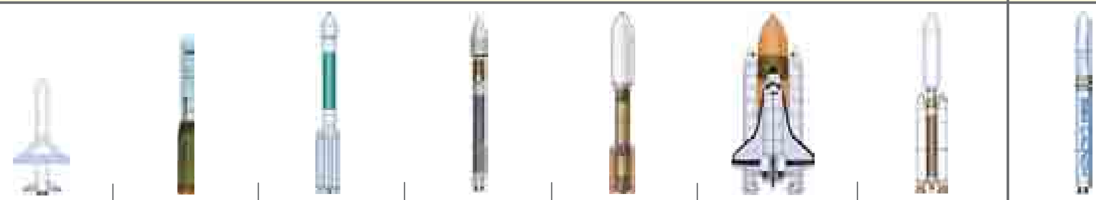
	SMALL			MEDIUM	INTERMEDIATE		HEAVY	
Vehicle	Minotaur	Pegasus XL	Taurus XL	Delta 2	Delta 4	Atlas 5	Delta 4 Heavy	Zenit 3SL
Company	Orbital Sciences	Orbital Sciences	Orbital Sciences	Boeing	Boeing	Lockheed Martin	Boeing	Sea Launch
First Launch	2000	1990	1994	1990	2002	2002	2004	1999
Stages	4	3	4	3	2	2	2	3
Payload Performance (LEO)	640 kg (1,410 lbs.)	440 kg (970 lbs.)	1,360 kg (3,000 lbs.)	5,100 kg (11,245 lbs.)	8,870 kg (19,555 lbs.) (Delta 4M) 13,330 kg (29,390 lbs.) (Delta 4M+ (5,4)	12,500 kg (27,560 lbs.) (Atlas 5-400) 20,520 kg (45,240 lbs.) (Atlas 5-500)	23,260 kg (51,280 lbs.)	N/A
Payload Performance (LEO polar)	340 kg (750 lbs.) (SSO)	190 kg (420 lbs.) (SSO)	N/A	3,895 kg (8,590 lbs.)	6,870 kg (15,150 lbs.) (Delta 4 M) 10,400 kg (22,930 lbs.) (Delta 4M+ (5,4)	N/A	20,800 kg (45,860 lbs.)	N/A
Payload Performance (GTO)	N/A	N/A	430 kg (950 lbs.)	430 kg (950 lbs.)	3,930 kg (8,665 lbs.) (Delta 4 M) 6,410 kg (14,130 lbs.) (Delta 4 M+ (5,4)	4,950 kg (10,910 lbs.) (Atlas 5-400) 8,670 kg (19,110 lbs.) (Atlas 5-500)	12,370 kg (27,270 lbs.)	6,000 kg (13,230 lbs.)
Launch Sites	VAFB	VAFB, Wallops, CCAFS	VAFB	CCAFS, VAFB	CCAFS, VAFB	CCAFS, VAFB	CCAFS, VAFB	Pacific Ocean

CCAFS – Cape Canaveral Air Force Station, KSC – Kennedy Space Center, VAFB – Vandenberg Air Force Base, WFF – Wallops Flight Facility
Source: FAA, AST. Format modified. See endnote 1.

Lockheed Martin markets and sells non-military launch services on the Atlas and the Russian Proton through International Launch Services (ILS), a joint venture with Khrunichev State Research and Production Center.

Lockheed Martin retired the Titan IV in 2005, whose heavy lift capability has been replaced by the Atlas V and Delta IV.[6]

EXHIBIT 2c. U.S. and FAA Licensed Launch Vehicle Performance in 2005



	UNITED STATES							SEA LAUNCH
Vehicle	Pegasus XL	Minotaur	Delta 2	Atlas 3	Atlas 5	Shuttle	Titan 4	Zenit 3SL
2005 Total Launches	1	2	3	1	2	1	2	4
2005 Licensed	0	0	0	0	1	0	0	4
Launch Reliability (2005)	1/1 100%	2/2 100%	3/3 100%	1/1 100%	2/2 100%	1/1 100%	2/2 100%	4/4 100%
Launch Reliability (Last 10 Years)	23/24 96%	4/4 100%	75/76 99%	6/6 100%	6/6 100%	41/41 100%	21/24 88%	17/18 94%
Year of First Launch	1994	1999	1990	2000	2002	1981	1989	1999
Active Launch Sites	CCAFS, Kwajalein, VAFB, WFF	VAFB	CCAFS, VAFB	CCAFS	CCAFS	KSC	CCAFS, VAFB	Odyssey Pacific Ocean Platform
LEO kg (lbs)	443 (977)	640 (1,410)	4,887 (10,751)	10,764 (23,709)	12,500 (27,558)	23,435 (51,557)	20,822 (45,808)	15,246 (33,541)
GTO kg (lbs)	–	–	1,769 (3,892)	4,500 (9,920)	7,640 (16,843)	5,663 (12,459)	8,276 (18,207)	6,100 (13,436)

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.
Source: FAA, AST. Format modified. See endnote 2.

Low-Cost Launch Vehicles—The Organisation for Economic Co-operation and Development (OECD) *Space 2030*:
"Despite the strong barriers to entry that prevail in the industry, some daring entrepreneurs are nevertheless attempting to challenge incumbents. The entry of low-cost launchers such as the Space Exploration Technology (SpaceX) Falcon-1 and Falcon-5, offered at USD 6 million and USD 12 million respectively, may indeed represent a major competitive threat for established launcher manufacturers. For instance, under present pricing models, the Falcon-5 launcher may be offered by SpaceX for up to 70 percent less than the cost for Boeing's Delta II and Delta IV mediums."

Space 2030: Tackling Society's Challenges, OECD 2004, page 108

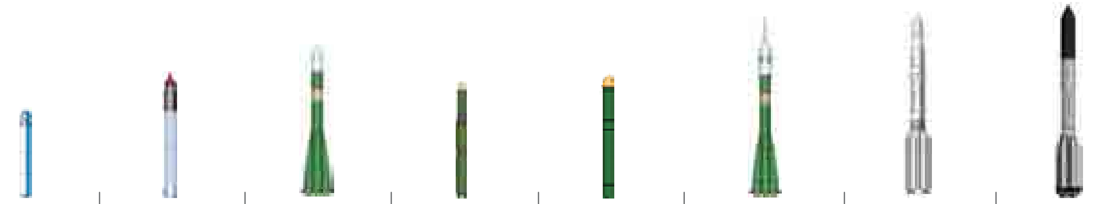
Sea Launch is an international partnership between The Boeing Company, RSC Energia of Russia, Kvaerner ASA of Norway, and SDO-Yuzhmash/PO-Yuzhmash of Ukraine. The U.S. partner, Boeing, contributing the composite payload fairing and payload mating adapter, while Yuzhmash contributes the first stage and Energia, the upper stage. The Zenit 3SL is launched in the Pacific Ocean, aboard a converted Norwegian mobile oil rig.

The Federal Aviation Administration's (FAA) *2006 Space Transportation Developments and Concepts* notes the orbital vehicles currently in development (see Exhibit 2f, page 28).[8]

Of these vehicles, the Zenit 3SLB and the Falcon family have sold launches. The Zenit 3SLB will be a modified version of the Zenit 3SL that is currently offered by Sea Launch. The Zenit 3SLB will be designed to launch at the Baikonur Cosmodrome in Kazakhstan. The only significant difference between the two vehicles is the payload fairing; the stages are identical.[9]

A C-17 aircraft flys by the Falcon 1 rocket while it sits on the launch pad on Omelek Island. *Image credit: SpaceX*

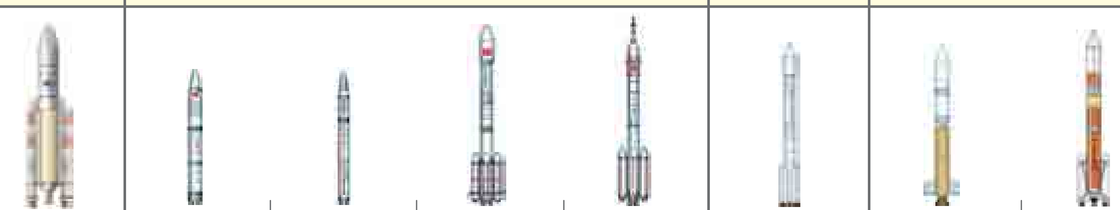
EXHIBIT 2d. Russian Launch Vehicle Performance in 2005



	RUSSIA							
Vehicle	Volna	Kosmos 3M	Molniya	Rockot	Dnepr	Soyuz	Proton K	Proton M
2005 Total Launches	1	3	1	2	1	11	3	4
Launch Reliability (2005)	0/1 0%	3/3 100%	0/1 0%	1/2 50%	1/1 100%	11/11 100%	3/3 100%	4/4 100%
Launch Reliability (Last 10 Years)	0/1 0%	5/5 100%	18/19 95%	6/7 86%	5/5 100%	91/94 97%	63/69 91%	11/11 100%
Year of First Launch	1995	1967	1960	1994	1999	1963	1967	2000
Active Launch Sites	Barents Sea (submarine)	Plesetsk	Plesetsk	Baikonur, Plesetsk	Baikonur	Baikonur, Plesetsk	Baikonur	Baikonur
LEO kg (lbs)	50 (110)	1,350 (2,970)	1,800 (3,960)	1,850 (4,075)	3,700 (8,150)	6,708 (14,758)	19,760 (43,570)	21,000 (46,305)
GTO kg (lbs)	—	—	—	—	—	1,350 (2,975)	4,430 (9,770)	5,500 (12,125)

Source: FAA, AST. Format modified. See endnote 2.

EXHIBIT 2e. European, Chinese, Indian, and Japanese Launch Vehicle Performance in 2005



	EUROPE	CHINA				INDIA	JAPAN	
Vehicle	Ariane 5	Long March 2C	Long March 2D	Long March 3B	Long March 2F	PSLV	M 5	H 2A
Country/Region	Europe	China	China	China	China	India	Japan	Japan
2005 Total Launches	5	1	2	1	1	1	1	1
Launch Reliability (2005)	5/5 100%	1/1 100%	2/2 100%	1/1 100%	1/1 100%	1/1 100%	1/1 100%	1/1 100%
Launch Reliability (Last 10 Years)	23/25 92%	13/13 100%	5/5 100%	5/6 83%	6/6 100%	7/7 100%	4/5 80%	6/7 86%
Year of First Launch	1996	1975	1992	1996	1999	1973	1997	2001
Active Launch Sites	Kourou	Jiuquan, Taiyuan, Xichang	Jiuquan	Xichang	Jiuquan	Satish Dhawan	Uchinoura	Tanegashima
LEO kg (lbs)	17,250 (37,950)	3,200 (7,048)	3,500 (7,048)	13,562 (29,900)	9,500 (20,900)	3,700 (8,140)	1,800 (3,968)	9,940 (21,868)
GTO kg (lbs)	10,500 (23,127)	1,000 (2,203)	1,250 (2,753)	4,491 (9,900)	3,500 (7,700)	800 (1,760)	—	4,100 (9,020)

Source: FAA, AST. Format modified. See endnote 2.

The Falcon launch vehicle is under development by Space Exploration Technology Corporation (SpaceX) with various proposed sizes and configurations for different payload requirements. The first Falcon 1 launch attempt was in March 2006, and failed due to a fuel tank leak at T+25s.[10] The Falcon line has an existing manifest of ten launches, three of which are for the Falcon 9, and seven for the Falcon 1.[11] The Organisation for Economic Co-operation and Development's (OECD) report *Space 2030* commented on the competitiveness of the Falcon's pricing, excerpted in the sidebar on page 26.[12]

China launches its second crewed spacecraft, *Shenzhou* VI, at the Jiuquan Satellite Launch Center. *Shenzhou* VI carried two taikonauts through 75 orbits in four days. *Image credit: AP Photo/ Xinhua, Zhao Jianwei*

Ariane 5 ECA carrying JCSAT-10 and Syracuse 3B clears the launch tower as it climbs out under the power of its Vulcain main engine and its two solid rocket motors. *Image credit: ESA/CNES/ARIANESPACE-Service Optique CSG*

2.1.1.1 Orbital Launch Events

The 55 launch events in 2005 included launches by organizations based in the United States, Russia, Europe, China, India, and Japan, and multinational organizations.[13] Notable among these were the last Titan mission, Inmarsat's 4F1 launch, and the space shuttle return-to-flight launch of STS-114 and subsequent grounding due to continued concerns over foam shedding from the eternal tank.[14] Exhibit 2i on pages 30-31 provides details on the 2005 launch events.

The FAA's Office of Commercial Space Transportation (FAA/AST) and the Commercial Space Transportation Advisory Committee (COMSTAC) prepare an annual forecast of international demand for commercial launch services. COMSTAC assesses demand for geosynchronous orbit (GEO) launches, and the FAA predicts demand for non-geosynchronous (NGSO) launches. Results of this study are shown in Exhibit 2g.[15]

EXHIBIT 2f. Orbital Launch Vehicles in Development, U.S.

NAME	DEVELOPER	TYPE	MARKET	FIRST LAUNCH
Zenit 3SLB	Space International Services	ELV	Commercial GEO satellite launch	2007
Falcon 1	Space Exploration Technologies Corporation (SpaceX)	RLV	Small satellite launch	2006
Falcon 5	Space Exploration Technologies Corporation (SpaceX)	RLV	Launch of medium sized satellites, ISS resupply	2007
Falcon 9	Space Exploration Technologies Corporation (SpaceX)	RLV	Launch of large satellites	2007
QuickReach	AirLaunch, LLC	ELV	Small satellite launch, responsive space operation	TBD
Aquarius	Space Systems/Loral	ELV	ISS resupply, small satellite launch	TBD
Eagle/Eaglet	E'Prime Aerospace Corporation	ELV	Small satellite launch	TBD
Falcon SLV	Lockheed Martin Corporation	ELV	Small satellite launch, responsive space operation	TBD
Nanosat Launch Vehicle	Garvey Spacecraft Corporation	ELV	Nanosatellite launch	TBD
Eagle SLV	Microcosm, Inc.	ELV	Small satellite launch, responsive space operation	TBD
SLC-1	Space Launch Corporation	ELV	Small satellite launch, responsive space operation	TBD

Source: FAA, AST. Format modified. See endnote 8.

Forecast International assesses worldwide demand for production of commercial, civil, military, and science satellites and the launch vehicles needed to carry them. Forecast International predicts total satellite production to be more than 800 units for 2006 to 2015, and with production of 682 expendable launch vehicles (ELVs) of various types to launch these satellites.[16]

EXHIBIT 2g. Commercial Space Transportation Satellite and Launch Forecasts

SATELLITES	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	TOTAL	AVERAGE
GSO Forecast (COMSTAC)	23	24	17	18	19	20	22	22	23	20	208	20.8
NGSO Forecast (FAA)	27	29	25	23	9	8	9	11	10	9	160	16.0
Total Satellites	50	53	42	41	28	28	31	33	33	29	368	36.8
LAUNCH DEMAND												
GSO Medium-to-Heavy	18	20	13	14	15	16	18	18	19	16	167	16.7
NGSO Medium-to-Heavy	8	8	5	3	2	1	2	2	3	2	36	3.6
NGSO Small	5	6	5	5	2	2	2	2	2	2	33	3.3
Total Launches	31	34	23	22	19	19	22	22	24	20	236	23.6

2.1.2 Suborbital Launch Vehicles

Suborbital launch vehicles are those that launch past the threshold of space and return without reaching orbit. The threshold of space is not necessarily a definitive point, but for the purpose of the Ansari X PRIZE, the highly publicized suborbital reusable launch vehicle (RLV) competition, it was defined as 100 km.[17] Sixty-five miles, or about 100 km, has been recognized as the border between the atmosphere and space for some time.

SpaceShipOne is shown gliding back to base on White Knight. Both vehicles were developed by Scaled Composites as part of their Tier One program. *Photo credit: Jim Campbell/Aero-News Network*

2.1.2.1 Commercial Suborbital Vehicles

The FAA noted in February 2005 that "there has been a resurgence of interest in commercial suborbital spaceflight, stimulated by the emergence of new markets, notably space tourism, and new vehicles developed by entrepreneurs."

EXHIBIT 2h. Announced Suborbital Space Tourism Agreements

VEHICLE DEVELOPER	VEHICLE NAME	TOURISM MARKETING COMPANY*	ESTIMATED FIRST OPERATIONS FLIGHT	ADVERTISED PRICE PER PASSENGER	PASSENGERS PER FLIGHT	PASSENGERS REGISTERED FOR FUTURE FLIGHTS**	LAUNCH SITE
Mojave Aerospace Ventures/Scaled Composites	SpaceShipTwo	Virgin Galactic	2007	$190,000	5	7,000	Mojave Airport, California
Rocketplane Ltd.	Rocketplane XP	Incredible Adventures	2007	$99,500	2	Unannounced	Burns Flat, Oklahoma
XCOR Aerospace	Xerus	Space Adventures	2007	$98,000	1	Unannounced	Mojave Airport, California

* Some operators have more than one marketing company.
** Space Adventures has reported more than 100 deposits for space flights for vehicles to be determined.

EXHIBIT 2i. 2005 Worldwide Orbital Launch Events

DATE	VEHICLE	SITE	PAYLOAD(S)	ORBIT	OPERATOR	MANUFACTURER	USE	COMML PRICE	L	M
1/12/2005	Delta 2 7925H	Cape Canaveral AFS (CCAFS)	Deep Impact	EXT	Jet Propulsion Laboratory (JPL)	Ball Aerospace & Technologies Corp.	Scientific		S	S
1/20/2005	Kosmos 3M	Plesetsk	Kosmos 2414 Tatiana	LEO LEO	Russian Ministry of Defense (MoD) Lomonosov Moscow State University	NPO Prikladnoy Mekhaniki Lomonosov Moscow State University	Navigation Development		S S	S S
2/2/2005	**V** Proton M	Baikonur	*AMC 12	GEO	SES Americom	Alcatel Espace	Communications	$70M	S	S
2/3/2005	Atlas 3B	CCAFS	USA 181	LEO	National Reconnaissance Office (NRO)	Classified	Intelligence		S	S
2/12/2005	**V** Ariane 5 ECA	Kourou	*XTAR EUR MaqSat B2 Sloshsat-FLEVO	GEO MEO MEO	XTAR Arianespace European Space Agency (ESA)	Space Systems/Loral EADS Dutch Space	Communications Test Development	$70M	S S S	S S S
2/26/2005	H 2A 2022	Tanegashima	MTSat 1R	GEO	Japan Aerospace Exploration Agency (JAXA)	Space Systems/Loral	Navigation		S	S
2/28/2005	**V** Zenit 3SL	Odyssey Launch Platform	*XM 3	GEO	XM Satellite Radio, Inc.	The Boeing Company	Communications	$70M	S	S
2/28/2005	Soyuz	Baikonur	Progress ISS 17P Teknologiya-42	LEO LEO	Russian Space Agency (Roscosmos) Roscosmos	RSC Energia Space Research Institute (IKI)	ISS Development		S S	S S
3/11/2005	**V** Atlas 5 431	CCAFS	*Inmarsat-4 F1	GEO	Inmarsat	Astrium	Communications	$70M	S	S
3/29/2005	Proton K	Baikonur	*Express AM2	GEO	Russian Satellite Communications Co.	NPO Prikladnoy Mekhaniki	Communications		S	S
4/11/2005	Minotaur	Vandenberg AFB (VAFB)	XSS-11	LEO	United States Air Force (USAF)	Lockheed Martin Corp.	Development		S	S
4/12/2005	Long March 3B	Xichang	*APStar 6	GEO	APT Satellite Co., Ltd.	Alcatel Espace	Communications		S	S
4/15/2005	Soyuz	Baikonur	Soyuz ISS 10S	LEO	Roscosmos	RSC Energia	ISS		S	S
4/15/2005	Pegasus XL	VAFB	DART	LEO	National Aeronautics and Space Administration (NASA)	Orbital Sciences Corp.	Development		S	F
4/26/2005	**V** Zenit 3SL	Odyssey Launch Platform	*Spaceway 1	GEO	Hughes Network Systems	The Boeing Company	Communications	$70M	S	S
4/29/2005	Titan 4B	CCAFS	USA 182	ELI	NRO	Classified	Intelligence		S	S
5/5/2005	PSLV	Satish Dhawan Space Center	Cartosat 1 Hamsat	LEO LEO	Indian Space Research Organization (ISRO) Amsat India	ISRO Amsat India	Remote Sensing Development		S S	S S
5/20/2005	Delta 2 7320	VAFB	NOAA N	LEO	National Oceanic and Atmospheric Administration (NOAA)	Lockheed Martin Corp.	Meteorological		S	S
5/22/2005	**V** Proton M	Baikonur	*DirecTV 8	GEO	DirecTV, Inc.	Space Systems/Loral	Communications	$70M	S	S
5/31/2005	Soyuz	Baikonur	Foton M2	LEO	European Space Agency	TsSKB Progress	Scientific		S	S
6/17/2005	Soyuz	Baikonur	Progress ISS 18P	LEO	Roscosmos	RSC Energia	ISS		S	S
6/21/2005	**V** Volna	Barents Sea	Cosmos 1	LEO	The Planetary Society	NPO Lavotchkin	Development		F	F
6/21/2005	Molniya	Plesetsk	Molniya 3K	LEO	Roscosmos	NPO Prikladnoy Mekhaniki	Communications	$1.15M	F	F
6/23/2005	**V** Zenit 3SL	Odyssey Launch Platform	*Intelsat Americas 8	GEO	Intelsat	Space Systems/Loral	Communications	$70M	S	S
6/24/2005	Proton K	Baikonur	*Express AM3	GEO	Russian Satellite Communications Co.	NPO Prikladnoy Mekhaniki	Communications		S	S
7/6/2005	Long March 2D	Jiuquan	SJ 7	LEO	China Academy of Space Technology (CAST)	CAST	Development		S	S
7/10/2005	M 5	Uchinoura	Astro-E2	LEO	JAXA	JAXA	Scientific		S	S
7/26/2005	Shuttle Discovery	Kennedy Space Center	STS 114 ISS LF-1	LEO LEO	NASA NASA	Rockwell International The Boeing Company	Crewed ISS		S S	S S
8/2/2005	Long March 2C	Jiuquan	FSW 21	LEO	China National Space Administration (CNSA)	Chinese Academy of Sciences	Scientific		S	S
8/11/2005	**V** Ariane 5G	Kourou	*Thaicom 4 (IPstar)	GEO	Shin Satellite Public Co.	Space Systems/Loral	Communications	$140M	S	S
8/12/2005	Atlas 5 401	CCAFS	Mars Reconnaissance Orbiter	EXT	JPL	Lockheed Martin Corp.	Scientific		S	S
8/14/2005	**V** Soyuz	Baikonur	*Galaxy 14	GEO	Pan American Satellite Corp.	Orbital Sciences Corp.	Communications	$40M	S	S

V Denotes commercial launch, defined as a launch that is internationally competed or FAA-licensed, or privately-financed launch activity.
* Denotes a commercial payload, defined as a spacecraft that serves a commercial function or is operated by a commercial entity.
Source: FAA, AST. Format modified. See endnote 13.

EXHIBIT 2i. 2005 Worldwide Orbital Launch Events (continued)

DATE	VEHICLE	SITE	PAYLOAD(S)	ORBIT	OPERATOR	MANUFACTURER	USE	COMML PRICE	L	M
8/23/2005	Dnepr 1	Baikonur	Kirari (OICETS)	LEO	JAXA	NEC Corp.	Scientific		S	S
			Reimei (INDEX)	LEO	JAXA	Mitsubishi Electric Corp.	Scientific		S	S
8/26/2005	Rockot	Plesetsk	Monitor E1	LEO	Roscosmos	Khrunichev State Research and Production Space Center	Remote Sensing		S	S
8/29/2005	Long March 2D	Jiuquan	FSW 22	LEO	CAST	CAST	Scientific		S	S
9/2/2005	Soyuz	Baikonur	Kosmos 2415	LEO	Russian MoD	TsSKB Progress	Intelligence		S	S
9/8/2005	Soyuz	Baikonur	Progress ISS 19P	LEO	Roscosmos	RSC Energia	ISS		S	S
9/9/2005	**V** Proton M	Baikonur	*Anik F1R	GEO	Telesat Canada	Astrium	Communications	$70M	S	S
9/22/2005	Minotaur	VAFB	STP R1	LEO	USAF	USAF Research Laboratory	Development		S	S
9/25/2005	Delta 2 7925-10	CCAFS	Navstar GPS 2RM-1	MEO	USAF	Lockheed Martin Corp.	Navigation		S	S
10/1/2005	Soyuz	Baikonur	Soyuz ISS 11S	LEO	Roscosmos	RSC Energia	ISS		S	S
10/8/2005	**V** Rockot	Plesetsk	Cryosat	LEO	ESA	Astrium	Remote Sensing	$13.5M	F	F
10/12/2005	Long March 2F	Jiuquan	Shenzhou 6	LEO	CNSA	Shanghai Academy of Spaceflight Technology	Crewed		S	S
10/13/2005	**V** Ariane 5G	Kourou	Syracuse 3 A	GEO	Delegation Generale pour l'Armement (DGA)	Alcatel Espace	Communications	$70M	S	S
			*Galaxy 15	GEO	Pan American Satellite Corp.	Orbital Sciences Corp.	Communications		S	S
10/19/2005	Titan 4B	VAFB	USA 186	LEO	NRO	Lockheed Martin Corp.	Intelligence		S	S
10/27/2005	**V** Kosmos 3M	Plesetsk	Beijing 1	LEO	Beijing Landview Mapping Information Technology Ltd.	Surrey Satellite Technology Ltd.	Remote Sensing	$12M	S	S
			Mozhayets 5	LEO	Mozhaiskiy Military Space Engineering Academy	Mozhaiskiy Military Space Engineering Academy	Development		S	S
			Ncube-2	LEO	Norwegian Student Satellite Project	Norwegian Student Satellite Project	Development		S	S
			Rubin 5	LEO	OHB System	OHB System	Development		S	S
			Sinah-1	LEO	Iran MoD	AKO Polyot	Intelligence		S	S
			SSETI Express	LEO	Aalborg University	ESA	Development		S	S
			Topsat	LEO	British MoD	Surrey Satellite Technology Ltd.	Development		S	S
			UWE-1	LEO	University of Wurzburg	University of Wurzburg	Scientific		S	S
			XI-V	LEO	University of Tokyo	University of Tokyo	Development		S	S
11/8/2005	**V** Zenit 3SL	Odyssey Launch Platform	*Inmarsat-4 F2	GEO	Inmarsat	Astrium	Communications	$70M	S	S
11/9/2005	Soyuz	Baikonur	Venus Express	EXT	ESA	Astrium	Scientific		S	S
11/16/2005	**V** Ariane 5 ECA	Kourou	*Spaceway 2	GEO	Hughes Network Systems	The Boeing Company	Communications	$140M	S	S
			*Telkom 2	GEO	PT Telkomunikasi	Orbital Sciences Corp.	Communications		S	S
12/21/2005	**V** Ariane 5G	Kourou	*Insat 4A	GEO	ISRO	ISRO	Communications	$70M	S	S
			MSG 2	GEO	Eumetsat	Alcatel Espace	Meteorological		S	S
12/21/2005	Soyuz	Baikonur	Progress ISS 20P	LEO	Roscosmos	RSC Energia	ISS		S	S
12/21/2005	Kosmos 3M	Plesetsk	*Gonets D1M 1	LEO	Smolsat	NPO Prikladnoy Mekhaniki	Communications		S	S
			Kosmos 2416	LEO	Russian MoD	NPO Prikladnoy Mekhaniki	Communications		S	S
12/25/2005	Proton K	Baikonur	Glonass K R1	MEO	Russian MoD	NPO Prikladnoy Mekhaniki	Navigation		S	S
			Glonass K R2	MEO	Russian MoD	NPO Prikladnoy Mekhaniki	Navigation		S	S
			Glonass K R3	MEO	Russian MoD	NPO Prikladnoy Mekhaniki	Navigation		S	S
12/28/2005	Soyuz	Baikonur	GIOVE A	MEO	ESA	Surrey Satellite Technology Ltd.	Navigation		S	S
12/29/2005	**V** Proton M	Baikonur	*AMC 23	GEO	SES Americom	Alcatel Espace	Communications	$70M	S	S

L and M refer to the outcome of the Launch and Mission: S = success, P = partial success, F = failure.
Note: All launch dates are based on local time at the launch site. Note: All prices are estimates.
Source: FAA, AST. Format modified. See endnote 13.

EXT = External Orbit. GEO = Geosynchronus Orbit. MEO = Medium Earth Orbit.
LEO = Low Earth Orbit. Explanations of these terms can be found on page 37.

EXHIBIT 2j. U.S. Commercial Suborbital Vehicles

COMPANY	VEHICLE NAME	VEHICLE TYPE	TAKEOFF	RECOVERY/LANDING
Acceleration Engineering	Lucky Seven	Liquid Fuel Rocket	Vertical/Land	Parafoil/Land
Advent Launch Services	Advent	Liquid Fuel Winged Rocket	Vertical/Water	Glide/Water
American Astronautics	The Spirit of Liberty	Liquid Fuel Rocket	Vertical/Land	Parachute/Land
Armadillo Aerospace	Black Armadillo	Liquid Fuel Rocket	Vertical/Land	Powered Descent/Land
Beyond-Earth Enterprises	Sapphire	Solid Fuel Rocket	Vertical/Land	Parachute/Land
Blue Origin	Not Announced	Liquid Fuel Rocket	Vertical/Land	Powered Descent/Land
Fundamental Technology Systems	Aurora	Liquid Fuel Rocket Spaceplane	Horizontal/Land	Glide/Land
High Altitude Research Corporation	Liberator	Liquid Fuel Rocket	Vertical/Water Platform	Parachute/Water
Masten Space Systems	XA	Liquid Fuel Rocket	Vertical/Land	Powered Descent/Land
Micro-Space	Crusader X	Bipod Rocket Sled	Vertical/Land	Parafoil/Water
PanAero	Condor-X	Multi-pod Rocket Glider	Horizontal/Land	Glide/Land
Rocketplane Limited	Rocketplane XP	Liquid Fuel Rocket/ Jet Spaceplane	Horizontal/Land	Horizontal/Land
Scaled Composites	SpaceShipOne/ White Knight	Two Stage Aircraft, Rocket	Horizontal/Land	Glide/Land
Space Transport Corporation	Rubicon	Solid Fuel Rocket	Vertical	Parachute/Water
SpaceDev	Dream Chaser	Hybrid Engine Spaceplane	Vertical/Land	Glide/Land
TGV Rockets	MICHELLE-B	Liquid Fuel Rocket	Vertical/Land	Powered Descent/Land
Vanguard Spacecraft	Eagle	Three Stage Rocket	Vertical/Land	Parachute/Water
XCOR Aerospace	Xerus	Liquid Fuel Rocket Spaceplane	Horizontal/Land	Glide/Land

Source: FAA, AST. Format modified. See endnote 20.

The FAA lists three vehicles with existing suborbital space tourism agreements, shown in Exhibit 2h on page 29.[18] Since that list was published, Space Adventures has teamed with Russia's Federal Space Agency (Roscosmos) and the Ansari X PRIZE financial backers to "develop a new breed of suborbital passenger ship." The deal involves "two separate contracts: one is between Space Adventures and Prodea, a Texas-based investment firm, and the other between Space Adventures and the Russian Space Agency."[19]

Powered by two jet engines and a rocket engine, the Rocketplane XP is a heavily modified Learjet 25 capable of reaching sub-orbital space. *Image credit: Incredible Adventures/Rocketplane Limited, Inc.*

The FAA also noted 18 suborbital vehicles under development by various companies in Exhibit 2j.[20] These vehicles are designed mainly to serve markets for suborbital tourism, but also may serve those for memorabilia, microsatellite delivery, and various science payloads.[21]

Other markets also may be served by derivatives of these vehicles, such as commercial resupply of the International Space Station (ISS) or deployment of small payloads and integrated upper stages to low Earth orbit (LEO).

2.1.2.2 Sounding Rockets

Sounding rockets are suborbital ELVs used for a number of reasons, including astronomical observations, atmospheric research, and microgravity experiments. Current commercial sounding rockets are listed in Exhibit 2k as reported in the FAA *2006 Commercial Space Transportation Developments and Concepts*.[22]

The Black Brant is one of the most successful sounding rockets with more than 800 launches and a success rate of 96.25 percent as of March 6, 2005. *Image credit: NASA*

2.1.2.3 Long Range Strategic Missiles

Intercontinental ballistic missiles (ICBM) and submarine-launched ballistic missiles (SLBM) fly a ballistic trajectory, normally intended to carry a nuclear warhead as a payload. While they do not orbit the Earth, the apogee of their flight brings them to altitudes at and well above LEO.

The strategic systems active in 2006 are listed in Exhibit 2l.[23,24,25,26,27]

EXHIBIT 2k. Sounding Rockets

NAME	COMPANY	STATUS
Black Brant	Bristol Aerospace Limited	Operational
Oriole	DTI Associates	Operational
Terrier-Orion	DTI Associates	Operational
Hybrid Sounding Rocket Program	Lockheed Martin-Michoud	Developmental
Norwegian Sounding Rocket Program	Lockheed Martin-Michoud	Developmental

Source: FAA, AST. See endnote 22.

(Note that the United Kingdom [UK] also maintains a long range arsenal consisting of submarine launched Trident II D-5s, obtained from the United States.)[28]

Three major ICBM systems were decommissioned in 2005. The U.S. completed retirement of the MX Peacekeeper ICBM after a phase-out period that began in 2002.[29] The U.S. Navy decommissioned the submarine launched Trident I C4, offloading the last missiles in October 2005.[30] The Peacekeeper had been operational since 1986, and the Trident I C4 since 1979. Additionally, Russia withdrew a major missile family from service in 2005, decommissioning the last of the rail-launched SS-24 M1s.[31]

EXHIBIT 2l. Operational Long Range Strategic Missiles

MISSILE NAME	COUNTRY	LAUNCH	RANGE (KM)	STAGES	PROPELLANT TYPE	YEAR DEPLOYED
Minuteman III ICBM (LGM-30G)	U.S.	Silo	13,000	3	Solid	1970
Trident II D-5 SLBM (UGM-133)	U.S.	Submarine	12,000	3	Solid	1989
Dong Feng-5/5A ICBM (CSS-4)	China	Silo	13,000	2	Liquid	1981
SS-18 Satan ICBM (RS-20)	Russia	Silo	11,000	2	Liquid	1975
SS-19 Stiletto ICBM (RS-18)	Russia	Silo	10,000	2	Liquid	1982
SS-25 Sickle ICBM (RS-12 Topol)	Russia	Land (mobile)	10,500	3	Solid	1985
SS-N-18 Stingray SLBM Mod 1 (RSM-50)	Russia	Submarine	6,500	2	Liquid	1982
SS-N-23 Skiff SLBM (RSM-54)	Russia	Submarine	8,300	3	Liquid	1985
SS-27 ICBM (RS-12M1/M2, Topol-M)	Russia	Silo/mobile	10,500	3	Solid	1997
M-45 SLBM	France	Submarine	6,000	3	Solid	1997

Source: Multiple sources. See endnotes 23-27.

2.1.3 Launch Sites

Major United States and international launch sites, according to Teal Group[32] and Astronautix,[33] are listed in Exhibit 2m. These launch sites are both commercial and government operated.

Ten states and commercial entities are proposing to build the first commercial spaceports primarily to support suborbital tourism.[34] Exhibit 2n shows all proposed U.S. spaceports and their development status.[35] Additionally, U.S.-based Space Adventures announced plans for spaceports in Singapore and the United Arab Emirates to support suborbital tourist flights.[36]

A payload launch vehicle carrying a prototype exoatmospheric kill vehicle is launched from Meck Island at the Kwajalein Missile Range on Dec. 3, 2001, for a planned intercept of a ballistic missile target over the central Pacific Ocean. *Image credit: DoD*

EXHIBIT 2m. International Launch Sites

NAME	LOCATION	COORDINATES
Cape Canaveral Air Force Station	Cape Canaveral, Florida	28 deg N, 80 deg W
Kagoshima	Kagoshima, Japan	31 deg N, 131 deg E
Kennedy Space Center	Kennedy Space Center, Florida	28 deg N, 80 deg W
Vandenberg Air Force Base	Vandenberg AFB, California	34 deg N, 120 deg W
California Space Port	Vandenberg AFB, California	34 deg N, 120 deg W
Kwajalein Island	Kwajalein Atoll, Marshall Islands	9 deg N, 167 deg E
Mojave Airport	Mojave, California	35 deg N, 118 deg W
White Sands Missile Range	Upham, New Mexico	32 deg N, 106 deg W
Spaceport America	Upham, New Mexico	32 deg N, 106 deg W
Kodiak Launch Complex	Kodiak Island, Alaska	57 deg N, 152 deg W
Mid-Atlantic Regional Spaceport	Wallops Island, Virginia	37 deg N, 75 deg W
Edwards Air Force Base	Mojave, California	35 deg N, 118 deg W
Jiuquan Satellite Launch Center (Shuang-cheng-tzu)	Jiuquan Region, Gansu Provence, China	41 deg N, 100 deg E
Tanegashima Space Center Spaceport	Tanegashima, Japan	30 deg N, 103 deg E
Palmachim Israeli Air Force Base	Palmachim, Israel	31 deg N, 34 deg E
Taiyuan Satellite Launch Center (Wuzhai)	Taiyuan, China	37 deg N, 112 deg E
Baikonur Cosmodrome	Baikonur, Kazakhstan*	46 deg N, 63 deg E
Centre Spatial Guyanias	Kourou, French Guiana	5 deg N, 52 deg W
Plesetsk Cosmodrome	Plesetsk, Russia	63 deg N, 40 deg E
Satish Dhawan Space Center	Srikarikota, India	13 deg N, 80 deg E
Xichang Satellite Launch Center	Xichang, Sichuan Provence, China	28 deg N, 102 deg E
Alacantra Launch Center	Alacantra, Brazil	2 deg S, 44 deg W

*Actually, the launch complex is about 200 miles southwest of Baikonur, near Tyuratam, Kazakhstan.
Source: Teal Group and Astronautix. See endnotes 32-33.

EXHIBIT 2n. Proposed Non-Federal Spaceports: Infrastructure and Status

SPACEPORT	LOCATION	OWNER/OPERATOR	LAUNCH INFRASTRUCTURE	DEVELOPMENT STATUS
Gulf Coast Regional Spaceport	Brazoria County, Texas	To be determined	No infrastructure at this time	The Gulf Coast Regional Spaceport Development Corporation has proposed constructing a spaceport in Brazoria County, Texas, 80 kilometers (50 miles) south of Houston.
Nevada Test Site	Nye County, Nevada	Department of Energy/Nevada Test Site Development Corporation	No launch infrastructure at this time Power and basic facilities available	Kistler was issued a sub-permit allowing it to operate a launch and recovery operation. Nevada Test Site Development Corporation is actively promoting the site as a spaceport for both reusable launch vehicles (RLVs) and conventional launchers.
Oklahoma Spaceport	Washita County, Oklahoma	Oklahoma Space Industry Development Authority (OSIDA)	4,115-meter (13,500-foot) runway, a 5,200-square-meter (56,000-square-foot) manufacturing facility, a 2,785-square-meter (30,000-square-foot) maintenance and painting hangar, and 435 square kilometers (168 square miles) of land available for further construction	The Clinton-Sherman AFB at Burns Flat was designated as the future spaceport. OSIDA is conducting a safety study of the proposed site and operations. An environmental impact study is underway.
South Texas Spaceport	Willacy County, Texas	To be determined	No infrastructure at this time	The final Texas Spaceport site has not been selected. Three sites are being considered at this time. Suborbital rockets have been launched near the proposed site.
Southwest Regional Spaceport	Upham, New Mexico	New Mexico Office for Space Commercialization	No infrastructure at this time	Plans for this site include a spaceport central control facility, an airfield, a maintenance and integration facility, a launch and recovery complex, a flight operations control center, and a cryogenic plant. Environmental and business development studies conducted.
Spaceport Alabama	Baldwin County, Alabama	To be determined	No infrastructure at this time	The master plan phase 1 has been completed. Phase 2 is expected to be completed by October 2005. While no land has been acquired for Spaceport Alabama, a green field site is under consideration in Baldwin County, across the bay from the city of Mobile.
Spaceport Washington	Grant County International Airport, Washington	Port of Moses Lake	4,100-meter (13,452-foot) main runway and a 3,200-meter (10,500-foot) crosswind runway	The site is certified as an emergency-landing site for the space shuttle. No additional infrastructure has been planned for this site.
Utah Spaceport	Wah Wah Valley, Utah	Utah Spaceport Authority	No infrastructure at this time	Plans for the proposed Utah Spaceport include a central administrative control facility, an airfield, maintenance and integration facilities for payloads and spacecraft, launch pads, a flight operation control center, and a propellant storage facility. State funding for development has not been provided since 2001.
West Texas Spaceport	Pecos County, Texas	To be determined	No infrastructure at this time	The Pecos County/West Texas Spaceport Development Corporation, established in mid-2001, has proposed the development of a spaceport 29 kilometers (18 miles) southwest of Fort Stockton, Texas. Spaceport infrastructure will include a launch site with a 4,570-meter (15,000-foot) safety radius, an adjacent recovery zone 4,570 meters (15,000 feet) in diameter, and payload integration and launch control facilities.
Wisconsin Spaceport	Sheboygan, Wisconsin	Owner: City of Sheboygan Operator: Rockets for Schools	A vertical pad for suborbital launches, in addition to portable launch facilities, such as mission control	Plans for developing additional launch infrastructure are ongoing and include creation of a development plan that includes support for orbital RLV operations.

Source: FAA, AST. Format modified. See endnote 36.

EXHIBIT 2o. In-Space Crewed Vehicles

VEHICLE	INITIAL LAUNCH (CREWED)	MAX CREW	COUNTRY	MISSION
Shuttle Orbiter	1981	7	U.S.	LEO
Soyuz	1965	3	USSR/Russia	LEO, Lunar
Shenzhou	2003	3	China	LEO, Lunar
CEV	2012	6	U.S.	LEO, Lunar
Clipper	2010	6	ESA/Russia	LEO, Lunar

2.1.4 In-Space Crewed Vehicles

Three countries, the United States, Russia, and China, have successfully placed human beings in orbit. Existing human-rated vehicles, as well as those in development or announced, are listed in Exhibit 2o (page 36).[37]

The space shuttle returned to flight in 2005, ending a two year hiatus that followed the *Columbia* tragedy. *Discovery's* STS-114 crew tested new safety measures and delivered supplies to the International Space Station (ISS).[38] Digital cameras installed for the first time on a shuttle flight captured a chunk of foam shed from the external fuel tank. A similar foam shedding incident is believed to have caused the loss of *Columbia*.[39] Fixing this problem had been a major focus of engineering efforts in the intervening time between flights. For the STS-121 shuttle flight in July 2006, NASA removed the protuberance air load (PAL) ramp, a protective ramp from which the foam loss in 2005 occurred.[40] The space shuttle is scheduled for retirement in 2010.[41]

EXHIBIT 2p. Commercial Orbital Transportation Services Finalists

COMPANY	LOCATION
Andrews Space	Seattle, Washington
*Rocketplane Kistler	Oklahoma City, Oklahoma
SpaceDev	Poway, California
SPACEHAB	Houston, Texas
*SpaceX	El Segundo, California
t/Space	Reston, Virginia

*Signed NASA Space Act Agreements in August 2006.

Michoud Assembly Facility, located in New Orleans, quickly recovered from damage during Hurricane Katrina in 2005.[42] The space shuttle's external fuel tank is produced at this facility.

China's *Shenzhou* ("Divine Vessel")[43] launched two taikonauts into orbit in 2005 for a mission lasting more than 115 hours. It was China's second human launch, following the launch of one taikonaut in October 2003. China's next human mission is expected to launch in 2007.[44] The *Shenzhou* capsule bears many design similarities to Russia's *Soyuz* reentry crew capsule.[45]

Russia's *Soyuz* has been the workhorse of Roscosmos, having been in production for more than 40 years.[46] The vehicle's separated reentry capsule and laboratory module optimize space with a minimum of weight.[47] In 2005, *Soyuz* took its third space tourist, Gregory Olsen, to the ISS.[48] Currently, the vehicle is used to rotate the crew of the ISS, (a service for which NASA pays), launching to the station twice in 2005.

April 28, 2003 rollout of a *Soyuz* TMA-2 Aboard an R7 Rocket. *Image Credit: Scott Andrews, NASA*

NASA is soliciting private companies to develop vehicles to provide crew and cargo services to the ISS[49] through the Commercial Orbital Transportation Services (COTS) program. Of 20 original proposals, there were six finalists. In August 2006, NASA signed Space Act Agreements with two: SpaceX for $278 million and Rocketplane Kistler for $207 million.[50] Exhibit 2p lists the six finalists.[51] Currently, ISS cargo supply is performed by Russia's unmanned *Progress* vehicle, a *Soyuz* redesigned for this purpose.[52]

NASA's Crew Exploration Vehicle (Orion) and Crew Launch Vehicle (Ares I) will play a central role in replacing the aging space shuttle fleet and providing human space transportation capabilities essential to NASA's ongoing mission to explore the Moon, Mars, and other bodies within our solar system.[53] Orion is the centerpiece of hardware designed to return U.S. astronauts to the Moon. The shape of the capsule will be similar to that of the *Apollo* capsules.

The largest spacecraft planned for Spacehab's Apex family is its 400 series, capable of carrying payloads of up to 12,300 kilograms. *Image credit: Spacehab*

Clipper (or "*Kliper*") was originally designed as a follow-on vehicle for the *Soyuz*. When an original design by Russia could not find funding in Russia,[54] Roscosmos sought and reached agreement with the European Space Agency (ESA) to collaborate on further design and development.[55] Representatives are currently investigating designs to perform a range of missions, including servicing the ISS and human lunar missions.

Satellite ground station

2.2 Satellites and Ground Stations

Satellites in use have four basic applications: communications, remote sensing, navigation, positioning and timing, and scientific experimentation (generally using a suite of sensors with variations of some or all of the other types). The sidebar describes the various satellite orbits.[56]

As geostationary (GSO) satellites remain in an essentially fixed position relative to the ground at all times, they can communicate with fixed ground stations continually. Medium Earth orbit (MEO) and low Earth orbit (LEO) satellites appear to "fly by" overhead and have a shorter communication window for a given station, from ten minutes for a LEO satellite to two hours or more for a MEO satellite.[57] Satellites in highly elliptical orbits may be in communication with a fixed ground station for up to eight hours.[58]

Satellite Orbits

- GSO [geostationary orbit] is synchronized with the Earth's rotation, orbiting once every 24 hours, and appears to an observer on the ground to be stationary in the sky.
- GEO [geosynchronous orbit] is a broader category used for any circular orbit at an altitude of 35,852 kilometers (22,277 miles) with a low inclination (i.e., over the equator).
- Non-geosynchronous orbit (NGSO) satellites are those in orbits other than GEO. They are located in low Earth orbit (LEO), lowest achievable orbit to about 2,400 kilometers, or 1,491 miles, medium Earth orbit (MEO, 2,400 kilometers to GEO), and all other high or elliptical orbits or trajectories.
- ELI is used to describe a highly elliptical orbit (such as those used for Russian Molniya satellites), and EXT is a designation used for orbits beyond GEO (such as interplanetary trajectories).

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2.2.1 Communications Satellites

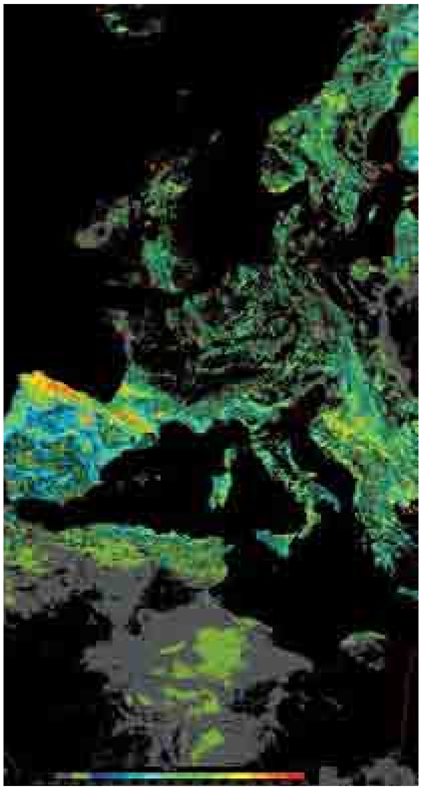
Currently, the Satellite Database maintained by Analytical Graphics, Inc. (AGI) shows that 536 active communications satellites are in orbit. Of these, 298 are in a geostationary (GSO) or geosynchronous (GEO) orbit.[59]

Teal Group Corporation projects a total of 176 GEO commercial satellites worth $28.3 billion will be built and launched from 2006 through 2015.[60]

EXHIBIT 2q. Communications Satellites by NORAD Attribution

DESIGNATION	SATELLITES
Arabia	3
ArabSat	1
Argentina	5
AsiaSat	3
Australia	4
Brazil	5
Canada	5
China	11
CIS	69
Egypt	2
ESA	2
EUTELSAT	16
France	6
Germany	4
Globalstar	45
Greece	1
IMSO	11
India	9
Indonesia	5
Israel	2
Italy	2
ITSO	24
Japan	26
Korea	3
Luxembourg	13
Malaysia	2
Mexico	3
NATO	2
Netherlands	5
New ICO	1
Norway	2
ORBCOMM	35
Philippines	1
Singapore	1
Spain	4
Spain/U.S.	1
Sweden	2
Thailand	4
Turkey	3
UAE	2
UK	3
U.S.	188
Total	**536**

In the satellite data published by the North American Aerospace Defense Command (NORAD), which monitors artificial objects in orbit,[61] satellites are designated either by their country of origin, or by their organization, company, or region. Exhibit 2q breaks down the number of communications satellites attributed to each country or organization.



Realtime Normalized Difference Vegetation Index (NDVI) data from a NOAA Advanced Very High Resolution Radiometer (AVHRR). NDVI is a quantity that measures greenness and vigor of vegetation. *Image credit: RSGB, University of Bern, and NOAA*

2.2.2 Remote Sensing Satellites

Remote sensing or imaging satellites are capable of increasingly high resolution images and ever-improving sensory data for civil, commercial, and national security customers. According to the American Society of Photogrammetry and Remote Sensing (ASPRS), 102[62] civil and commercial land imaging satellites with resolutions greater than 39 meters are in orbit as of February 2006. These satellites are shown by type in Exhibit 2r. ASPRS defines high resolution systems as those in the .5 to 1.8 meter range, while mid-resolution is defined as those from 2.0 to 39 meters.

Four of these 102 satellites are privately funded, three from the United States and one from Israel, each aimed at providing high resolution images to the military market.[63]

GeoEye-1, scheduled for launch in early 2007, will be equipped with the most advanced technology ever used in a commercial remote sensing system. The satellite will be able to collect images at 0.41-meter black and white and 1.65-meter multispectral resolution. The image is a simulation of a .41-meter resolution image of Coors Field in Denver, Colorado. *Image credit: GeoEye*

The two major U.S. remote sensing companies are DigitalGlobe and GeoEye.[64] In January 2006, ORBIMAGE acquired former rival Space Imaging for $58.5 million from its parent companies, Raytheon Company and Lockheed Martin, to form GeoEye.[65]

The 1992 U.S. Land Remote Sensing Act gives the Secretary of Commerce the right to block photos or distribution of photos of a particular area on the globe (shutter control), upon advice from the secretaries of Defense and State.[66] During military operations in Afghanistan, the U.S. military bought exclusive rights to all commercially available imagery of Afghanistan, achieving the same end through commercial means.[67] Leading into the Iraq conflict, the DoD told *Space News* that the amount of commercial capability made neither "shutter control" nor "checkbook shutter control" particularly effective.[68]

EXHIBIT 2r. Civil and Commercial Remote Sensing Systems

CATEGORY	NUMBER ON ORBIT
Optical	30
Radar	4
High Resolution	24
Mid Resolution	44
Total	**102**

The U.S. military uses remote sensing technology for a number of applications, including reconnaissance, mapping, and weather prediction. Limited public information is available from resources such as Astronautix[69] and GlobalSecurity.org.[70] According to these sources, major military remote sensing systems currently on orbit are listed in Exhibit 2s.

Artist's concept of NAVSTAR GPS above Earth. *Image credit: USAF Research Laboratory*

2.2.3 Positioning Satellites

The U.S. NAVSTAR (Navigation Signal Timing and Ranging) GPS constellation consists of 24 active and four spare satellites in MEO. According to the DoD, the fundamental concept of GPS is to use simultaneous distance measurements from four satellites to compute the position and time of any receiver. The GPS signal is available without cost to users around the world and has spawned many commercial applications.

According to the NAVSTAR program office, GPS satellites provide

- 24-hour, worldwide service
- Highly accurate, three-dimensional location information
- Precision velocity and timing services
- Accessibility to an unlimited number of global military, civilian, and commercial users[71]

EXHIBIT 2s. U.S. Military Remote Sensing Systems

NAME	TYPE	INITIAL OPERATION	PURPOSE	SPECTRUM
KH-12 (Improved Crystal)	Imaging	1992	Photographic reconnaissance	Visible light, near infrared light, thermal infrared
Lacrosse/ONYX	Radar Imaging	1988	Imaging reconnaissance (especially through cloud cover)	Microwave imager
DSP (Defense Support Program)	Infrared Sensing	1990	Detect missile plumes, thereby detecting and reporting missiles launched, space launches, and nuclear detonations	Infrared
DMSP-5D	Meteorology	1960s	Weather data for operations	Visual, infrared, microwave temperature, x-ray spectrometer, ionospheric/scintillation monitor, precipitating electron/ion spectrometer, microwave imager
Multi-Spectral Thermal Imager	Imaging	2000	Identify nuclear and chemical weapons plants/collaboration with DOE	15 spectral bands, from visible to long wave infrared

Source: Global Security and Astronautix. See endnotes 69-70.

Other positioning constellations are operated by Russia (Global Navigation Satellite System, or GLONASS) and China (Beidou). Europe launched the first test satellite in the Galileo system in December 2005. Japan is developing the Quasi-Zenith system, a regional augmentation of the GPS signal, with a 2008 planned launch.[72] Current and planned navigation constellations are shown in Exhibit 2u (page 41).[73]

This image shows the initial ejecta that resulted when NASA's Deep Impact probe collided with comet Tempel 1. It was taken by the spacecraft's medium-resolution camera 16 seconds after impact. *Image Credit: NASA/JPL-Caltech/UMD*

2.2.4 Scientific Satellites

Currently, 102 scientific satellites are in orbit around the Earth.[74] These satellites address a wide array of scientific issues. For example, NASA characterizes scientific satellites by the following types: astronomy, earth science, planetary science, solar physics, space physics, life science, and microgravity.[75]

EXHIBIT 2t. Deep-Space Probes Launched in 2005/2006

NAME	MISSION/DESTINATION	AGENCY
Deep Impact	Comet Tempel 1	NASA
MRO	Mars	NASA
Venus Express	Venus	ESA
New Horizons 1	Pluto	NASA

Source: Analytical Graphics, Inc. See endnote 79.

One of the more well known scientific satellites, the Hubble Space Telescope, was the subject of debate in 2005, as funding for a shuttle servicing mission was cut,[76] and later conditionally restored.[77]

According to NASA's National Space Science Data Center (NSSDC) Master Catalog, several scientific satellites were launched in 2005, which are listed in Exhibit 2v (page 42).[78]

Probes journey beyond Earth orbit, typically with a science mission. There are 13 active probes in space.[79] Four probes were launched in 2005 and early 2006, as seen in Exhibit 2t.

ESA's SMART-1: testing solar electric propulsion and studying the Moon. *Image credit: ESA*

The European Space Agency's SMART-1 arrived in lunar orbit in November 2004 and spent all of 2005 inventorying chemical elements on the lunar surface and investigating geological features.[80]

The United States, China,[81] Russia, and Japan all have plans for lunar missions starting in 2008.[82]

2.2.5 Ground Stations

Ground station infrastructure provides command, control, tracking, and telemetry systems for launch vehicles, satellites, and other platforms. Worldwide tracking systems operated by government agencies support launch command and control. Satellite ground stations are operated either by commercial or government entities; their components include the large satellite receivers used to transmit and receive signals to and from satellites on orbit for the purpose of communication, navigation, or data transfer.

End-user devices that incorporate satellite signals are treated in 3.0, *Space Products and Services*.

2.3 In-Space Platforms

The largest in-space platform ever constructed is the International Space Station (ISS). "Led by the United States, the ISS draws upon the scientific and technological resources of 16 nations: Canada, Japan, Russia, 11 nations of the European Space Agency [Belgium, Denmark, France, Germany, Italy, the Netherlands, Norway, Spain, Sweden, Switzerland, and the United Kingdom], and Brazil,"[83] according to NASA. The station is currently 146 feet long, with 240 square feet of solar arrays, a habitable volume of 15,000 cubic feet, and weight of 404,069 lbs.[84] All but one of the remaining planned shuttle flights (the Hubble Space Telescope repair mission) through 2010 will be used to complete assembly of the station as designed. Research conducted on the ISS includes materials research, studies on the effects of microgravity on human physiology, crew Earth observation, and crystal growth.[85]

EXHIBIT 2u. Current Navigation and Positioning Constellations

NAME	COUNTRY	SATELLITES (COMPLETE, NOT INCLUDING SPARES)	CURRENT OPERATIONAL SATELLITES	ORBIT	COVERAGE
NAVSTAR GPS	U.S.	24	24	MEO	Global
Galileo	ESA	27	1	MEO	Global
GLONASS	Russia	24	13	MEO	Global
Beidou (Twin Star)	China	3	3	GEO	Regional
Quasi-Zenith	Japan	3	0	GEO	Regional

A privately financed company based in Las Vegas, Nevada, Bigelow Aerospace is licensing technology from NASA to build an inflatable in-space platform that could enable a number of on-orbit applications. Bigelow's prototype inflatable platform was launched July 12, 2006, aboard a Russian- and Ukrainian-built Dnepr rocket, launched from Russia's Yasny Launch Base by International Space Company (ISC) Kosmotras.[86] Since the module is inflatable, internal volume is not strictly limited to the diameter of the launch vehicle. According to *Popular Science*, founder and president Robert Bigelow wants to have this platform outfitted as an orbiting hotel by 2010.[87] Bigelow has stated that he will personally invest a total of $500 million in the project through 2015.

EXHIBIT 2v. Scientific Satellites—2005 Launches

NAME	SPONSOR	MISSION
Sloshsat FLEVO	ESA	Microgravity (Fluid Dynamics)
Tatiana	CIS	Space Physics (Radiation)
Shi Jian 7	China	Space Physics
Astromag FF	NASA	Astronomy
Suzaku	JAXA	Astronomy
Cartosat 1	ISRO	Earth Science
FSW 21	China	Earth Science
FSW 22	China	Earth Science
Monitor-E	Russia	Earth Science
MSG 2	ESA	Earth Science
Mtsat-1R	JAXA	Earth Science
NOAA 18	NOAA	Earth Science Solar Physics Space Physics
Sihah 1	Iran	Earth Science
SSETI-Express	Sweden	Earth Science
TopSat	UK	Earth Science
Tsinghua	China	Earth Science
Reimei	JAXA	Earth Science Space Physics
Foton M-2	Roscosmos	Life Science Microgravity
Shenzhou VI (SZ-6) Orbital Module	China	Scientific Research

Source: NASA. See endnote 75.

2.4 Surface Systems

Surface systems are those systems that operate on the surface of a planet. Current operational surface systems include the NASA Jet Propulsion Laboratory (JPL) Mars Rovers, *Spirit* and *Opportunity.* These robots were launched in June and July 2003, with

This view is Earth's distant horizon through International Space Station solar array panels as photographed by an Expedition 13 crew member. *Image credit: NASA*

Bigelow Aerospace has planned a series of inflatable structure tests in space. The plan is to evolve testing and hardware to establish the Nautilus outpost in Earth orbit. *Image credit: Bigelow Aerospace*

the purpose of understanding the history of water on Mars.[88] They continue to be operational into 2006, well past their 90-day prime mission.

NASA's plan for space exploration includes plans for establishing bases on the Moon. According to NASA's Exploration Systems Architecture Study (ESAS) report, activities on the Moon will "consist of a balance of lunar science, resource use, and Mars-forward technology and operational demonstrations."[89] According to this document, the outpost is to be built incrementally, with cargo left behind after each sortie mission. The most likely site for the outpost would be one of the polar regions of the lunar surface, based on the assumption that water ice may be available.

2.5 Institutional Infrastructure

Institutional infrastructure includes finance, investment, insurance, and marketing firms that support space activities.

Space insurance is a critical source of institutional infrastructure. Satellites can be insured with a number of policies that cover different phases of the launch event. Types of space insurance are listed in Exhibit 2w on page 44, as reported by the FAA.[90]

Shown here is a synthetic image of the Mars Rover, *Opportunity*, which has been exploring Mars since it landed on Jan. 24, 2004. *Image credit: Mars Exploration Rover Mission, Cornell, JPL, NASA*

The FAA notes that space insurance is "usually a small, specialty line of business within a larger multinational insurance conglomerate."[91] The major space insurance brokers are Aon Corporation, Marsh Space Projects, and Willis and International Insurance Brokers.[92]

Launch insurance rates typically run at around 20 to 23 percent of the value of the satellite and launch vehicle,[93] while on-orbit insurance rates are normally between 2.5 and 3 percent per year.[94] Third party insurance is required as a condition of receiving an FAA license for commercial launch.

Other types of non-engineering firms support satellite and launch vehicle manufacturing and services. These firms offer services ranging from finance to market research to advertising and public relations. Little comprehensive data is available on the roles these types of firms play in the space industry.

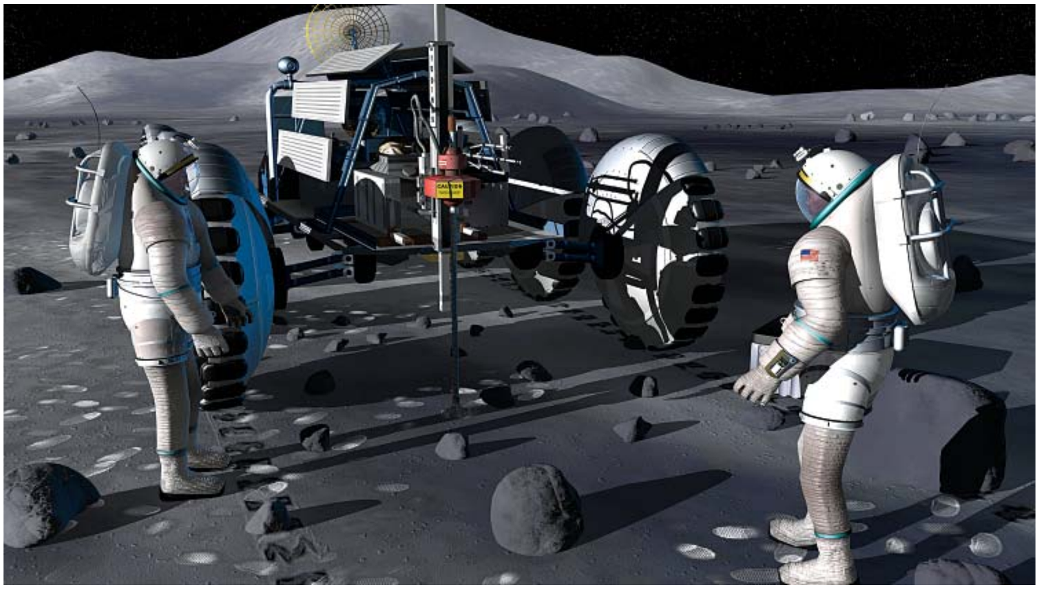
Depending on the context, institutional infrastructure also can be considered to include corporate investment (rather than contractually funded investment) by space manufacturing firms in research and development.

EXHIBIT 2w. Space Insurance Types

TYPE	COVERAGE
Pre-launch insurance	Damage to a satellite or launch vehicle during construction, transportation, and processing phases
Launch insurance	Loss of a satellite during launch
In-orbit policies	Insure satellite technical problems and damage in their proper orbit
Third-party liability and government property insurance	Protects launch service providers and customers in the event of public injury or government property damage, caused by launch or mission failure

Source: FAA, AST. See endnote 90.

U.S. satellite and launch manufacturers who are defense contractors invest in technology development through Independent Research and Development (IR&D). IR&D is "research and development initiated and conducted independent of DoD control and without direct DoD funding."[95] It may include any type of research and development work as part of an existing contract that results in a greater capability or a reduction in cost. The DoD encourages these activities, and costs incurred are "recoverable as 'indirect expenses' on contracts covered by DoD cost accounting standards."[96] In practice, about half of costs are recovered in this way.[97]



Lunar Surface Drilling. In this artist's concept, two astronauts watch carefully as their drill bores down into the top layers of the lunar surface. *Image credit: NASA*

2006

THE SPACE REPORT

SPACE PRODUCTS AND SERVICES

3.0

3.0

Space Products and Services | 3.0

We have characterized space products and services as directly enabled by space infrastructure and intended to be in the space environment or directly interacting with the space environment.

This section is organized by satellite-related products and services and in-space activities; see Exhibit 3a for detailed categories covered.

EXHIBIT 3a. Topics Covered in Space Products and Services

3.0 Space Products and Services
3.1 Satellite-Related Products and Services
3.1.1 Communications Satellites
3.1.1.1 Television/Video
3.1.1.2 Telephony
3.1.1.3 Radio
3.1.1.4 Data Communications
3.1.2 Remote Sensing Satellites
3.1.3 Satellite Positioning
3.1.4 Service Integration and New Markets
3.1.4.1 Satellite Converged Media
3.1.4.2 Geoinformatics
3.2 In-Space Activities
3.2.1 Platform-Based In-Space Activities
3.2.1.1 Science and Research
3.2.1.2 Accommodations
3.2.2 Transportation-Based In-Space Activities
3.2.2.1 Research and Exploration
3.2.2.2 Tourism
3.2.2.3 Missile Defense

The year 2005 saw growth in subscribers and offerings for mobile satellite services, launches of probes to explore Mars and Venus, a probe landing on Saturn's moon Titan, and growth in commercial space transportation services.

Artist's concept of the Cassini orbiter, which has made many discoveries since its launch, including finding two new moons of Saturn. *Image credit: Jet Propulsion Laboratory/ NASA*

Mobile satellite services' subscribership continued to grow, with new offerings by satellite radio providers and mobile television services in Japan and Korea. Inmarsat began offering service through its broadband global access network (BGAN), the first global, mobile broadband network. Additionally, the Federal Communications Commission (FCC) gave a boost to the mobile services industry by allowing mobile service providers to obtain licenses to reuse their spectrum for complementary terrestrial services.

The Mars Reconnaissance Orbiter and Venus Express launched in 2005 to explore the inner solar system, and the Huygens probe landed on Titan, Saturn's largest moon. The Huygens probe represents the first landing in the outer solar system.

Interest in new commercial space transportation providers increased in 2005. NASA selected competitors for its Commercial Orbital Transportation Services (COTS) to resupply the International Space Station and selected two finalists, SpaceX and Rocketplane Kistler. Greg Olsen became the third space tourist to travel into orbit. More than 150 people had made deposits to Virgin Galactic for suborbital space flights, as of April 2006.

U.S. Military Use of Commercial Communications Satellites

"Since the terrorist attacks of Sept. 11, 2001, the U.S. government has become the satellite industry's single largest customer and the Defense Department has been the biggest driver behind the new wave of demand," said Don Ritter, vice president of government services at PanAmSat G2 Satellite Solutions. "The role of the commercial satellite operators has gone from augmentation to becoming strategic partners with the Department of Defense," he added.

"The U.S. government's use of commercial satellite services hit an estimated $500 million a year by 2002 and is expected to reach $1.5 billion a year by 2007," said Robert Turner, director of government services at New Skies Satellites of The Hague, the Netherlands. "The demand is growing at a double-digit percentage rate annually," he added.

"Roughly 60 percent of the [government's] use of commercial satellite services is coming from the Department of Defense," Turner said. "The military has the broadest requirements that include services and solutions that are global in scope," he added.

"The remaining 40 percent of the U.S. government's use of commercial satellite services comes from a variety of agencies that include the intelligence community and the State Department," Turner explained.

http://www.space.com/spacenews/archive05/Milsat_061305.html

3.1 Satellite-Related Products and Services

At their most basic functional level, communications satellites relay data (telephone calls, television, radio, Internet traffic), remote sensing satellites acquire and transmit data (imagery, atmospheric data), and navigation satellites generate and transmit data (locational, timing). These capabilities create the products and services discussed below. The many different industries in which these basic products and services are used are discussed in 5.0, the *How Space Products and Services Are Used* section of this report. Satellites are owned and operated commercially, as well as by civil and military government organizations. Additionally, governments may purchase commercial satellite capacity. The U.S. government is the commercial satellite industry's largest customer, as explained in the sidebar on page 48.

EXHIBIT 3b. Communications Satellite Frequencies

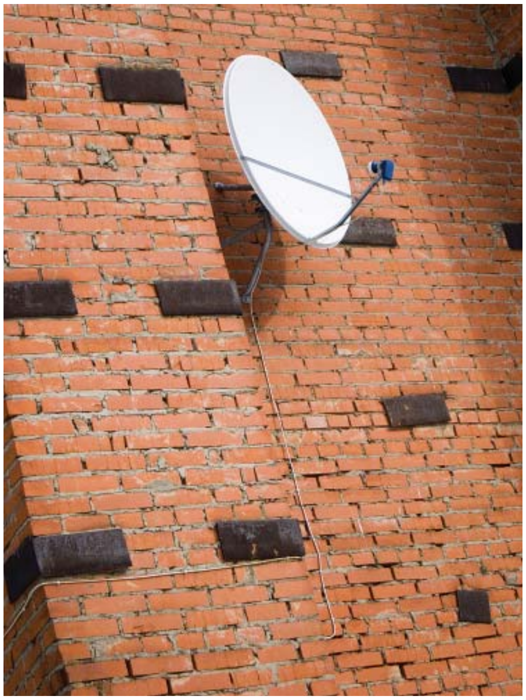
BAND	FREQUENCY	TYPICAL USE
UHF-band	300 to 1,000 MHz	Mobile data
L-band	1 to 2 GHz	Mobile telephone, data
S-band	2 to 4 GHz	Radio, mobile television
C-band	4 to 8 GHz	Telephone, television, data
X-band	8 to 12 GHz	Military
Ku-band	12 to 18 GHz	Telephone, television, data
Ka-band	18 to 40 GHz	Television, data
V-band	40 to 75 GHz	Broadband

3.1.1 Communications Satellites

Communications satellites may be used as a network backbone or to connect directly to fixed end-users (Fixed Satellite Services, or FSS) or mobile end-users (Mobile Satellite Services, or MSS). They support point-to-point communication and are particularly useful for point-to-multipoint applications. Different types of satellites operate in different frequency bands, shown in Exhibit 3b, Communications Satellite Frequencies. Countries have slightly varying definitions of these bands.

3.1.1.1 Television/Video

Direct-to-Home Television: Direct-to-home (DTH) television is the transmission of television programming directly to end-user equipment. Other terms are direct broadcast and satellite television. The term broadcast service satellite (BSS) is often used to describe satellites offering these services. BSS satellites operate in the Ku-band and Ka-band. In the United States, satellites offering these services are called direct broadcast satellites (DBS). Satellites deliver television signals to DTH satellite dishes, through providers such as DIRECTV (U.S.), ExpressVu (Canada), BSkyB (Europe) and SKYPerfecTV (Japan).[98] Exhibit 3c (page 50) shows the Top 15 DTH television providers as reported by The *SkyREPORT* in April 2003.[99] Updated subscribership estimates for selected providers (as of early 2006) from The BRIDGE Media Group, publisher of *SkyREPORT,* are DIRECTV, 15.4 million; EchoStar (DISH), 12.3 million; BSkyB, 8.2 million; and SKYPerfecTV, 3.6 million.



Broadcast and Cable Television: Satellites are used to transmit television programming to broadcast affiliates or cable head-ends. These services are typically provided by leasing C-band and Ku-band transponders on Fixed Satellite Service (FSS) satellites.

Mobile Satellite News Gathering: Satellites are used to send television news feeds from news vans directly to broadcast distributors. News vans transmit in the C- and Ku-bands to distributors via GEO satellites.

Mobile Television: Satellites are used to transmit television programming to cell phone-sized mobile handsets. Currently, these services are offered only in Japan and South Korea. This service, offered by Mobile Broadcasting Corp. (MBC), is called satellite digital media broadcasting (S-DMB) and uses the MBSat-1 S-band satellite to provide television via cell phone service.[100] Similar services are being considered in India and other countries.[101] Satellite television also can be provided for cars and other mobile vehicles. RaySat recently introduced a rooftop antenna for cars in Japan called the TeleRay. According to RaySat, "The TeleRay is compatible for use with all mobile TV receivers currently on the market in Japan, and is optimized to receive SKYPerfecTV signals, in addition to Free-to-Air BS channels."[102] In the United States, DIRECTV offers the Total Choice Mobile Package for vehicles.

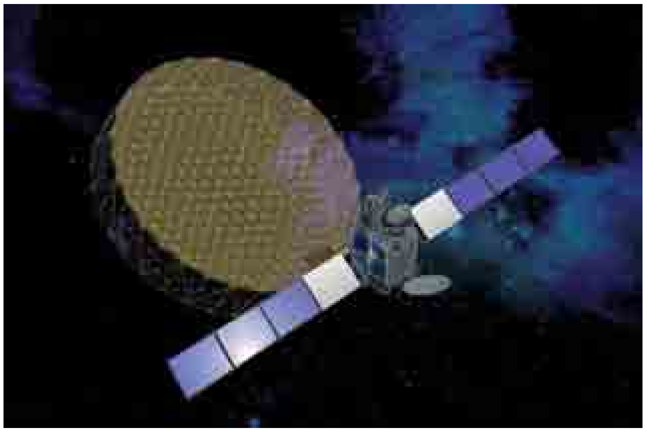
EXHIBIT 3c. Worldwide DTH Platforms

RANK	SERVICE	COUNTRY/REGION	SUBSCRIBERS
1	DIRECTV	U.S.	11.42 Million (March 2003)
2	Echo Star's DISH Network	U.S.	8.188 Million (Dec. 2002)
3	BSkyB	UK/Ireland	6.562 Million (Dec. 2002)
4	SkyPerfecTV	Japan	3.383 Million (Jan. 2003)
5	Premiere World	Germany	2.8 Million (Jan. 2003)
5	Canal Satellite Digital	Spain	2.8 Million (Jan. 2003)
6	Canal Satellite	France	2.2 Million (Jan. 2003)
7	Sky Italia	Italy	2.074 Million (Jan. 2003)
8	DIRECTV Latin America	Latin America Region	1.582 Million (March 2003)
9	Bell ExpressVu	Canada	1.3 Million (Dec. 2002)
10	Multichoice	South Africa/Sub-Saharan Africa	1.28 Million (Jan. 2003)
11	TPS	France	1.1 Million (Jan. 2003)
12	Star Choice	Canada	796,000 (Feb. 2003)
13	Sky/Net Sat	Brazil	732,000 (Jan. 2003)
14	Sky/Innova	Mexico	705,900 (Jan. 2003)
15	Sky	New Zealand	517,000 (Jan. 2003)

Source: BRIDGE Media Group, Inc. See endnote 99.

Digital Movie Distribution: Digital movie distribution involves the delivery of movies to theaters for broadcasting via broadband satellites. Satellite distribution has been demonstrated in the United States; however, the market for satellite distribution is still developing.[103]

Non-Commercial Activities: The U.S. military uses satellite video communications for teleconferencing and video data streams. Military video data is distributed through the Global Broadcast Service (GBS), which includes leased commercial satellites and communication packages on the Navy UHF follow-on (UFO) satellites.[104]



Artist concept of Mobile Broadcasting Corporation's MBSat in on-orbit configuration. *Image credit: MBC*

3.1.1.2 Telephony

Trunking: Satellites have provided trunking for long-distance telephone service for decades. Most long-distance traffic is now routed over cable, avoiding the lag and other reductions in quality (such as echo) associated with satellite telephone calls. Areas or countries lacking terrestrial backbone still rely on satellite connectivity to the publicly-switched telephone network. Telephone companies or nations lease C-band or Ku-band transponders on GEO satellites. Telephony, along with broadcast television, discussed above, and data services are common FSS applications. The *Top 26 FSS Operators* for 2005, as listed by *Space News*, are shown in Exhibit 3d (pages 52-53). However, the purchase of PanAmSat by Intelsat, completed in 2006, created the largest global satellite entity, with more than 50 satellites in orbit, and shifted the current order of the top four FSS operators listed here. The new Intelsat is the largest FSS operator by revenues, with SES Global of Luxembourg now the number two operator. [105]

Mobile telephony services can provide near-global coverage by communicating directly with a satellite. *Image credit: Iridium*

Mobile Telephony: Satellites also provide mobile telephony services. Satellite mobile telephony enables regional to near-global coverage depending on the satellite or constellation, using handsets that communicate directly with a satellite. Mobile satellite telephone service is provided by satellite constellations in LEO, such as Iridium and Globalstar, and by satellites in GEO, such as Inmarsat, Thuraya, and ACeS. These services are provided by satellites primarily using the L-band. Satellites providing mobile phone and data services often are referred to as mobile satellite service (MSS) satellites. These systems also provide mobile data services such as messaging, paging, and asset tracking. Additionally, Inmarsat began providing mobile broadband data services in 2005. Mobile data and mobile phones are often referred to together as MSS; revenue from both services is shown in MSS estimates. Another type of satellite wireless service, using very small aperture terminal (VSAT) networks, is discussed in 3.1.1.4, the *Data Communications* section of this report. MSS systems also provide military communications. In December 2000, the U.S. military signed a $72 million contract with Iridium.[106]

In February 2005, the FCC announced that MSS operators could apply for ancillary terrestrial component (ATC) licenses. ATC allows MSS operators to reuse their allocated spectrum to provide terrestrial services complementary to their satellite offerings. This decision essentially grants these operators free terrestrial spectrum. The concept was introduced by Mobile Satellite Ventures (MSV).[107] Currently, Inmarsat, MSV and MSV Canada, TerreStar Networks, and ICO Satellite Management[108] have been granted licenses to develop this terrestrial component of their network. According to Application Technology Strategies, Inc., "MSV intends to serve the now-popular hand-held data devices like advanced mobile phones and wireless PDAs. With ATC and a new generation of high-powered L-band satellites, an appropriate handset or laptop can roam from a terrestrial wireless system using cell towers to a satellite under clear line-of-sight conditions."[109]

3.1.1.3 Radio

Broadcast Network Radio: Radio programming and feeds are distributed to broadcast affiliates over FSS satellites. These types of radio services use C-and Ku-band transponders. For example, in the United States, the Public Radio Satellite System (PRSS), which is managed

EXHIBIT 3d. Top Fixed Satellite Service Operators

RANK	COMPANY	LOCATION	2005 REVENUE	2004 REVENUE	SATELLITES IN ORBIT	SATELLITES ON ORDER	REMARKS
1	SES Global	Luxembourg	$1.48 billion	$1.56 billion	30	6	In euro-to-euro terms, SES Global reported a 16.7 percent increase in revenues. Growth is masked by 2005 rebound of U.S. dollar. Satellites on order include Ciel-2, for Canadian satellite startup 49 percent SES-owned.
2	Intelsat Ltd.	Bermuda/U.S.	$1.17 billion	$1.04 billion	28	1	Purchase of PanAmSat expected to occur before September. Combined company will be world's largest FSS operator by revenues.
3	Eutelsat	France	$885 million	$1.037 billion	22	3	Successful IPO in November; Hot Bird 8 satellite awaiting ILS Proton return to flight. Revenues are for fiscal year ending June 30.
4	PanAmSat Holding	U.S.	$861 million	$827.1 million	24	1	Galaxy 16 satellite launched June 18; sale to Intelsat imminent. Company purchased EuropeStar in 2005, including satellite renamed PAS-12. Satellite on order to be owned equally with JSAT Corp.
5	Telesat Canada	Canada	$407.3 million	$300.7 million	6	2	Sales were up 31 percent before effects of Canadian/U.S. dollar exchange rate. Company's owner, BCE Inc., plans partial sale this year to raise cash.
6	JSAT Corp.	Japan	$373 million	$430.7 million	9	3	Satellite on order, Horizons-2, to be co-owned with PanAmSat. Revenues are for fiscal year ending March 31, 2006. Company expects revenue decline this year.
7	New Skies Satellites	Netherlands	$240.5 million	$210.7 million	5	1	Company has been purchased by SES Global in a $1.15 billion transaction in March. New Skies to remain a distinct operating division within SES.
8	SingTel Optus	Australia/Singapore	$165 million	$167.7 million	5	2	Optus parent SingTel is 20.33 percent owner of APT Satellite Holdings. Fleet includes four Optus satellites, and the ST-1 satellite.
9	Star One	Brazil	$164.5 million	$152.5 million	4	2	Company is 20 percent owned by SES Global. Two satellites on order with Alcatel Alenia Space are scheduled for launch in late 2006 and 2007. In local currency, revenues were down five percent.
10	Space Communications Corp.	Japan	$153.7 million	$217.6 million	4	1	Superbird-7 satellite ordered from Mitsubishi Electric, an SCC shareholder, for launch in early 2008. 2005 figures are for year ending March 31, 2005.
11	Loral Space and Communications	U.S.	$152 million	$141.2 million	4	1	Company re-entered North American market in March and is part owner of C-and Ku-band capacity aboard just-launched Satmex 6 satellite. 2004 sales exclude $87 million in sales-type lease contracts.
12	Arabsat	Saudi Arabia	$150 million	$140 million	4	2	Fleet includes two satellites leased from Eutelsat and PanAmSat. Arabsat 4A launched in February was lost in launch failure; 4B is scheduled for launch this year, and two more satellites may be ordered this year.

Note that SES Global and New Skies completed a merger in March, 2006; and Intelsat and PanAmSat completed a merger in July, 2006.

EXHIBIT 3d. Top Fixed Satellite Service Operators (continued)

RANK	COMPANY	LOCATION	2005 REVENUE	2004 REVENUE	SATELLITES IN ORBIT	SATELLITES ON ORDER	REMARKS
13	Russian Satellite Communications Co.	Russia	$143.5 million	$114 million	11	1	Express AM-11 satellite failed in orbit in March 2005; company in late 2005 entered into agreement with PT Telekom of Indonesia to explore a commonly developed satellite.
14	Hispasat S.A.	Spain	$117.6 million	$115.1 million	6	0	Commercial X-band satellites Xtar-Eur and Spainsat, managed by Hisdesat consortium and Loral, are now in orbit.
15	KT Corp.	South Korea	$115.3 million	$116.8 million	2	1	Civil/military Koreasat 5 satellite, built by Alcatel Alenia Space, launched in August 2006.
16	AsiaSat	Hong Kong	$113.5 million	$129.3 million	3	1	Company is 34.1 percent owned by SES Global. AsiaSat 5 satellite, on order from Loral, scheduled for launch in 2008.
17	Telenor Satellite Broadcasting	Norway	$97.8 million	$110 million	3	1	Parent company Telenor no longer wants to sell satellite operator. A Thor 3R satellite order is likely in early 2007.
18	Shin Satellite Public Co. Ltd.	Thailand	$86 million	$79.7 million	5	0	Revenues are only for satellite-lease division. Thaicom 4/iPSTAR broadband satellite launched in August 2005. Thaicom 5 launched in May 2006.
19	Satmex	Mexico	$71 million	$70 million	3	0	Satmex 6 launched May 27, 2006, after more than two years in storage; a financial reorganization under Mexican bankruptcy law appears near to completion.
20	Nilesat	Egypt	$66 million	$55.7 million	2	0	Company will lease Eutelsat's Hot Bird 4 satellite and move it to seven degrees west slot later this year to meet demand surge; a Nilesat 103 satellite order is expected late this year or early 2007.
21	Broadcast Satellite System Corp.	Japan	$62.5 million	$75.7 million	4	1	2005 figures are for fiscal year ending March 31, 2005.
22	Turksat/Eurasiasat	Turkey	$57.1 million	$21 million	2	1	Turksat 3A, on order with Alcatel Alenia Space, to replace Turksat 1C in 2008.
23	SES Sirius	Sweden	$45.9 million	$54.4 million	2	1	Company is 75 percent owned by SES Global.
24	APT Satellite Holdings Ltd.	Hong Kong	$43.4 million	$35.7 million	5	0	Apstar 6 entered commercial service in June 2005, replacing Apstar 1A. Apstar received $2 million in late-delivery reimbursement. APT signed strategic cooperation accord with Intelsat in December on mutual sharing of capacity.
25	Measat Global Berhad	Malaysia	$35 million	$34.2 million	2	2	Measat-3, under construction at Boeing, is scheduled for launch late 2006. Measat 1R was ordered from Orbital Sciences for delivery in mid-2007.
26	PT Telkom	Indonesia	$24.4 million	$22.7 million	2	0	Palapa B-4 satellite was retired in August 2005. Company reports increased demand for VSAT networks.

Notes: Chart includes data for companies providing fixed satellite services, defined as leasing transponders for television broadcasting, data transmission, telephony and other services. Source is company financial reports and company management statements. Figures are for calendar year ending Dec. 31, 2005, unless otherwise noted. Non-U.S. currencies converted into U.S. dollars using interbank exchange rate on Dec. 31, 2005, for 2005 figures, and Dec. 31, 2004, for 2004 figures.
Source: Space News. Format modified. See endnote 105.

by National Public Radio (NPR), provides radio feeds to more than 400 ground stations via C- and Ku-band links as part of the nonprofit public radio network.[110] A similar satellite feed system is operated by the American Forces Radio and Television Service (AFRTS) that provides American media to troops stationed overseas.[111]

Bob Evans VSAT Network—

The geographical reach of VSAT technology was a prime reason why Bob Evans Farms deployed a 481-site network. The national restaurant chain teamed with Spacenet to link its retail stores and corporate headquarters to an always-on IP VSAT service. And the network was up and running in five weeks. The company looked into frame relay, DSL and ISDN service options, but chose a VSAT network because it was the only technology that could reach all locations and was the most cost-effective. The VSAT network reduced credit card authorization time from 15 seconds to 3 seconds. Using the VSAT network, Bob Evans also added e-mail, streamlined the company's inventory process by creating a browser-based invoice application and added human resource application to the network.

"VSAT Services Are Finding New Customers," Network World, February 2002

Subscriber service-based XM Satellite Radio uplink dish. *Image credit: XM Satellite Radio*

Satellite Radio: Audio content is transmitted directly to end-user equipment such as cars, handheld radios and cell phones via digital audio radio service (DARS) satellites operating in the S- and L-bands. Three companies currently provide satellite radio services: XM Satellite Radio, Sirius Satellite Radio, and WorldSpace. XM serves 5.9 million subscribers, and Sirius serves more than 3.3 million subscribers;[112] each system uses three S-band satellites. WorldSpace serves more than 115,000 subscribers.[113] WorldSpace has two L-band satellites whose combined footprint covers 130 countries including India, China, all of Africa and the Middle East, and parts of Western Europe.

3.1.1.4 Data Communications

Data communications services include very small aperture terminal (VSAT) services, Internet backhaul, direct-to-home broadband, and mobile data.

VSAT dish in remote setting readied for transmissions. *Image credit: TC Communications*

Very Small Aperture Terminal Services: VSAT networks transmit data, voice, and video among an unlimited number of geographically dispersed sites. VSAT networks use satellites operating in C-, Ku-, or Ka-bands. Examples of VSAT data services include linking field offices to headquarters, client transactions such as credit-card verifications, and ATM transactions.

VSAT networks offer advantages in areas with little or no terrestrial infrastructure. In these areas, governments may develop VSAT networks to bring basic telephone and data services to otherwise unconnected areas. Building out terrestrial infrastructure to small remote communities can be cost prohibitive, so VSAT networks are used to extend telephone service. Countries currently operating VSAT networks for remote public telephony include South Africa, Botswana, Indonesia, Chile, Peru, Kazakhstan, Bangladesh, Pakistan, Thailand, and Ethiopia.[114] VSAT networks also are used by nations to provide tele-education and telemedicine services. VSAT networks have remained competitive in areas with well-built terrestrial infrastructure, including the United States. VSAT networks are attractive to corporations with many remote offices such as retail and restaurant chains, as well as oil companies. This is because the price of VSAT terminals has become relatively low, now between $1,000 and $2,000 per terminal, and monthly service fees can be as low as $60 per month.[115] More typical pricing is approximately $150 per month.[116] VSAT networks can provide all locations with the same network capability and can be expanded to reach new locations more easily than terrestrial options. The user also can easily expand VSAT services; since VSATs are IP ready, the user can upgrade to new services without requiring new terminal equipment. Additionally, VSATs offer companies centralized control over their networks since the entire hub and spoke architecture is supported by one provider.[117]

Broadband-to-Home: Like direct-to-home television services, broadband data services are delivered directly to end-user equipment. Service providers include WildBlue, which began offering a service in 2004, and VSAT operators such as HughesNet or Gilat.

Broadband-to-Home

Consumer broadband services offered by WildBlue Communications, Inc. and Telesat Canada in North America attracted thousands of customers by the end of 2005, and hundreds of thousands are expected to sign up by the end of 2006. "This rate of growth would not be possible without effective network operations on a scale never before seen on satellite," says Marc Agnew, vice president, broadband systems at California-based ViaSat, Inc.

According to Don Osborne, president at Advantech Satellite Networks, Inc., the implementation of such techniques as DVB-S2 adaptive coding and modulation, along with adaptive carrier rates on the inbound channels, has made an enormous difference for the service providers. If everything goes according to plan, enterprise customers soon will start migrating to Ka-band to access cheaper satellite terminals and more affordable bandwidth. "Ka-band satellite broadband terminals will price below $300 within a few years and will be fully capable of supporting enterprise applications with an integrated VPN product," says Agnew. "The emergence of IPTV (Internet Protocol TV) plays into Ka-band as an IP multicast service delivered over the same broadband pipe as the customer's Internet service."

http://www.satellitetoday.com/cgi/pub/via/via05010603.html

Internet Backbone: As with telephone trunking and broadcast and cable television relay, satellites are used to augment terrestrial Internet and transmit the signal in areas where the terrestrial infrastructure is lacking.

Mobile Data Services: Satellites are used to provide messaging, paging, and e-mail to mobile devices as well as fixed and mobile asset tracking services. These services are primarily narrowband services. In 2005, however, Inmarsat introduced its broadband global access network (BGAN) service, the first mobile phone and broadband mobile data network with worldwide coverage. The BGAN system transmits to laptop-sized receivers or notebooks. During the 22rd National Space Symposium in 2006, Gene Jilg, Vice President, Advanced Systems, Inmarsat, showed the newest BGAN receiver; it was half the size of a laptop, more the size of a passport wallet.

The Deep Space Network is designed to allow continuous radio communication with spacecraft. The Canberra Complex features the largest dish in the network with its 70m (230 ft.) parabolic antenna that can track a spacecraft 10 billion miles away. *Image credit: JPL/NASA*

Non-Commercial Services: Data communications services also are used by civil and military governments. NASA operates the Deep Space Network (DSN), which provides a two-way communications link with automated spacecraft exploring the universe. The ground component of DSN is a series of three antenna arrays "placed approximately 120 degrees apart around the world: at Goldstone, in California's Mojave

An information system technician performs a communications check with an Inmarsat satellite phone system to establish communications with the Military Sealift Command (MSC) hospital ship USNS *Mercy* (T-AH 19) during earthquake disaster relief in Nias, Indonesia. *Image credit: U.S. Navy photo by Photographer's Mate 2nd Class Jeffrey Russell*

Desert; near Madrid, Spain; and near Canberra, Australia."[118] The Tracking and Data Relay Satellite System (TDRSS), which is composed of seven geosynchronous satellites, provides signal relay and tracking services between LEO spacecraft and fixed ground stations.[119]

3.1.2 Remote Sensing Satellites

Different wavelengths of light are ideal for different sensing activities. For example, radar technology, which uses microwave frequencies, can observe clouds, aerosols, volcanic plumes, sea-surface temperatures, ocean color, vegetation, land cover, snow, ice, fires, and many other phenomena. Visible light and near infrared portions of the spectrum can perceive fine detail and can be used for mineral and soil mapping, precision agriculture, and forestry. Satellite and ground equipment can combine data from different wavelengths to extract even more information. Profilers and sounders can monitor several frequencies, providing Earth observation satellites with a vertical profile of atmospheric temperatures, moisture, ozone, wind speed, and trace gases, while differential interferometers can resolve displacements of a few centimeters on the Earth's surface.

The DoD and national security agencies could also use a variety of Earth observation satellites, like Space Based Infrared System (SBIRS) under development, Fast On-orbit Recording of Transient Events (FORTÉ), and the Multispectral Thermal Imager (MTI) that provide intelligence through a variety of sensors, including multi-spectral imagery, thermal images and event classification, radio burst detectors, and radar imaging.[120] Some military applications of Earth observations include weather satellites, intelligence gathering, submarine tracking, early warning satellites, and nuclear explosion detection. As noted in the sidebar on page 57, U.S. national security agencies are a significant customer for commercial imagery. It will take time for remote sensing companies to build a robust commercial marketplace. According to the report *Space 2030*, "It has been estimated that ORBIMAGE [now GeoEye] and DigitalGlobe have about seven years to build up the commercial market necessary to have a non-U.S. government funding source to support a third generation of commercial imagery satellites. This is no easy task, although there are encouraging signs; significant gains in commercial business have been achieved recently. For instance, the non-U.S. government revenues of DigitalGlobe grew by 40 percent in 2004, and GeoEye's commercial business is growing by 15 to 20 percent a year, although it represents only 10 percent of total revenue ($20 million of $200 million)."[121]

SBIRS High is the nation's next-generation missile warning system and also will provide greatly expanded capabilities for intelligence, surveillance and reconnaissance (ISR) missions. *Image credit: Lockheed Martin*

An alternate form of intelligence gathering detects transmissions from broadcast and radio signals to collect intelligence on strategic communications or track the point of origin for the transmission through telemetry intelligence or radar intelligence.[122]

3.1.3 Satellite Positioning

The GPS signal from the U.S. NAVSTAR system is free to the user; the applications discussed here are value-added products and services that use the GPS signal. GPS chipsets are dropping in size and cost and are increasingly versatile, and many applications integrate a GPS chipset into another product (such as a cell phone), while others use GPS-dedicated receivers. New GPS applications continue to emerge. Research firm ABI identifies 11 GPS market segments.[123] Examples of each are provided below.

Whither The Remote Sensing Market Place — Dr. Ray Williamson

"Satellite imagery sales were helped along by increasing tensions in Afghanistan and then Iraq. In time, foreign purchases and major contracts for data (ClearView and NextView) from the U.S. National Geospatial-Intelligence Agency (NGA) brought growth and a measure of stability to the data market. The acquisition of Space Imaging by ORBIMAGE [now known as GeoEye] has also further stabilized the industry."

"Despite this relatively rosy picture, the remotely sensed data marketplace is not yet flourishing, especially in the commercial sector. Today, most data are still purchased by the federal government, and sales to local government or the private sector are highly limited. Yet, if inexpensive data applications can be found and fully exploited, the overall marketplace could expand much more than it has to date. As noted by the recent ASPRS Remote Sensing Forecast (see Imaging Notes, summer 2004), several commercially important sectors are currently underserved. These include real estate, insurance, and telecommunications. All of them can make greater use of RS data if transformed into targeted information and presented in innovative, attractive forms."

http://www.imagingnotes.com/go/page2a.php?menu_id=24

- **Aviation:** The commercial aviation industry relies on GPS for navigation and aircraft tracking. The U.S. operates Automatic Dependent Surveillance-Broadcast (ADS-B) system, an airspace tracking system which acquires GPS information for an aircraft and broadcasts this information to ground stations and neighboring aircraft.[124] With the aid of the Wide Area Augmentation System (WAAS), which provides corrections to the GPS signal,[125] ADS-B can calculate accurately the location and velocity for all equipped aircraft and provide radar-like tracking for U.S. air space.

Phone lines, satellite dishes, and a cell tower as seen during sunset

- **Communication:** GPS chipsets are being integrated into phones and wireless devices for navigation and location query applications. Software like SnapTrack's SnapSmart allows owners of GPS-enabled phones to access location and navigation data, while the Caffeine Finder GPS software by Greystripe can be used with a BlackBerry to give the location of the nearest coffee shop or restaurant along with a review, address, and map.[126] The FCC's wireless Enhanced 911 regulations, often referred to as E911, require cell phone providers to know the location of a call in the event of an emergency.[127] This information can be provided with integrated GPS chipsets in cell phones or through signal calculations like Time Difference of Arrival (TDOA) that determines the location of a caller based upon the time it takes the signal to reach the nearest cell tower.

- **In-Vehicle Navigation:** Often referred to as telematics or automotive telematics, vehicle navigation systems and dashboard copilots (such as TomTom) use GPS signals and pre-programmed geospatial data to provide routing information.[128] Dynamic route guidance systems can update navigation software automatically and account for road conditions using cellular technology or data from satellite radios.[129] Services like OnStar and Neverlost offer value-added amenities such as automatic notification of air bag deployment, remote door locks, theft tracking, emergency assistance, vehicle diagnostics, and local directory information.[130]

Vehicle navigation systems and dashboard copilots use GPS signals and pre-programmed geospatial data to provide routing information.

- **Machine Control:** GPS assisted software can provide precision control for automated systems. This application has seen use in agriculture where tractors use remote sensing data, automated software, and a GPS receiver to plow, plant, or harvest a field in a precise pattern that minimizes waste and saves time.[131]
- **Marine:** Satellite navigation systems were originally designed for naval vessels and submarines. GPS-equipped submarines can locate their position accurately and quickly, a necessary component of accurate strategic missiles.[132] Commercial shipping and recreational boating also rely on GPS systems for standard navigation, safety, and novel applications like guidance to an optimum fishing hole.[133]
- **Military:** Precision guided bombs, Air Force navigation, and force tracking are only a few of the military applications for GPS. Unmanned Aerial Vehicles (UAVs) use GPS and Inertial Measurement Units to control attitude, direction and speed.[134] Nations also use GPS to track border patrols providing national security.
- **People and Animal Tracking:** GPS-enabled transmitters can be used to track pets, livestock, and "tagged" wildlife. Similar technology can be used to assure the safety of children and the elderly with Alzheimer's disease or other mental ailments.[135] Search and rescue systems often use GPS or the international COSPAS-SARSAT system to coordinate rescue operations and quickly locate lost or injured individuals.
- **Recreational:** Recreational users like hikers, boaters, and cross-country skiers depend on GPS units for location information. In addition, a small community of users has built games around GPS receivers. In Geocaching, participants use a GPS receiver to find and hide "caches" (waterproof containers holding a logbook and usually a small trinket or toy) anywhere in the world.
- **Surveying and Mapping:** With the WAAS and other GPS correction networks, like the European Geostationary Navigation Overlay Service (EGNOS), it is possible to calculate extremely precise positions used for land surveys and topographical mapping. Geologists have used GPS transmitters to map motions associated with plate tectonics and provide a better understanding of global geological systems.[136]
- **Timing and Synchronization:** GPS receivers can provide atomic clock level of accuracy and precision in timing. GPS timing is used in financial transactions such as timing the sequence of financial transactions at ATMs. Precise timing and synchronization also is used to control the flow of network information in wireless infrastructure to maximize the use of bandwidth.
- **Vehicle Tracking:** GPS receivers can be used to track fleets, estimate delivery times, locate stolen vehicles, and reduce costs associated with wasted fuel and run times. When coupled with the General Packet Radio Service (GPRS), or an alternate communications infrastructure and a Web interface, GPS units can provide real-time updates to dispatching centers for comprehensive fleet management.

Unmanned Fire Scout helicopter on approach to Navy vessel. *Image credit: U.S. Navy*

A trumpeter swan with Argos PTT collar made by Habit Research. The collar transmits to a receiver and has optional GPS tracking capabilities. *Image credit: Habit Research*

3.1.4 Service Integration and New Markets

Satellite functions are increasingly blended and the distinctions among them blurred, especially given the increased integration of satellite-based services with terrestrial services: data is carried over phone lines, voice traffic is carried over the Internet, satellite video is pushed to cell phones, and navigation data is integrated with communications capabilities and imagery.

EGNOS will help improve transport services and trace vehicles. *Image credit: ESA*

New terms are continually coined for new types of applications, and the way terms are used changes almost as rapidly. While there is no concensus on terminology appropriate for new types and combinations of satellite applications, two useful terms have emerged: "converged media," encompassing satellite services such as video, voice, data communication, and radio; and "geoinformatics," encompassing imagery, navigation, positioning, and timing. Even these categories have crossover—navigation data integrated with communications capabilities, for example.

3.1.4.1 Satellite Converged Media

Satellite converged media applications evolved rapidly in 2005, particularly for satellite services delivered directly to end-users and mobile services. For example:

- Satellite television provider DIRECTV is offering up to 25 channels of programming from satellite radio provider XM Radio at no additional cost to subscribers.[137] Echo Star has a similar arrangement with Sirius.[138]
- Satellite-delivered television (called digital multimedia broadcasting) is available on cell phones in Korea and Japan. Japan's Mobile Broadcasting Corporation (MBC) uses MBSat to deliver CD-quality audio, MPEG-4 video, and data to mobile devices in Japan. MBC uses a hybrid network (satellite with terrestrial gap-fillers) to ensure reception between buildings.
- Mobile Satellite Ventures (MSV) plans for two-way wireless phone and broadband service. MSV plans a hybrid satellite/terrestrial system using terrestrial L-band, the cellular network, and high powered digital L-band satellites. MSV has also talked with both DIRECTV and EchoStar (DISH) about the possibility of using MSV to add both voice and high-speed data to its services.[139]
- DISH and DIRECTV recently signed five-year deals with WildBlue Communications to provide satellite broadband Internet service. The service targets rural consumers and offers speeds ranging from half a kilobit to 1.5 megabits per second.[140]

Hybrid solutions are combining satellite and terrestrial capabilities —

- Bundled offerings and partnerships with terrestrial companies are expanding.
- New spectrum allocations support this growth, including MSS with Ancillary Terrestrial Component (ATC).
- Advanced mobile phone services with data and video are leveraging satellite backhaul capabilities.

Satellite Industry Association, *2006 State of the Satellite Industry*

3.1.4.2 Geoinformatics

Geoinformatics activities represent the convergence of remote sensing and position, navigation, and timing (PNT) space applications. For example:

- Resource identification and harvesting using remote sensing applications for resource detection and classification along with GPS enables automation of labor intensive but routine tasks like farm irrigation and harvesting and assists with mining.
- Google Earth uses satellite images, maps and geographic information to allow users to search the globe. With Google Earth Plus and other similar applications, users can import waypoints and tracks from GPS devices.
- Satellite enterprise services integrate GPS receivers with telecommunications and GIS databases to provide real-time management and tracking of mobile objects including people, pets and property.[141]

Backdropped by the blackness of space and Earth's horizon, this full view of the International Space Station was photographed by a crewmember onboard the Space Shuttle *Discovery* following the undocking of the two spacecraft. *Image credit: NASA*

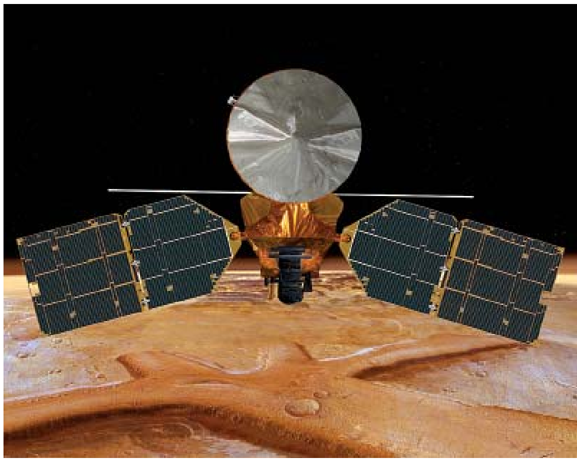
3.2 In-Space Activities

In-space activities encompass human, robotic, and cargo activities on platforms or vehicles. Examples range from research on the International Space Station (ISS) to scientific probes to space tourism to missile defense.

3.2.1 Platform-Based In-Space Activities

Platform-based in-space activities encompass science, research, accommodations, or other activities that occur in space. Many different types of platforms are used to conduct science, research, and commercial activities in space. These include satellites, probes, in space telescopes, the ISS, and space shuttle. Hardware for these activities is described more fully in 2.0, the *Space Infrastructure* section of this report.

Artist's concept of the Mars Reconnaissance Orbiter, which is in orbit around Mars. It is equipped with eight instruments with which to explore the planet and its weather systems. *Image credit: NASA/JPL*



3.2.1.1 Science and Research

Science and research conducted in space are primarily government-sponsored programs, though some experiments are carried out solely by universities and some commercial companies. Science and research activities conducted in space encompass the study of the Earth, the sun, our solar system, and the universe.

2005 highlights of science activities include

- August launch of the Mars Reconnaissance Orbiter (MRO). The MRO will study the history of water on Mars and become the first link in a communications bridge back to

Earth. The purpose of this bridge is to become an "interplanetary Internet" to be used by spacecraft in later years. Additionally, MRO carries a camera system to be used to guide precision landings on Mars by future spacecraft missions, including human missions.[142]

- November launch of Venus Express. Venus Express will study the Venusian atmosphere, planetary surface characteristics and interaction of the planet's environment with the solar wind. Venus Express reached its final orbit in May 2006.[143]
- The Huygens probe of the Cassini-Huygens spacecraft landed on Saturn's largest moon Titan in January 2005.[144] Throughout the mission, the landing data was collected, providing a detailed picture of Titan's atmosphere and surface. The Titan landing is the only landing to take place in the outer solar system and the furthest from Earth.[145]
- In July 2005, the Deep Impact mission's fly-by spacecraft successfully launched an "impactor" spacecraft that collided with the Tempel 1 comet. The Deep Impact mission was designed to study the composition of comets and has reported deposits of solid water ice on the surface of the comet.[146]

The ISS is currently the only in-space science and research facility. The ISS can be used as a test bed for exploration systems and a platform for biological and physical research in space.

European Space Agency astronaut Thomas Reiter, Expedition 13 flight engineer, works with sample tubes in the Zvezda Service Module of the International Space Station. *Image credit: NASA*

Examples of research conducted on the ISS are

- The Dust and Aerosol Measurement Feasibility Test (DAFT) and Capillary Flow Experiment (CFE), which provide data on the physical properties of systems in microgravity, is necessary for engineering next generation spacecraft.[147]
- Human physiology experiments, including the ESA's Chromosomal Aberrations in Blood Lymphocytes of Astronauts 2 (Chromosome-2) experiments, renal stone experiments, and an analysis of astronaut journals to analyze Behavioral Issues Associated with Isolation and Confinement.[148] These studies use the astronaut's body as a natural laboratory.
- Material studies where an experimental rack is placed outside the station exposing various materials to the space environment, colloidal research on suspended particulates in a fluid, and protein crystal growth observations.[149]

3.2.1.2 Accommodations

The ISS is currently the only in-space platform capable of accommodating human beings in orbit. It is used primarily by astronauts from international space agencies. However, three space tourists have stayed for one week each aboard the ISS.

In July 2006, Bigelow Aerospace began on-orbit tests of its space facility, which reportedly will be used as a space hotel.[150] Details on Bigelow's concept can be found in 2.3, the *In-Space Platforms* section of this report.

3.2.2 Transportation-Based In-Space Activities

Transportation activities include tourism, research and exploration, and missile defense. These activities include any that involve moving a payload through space, orbital or suborbital.

The children are touching a Mars rock in *Exploration in the New Millennium* at Kennedy Space Center Visitor Complex. *Image credit: KSC Visitor Complex*

3.2.2.1 Research and Exploration

ISS cargo resupply encompasses the requirements to ferry cargo to the International Space Station. The current capability is limited to the space shuttle and Russian *Progress* cargo vehicles. In 2005, six such launches to resupply the ISS were made from the Baikonur Cosmodrome. In 2005, NASA announced Commercial Orbital Transportation Services (COTS) demonstrations, intended to procure these ISS cargo and crew resupply services from a commercial source within the United States.[151] Six competitors were chosen by NASA to compete to resupply the ISS through a COTS contract. The six competitors were Andrews Space, Rocketplane Kistler, SpaceDev, SpaceX, SpaceHab, and t/Space.[152] In August 2006, Rocketplane Kistler Corporation and SpaceX were chosen as the COTS program finalists.

A new U.S. program for space exploration was announced in January 2004,[153] and commits NASA to a long-term human and robot exploration program, beginning with lunar sorties, and eventually moving toward human exploration of Mars and "other destinations."[154] To accomplish these goals, NASA is retiring the space shuttle in 2010 and developing a new vehicle that is capable of lunar missions, the Crew Exploration Vehicle (Orion). NASA is attempting to accomplish this goal without a significant increase in funding.

3.2.2.2 Tourism

Space Adventures has brokered deals with five individuals to fly on a Russian *Soyuz* into orbit and stay for one week aboard the ISS. Three of those individuals (Mark Shuttleworth, Dennis Tito, and Greg Olsen) have completed their flights. Anousheh Ansari was to fly in September 2006, and Charles Simonyi signed a contract in April 2006. Ansari was a late replacement for Daisuke Enomoto, who was unable to fly for medical reasons.[155] The price for these flights is \$20 million.[156] The emerging market for suborbital space travel has begun to generate revenue as well, though there has not yet been a commercial suborbital tourist flight. The lower initial price point of \$200,000[157] makes the suborbital market more accessible.

Passengers experience weightlessness aboard a Zero-G aircraft performing a dive maneuver. *Image credit: Zero-G*

Space Services Inc. of Houston, Texas, offers memorial spaceflights, launching a symbolic portion of a person's cremated remains into space. These memorials are a small secondary payload on a commercial or scientific satellite launch. Space Services offers Earth return services, Earth orbit services, lunar services, and Voyager (deep space) services.[158]

Additionally, millions of tourists have visited terrestrial space attractions like the Kennedy Space Center Visitor Complex, Kansas Cosmosphere, Mission Space, and more. This space-themed terrestrial tourism is discussed more fully in 6.0, the *Impacts* section of this report.

3.2.2.3 Missile Defense

Transportation-based activities also can be considered to include U.S. efforts at ballistic missile defense. The Missile Defense Agency (MDA) was established in 1999 "to deploy as soon as is technologically possible an effective National Missile Defense system capable of defending the territory of the United States against limited ballistic missile attack."[159] The MDA uses an integrated system of sensors and weapons to detect and destroy incoming ballistic missiles in their boost, midcourse, or terminal phase.[160] The system includes satellite tracking, several modes of radar, kinetic energy interceptors, airborne lasers, multiple kill vehicles, and patriot missiles, among other capabilities.[161] Additional military programs like the Space-Based Infrared Systems (SBIRS) program support missile defense. Although much of the hardware under development by the MDA is not intended to operate in space, these systems are generally designed to interact with in-space hardware, and can be considered to be space infrastructure in the same way that satellite ground stations are part of the space infrastructure.

An Arrow anti-ballistic missile interceptor is launched from its mobile platform during a joint Israel/United States developmental test at the Point Mugu Sea Range in California. *Image credit: Missile Defense Agency, DoD*

BUDGETS AND REVENUES

4.0

4.0

Budgets and Revenues | 4.0

This section looks at global economic activity associated with space infrastructure and space products and services. Our objective is to provide multiple sources of data where they exist and fully document them to aid the reader in doing analysis, evaluating data, and making judgments. For each sub-sector, different industry estimates have been identified and shown in tables. Revenue estimates used in estimating total dollar value for space activity are denoted with an asterisk (*) and were chosen based on the extent of research, reliability of data, and/or strength of methodology, given the information available. Revenues shown are global revenues unless noted. Exhibit 4a lists the topics covered in this section.

EXHIBIT 4a. Topics Covered in Budgets and Revenues

4.0 Budgets and Revenues
4.1 Space Infrastructure
4.2 Space Products and Services
4.2.1 Satellite Services
4.2.1.1 Communication
4.2.1.2 Remote Sensing
4.2.1.3 Satellite Positioning
4.2.2 Platform-Based In-Space Activities
4.2.3 Transportation-Based In-Space Activities
4.3 Government Space Budgets
4.4 Summary of Space Products and Services

4.1 Space Infrastructure

According to the FAA, the international commercial launch vehicle industry generated $1.2 billion in revenue in 2005,[162] accounting for launches of 31 payloads.[163] The Satellite Industry Association (SIA) estimates the total launch vehicle industry at $3.0 billion, including government and commercial (See Exhibit 4b). While the SIA does not break out revenue by commercial and government, it notes that, of the 39 commercial launches in 2005, 54 percent were government customers, and 46 percent non-government. [164]

EXHIBIT 4b. Global Launch Industry 2005 Revenue Estimates

TYPE	REVENUE	SOURCE
Commercial	$1.2 B*	FAA
Commercial and Government	$3.0 B	SIA

According to the SIA, 2005 total commercial and government satellite manufacturing revenue was $7.8 billion (Exhibit 4c).[165] Of this, 71 percent of revenue was from government satellites ($5.54 billion) and 29 percent was non-governmental ($2.26 billion). This number counts the revenues for the payload in the year in which it was launched, not necessarily the year the revenue was realized. Also, the revenue is totaled in then-year dollars; it is not adjusted for inflation. In terms of orders placed in 2005, manufacturing contracts were awarded for 19 GEO commercial satellites in 2005, according to Teal Group Corporation.[166] For competitive reasons, not all satellite manufacturing awards are announced, and the numbers Teal Group reported may be understated.

EXHIBIT 4c. Satellite Manufacturing 2005 Revenue Estimates

TYPE	REVENUE	SOURCE
Commercial	$2.26 B*	SIA
Government	$5.54 B	SIA
Overall	**$7.8 B**	**SIA**

Forecast International predicts total satellite production to be more than 800 units for 2006 to 2015. It expects 682 expendable launch vehicles (ELVs) of various types will be produced to launch these satellites, for an expected ELV market of $45.9 billion between 2006 and 2015.[167]

The budgets for probes are included in the budgets for the government space agencies. (Government space agency data is shown in 4.3, the *Government Space Budgets* section of this report.) The total budget for Deep Impact was $330 million,[168] while the total budget for ESA's Venus Express was $262 million (in 2005 USD).[169] The Mars Reconnaissance Orbiter and New Horizons received $104 million[170] and $116 million,[171] respectively, from NASA in 2005.

Ultra small aperture terminals (USAT) can provide uplinks as fast as 1.5 Mbps as well as downlinks up to 45 Mbps. Applications for USATs include high speed Internet service, electronic banking and real-time video conferencing.
Image credit: NASA

The budget for the ISS is included in the NASA budget. According to the Fiscal Year (FY) 2005 operating plan, NASA budgeted $1.68 billion for the ISS in 2005.[172] As a part of this budget, NASA paid $240 million[173] to Russia for launches to the ISS for cargo resupply and crew rotation. Robert Bigelow of Bigelow Aerospace has publicly stated that he will invest a total of $500 million in his company through 2015.

Ground equipment revenues were $25.2 billion in 2005, according to SIA data.[174] These revenues include infrastructure elements such as mobile terminals, gateways, control stations, as well as end-user equipment such as very small aperture terminals (VSATs) and ultra small aperture terminals (USATs), direct-to-home (DTH) broadcast dishes, satellite phones and digital audio radio satellite (DARS) equipment.[175] Therefore, this number overstates the revenue associated with ground station infrastructure. This number also does not include revenues for end-user electronics (such as PDAs and cell phones) that incorporate GPS chip sets. Consumer electronics are treated in sections 3.0, *Space Products and Services,* and 5.0, *How Space Products and Services Are Used.*

EXHIBIT 4d. In-Space Platforms 2005 Budget Estimates

ELEMENT	REVENUE	SOURCE
ISS	$1.68 B	NASA
Bigelow Aerospace	N/A	

The revenue for space insurance in 2005 was $880 million.[176] Independent Research and Development (IR&D) costs are estimated at $3 billion, half of which was retroactively funded by the DoD.[177] Assuming that the proportion of aerospace IR&D to space IR&D is the same as the proportion of aerospace research, development, test, and evaluation (RDT&E) ($33.8 billion)[178] and space RDT&E ($11 billion),[179] the IR&D covered by corporations is about $500 million.

EXHIBIT 4e. Ground Equipment 2005 Budget Estimate

REVENUE	SOURCE
$25.2 B*	SIA

The Aerospace Industries of America (AIA) reports U.S. imports and exports of some space hardware. Data for 2005 is shown in Exhibit 4g. AIA also reports revenues and employment for the broader aerospace industry (including aircraft, missiles, and space systems) in *Aerospace Facts and Figures.*[180]

EXHIBIT 4f. Institutional Infrastructure 2005 Expenditure Estimates

EXPENDITURES		SOURCE
2005 Insurance Premiums	$0.88 B*	*Via Satellite*
IR&D	$0.5 B*	Estimate

EXHIBIT 4g. AIA Estimate of Aerospace Sales, 2005

	VALUE	SOURCE	DESCRIPTION
U.S. Imports	$0.49 B	AIA 2005 Year-end review	2005 U.S. imports for spacecraft, missiles, rockets, and parts[181]
U.S. Exports	$0.39 B	AIA 2005 Year-end review	2005 U.S. exports for military and civil spacecraft, satellites, and parts[182]
U.S. Space Sales	$37.30 B	AIA 2005 Year-end review	2005 sales based on NAICS 3761 guided missiles and space vehicles, 3,764 space propulsion units and parts, and 3,769 space vehicle equipment and components, also includes RDT&E[183]
U.S. Missile Sales	$15.30 B	AIA 2005 Year-end review	2005 sales based on NAICS 3,761 guided missiles and space vehicles, also includes RDT&E[184]
Missile Defense	$9.20 B	AIA	2005 RDT&E for Missile Defense Agency[185]

Source: Aerospace Industries Association. See endnotes 180-185.

4.2 Space Products and Services

4.2.1 Satellite Services

In the exhibits associated with this section, we summarize published estimates from different sources for types of satellite services, and we also indicate which we have used in our rollup estimate (*). We have selected the estimate based on the extent of research, reliability of data, and/or strength of methodology, given the information available.

EXHIBIT 4h. Fixed Satellite Service (FSS) 2005 Revenue Estimates

SOURCE	ESTIMATE
SIA	$9.80 B*
Euroconsult	$7.00 B

SIA FSS data includes telephone trunking, broadcast and cable TV, VSAT and other data communication, and remote sensing.

EXHIBIT 4i. Mobile Satellite Service (MSS) 2005 Revenue Estimates

SOURCE	ESTIMATE
SIA	$1.70 B
Northern Sky	$1.80 B*
Gartner	$1.20 B

Estimates include both mobile telephony and mobile data. Gartner data from voice service providers only.

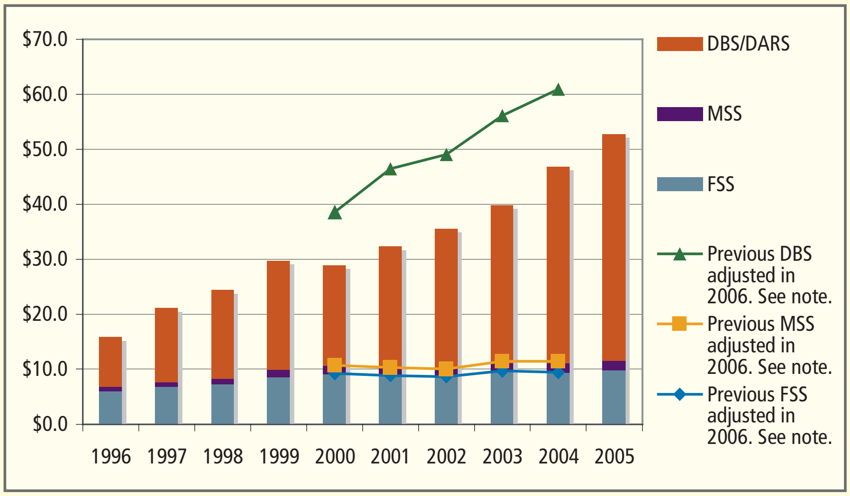
4.2.1.1 Communication

Telephone Services: SIA's *Satellite Industry Survey* does not report telephone trunking revenue (i.e., telephony-related revenue from transponder leasing) separately, but as part of the FSS market. SIA also includes VSAT revenue, revenue from data and video transponder leasing, and remote sensing in FSS revenue, for a total of $9.8 billion. Euroconsult lists FSS market revenue as $7.0 billion for 2005; this number is based on revenues from all 36 FSS satellite operators (see Exhibit 4h).[186]

Both SIA and Northern Sky Research (NSR) estimate revenue from MSS satellite services at about $2 billion for 2005.[187] These estimates include both mobile telephony and mobile data (such as messaging, e-mail, and new mobile broadband services). Exhibit 4j illustrates the Satellite Industry Association's revenue estimates since 1996. The Gartner Group estimates 2005 revenue from MSS voice service providers only as $1.2 billion (see Exhibit 4i).[188]

EXHIBIT 4j. Historical Satellite Industry Revenue Data

The Satellite Industry Association has been providing revenue estimates since 1996, providing time series data in a number of industry segments. Satellite services is one of the industry segments for which revenues are estimated by SIA (as well as manufacturing and launch services, discussed in 2.0, the *Space Infrastructure* section of this report).



Source: 2005 and 2006 Satellite Industry Indicators, SIA. Note that when SIA released its 2005 estimates, estimates for the period 2000 to 2004 differed from previous years' reports for DBS television service revenues and slightly revised several other values for MSS and FSS. According to the SIA, the underlying model assumptions are periodically updated based on new information received by survey respondents. In 2005, the SIA had its best response rate to date and was the first year a DBS provider participated in the survey. Due to data obtained from these services, the underlying revenue models were updated, resulting in changes to revenue estimates. The overstatement of DBS industry revenue for the period 2001 to 2004 period was about 50 percent; the change in estimated value ranges from $9.6 billion to $15.9 billion per year.

Source: SIA. See endnote 194.

Radio Services: Revenue in 2005 for satellite radio was about $0.81 billion, from three firms (Exhibit 4k): XM Radio, reporting 2005 revenues of $560 million;[189] Sirius Satellite Radio, reporting 2005 revenues of $240 million;[190] and WorldSpace, reporting 2005 revenues of $11 million.[191] SIA's estimate for this segment is not released separately from its DBS estimate.

EXHIBIT 4k. Direct Radio (DARS) 2005 Revenue

COMPANY	REVENUE
XM	$0.56 B
Sirius	$0.24 B
Worldspace	$0.01 B
TOTAL	**$0.81 B***

EXHIBIT 4l. Satellite Television (DBS) 2005 Revenue Estimates

SOURCE	ESTIMATE
SIA	$40.49 B
In-Stat	$46.00 B*

SIA estimate adjusted to exclude DARS revenue.

An XM personal satellite radio receiver capable of saving songs directly frrom the satellite feed. *Image credit: XM Satellite Radio*

Jupiter Research, in its report *U.S. Satellite Radio Forecast, 2005 to 2010*, announced that it expects the U.S. digital satellite radio market to experience 35 percent compound annual growth through 2010, growing from 12 million installed units in 2005 to 55 million units in 2010. Much of this growth, it says, will be in transportable devices, which accounted for 66 percent of sales in 2005, and is expected to account for 60 percent of sales through 2010. In particular, Jupiter projects in-car-device annual sales to grow from 2.5 million units in 2005 to 6.9 million units in 2010.[192] A publication by Veronis Suhler Stevenson Partners, LLC (VSS), *2005 Communications Industry Forecast Highlights*, forecasts a 132.4 percent growth in satellite radio subscription, and a 112.8 percent growth in satellite radio advertising for 2005. This will bring total satellite radio spending to $680 million in 2005, a 131.8 percent increase from the previous year. Through 2009, VSS forecasts that the "unprecedented expansion of satellite radio" will drive broadcast and satellite radio's combined revenues to grow at a compound annual rate of 6.2 percent.[193]


Multiple satellite dishes are shown on these rooftops in Croatia.

Television Services: Revenues from transponder leases for broadcast and cable television services are included in Exhibit 4h in FSS revenues as estimated by SIA and Euroconsult.

Direct-to-home television services (referred to as DBS or DTH services) represent the largest portion of satellite services revenue. SIA estimates 2005 DBS/DARS industry revenue of $41.3 billion, which yields a DBS estimate of $40.49 billion net of the $810 million in 2005 revenues reported by the three DARS providers (Exhibit 4l).[194] SIA estimates DBS subscribership at 80 million in 2005. In-Stat, in its 2006 report, *Worldwide Satellite Pay-TV Market*, puts 2005 DTH television revenue at $46 billion. Additionally, In-Stat estimates the market will reach $80 billion in revenue and 100 million subscribers by 2009.[195] According to the OECD report, *Space 2030*, "DTH platforms currently broadcast more than 7,200 TV channels and spend around $16 billion in programming a year."[196]

Mobile Broadcasting Corp. (MBC) of Japan and TU Media Corporation in Korea are offering mobile satellite television services to subscribers.[197] TU Media Corporation reported that 50,000 customers were added in the first month of operation, and the company's goal was 600,000 for 2005.[198]

EXHIBIT 4m. Data Communications Revenue Estimates

SOURCE	DESCRIPTION	ESTIMATE
Comsys	VSAT Services Revenue (2004)	$3.9 B
Frost & Sullivan	VSAT Terminals 2005	$0.5 B
Northern Sky	Revenue from Corporate VSATs (2004)	$1.8 B
Northern Sky	Satellite Broadband Internet 2005	$2.7 B

Note: Mobile data communications services are included in MSS estimates.

Data Communications: There are many estimates of revenue associated with different types of VSAT activities and hardware (Exhibit 4m). For example, Frost and Sullivan reports in its 2006 *World VSATs Markets* that VSAT terminal sales totaled $445.9 million in 2005.[199] Northern Sky Research (NSR) details the VSAT data communications industry in its report *Broadband Satellite Markets, 5th edition,* published in 2005. In this report, NSR estimates the satellite broadband industry generated $2.7 billion in 2005 from 1.01 million subscribers.[200] NSR estimates the North American market at 344,000 subscribers with total revenues of $300 million; it expects this market to grow to $600 million and more than 900,000 clients by 2010.[201] NSR also concludes that leased bandwidth on commercial telecommunication satellites will become increasingly important for government and military communications. U.S. military demands are a primary driver in the expected increase in revenues from $1 billion in 2003 to more than $4.8 billion in 2012.[202] According to NSR, revenue due solely to corporate VSATs in 2004 totaled about $1.76 billion.[203] The 2005 VSAT Report by Comsys estimates the total revenue from VSAT services in 2004 was $3.88 billion.[204]

Secure satellite communications in the field bring needed information to warfighters on the battlefield. *Image credit: BAE Systems*

SIA's *Satellite Industry Survey* reports both narrowband and broadband VSAT revenue as part of the $9.8 billion FSS market, which includes telephone, data, and video transponder leasing as well as remote sensing in FSS revenue.[205] To ensure consistency and to eliminate double counting, the SIA estimate of revenue is used.

Revenue for mobile data services is included in the estimate of MSS discussed in telephony revenues above and includes messaging, paging, and e-mail to mobile devices as well as fixed and mobile asset tracking services and Inmarsat's BGAN service.

4.2.1.2 Remote Sensing

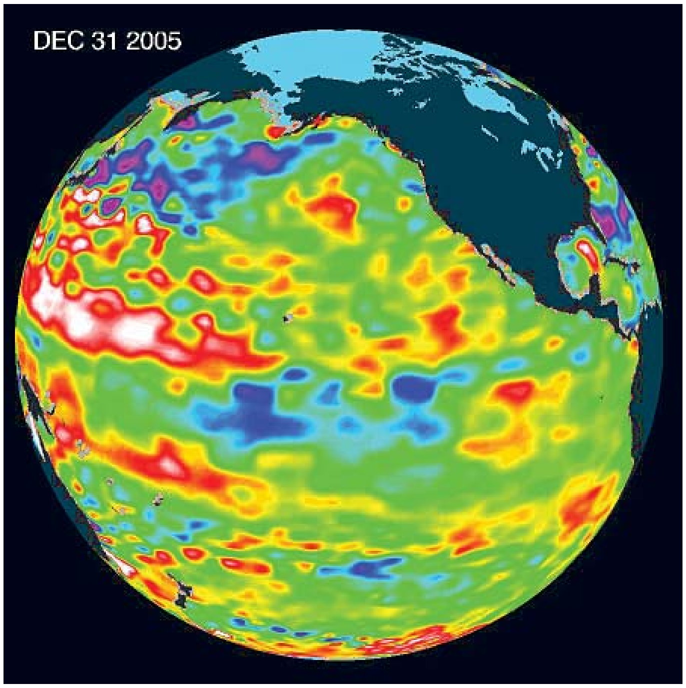
SIA reported that revenue for global commercial satellite remote sensing increased approximately 18 percent from 2004 to 2005, driven by evolving business opportunities, new and continuing military and intelligence imagery contracts, and expanding civil and commercial imagery markets, including online mapping services. The SIA includes remote sensing as part of its FSS revenue estimate.[206]

EXHIBIT 4n. U.S. Remote Sensing 2005 Revenue Estimate

SOURCE	DESCRIPTION	ESTIMATE
ASPRS	Sale of satellite imagery	$1.12 B

2005 projection from 2002

NASA, NOAA, and the American Society for Photogrammetry and Remote Sensing (ASPRS) have initiated a ten-year forecast study of the remote sensing and geospatial information industry. ASPRS defines the industry "as those commercial firms, not-for-profit organizations, governmental agencies and academic institutions involved in the capture, production, distribution, and application of remotely sensed geospatial data and information."[207] Survey respondents from across the United States and Canada provided baseline data from 2001 and 2002. Phase IV of the 10-Year Industry Forecast will be published by the ASPRS in the fall of 2006. In phases I-III, researchers gathered data from suppliers and users of "remotely sensed data," (i.e., image-based GIS, photogrammetry, and remote sensing), in order to provide a forecast for the remote sensing industry in the U.S. The data from phases I and II indicated a cumulative annual growth rate (CAGR) for the U.S. remote sensing industry between nine and 14 percent. When extrapolated from 2001, this yields an estimated total geospatial sales of $3.3 billion for 2005, of which the space component is 34 percent or $1.12 billion (Exhibit 4n). According to Dr. Ray Williamson who is working on this study, the data from phase IV, which solely concentrates on the users of data, does not support a continued CAGR of nine to 14 percent. Rather, the data shows a downturn or leveling off within the remote sensing industry. One theory expressed by Dr. Williamson attributes this slowing to a reduction in the average cost/pixel of data, which limits revenue growth within the industry. This discrepancy also could be due to changes within the survey between phases and limited accuracy due to study respondents with imperfect knowledge. At this time, the researchers have not tried to assess the global market, although this issue could be addressed in a future project.



Ocean surface topography data, like this example, is gathered by the TOPEX/Poseidon and Jason-1 satellites. *Image credit: NASA/JPL/Caltech*

In 2004, Forecast International released a satellite-centric market analysis of the remote sensing industry. *The Market for Civil and Commercial Remote Sensing Satellites* estimated that between 2004 and 2013, approximately 170 remote sensing satellites would be manufactured, representing a $15.5 billion investment. It said the majority of these systems, 130 satellites, would be built in the first five years of the forecast period.[208]

4.2.1.3 Satellite Positioning

ABI Research estimates global market revenues for satellite-based positioning technologies for all applications at $21.8 billion for 2005, see Exhibit 4o (page 72), The Industrial Technology Research Institute estimated 2003 GPS production value at $13 billion and growing. Trends in GPS growth were reported in *Business Week,*[209] along with a discussion of the entrance of "mainstream" electronics firms into the GPS marketplace:

> *The entrance of Sony and Philips underscores the evolution of the GPS (global positioning system) market from a niche product popular with hunters, hikers, and boaters into a thriving consumer business. In the last several years, companies like $1 billion (2005 sales) Garmin (GRMN) and Lowrance Electronics in the U.S., Dutch producer TomTom, and Magellan GPS, a unit of French defense contractor Thales, have become a staple of motorists who want 'navigation' units in their cars. They are particularly popular as an aftermarket purchase.*

Dutch TomTom and GM's OnStar both generated nearly $1 billion in revenue for 2005.[210] The article reported that analyst Ron Stearns of Frost and Sullivan in San Antonio, Texas estimated the "automotive portion of the consumer GPS business at $922 million and anticipates that consumers will buy more than 1.2 million units this year," as well as outdoor units aimed at hikers and boaters, for a total of more than four million units and $1.8 billion in sales. It noted that by 2010, "Stearns expects combined unit sales (both automotive and outdoor markets) of $8.3 million and $2.7 billion in revenue."[211]

A Garmin in-vehicle GPS navigation unit. *Image credit: Garmin*

EXHIBIT 4o. Satellite-Based Positioning Technologies 2005 Revenue Estimates

DESCRIPTION	ESTIMATE	SOURCE
Global market revenues for all satellite-based positioning technologies	$21.8 B	ABI Research*
2003 revenues	$13.0 B	Industrial Technology Research Institute

EXHIBIT 4p. Space Tourism (Accommodations and Travel)

DESCRIPTION	ESTIMATE	SOURCE
Greg Olsen July 05	$0.20 B	Space Adventures
Virgin Galactic deposits	$0.01 B	*The Economist*
Total	**$0.21 B**	
Developing spacecraft and infrastructure	$1.00 B	*The Economist*

4.2.2 Platform-Based In-Space Activities

Science and Research: Currently, most platform-based in-space activities are conducted by international space agencies and the military. Budgets for these activities are included in government space agency budgets, shown in section 4.3, *Government Space Budgets.* While not shown here, some data on government expenditures broken down by type of activity is available. However, cautionary interpretation is important as definitions of types of activity and methods of calculation vary significantly from country to country.

Accommodations: The $20 million in revenue associated with Greg Olsen staying aboard the ISS in 2005 is included in the tourism revenue in Exhibit 4p.[212]

4.2.3 Transportation-Based In-Space Activities

Research and Exploration: In 2005, six ISS resupply launches were made from the Baikonur Cosmodrome. NASA paid Roscosmos $40 million per launch.[213] NASA's planned funding for COTS is shown in Exhibit 4q.[214] In 2005, NASA spent $6.7 billion on space operations, (which includes the shuttle and ISS) and spent $2.7 billion on exploration systems.[215] Note that these funds are reflected in the overall NASA budget shown in Exhibit 4r (page 74).

Tourism (Travel): Space Adventures' price for a week trip to ISS, such as the one Greg Olsen took in 2005, is $20 million. *Space News* reported that Virgin Galactic has collected deposits from more than 150 people[216] who want to take a suborbital flight on SpaceShipTwo, which has yet to be completed. *The Economist* reported that more than $1 billion has been committed to building private spaceships and associated infrastructure.[217] Commercial revenue for commercial flights includes an unknown amount (according to the FAA)[218] of revenue to Space Adventures and $14 million in deposits for Virgin Galactic.[219] The latter plans to begin launching in 2007 or 2008.[220]

EXHIBIT 4q. NASA Commercial Orbital Transportation Services (COTS) Funding

FY 06	FY 07	FY 08	FY 09	TOTAL
$50 M	$120 M	$200 M	$130 M	$500 M

Missile Defense: The U.S. Missile Defense Agency (MDA)'s FY 2005 budget is $9.0 billion.[221] See Exhibit 4s (page 75) for government space agency budget. While some of the MDA budget is focused on ground-, sea-, and air-based systems, as opposed to in-space systems, the entire budget is included since those elements of the missile defense system are primarily used to track and control systems operating in the space environment.

4.3 Government Space Budgets

Government space budgets are used for both infrastructure and products and services. U.S. government space spending constitutes the vast majority of global government space spending; the DoD and NASA receive the largest share of U.S. space funds.

NASA's FY 2006 budget is approximately $16 billion. The NASA FY 2006 Budget Request forecasts relatively small (1.8 percent to 3.1 percent) annual increases in the total NASA budget, bringing the total budget to $18.03 billion by FY 2010. (See Exhibit 4r, page 74)[222]

Determining the DoD's space budget is more complex. This report includes budget figures drawn from the DoD's virtual space major force program (vMFP). In DoD usage, a major force program is a "budgeting mechanism that aggregates related budget items into a single program to track program resources independent of the appropriation process and contains the resources needed to achieve an objective or plan."[223] There is no major force program for space funding, and, as a result, one of the recommendations of the Commission to Assess United States National Security Space Management and Organization (Space Commission) in 2001 was to create such a space major force program.[224] Rather than create an entirely new, separate major force program just for space, DoD elected to create a "virtual" major force program that would draw space-related budgetary data from the pre-existing major force programs.[225]

Russian ground personnel members carry U.S. millionaire Gregory Olsen shortly after the landing near the town of Arkalyk in northern Kazakhstan. Olsen paid $20 million to live aboard the ISS for one week. *Image credit: AP/Ivan Sekretarev*

The vMFP was established by the director of Program, Analysis, and Evaluation (PA&E) and the deputy director of Central Intelligence for Community Management (DDCI/CM) and is reviewed annually by the DoD Executive Agent for Space (the Secretary of the Air Force).[226] The Secretary of the Air Force recommends changes to the content of the vMFP as part of this annual review. The

PA&E office does make available publicly a detailed breakdown of the contents of the vMFP. However, according to DoD Directive 5101.2, which directs the establishment of the vMFP, space systems are defined as:

> *All of the devices and organizations forming the space network. These consist of spacecraft; mission package(s); ground stations; data links among spacecraft, ground stations, mission or user terminals, which may include initial reception, processing, and exploitation; launch systems; and directly related supporting infrastructure, including space surveillance and battle management/command, control, communications, and computers.*[227]

There are a few concerns in using this virtual major force program (vMFP) as a definitive source for U.S. DoD space budget expenditures. First, this vMFP is an aggregate of budgetary

EXHIBIT 4r. National Aeronautics and Space Administration President's FY 2006 Budget Request

(BUDGET AUTHORITY, $ IN MILLIONS) BY APPROPRIATION ACCOUNT BY MISSION DIRECTORATE BY THEME	INITIAL OPERATING PLAN 12/23/04 FY 2005	FULL COST **FY 2006**	FY 2007	FY 2008	FY 2009	FY 2010	CHAPTER NUMBER
Science, Aeronautics, and Exploration	**9,334.7**	**9,661.0**	**10,549.8**	**11,214.6**	**12,209.6**	**12,796.1**	SAE SUM-1
Science*	**5,527.2**	**5,476.3**	**5,960.3**	**6,503.4**	**6,853.0**	**6,797.6**	SAE 1
Solar System Exploration	1,858.1	1,900.5	2,347.7	2,831.8	2,998.9	3,066.1	SAE 2
The Universe	1,513.2	1,512.2	1,531.5	1,539.4	1,495.0	1,406.7	SAE 3
Earth-Sun System	2,155.8	2,063.6	2,081.2	2,132.2	2,359.0	2,324.8	SAE 4
Exploration Systems**	**2,684.5**	**3,165.4**	**3,707.0**	**3,825.9**	**4,473.7**	**5,125.5**	SAE 5
Constellation Systems	526.0	1,120.1	1,579.5	1,523.7	1,990.9	2,452.2	SAE 6
Exploration Systems Research and Technology	722.8	919.2	907.3	989.2	1,050.3	1,078.5	SAE 7
Prometheus Nuclear Systems and Technology	431.7	319.6	423.5	500.6	614.0	779.0	SAE 8
Human Systems Research and Technology	1,003.9	806.5	796.7	812.4	818.5	815.8	SAE 9
Aeronautics Research	**906.2**	**852.3**	**727.6**	**730.7**	**727.5**	**717.6**	SAE 10
Aeronautics Technology	906.2	852.3	727.6	730.7	727.5	717.6	SAE 11
Education Programs	**216.7**	**166.9**	**154.9**	**154.7**	**155.4**	**155.4**	SAE 12
Education Programs	216.7	166.9	154.9	154.7	155.4	155.4	SAE 13
Exploration Capabilities	**6,704.4**	**6,763.0**	**6,378.6**	**6,056.7**	**5,367.1**	**5,193.8**	EC-SUM 1
Space Operations	**6,704.4**	**6,763.0**	**6,378.6**	**6,056.7**	**5,367.1**	**5,193.8**	EC 1
International Space Station	1,676.3	1,856.7	1,835.3	1,790.9	2,152.3	2,375.5	EC 2
Space Shuttle	4,543.0	4,530.6	4,172.4	3,865.7	2,815.1	2,419.2	EC 3
Space and Flight Support	485.1	375.6	370.9	400.0	399.7	399.1	EC 4
Inspector General	**31.3**	**32.4**	**33.5**	**34.6**	**35.2**	**37.3**	IG 1
TOTAL	**16,070.4**	**16,456.3**	**16,962.0**	**17,305.9**	**17,611.9**	**18,027.1**	
Year-to-Year Increase		2.4%	3.1%	2.0%	1.8%	2.4%	
Emergency Hurricane Supplemental	126.0						

*Science Mission Directorate reflects the combination of the former Space Science and Earth Science Enterprises.
**Beginning in FY 2006, Exploration Systems moves from Exploration Capabilities to Science, Aeronautics and Exploration. Exploration Systems Mission Directorate reflects the combination of the former Biological & Physical Research and Exploration Systems Enterprises.
Totals may not add due to rounding.
Source: NASA. Format modified. See endnote 215.

data, some of which is unclassified and some of which is classified. For this reason, DoD PA&E cannot make publicly available a detailed accounting of the dollars and programs that make up the total vMFP dollar amount. This makes a thorough analysis of how this funding is being allocated impossible.

Secondly, according to DoD sources, there are no definitive criteria for what should or should not be considered a "space effort" for the purposes of including or excluding a program's budgetary data in the vMFP. As a result, there could be significant variability from year to year with regard to specific programs as they are reported in the vMFP.

Finally, the DoD could decide to include or exclude certain expenditures from the vMFP, not based on whether they qualify as a space activity, but on potential political or funding ramifications.

Because of these issues, readers should be aware that the vMFP data for FY 2005 is almost certainly not an accurate reflection of the true level of DoD spending on space activities. Despite these concerns, we have chosen to report the aggregated data from the vMFP, as it represents the most accurate publicly available DoD budgetary data for space.

The U.S. DoD forecasts budget expenditures using the Future Years Defense Program (FYDP), which is the official DoD document summarizing forces and resources associated with programs approved by the Secretary of Defense. It projects spending by service, by appropriations account (research, development, test, and evaluation, operations and maintenance, etc.), and by major force program (strategic forces, airlift/sealift, research and development, etc.). The FYDP is updated every two years, and aggregates the projected expenditures for all the services for the next six years. It is unclear at this time whether the data for the space vMFP is collected for these six-year projections. The current FYDP is reflected in the outlays of the National Defense Budget Estimates for FY 2007.[228]

EXHIBIT 4s. Government Agency Space Budgets (Civil and Military)

AGENCY	BUDGET	SOURCE
U.S. DoD Space	$21.70 B	CRS[232]
NRO	$7.50 B	Global Security[233]
NGA	$2.00 B	Global Security[234]
Missile Defense Agency	$9.00 B	MDA[235]
NASA	$16.10 B	NASA[236]
NOAA	$0.90 B	NOAA[237]
DOE	$0.03 B	DOE[238]
FAA	$0.01 B	FAA[239]
ESA	$3.70 B	ESA[240]
Russia (Roscosmos)	$0.70 B	RIA Novosti[241]
France (CNES)	$0.60 B	OECD[242]
Italy (ASI)	$0.40 B	ASI[243]
UK (BNSC)	$0.10 B	BNSC[244]
Japan (JAXA)	$2.50 B	*Space News*[245]
India (ISRO)	$0.70 B	ISRO[246]
Canada (CSA)	$0.30 B	CSA[247]
China (CNSA)	$0.50 B	*The Space Review*[248]
Germany (DLR)	$0.30 B	*Space News*[249]
Non-U.S. military space	$2.29 B	Euroconsult[250]

Non-U.S. military estimates, which are for 2004, include the following countries: United Kingdom, France, Russia, Germany, Belgium, Spain, Italy, and Israel. China's budget includes both military and civil expenditures. Note that the estimate of China's space budget is controversial. At a NASA budget hearing in April 2006, much of the discussion was about the possible size of China's space program and its ability to complete its plans to land astronauts on the Moon in 2017. When asked about the size of China's program, The Honorable Dr. Michael D. Griffin, NASA administrator, noted "that China has 200,000 engineers and scientists working on its space program compared to the 75,000 full-time equivalents NASA can afford under its budget."[229] While China reports its space budget as $500 million, many observers feel that China understates its expenditures for political reasons. In a 2003 article by *Space News*, Dean Cheng, Center for Naval Analysis Asian affairs specialist, estimates the Chinese space program receives about $1.5 to $2.0 billion annually.[230] A Forecast International report, *Western Military Satellites: 2005-2014*, projects that 118 dedicated military satellites are earmarked for production during the next ten years, with an associated revenue of $41 billion. The 118 figure includes satellites of all sizes and price ranges.[231]

Government space budgets are shown in Exhibit 4s (page 75). Some of the values shown are estimates, notably U.S. national security space budgets.

4.4 Summary of Space Products and Services

Exhibit 4t is a compilation of selected estimates of revenue to industry and government budgets associated with global space activity. In general, industry revenue estimates exclude identifiable purchases by government. The estimates included were selected to provide the most complete and consistent estimate feasible. However, some incompatibilities and inconsistencies remain, and cannot be resolved with available data. In addition, some types of data are not available. Please note the following issues with the data included in the estimated total of $180 billion.

- Transponder leasing revenues are included in the estimate of FSS revenues. The revenues associated with value-added services using leased transponders are included in the estimates of DTH television (where some non-U.S. providers use leased transponders).
- Military purchases of satellite capacity are double-counted; they are included in government budgets (primarily the U.S. DoD) and are also included in the estimate of FSS revenues.
- Manufacturing estimates for satellites include major subcontractors as well as prime contractors.
- Some types of data are missing:
    - Government budgets for countries with small space offices or activities
    - Lower tier manufacturing subcontractor revenues
    - Revenues for space-specific activities of certain types of non-engineering firms such as marketing, finance, public relations, and more

There is insufficient data for us to make a definitive adjustment in these cases. We highlight these issues so readers can make their own determinations regarding what is appropriate to include or exclude, and where rough estimates may be useful, to meet their own specific information needs.

See the discussion in 1.1, the *Methodology* section of this report, for additional detail on the categories and definitions used for these estimates.

EXHIBIT 4t. Global Space Activity Revenues and Budgets, 2005 (in $ Billions)

TYPE	VALUE	SOURCE	DESCRIPTION
Infrastructure	**$28.7 B**		
Satellite manufacturing (commercial)	$2.30	SIA	2005 revenue from production of commercial satellites[251]
Launch industry (commercial)	$1.20	FAA	2005 revenue from sale and launch of commercial launch vehicles[252]
Ground stations and equipment	$25.20	FAA	2005 revenue from mobile terminals, gateways, control stations, VSAT/USAT, DBS dishes, handheld phones and DARS equipment[253]
Infrastructure Support Industries	**$1.38 B**		
Internal research and development (IR&D)	$0.50	DoD	Estimate of space industry IR&D not recovered from the government[254]
Insurance	$0.88	*Via Satellite*	2005 gross industry premiums[255]
Satellite Services	**$80.21 B**		
Direct-to-home television	$46.00	In-Stat	2005 direct-to-home pay TV revenue[256]
Satellite radio	$0.81	XM, Sirius, WorldSpace	2005 revenue for XM,[257] Sirius,[258] and WorldSpace[259]
FSS	$9.80	SIA	2005 revenue from VSAT services, remote sensing, and transponder agreements[260]
MSS	$1.80	Northern Sky Research	2005 revenue from wholesale and retail MSS satellite services from narrowband voice to next generation broadband[261]
GPS equipment and chipsets	$21.80	ABI Research	2005 projection from 2004 revenue includes marine, military, GIS, timing, asset and people tracking, animal, recreation, communication, in vehicle navigation system[262]
Space Transportation Services	**$0.03 B**		
Tourism (orbital)	$0.02	Space Adventures	2005 revenue from Greg Olsen flight[263]
Tourism (suborbital)	$0.01	*The Economist*	2005 down payments from 157 customers for suborbital flights[264]
U.S. Government Space Budgets	**$57.24 B**		
DoD Space	$21.70	CRS	FY 2005 budget request for all services[265]
National Security	$7.50	Global Security	FY 2006 NRO budget request[266]
National Security	$2.00	Global Security	FY 2006 NGA budget request[267]
Missile Defense Agency	$9.00	MDA	FY 2005 budget for U.S. ballistic missile defense program[268]
NASA	$16.10	NASA	FY 2005 operating plan[269]
NOAA	$0.90	NOAA	NOAA National Environmental Satellite, Data and Information Service FY 2005 budget request[270]
DOE	$0.03	DOE	FY 2005 DOE space and defense budget request[271]
FAA	$0.01	FAA	FY 2005 FAA AST budget request[272]
International Government Agency Space Budgets	**$12.09 B**		
ESA	$3.70	ESA	Estimated 2006 budget[273]
Russia (Roscosmos)	$0.70	RIA Novosti	2005 allocation based on multi-year operating plan[274]
France (CNES)	$0.60	OECD	2005 agency budget, excluding ESA[275]
Italy (ASI)	$0.40	ASI	2005 budget, excluding ESA[276]
UK (BNSC)	$0.10	BNSC	2004-05 funding, excluding ESA[277]
Japan (JAXA)	$2.50	*Space News*	2004 budget[278]
India (ISRO)	$0.70	ISRO	2005-06 ISRO budget estimate[279]
Canada (CSA)	$0.30	CSA	2005-06 financial resources, excluding ESA[280]
China (CNSA)	$0.50	*The Space Review*	2006 estimated annual expenditures[281]
Germany (DLR)	$0.30	*Space News*	2005 budget, excluding ESA[282]
Non-U.S. military space	$2.29	Euroconsult	2004 non-U.S. military space budget estimates, excluding China[283]
TOTAL	**$179.65 B**		

2006

THE SPACE REPORT

HOW SPACE PRODUCTS AND SERVICES ARE USED

5.0

5.0

How Space Products and Services Are Used | 5.0

A single space product or service can meet many needs. For instance, positioning satellite services are used for military logistics, in-vehicle navigation systems such as TomTom, guest assistance at Rosewood Hotels & Resorts, and GPS games such as geocaching, a global GPS-enabled treasure hunt.

EXHIBIT 5a. Topics Covered in How Space Products and Services Are Used

- 5.0 How Space Products and Services Are Used
- 5.1 Accommodations
- 5.2 Energy and Earth Resources
- 5.3 Governance and the Public Good
- 5.4 Healthcare and Biotechnology
- 5.5 Homeland Security, Defense, and Intelligence
- 5.6 Lifestyle Media
- 5.7 Retail, Finance, and Management
- 5.8 Science and Academia
- 5.9 Transportation, Warehousing, and Manufacturing

Geocaching and benchmark hunting involve players locating caches or control marks with the help of handheld GPS units (seen here). *Image credit: Steve Burton*

This section describes multiple applications of space products and services in all sectors of the global economy (listed in Exhibit 5a). The discussion aims at providing insight into how space products and services serve functions that many people may not associate with space systems.

For example, satellites provide a host of applications which increase food production and minimize cost. Remote sensing data can identify diseased crops and predict future yields. Geospatial software and GPS-enabled farm equipment allow for precision agriculture and reduce fertilizer waste. Satellites also enable short term weather forecasts, which can prevent crop loss.

Hurricane Katrina, seen with remote sensing equipment, makes landfall on the Louisiana shoreline. *Image credit: NASA*

The aftermath of Hurricane Katrina emphasized the role of space in disaster prediction, relief, and search and rescue operations. In addition, major disasters like Katrina and the 2004 tsunami in Southeast Asia highlight the role of international organizations in disaster management. The World Meteorological Organization (WMO) provides a forum for exchanging satellite data, while the Disaster Monitoring Constellation (DMC), pioneered by Surrey Satellite Technology Ltd. (SSTL), represents a novel way of applying national space infrastructure to international disasters.

Commercial transportation and consumers continue to rely on GPS navigation systems for day-to-day guidance. Additionally, real time

A new generation of farmers is using aerial and satellite remote sensing imagery (like this 4-meter resolution image from IKONOS) to monitor a wide range of variables that affect their crops. *Image credit: GeoEye*

data integration has enabled applications like automatically adjusting tires and reactive routing software. Mobile devices like cell phones and PDAs can be equipped with GPS chipsets and software applications to provide novel utilities for users like the BlackBerry Caffeine Finder.

VSAT (very small aperture terminal) networks can be used by governments for coordinating electronic voting and telemedicine. Venezuela recently used the Gilat VSAT network in its 2004 elections. Across the globe in India, satellites enable a telemedicine network that connects rural hospitals with specialty centers in major cities to increase the quality of healthcare. This model has been successful and is currently being considered for a pan-African telemedicine network.

Satellite applications also benefit retailers and small convenience stores like 7-Eleven. In Japan, 7-Eleven stores are connected via a robust network with satellite backups that enable the convenience store to record purchases accurately, track consumer trends, and schedule several deliveries a day. In addition, satellite weather data is used to predict local consumer demand so the stores can adjust inventory accordingly.

The nine categories that follow in 5.0 provide more detail and also describe potential applications of space products and services in each of the areas discussed.

Deep space communications satellite dish

The Accommodations section includes establishments in the hospitality industry such as hotels, travel planning, and reservation services.

5.1 | Accommodations

Hotels in remote tourist locations use VSATs to keep track of bookings and current capacity. In 1999, Best Western had 560 sites connected by a VSAT network,[284] while, more recently, Six Continents Hotels, Inc., contracted Gilat to provide a satellite network to more than 2,500 locations in the United States and Canada.[285] Some hotels offer access to satellite communications to their guests. Video & Suono, a distributor of Skylogic broadband Internet, has installed terminals in Athena Grand Hotel in Athens, Greece, and the Gelina Village Resort & Spa in Corfu, Greece, to provide fixed terminal and wireless hotspot Internet access to guests.[286]

A young girl takes advantage of a WiFi hotspot outside.

Hotels also use custom, interactive satellite television that provides their guests with premium channels and additional services.[287] These services are provided by companies such as VDA, which distributes its content directly to hotels through a partnership with NetISat.[288]

2005 HIGHLIGHT

- Greg Olsen becomes the third tourist to visit the ISS

Satellite-enabled capabilities are sometimes used to enhance guest services. In 2005, Rosewood Hotels & Resorts started offering its guests an alternative to paper maps when looking for directions. Now at three locations—the Carlyle, New York, the Mansion on Turtle Creek, Dallas, Texas, and Hotel Crescent Court, Dallas, Texas—guests can request a handheld GPS navigation unit.[289] These GPS units have walking and driving functions and are preprogrammed to include popular attractions around the hotels. When the guest is ready to return, the navigation systems automatically guide them back to the hotel.

Skylogic's Eutelsat not only broadcasts TV and radio, but also helps keep remote locations connected with the outside world. *Image credit: Skylogic*

Travel planning services that combine flight, hotel, and rental car reservations and purchases benefit from VSAT connections to hotel servers and the Internet. Examples of these companies include traditional travel agents, as well as online planning services such as Expedia, Orbitz, and Travelocity. By interfacing directly with the hotel, these services can identify open rooms and cancellations to offer lower prices and competitively packaged deals.

The first orbital fare for a ticket to space was paid by McDonnell Douglas to launch Charles D. Walker and a Continuous Flow

Electrophoresis System (CFES) experiment. Walker spent six days and 56 minutes in space on STS 41-D in September 1984.[290] More recently, Greg Olsen paid Roscosmos $20 million for a ten-day trip to the ISS.[291] While several companies hope to enter the space accommodations market, currently the International Space Station is the only accommodation for space tourism in orbit.

Elon Musk, founder of SpaceX, is focused on building a family of launch vehicles, the Falcon rockets, intended to reduce the cost and increase the reliability of space access by a factor of ten. *Image credit: SpaceX*

Bigelow Aerospace has planned a series of inflatable structure tests in space. The plan is to evolve testing and hardware to establish the Nautilus outpost in Earth orbit. *Image credit: Bigelow Aerospace*

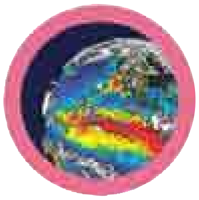
The Future

Satellites will continue to provide niche services and connectivity for the hospitality industry. In areas without terrestrial cable, television is not economical, and hotels will continue to rely on direct-to-home services to provide guests with premium content.

In space, accommodations are among the long-term goals (20 to 30 years) of several privately funded space companies. SpaceX's founder Elon Musk has often stated his personal goal, and one of the goals of his company, is to help humanity become a "space-faring civilization."[292] A technology demonstration for Bigelow's inflatable modules, which include a one-third scale mockup, was launched in July of 2006.[293] These plans are echoed by Virgin Galactic, whose promotional video to its suborbital flights ends with an animation of an orbital vehicle preparing to dock with a space station. While the market for in-space tourism is unknown, various studies estimate demand from 60 passengers per year to 10,000; and demand depends greatly on ticket price and the social-economic state of developed countries.[294] According to the OECD *Space 2030*, adventure tourism has become increasingly profitable, and space tourism could provide a niche market for adventure seekers with means.[295]

Space Applications

- Travel reservation services
- Space hotels
- Television content distribution to hotels
- Hospitality communications
- GPS handhelds



The Energy and Earth Resources section includes a class of establishments that use, analyze, maintain, or work with natural resources or processes. This includes agriculture, mining, forestry, hunting, and similar activities. This group also includes the public and scientific elements concerned with the management of natural resources. Regulation and conservation of land, wildlife, forest use, and mineral deposits are included in this group. Water resource management, particularly through the use of pipelines, is also encompassed in this area.

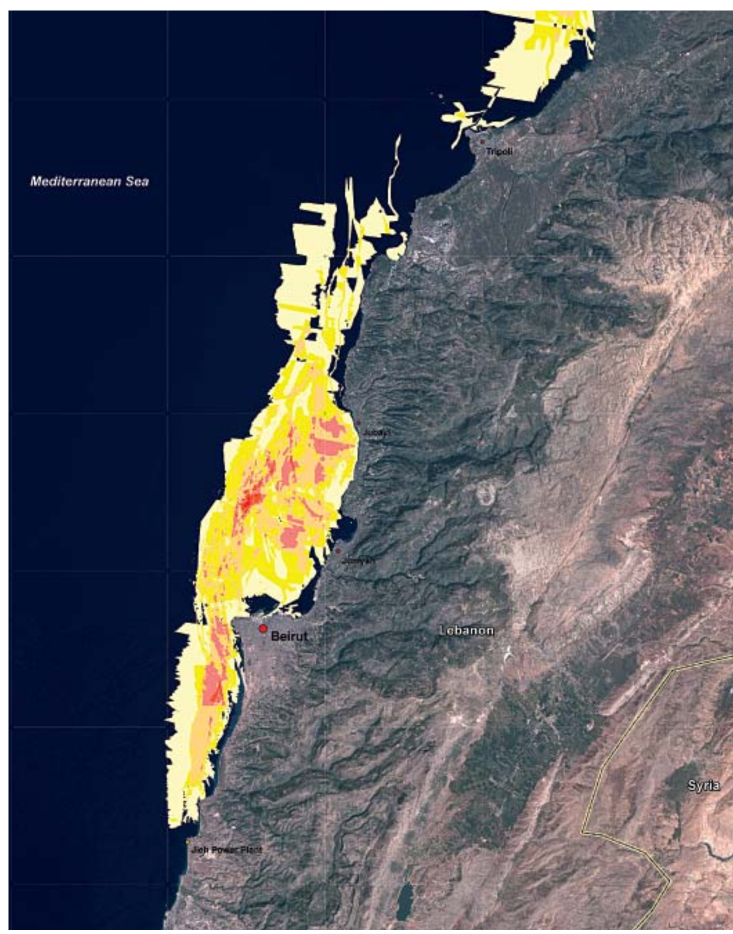
Icon image credit: NASA

5.2 | Energy and Earth Resources

The dominant space technology that supports energy and Earth resources is remote sensing. Remote sensing images are not limited to the wavelengths of light that can be seen by the human eye. Earth sensing satellites record primarily microwave, infrared, and visible light wavelengths. By recording data from various spectra bands, multi- and hyper-spectral instruments can penetrate and image diverse environments, including under water, ocean and land surfaces, or features in the atmosphere. This unique capability supports a host of resource identification and management capabilities.

Satellites are completely embedded in our experience of weather forecasting; every nightly news show presents a composite map of satellite images to show weather patterns. Among the most memorable images of 2005 are satellite images of the massive Hurricane Katrina (page 80) moving toward the Gulf Coast and before and after images of New Orleans. Remote sensing instruments record visible and infrared images, thermal radiation measurements, and temperature profiles to predict the weather. As the recently launched NOAA-18 satellite orbits the globe, capturing and disseminating valuable environmental data, it is helping improve the National Oceanic and Atmospheric Administration (NOAA)'s long-range climate and seasonal outlooks, including forecasts for the potentially devastating El Niño and La Niña.

International organizations, such as the World Meteorological Organization (WMO), facilitate the exchange of satellite data and provide early warning in the event of a natural disaster.[296] Another international endeavor began with Surrey Satellite Technology, Ltd., which assisted in developing five low-cost satellites in an international partnership for disaster monitoring. The Disaster Monitoring Constellation (DMC) is composed of independently-owned national satellites. However, in the event of a disaster, the constellation works as a coordinated system to provide multi-spectral imagery and daily revisit capability over the afflicted area.[297] Several national programs also have been created to monitor severe weather like Japan's Tropical Cyclone Database.[298]



A composite image of six satellite observations of an oil spill off the Lebanese Coast. *Image credit: German Aerospace Center*

The agriculture industry leverages weather forecasting technologies and satellite systems that increase the accuracy of local forecasts. More accurate short-term forecasts can prevent crop loss and save an additional $40 million per year.[299] In addition, remote sensing satellites offer near-real-time observations of precipitation levels and monitor soil and crop conditions. This helps analysts gauge planting and growing conditions, as well as predict the size of the harvest or potentially devastating droughts. GPS technology is instrumental in the planting and harvesting of those crops, as large agricultural enterprises use tractors guided by GPS telemetry to plant, fertilize, and harvest with greater efficiency.[300] High-end telemetry products offer autonomous steering capabilities.[301] Farmers can customize fertilizer and irrigation needs to the square meter reducing costs and benefiting both the farmer and the environment. In one experiment described in a University of North Dakota report, precision agriculture saved $14.67 per acre and reduced the amount of fertilizer necessary by one third.[302]

The 1991 Landsat image on top shows a coastal area where 143 square kilometers of wetlands were converted to shrimp ponds. By the time ASTER, one of the Terra Satellite's imaging instruments, acquired the bottom image in 2001, 243 square kilometers had been converted, eliminating 83 percent of the wetlands. *Image credit: NASA/GSFC/METI/ERSDAC/JAROS and U.S./Japan ASTER Science Team*

Remote sensing data also is used extensively in resource exploration. Satellite images can be used for fracture analysis, hydrocarbon indications, and geologic interpretation to determine the candidate areas for oil, gas, or mineral exploration. Analysts determine the best sites for more extensive, terrestrial exploration.

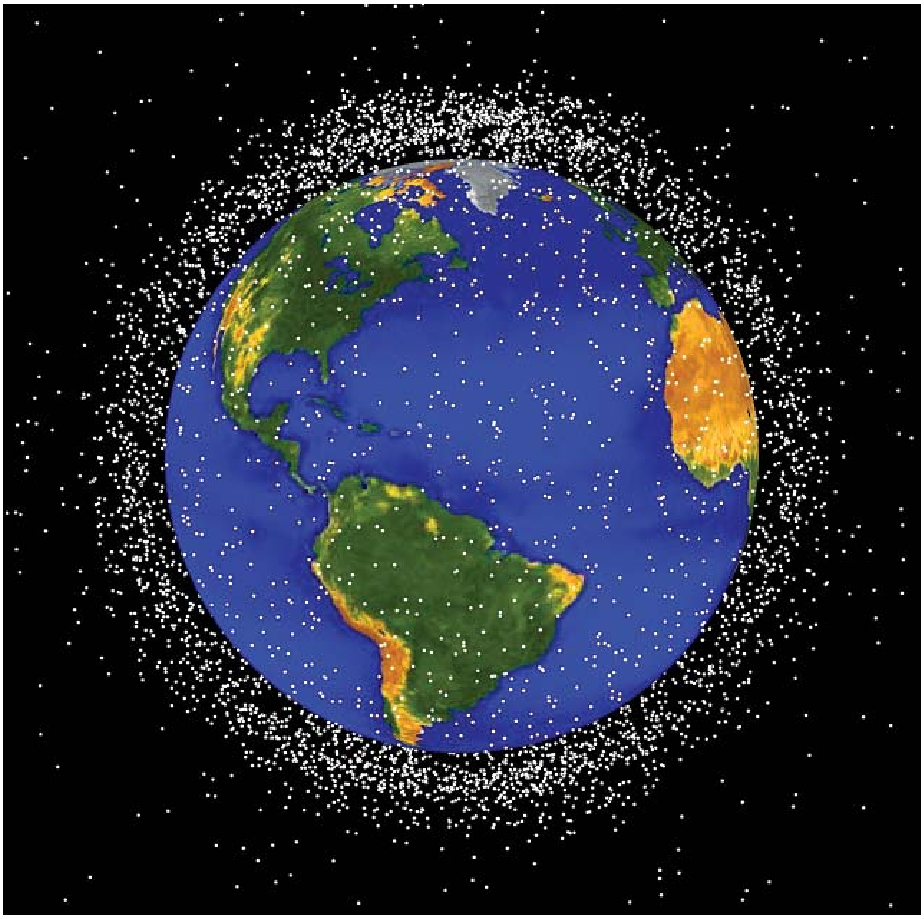
Web-based Google Maps and stand-alone Google Earth offer satellite imagery free to the public. *Image credit: Google*

A novel application of satellite capabilities that supports retail operations came online in 2005 with the launch of Google Earth—an interactive, 3D map of the Earth's surface constructed entirely of satellite images, taken by using various instruments and at various times in a mosaic fashion. Google Earth features maps and driving directions, but also the capability to search for ATMs, restaurants, movie theaters, grocery stores, schools, and so on. MSN Virtual Earth, launched in the wake of Google Earth, provides many of the same services. In addition, since it offers images at 45 degree angles, it is possible to read retail storefronts from the images. According to Nielsen/NetRatings, Google has 380 million unique users a month, while Google Earth accounts for 0.22 percent of Google's market share.[303]

2005 HIGHLIGHTS

- "The track forecasts for 2005 may set new accuracy records," said VADM Conrad Lautenbacher, USN, (Retired), Administrator of NOAA.
- NOAA-18 is an international effort launched on May 20, 2005. Located in polar orbit, it captures valuable environmental data and will improve long-range climate and seasonal outlooks, including forecasts for El Niño and La Niña.
- GEOS-18 lifted off on Friday, June 24, 2005, and provides improved data critical for fast and accurate NOAA weather forecasts.
- Google and Microsoft launched "Google Earth" and "MSN Virtual Earth," respectively, providing interactive satellite images and maps of the Earth.

Another application of satellite imaging is to plan right-of-ways and monitor pipelines for the oil and gas industry. In Siberia, satellites have been used to assess pipeline movement and strain due to the changes in the surrounding permafrost.[304] Leaks can be found with satellite thermal imaging by detecting temperature differentials along the pipe that are characteristic of pressure drops. Satellite communications also can play an important role in monitoring pipelines that often have automated sensors in remote locations. The Trans-Alaska Pipeline System (TAPS) uses 11 satellite arrays, at a total cost of $5 million, to act as backups for the 800-mile fiberoptic communication network.[305]

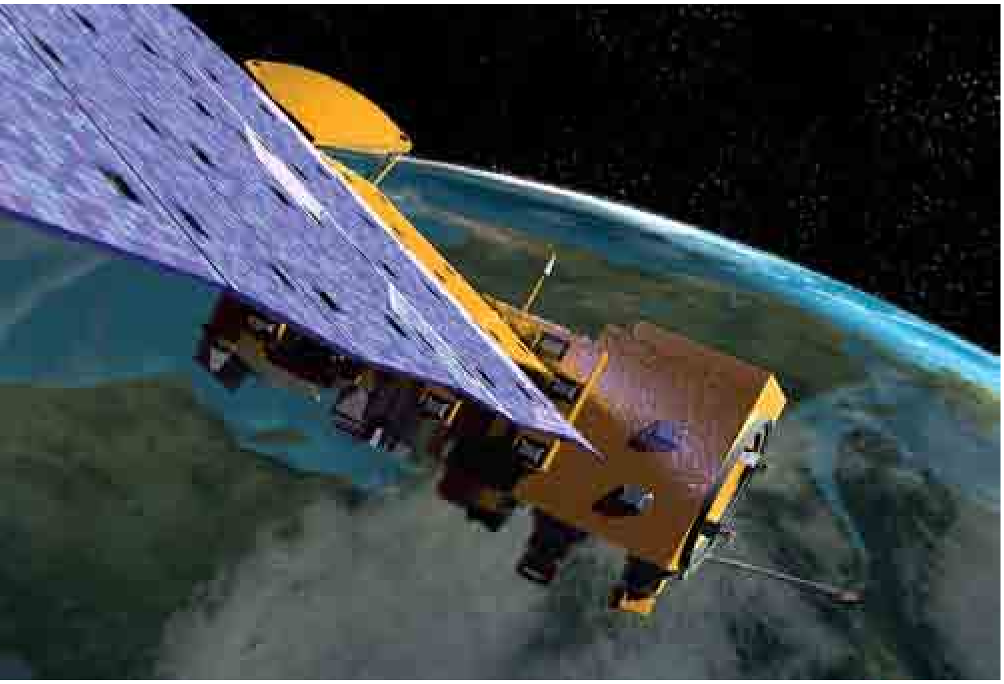


An image from NASA's Orbital Debris Program Office shows the satellites and the orbital debris circling the Earth in LEO. *Image credit: NASA*

The Future

Remote sensing satellites will continue to be used for resource identification and management. The demand for energy is expected to rise, resulting in a greater reliance on hyper-spectral sensors for oil and gas exploration.[306] In addition, remote sensing data will continue to have increasing applications in land monitoring and management.

65 countries, the European Commission (EC) and more than 40 international organizations are supporting the development of a Global Earth Observation System of Systems (GEOSS) during the next decade. GEOSS is proposed as an overarching system of existing and future earth observations systems. The goal for this cooperative effort is to enable the partners to use existing systems more efficiently, coordinate their efforts to address common needs, and make decisions based on common sources of data. Areas that the initiative hopes to address include environmental factors affecting human health and well-being, management of energy resources, climate variability and change, weather, and biodiversity. The initiative is intended to enable a global community capable of forecasting winter weather months in advance, or predicting where the next outbreak of malaria, SARS, or West Nile virus is likely to hit. According to Samuel Bodman, U.S. Secretary of Energy, "Improving the accuracy of temperature forecasts by just one degree Fahrenheit, which would allow electricity generating plants to better plan for peak demand, could save $1 billion a year."[307] More effective forecasts



Aqua is a NASA Earth Science satellite mission collecting data about the Earth's water cycle, including evaporation from the oceans, water vapor in the atmosphere, clouds, precipitation, soil moisture, sea ice, land ice, and snow cover on the land and ice. *Image credit: NASA*

of climate, drought, and air and water quality will also be possible.

Of growing concern to the international community is orbital debris—ranging from paint flecks to entire upper stages—resulting from half a century of space access. It is estimated that 100,000 to 150,000 objects larger than one centimeter remain in orbit.[308] Several organizations are currently discussing the problem of space debris, including the Inter-Agency Space Debris Coordination Committee (IADC) and the Scientific and Technical Subcommittee of the United Nations (UN) Committee on the Peaceful Uses of Outer Space (UNCOPUOS). Continued access to space could depend on mitigation efforts for orbital space debris.

As the space infrastructure continues to grow, it is possible to expand the sphere of economically useful resources into space and neighboring planetary bodies. NASA, ESA, and the Japanese Aerospace Exploration Agency (JAXA) are among the space agencies that have conducted studies or workshops to address the feasibility of using extra-terrestrial resources, or In Situ Resource Utilization (ISRU).[309] Potential space resources include water, solar wind implanted volatiles, lunar soil, and Martian atmospheric constituents, which could significantly reduce the mass and cost of exploratory missions. In addition to resources that may be less expensive if accessed and used in space, some materials have intrinsic value on Earth. In the long term (20+ years), this could include Helium-3 (an input to fusion reactions) and platinum group metals (catalysts in fuel cells), which could drive commercial investment in space mining.[310]

Space Applications

- Environmental risk assessment
- Agricultural monitoring
- Well monitoring
- Resource exploration
- Pipelines
- Mineral exploration
- Oil finding/ assessing
- Weather tracking
- Emergency mapping
- Treaty verification
- Ecological monitoring
- Ozone monitoring
- Land use monitoring
- Pollution monitoring
- GPS controlled tractors
- Wild animal tracking
- Orbital debris remediation

5.3 | Governance and the Public Good

Natural disasters often disable vital terrestrial communication networks. In these instances, telecommunications satellites can preserve communication within a devastated area. Satellite phones provide instant communication infrastructure for first responders and their command centers. Satellite data and phone networks can be set up quickly to aid in disaster management activities, helping the government and other institutions with activities such as organization of relief efforts. Both Globalstar and Iridium deployed more than 10,000 satellite phones each after Hurricane Katrina hit the U.S. Gulf Coast in August 2005.[311] These phones provided the necessary communication infrastructure for the National Guard, American Red Cross, the Federal Emergency Management Agency (FEMA), cellular and wireless service providers, utility workers, and reporters.

The Governance and the Public Good section consists of federal, state, and local government agencies and activities related to public programs overseen by these agencies. Additionally, this area consists of philanthropic organizations that administer and oversee funds, goods, or other support to charitable causes.

Icon image credit: U.S. Department of Homeland Security

Satellite radio and television companies provided dedicated stations for hurricane-related information. After the devastating tsunami in 2004 in Southeast Asia, satellite communication terminals provided links and Internet access for non-governmental organizations, like the Red Cross and the local population. These terminals also allowed for clear communications between the shore and the hospital ship USNS *Mercy*. [312]

This illustration shows the Iridium satellite constellation network consisting of 66 active satellites. *Image credit: Iridium*

Remote outposts and naval vessels also can benefit from the high bandwidth mobile communication network offered by satellites. In 2006, the Canadian Coast Guard selected Telesat to provide ship-to-shore communications via satellites.[313]

Commissioned in 1986, the USNS *Mercy* is a converted oil tanker dispatched around the world in support of U.S. Armed Forces deployed ashore, as well as helping in disaster relief efforts, including Katrina. *Image credit: U.S. Navy*

Satellite capabilities are enabling dependable voting mechanisms in governments around the world. An e-voting satellite network, such as Gilat's VSAT network, consists of a satellite dish and modem at each polling site connected to a central hub.[314] Each poll operates electronic voting machines, which are connected to the central hub database via these very small aperature terminal (VSAT) connections. Votes are collected and processed at the hub, where final results are generated. For added security, a real-time backup of all data is stored in an additional data center. In August 2004, about 10 million people in Venezuela, 70 percent of the eligible voters, used Gilat's system to vote on a presidential referendum.[315]

Satellite communications have allowed governments in developing nations to establish e-governance portals and services without investing in terrestrial infrastructure. In Mexico, a distance learning course was beamed via satellite and the Internet to more than 1,800 teachers.[316] Several governments, like the Gujarat State Wide Area Network (GSWAN) in India, have established VSAT networks to communicate between offices and bring governmental services to remote provinces.[317] Recently, agreements were made to begin work on a pan-African e-government project that would connect 116 locations and 53 heads of state to a communication/tele-education/telemedicine network. India is providing both technical expertise and several hubs for this network that will connect five universities, 53 learning centers, 10 super specialty hospitals, and 53 remote hospitals together via fiber, wireless links, and VSAT networks.[318]

The U.S. Coast Guard, shown here in a rescue off the coast of Texas, uses GPS to increase rescue success rates. *Image credit: U.S. Coast Guard*

Remote sensing satellites are used in urban planning, such as estimating population density and regional growth. Analysis and processing of satellite images can create maps that identify building use. Such patterns can also be analyzed over time. In this way, the number of residential dwellings can be estimated from high-resolution satellite images of cities. Dwelling estimates can then be aggregated to any geographical unit of analysis, population estimates for cities, and a dwelling density surface that can be categorized into any number of residential land-use classes.[319] In addition, remote sensing can be used to monitor national parks and discern damage due to forest fires or drought.[320]

Search and rescue (SAR) missions often use satellite communications along with data from GPS receivers to improve success rates. The searchers' safety and success are increased when there is an accurate record of their positions. For areas that have been mapped (for example, using satellite imagery), GPS units can be programmed with coordinates of dangerous sites (mine shafts or cliffs) to warn searchers as they approach. Search dogs commonly wear GPS receivers so the search team can track the area the dog has covered.[321] SAR systems like COSPAS-SARSAT, an international constellation of LEO and GEO satellites with ground support, can identify and communicate the location of distress beacons, significantly increasing the chance for rescue. More than 18,800 people have been rescued with the aid of satellites through the COSPAS-SARSAT program.[322] In addition, individual communication satellites like India's INSAT-3A can be equipped with an interoperable SAR transponder, complementing the COSPAS-SARSAT system.

Burning of Savanna grasslands in Mozambique is photographed by astronauts aboard the space shuttle. The fire plumes, containing particulates and grass, travel thousands of kilometers from their origin. *Image credit: NASA*

In addition to fleet management, police officers regularly use GPS systems. Florida, Missouri, Ohio, and Oklahoma recently passed laws requiring lifetime electronic monitoring for individuals who have committed certain crimes.[323] A combination of an electronic anklet and a GPS transmitter allows officers to respond immediately if a convict enters an area which is off limits. New Jersey uses GPS receivers in police cars to record the longitude and latitude of traffic accidents.[324] There is a growing trend of GPS records being introduced as evidence in criminal cases, most notably in the trial of Scott Peterson, which has led to state Supreme Court cases concerning the constitutionality of satellite surveillance.[325]

2005 HIGHLIGHTS

- The National Geospatial-Intelligence Agency (NGA) purchased remote sensing imagery and distributed it for hurricane clean up efforts.
- ESA launched Meteosat-9, a satellite designed to monitor weather, as well as hydrology, agriculture, and the environment.
- Disaster response teams rely on satellite communication and remote sensing products and services in the regions of Southeast Asia devastated by the December 26, 2004, tsunami.

The Future

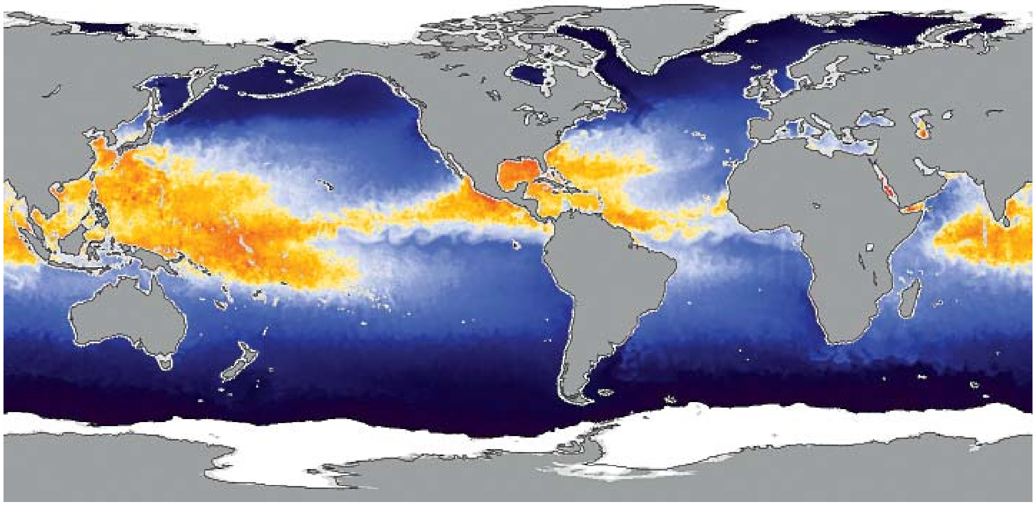
As expressed by the OECD, space can make a valuable contribution to the challenges that may face our societies and governments in the future. Space platforms can monitor air pollution and greenhouse gases for assessment and management, as well as natural disasters, enabling effective responses.[326] The aftermath of Hurricane Katrina showcased the use of satellite capabilities for disaster management, communications, monitoring, and search and rescue. By establishing a national or worldwide system similar to the Disaster Monitoring Constellation (DMC) or Mobile Enhanced Situational Awareness (MESA) Network, being developed by XM Satellite Radio and Raytheon Company, relief workers can respond immediately to any natural or manmade disaster. The UNCOPUOS and the *International Charter "Space and Major Disasters"* have provided an initial framework for a cooperative international disaster management system which could facilitate future disaster response.[327]

Space Applications

- E-voting
- Disaster management
- Post-disaster communication
- Emergency response
- Population forecasting
- Search and rescue
- Natural disaster tracking/ monitoring
- Law enforcement
- Civil planning (pipelines)

Monitoring and managing land use via remote sensing satellites is likely to be increasingly important for local governments.[328] Remote sensing data has been used for population estimation since 1960, but the methodology of modeling population and population density accurately is still the subject of academic discussion. Since restrictions in the United States were lifted in the mid-90s, the potential for further development exists for the commercial remote sensing industry. The Department of Transportation (DOT), in partnership with NASA, is studying technologies like hyperspectral satellite imaging, that can identify subtle differences in highway composition and locate roads that need to be repaired.[329]

Europe is considering satellite navigation to enable an elimination of toll booths and increase road safety. The EU Commission envisions a toll system based on satellite navigation and mobile telecommunications systems. Galileo is intended to be the backbone of this "pay-as-you-drive" system.[33]



This image from the Aqua satellite shows "hurricane-ready" water temperatures (waters above 28° C / 82° F). This data caused the National Hurricane Center to decrease its hurricane predictions for 2006. *Image credit: NASA*

5.4 | Healthcare and Biotechnology

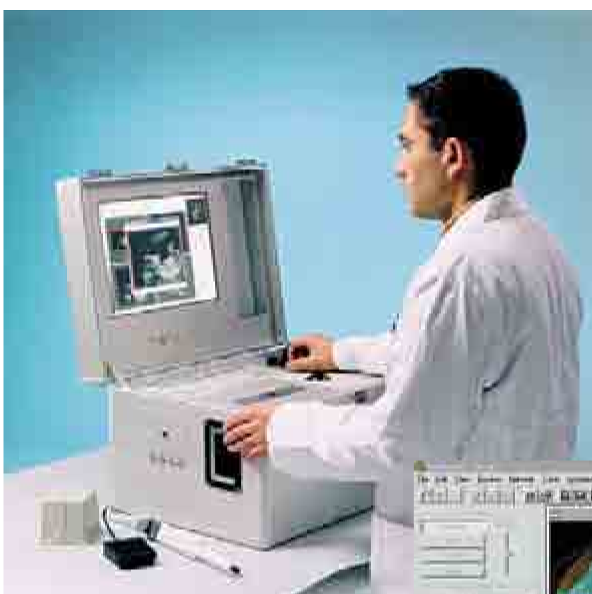
Space enables a variety of health and biotechnology applications including telemedicine, tracking of disease and allergy vectors, and biotechnology research.

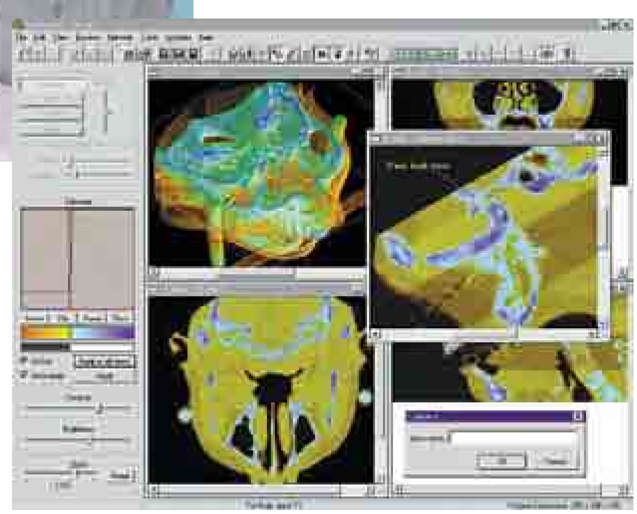
The Healthcare and Biotechnology section encompasses most medical-related enterprises, and also includes the industrial and environmental applications of biotechnology. Healthcare includes all highly-skilled research, as well as the range of establishments providing health services and social assistance for individuals. Biotechnology is the use of cellular and bimolecular processes for research, development, and/or manufacturing.

Most telemedicine connections feature a video conference feed and data connections between the doctor and the patient. Locally, the patient has a package of diagnostic tools to transmit blood oxygen levels, heart rates, blood pressure, and body temperatures over the Internet. Diagnostic sensors can include "wristwatches that monitor the heart, cell phones that can prick the finger of a diabetic patient and send the information to a doctor, and bedroom floor sensors that can discern an elderly patient's unsteady gait."[331] Data collected by these sensors can be transferred to a TCP/IP satellite system, such as the Interactive Satellite Multimedia Information System (ISIS) and beamed to a hospital anywhere in the world.[332]

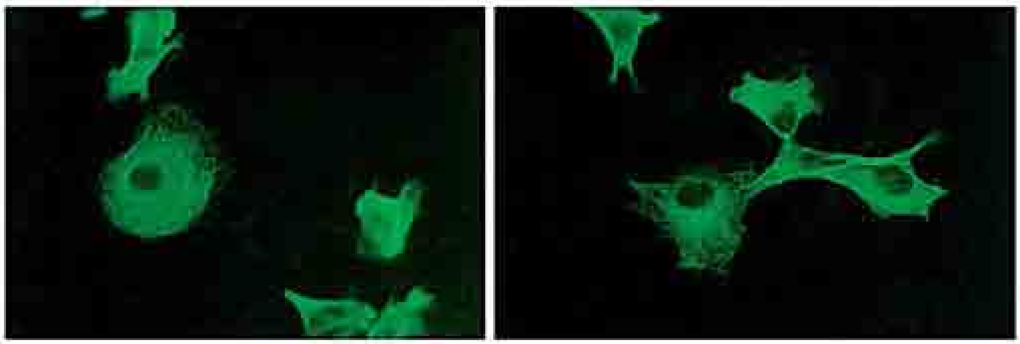
The TeLeCare terminal is capable of sending health information gathered by the attached instruments over a two-way satellite or land line. *Image credit: TeLeCare*

Telemedicine is used in the United States to connect rural areas to areas that have a greater density of doctors and specialists. Even where healthcare is available, many locations do not have available a full suite of specialists such as adult psychiatrists, pediatric psychiatrists, dermatologists, neurologists, specialized wound care consultants, genetic counselers and radiologists. The size of the telemedicine market in the United States in 2004 was estimated at $243 million with 200 telemedicine programs.[333]





TeleInViVo allows two doctors in different locations to see the same information at the same time. This allows remote or impoverished locations access to specialists. *Images credit: Fraunhofer IGD*



Biomedical research offers hope for a variety of medical problems, from diabetes to the replacement of damaged bone and tissues. Cell culturing, such as this bone cell culture, is part of an ISS payload including a tissue engineering investigation to better understand how synthetic bone can be used to treat bone-related illnesses and bone damaged in accidents. Millenium Biologix, Inc. is exploring the potential for making human bone implantable materials by seeding its proprietary artificial scaffold material with human bone cells. Space-grown bone implants have potential for dental implants, long bone grafts, and coating for orthopedic implants such as hip replacements. *Image credit: NASA Marshall Space Flight Center (NASA-MSFC)*

2005 HIGHLIGHT

- Implementation of e-mail-based telemedicine service, connecting two villages in Cambodia with physicians at Massachusetts General and Brigham & Women's Hospitals in Boston

Telemedicine shows promise in developing countries where traditional healthcare infrastructures are not developed or are isolated to large population centers. India is committed to telemedicine, where 75 percent of the population lives in rural areas but 75 percent of the doctors live in cities. India's telemedicine program began in 2001 and uses INSAT telecommunication satellites to connect remote hospitals with large "super specialty" hospitals in the major cities. As of 2005, India had connected 120 remote hospitals and health centers with 32 specialty hospitals and a single "mobile health service vehicle," an RV with telemedicine capabilities.[334] Telemedicine can significantly reduce hospital stays and other healthcare costs. Robert E. Litan of the Brookings Institution estimates that reduced costs associated with broadband telemedicine could save $1 trillion during the next 25 years.[335]

Protein crystals, like the HIV reverse transcriptase seen here, grow larger and more naturally in microgravity. *Image credit: NASA*

Many hospitals use satellite communication networks as back-up in case terrestrial line service is interrupted or in case of problems with the power grid. For instance, 32 acute care hospitals in Connecticut use a system dubbed MedSat for such cases.[336] This system was installed by Liberty Communication, Inc., and operates on a satellite-based radio dispatch network by Mobile Satellite Ventures (MSV).

On a larger scale, remote sensing satellites are used to monitor the global spread of certain diseases. NASA's Center for Health Applications of Aerospace-Related Technologies (CHAART) uses a network of more than 45 satellites, owned by more than one dozen countries, to monitor those diseases which are thought to have a close connection to environmental conditions.[337] Diseases such as cholera, malaria, Lyme disease, Chagas' disease, Onchocerciasis, and yellow fever can be tracked by monitoring the ecology of these disease organisms, their vectors, their reservoirs, and hosts. Images from the program's more than 200 sensors are processed and analyzed through collaboration with the National Institute of

Allergy and Infectious Disease, part of the National Institutes of Health (NIH), and the Centers for Disease Control and Prevention (CDC).

Telemedicine allows doctors to connect with patients and specialists from around the world. *Image credit: ESA*

Space applications of biotechnology include microgravity research. Biotechnology research is prominent among science payloads aboard the International Space Station, following previous success on the space shuttle and the decommissioned Mir Space Station. Station biotech research focuses on two fundamental areas: cell science and crystal research. Cell science is basic research that studies the effects of microgravity on the behavior of cells. Protein crystal research examines general crystal growth processes and has potential impact on a small terrestrial market for protein structure models and drug delivery vehicles. Cells grown in microgravity tend to behave more like cells in a living body than cultures in traditional laboratory settings. The discovery of this behavior in breast cancer cells aboard the ISS in 1997 led to research to create a rotating bioreactor which keeps cells permanently suspended in a fluid, allowing them to grow in three dimensions instead of on a flat petri dish.[338]

Space Applications

- Internet to health clinics
- Telemedicine (data)
- Telemedicine (interactive)
- Disease tracking
- Orbital bioresearch
- Gene transfer among plants

The Future

The OECD notes that telemedicine is one of the most promising applications of space telecommunication services. Trends of increased mobility and transport costs, along with military interest, are cited as demand drivers for space-enabled telemedicine.[339] Global payments for telemedicine products and services reached $6.28 billion in 2003, and some

expect this to near $10 billion by the end of 2006.[340] This growth pattern is likely to continue since telemedicine is proven to be an affordable way to spread access to medical knowledge and services. Significant possibilities exist for extending the availability of specialists into sparsely populated regions of the United States, and even greater possibilities exist for bringing medical expertise into underdeveloped areas of the world. In 2007, India is scheduled to launch a dedicated telecommunications satellite, called Healthsat, that will provide transponders for the tele-health network.[341]

The use of satellite monitoring for infectious diseases supports the recent increase in funding and support for environmental diseases by organizations such as the UN Global Fund, the London School of Hygiene & Tropical Medicine, and the Bill & Melinda Gates Foundation.

Greater biotechnology research and manufacturing is among the far-term prospects (20-30 years) for space enterprise, given more affordable access and orbital platforms. However, there are several current applications of biotechnology to space science and exploration, including research efforts in food production, microbial ecology in closed space habitats, and sensors for monitoring astronauts' health.[342] In the near term, biotechnology is likely to have an increasing role in supporting space missions.

Dr. Jeff Sakamoto, a material scientist in the Power and Sensor Technology section at JPL, holds one of the nerve guidance devices currently being tested at the University of California, San Diego. The technology might one day help people living with spinal cord injuries. *Image credit: NASA/JPL*

5.5 | Homeland Security, Defense, and Intelligence

The Homeland Security, Defense, and Intelligence section encompasses activities and industries directly related to government military activities (both on and off the battlefield) as well as civil government activities for protecting citizens and national interests.

Battlefield communications are essential for an efficient and effective mission. High-bandwidth wireless communications systems generally require line-of-sight between the transmitter and receiver of information. This limits the range of these systems, requiring placement of repeater towers along logistics routes and between the battlefield and area command. Alternatively, low-bandwidth frequencies such as High Frequency (HF) can be used to extend the range of terrestrial radio communications by bouncing signals off the ionosphere, but these signals are usually of poor quality and very susceptible to noise and interference. Satellites provide an attractive alternative solution that does not require line-of-sight between the transmitter and receiver for high-bandwidth communications. Until recently, satellite broadband communications systems were not compact and rugged enough to be used in combat areas. However, the U.S. military has developed satellite transmitters and receivers that can fit on Humvees to be deployed into the battlefield and provide voice, video, and data communications. Unmanned Aerial Vehicles (UAVs), such as the U.S. Predator Drone, have proven invaluable as reconnaissance and covert strike tools and are under great demand by military commanders. Predator satellite communications systems consist of a satellite dish and associated support equipment. The satellite system allows Predator to communicate beyond line-of-sight with its ground control station. In addition, satellite communications can be a vital link between command centers and first responders, supporting contingency operations resulting from terrorists' attacks.

Soldiers with "A" Company, 2nd Batallion, 504th Parachute Infantry Regiment, maintain tactical satellite telephone communication during a search for Taliban fighters, in support of *Operation Enduring Freedom. Image credit: DoD/SSG Leopold Medina, Jr.*

Defense and intelligence agencies also rely on remote sensing satellites to provide images to increase awareness of a battlefield, target, or national border. The military uses both UAVs and satellites as platforms for these sensors, and these systems may include aerial cameras, Earth-orbiting multi-spectral sensors, and imaging radar systems. The military relies on remote sensing and particularly high-resolution images for diverse activities such as battle damage assessment, natural disaster assessment, target monitoring, and situational awareness including tracking both friendly (blue) and enemy (red) forces. Blue and red force tracking involves aggregating and streamlining raw satellite, UAV, and direct intelligence data onto a commander's display terminal, enabling more effective situational awareness on the battlefield.

The RQ-9 Predator B is a UAV developed by General Atomics Aeronautical Systems for use by the U.S. Air Force and the U.S. Navy, designed for long endurance high altitude surveillance. The Predator can also be modified to carry an armament of missiles or bombs. *Image credit: General Atomics*

Remote sensing weather satellites also are an important element of military activities. Weather satellites provide a continuous view of weather patterns over the battlefield through a suite of sophisticated instruments. These include high-resolution spatial and temporal images and full-time operational soundings that measure vertical temperature and moisture profiles of the atmosphere. With such visibility, these satellites can monitor storm development and track movements, as well as identify triggers for severe weather, such as tornadoes, flash floods, hail storms, and hurricanes. The Defense Meteorological Satellite Program (DMSP) provides up-to-date weather information for the armed services with five sun-synchronous meteorological satellites.[343] DMSP 5D-3 F16, which was launched in 2003, is capable of 60 days of autonomous operation, between 1.3 and 3.0 Mbit/s data stream of stored data, and 88.75 kbit/s downlink of real-time data to the field. In addition, this satellite is capable of UHF transmissions that can be received by a radio antenna.[344] Consequently, commanders in the field can receive accurate real-time data, necessary for planning and coordinating complex operations. In 1994, NOAA began to merge DMSP and civilian weather satellite constellations to increase efficiency and improve forecasting accuracy.[345]

Remote sensing allows commanders to monitor battles and implement strategy in real time. It also allows for post-battle evaluation as seen here. *Image credit: U.S. DoD*

The U.S. Military's Global Positioning System (GPS) was completed in 1993. Initially, the system was developed to create a single navigation system used by all forces and for precision weapon delivery. The system is still used for munitions guidance and has become an integral part of logistics tracking and navigation and control of UAVs.

Precision-guided munitions are employed to an increasing degree. GPS satellites enable pinpoint locating of enemy targets; communication satellites relay targeting data to the appropriate command centers, then decide which targets to assign to which aircraft; the pilots then load this targeting information into their satellite-guided Joint Direct Attack Munitions (JDAMs). JDAMs are tailkits with satellite-guidance systems and navigational fins, that may be fitted onto general purpose unguided bombs providing the intelligence and capability to hit within a few yards of the target. If the targets change while airborne, new targeting information may be sent via satellite links directly to the pilots and downloaded into their bombs. In 1944, it took 835 B-29 flights to achieve four percent damage of a Japanese aircraft-engine plant. Today, a single bomber with satellite-guided bombs can shut down a plant.

The first modernized GPS satellite, featuring additional navigation signals to benefit military and civilian users, was launched in 2005. The improvements will provide greater accuracy, added resistance to interference, and enhanced performance for all users, according to the U.S. Air Force. The advancements for the military will provide warfighters with a more robust, jam-resistant signal and enable better targeting of GPS-guided weapons in hostile environments.

2005 HIGHLIGHTS

- The USAF successfully launched the XSS-11 to test autonomous rendezvous and docking technology on November 4, 2005.
- The GPS 2R-M1 will provide greater accuracy, added resistance to interference, and enhanced performance for all GPS users.

Nations also use satellite systems to aid in border protection. GPS signals are used to monitor border patrols through the use of embedded GPS receivers and home-base monitoring/communication devices that display patrol location on 3D maps of the relevant territory. Blue Force Tracking system, developed by the U.S. military to improve battlefield situational awareness, allows both for tracking patrols and optimizing positioning and communications among patrols. Satellite remote sensing images, with imagery from UAVs, are used to identify movement and recent passage across national borders. Commercial systems, such as GeoEye,[346] provide disaster risk assessment and emergency preparedness to homeland defense agencies within North America. Satellite imagery also enhances the precision and management of border control planning and as evident in its use during the $1.5 billion fence/wall construction between Israel and Palestine.

An F-15 Eagle is seen dropping MK-84 JDAMs. Each bomb can be individually targeted, which allows heavy bombers like the B-2 Spirit to drop 80 bombs at once and hit 80 pre-specified targets. *Image credit: Edwards Air Force Base/ Bobbi Garcia*

In addition to aiding border patrols, Blue Force Tracking provides the ability to monitor key personnel during potentially dangerous situations, as in the 2005 presidential inauguration.[347] Improved situational awareness and open communication allows law enforcement to react faster and more decisively in the event of an emergency.

Space also is used for suborbital force application via the use of Intercontinental Ballistic Missiles.

Space Applications

- Digital battlefield terminals
- Sensor monitoring
- Signal tracking
- Vehicle command and control
- Signal jamming
- Military communications
- Battle damage assessment
- Battlespace awareness
- Launch event monitoring
- Weather forecasting
- Targeting/ atmosphere monitoring
- On-orbit and Earth Telemetry, Tracking, & Command systems
- Real-time sensor to handheld
- Arms control treaty verification
- Space catalog
- Border protection
- UAV navigation and control
- Logistics tracking
- Munitions guidance
- On-orbit sparing
- On-orbit servicing
- Suborbital force application

The Future

Space systems are an ideal technology for many military applications and will continue to play key roles in homeland security, defense, and intelligence arenas. For communications, satellites provide an "over-the-horizon" capability that is not matched by terrestrial communication systems. As end-user equipment receivers become smaller and more portable and the data to support decision makers and battlefield commanders becomes greater, increased use of satellites in military communications systems is likely. Use of all types of remote sensing satellites will continue to expand as the need for situational awareness grows at an ever increasing pace. Additionally, the U.S. military is researching and developing an on-orbit servicing platform. This platform would be able to maneuver through space to a satellite either to repair or replace damaged parts, or possibly, to refuel satellites reaching the end of propellant stores. This application would significantly impact the civil and commercial sectors as well; whole systems are currently restricted to software servicing, retirement to a graveyard orbit, or a dangerous and expensive crewed mission—as in the case of the Hubble Space Telescope. While the military is likely to be a major driver in developing this technology, the ability to service satellites will increase the quality of commercial services, allow providers to keep their electronics up-to-date, and reduce costs due to weight and backup satellites.[348]

Results of demonstrations for servicing satellites on-orbit will be analyzed in the near future. These results will help determine the next steps in research for improving the availability of military assets on orbit.

The Department of Homeland Security (DHS) also is working on a satellite wireless communications system which will allow mobile e-mail and voice communications to operate if the cellular infrastructure is compromised.[349] An alternate emergency communication infrastructure, the Mobile Enhanced Situational Awareness (MESA) network, is being developed by XM Satellite Radio and Raytheon Company, which could be broadcast to emergency personnel during a crisis. Raytheon Company and WorldSpace have already used this network to keep relief workers in Asia connected.[350]

A satellite transport terminal installed by members of Communications-Electronics Life Cycle Management Command, Department of Homeland Security, sits next to a courthouse in Louisiana. *Image credit: DoD/MSGT Brian Brownsberger, USAF*

5.6 | Lifestyle Media

The distribution of creative content and information is enhanced, and sometimes uniquely possible, through the use of communications satellites. In addition, the convergence of digital media is creating novel user applications with satellite and space-terrestrial hybrid networks.

Satellite TV is capable of being viewed on cell phone-sized receivers.

Satellites provide Internet backbone that augments terrestrial networks, filling where Internet traffic has changed international communication patterns and overburdened available terrestrial or undersea cables. Satellites are an important resource for establishing Internet connections in countries with limited landline telephony backbone. Some organizations, such as the Church of Jesus Christ of Latter-day Saints, have an extensive digital satellite network that brings together distant members—from remote islands in the Pacific to villages in Africa.

In addition to providing backbone, satellite services can deliver "last mile" Internet service. VSATs provide an important link to the satellite Internet backbone for remote organizations or communities. VSATs are relatively inexpensive—about $2,000 to install a 1.2 – 1.8 meter ground station—which has led to the use of more than one million units in 120 different countries.[351] Often, developing nations use VSATs in conjunction with wireless and fiber networks to provide Internet, data, and voice services in rural areas. Currently, India and several African countries are developing a network on this model.[352] Satellite VSATs also have a modular property which enables a wide range of different networks—from the 10,000 nodes

Cultural products including movies, television, music, and Internet content are some of the most visible sectors of the economy. The Lifestyle Media section includes both the production and the distribution of these cultural and information products. This area also includes the facilities and companies that provide these recreational, cultural, or entertainment services to customers. In addition, this sector encompasses the broader segment of telecommunications including telecommunications resellers and carriers.

Icon image credit: Sirius Satellite Radio used by the U.S. Postal Service to small inter-business networks like Allied Domenq Spirits & Wine with two VSAT nodes.[353]

Individuals and small businesses can use satellites to access high-speed Internet services. Service providers like WildBlue and StarBand sell two-way personal satellite dishes connected to the Internet for a monthly fee. While these services do not provide the bandwidth and networking ability of a VSAT, they are considerably cheaper. Satellites also are used to provide Internet connectivity to those places where wires are impossible, such as airplanes in flight or ships at sea.

The "Live via Satellite" icon on the television screen might be lost behind scrolling news bars and channel logos today, but satellites continue to play a significant role in the collection and distribution of television content. Satellites enable news organizations to upload live video and audio feed from all corners of the world. Live content is captured with a television camera, translated into satellite signals and transmitted from a dish-equipped news van to a GEO satellite. The signal is then amplified and sent back to the television station where it is received and broadcast on the news.

Satellite signals also carry television content, directly and indirectly, to viewers. Companies, such as DIRECTV, broadcast television stations to more than 27 million household subscribers, who use small satellite dishes to access the television content directly.[354] Satellite TV has been adopted in Europe, and, as of 2003, there were more than 6.8 million direct-to-home satellite TV subscribers in the UK.[355] At 80 cm, European dishes are about twice the size of the standard 18 in. dish (45 cm) used in America, and larger antennas are necessary for some locations. Asia provides a new market for satellite TV and more than seven million customers have already joined one of the 17 Asian carriers.[356] Satellite broadcasting has very efficient economies of scale because a single satellite can service an entire geographical area, independent of the users in that area. Mobile Broadcasting Corp. (MBC) of Japan and TU Media Corporation in Korea miniaturized the DIRECTV model and started offering satellite television services that can be received by specialized mobile phones.[357] TU Media Corporation began service in May 2005, and gathered 585,000 subscribers in its first year of service.[358] Currently, this service is restricted to Japan and Korea; however, other countries are considering implementing satellite mobile television.

Even traditional cable companies and over-the-air broadcast stations receive most of their content via satellite. For instance, Discovery Communications, Inc., produces content for more than 100 global networks including The Discovery Channel, TLC, and Animal Planet.[359] This content is sent by satellite to media distribution companies around the world that compile it into their own formats and feed it to subscribers. In certain cases, for example, network news feeds this content is broadcast without encryption and can be received on a standard satellite antenna without paying for a premium service.

2005 HIGHLIGHTS

- Spaceway 2, launched on Nov. 16, 2005, will use its Ka-Band payload to expand and enhance DIRECTV's direct-to-home television service and provide broadband services across the United States.
- Hot Bird 7A launched on March 13, 2005, by an Arianne V ECA and will be capable of delivering twice the TV and broadband capability of previous models.
- Telesat Canada's Anik F2 began 2-way Ka-band broadband service in North America.
- Inmarsat raised $669 million in a successful IPO.

In 1997, the FCC auctioned two satellite radio licenses to Sirius and XM for $83.3 and $89.9 million, respectively.[360] Since then, Sirius and XM launched several GEO satellites that broadcast to digital radios with small satellite antennas. As of March 2006, more than 10.5 million subscribers in the United States pay for satellite radio services, generating $800 million in revenue.[361] Satellite radio has been introduced into Asia, Europe, the Middle East, and Africa by WorldSpace, which began broadcasting in 1999. Several digital applications of satellite radio are starting to be bundled with the service, including handheld music recorders that store media from the broadcast service. Satellite radio can provide near real-time news and traffic updates which interface with a car's navigation system and provide re-routing capabilities and minimize commute times.[362]

Space Applications

- Internet backbone
- Internet-to-end user residential
- Internet-to-end user small business
- Paging backbone
- Voice over IP telephone
- Long distance telephone trucking
- Remote telephony
- In-flight Internet
- Digital content to cell phones
- Internet entertainment (hot spots/public/ Internet café)
- Tourism tele-exploration
- Satellite television
- Broadcast and cable television distribution
- Digital movie distribution to theaters
- News gathering
- Satellite radio
- Location-based community networks
- GPS games
- Cell phone network timing
- On-orbit filmmaking

Satellites provide communications connections when ground-based options are not available. Satellite phones allow passengers on cruise ships and high speed trains, explorers in remote areas, and people in rural villages to make phone calls to anywhere in the world. Globalstar and Iridium provide global satellite phone service through a network of LEO satellites that provide voice and data services to 350,000 customers worldwide. [363] Satellite phone customers require a specialized phone that can send and receive data from the satellite and a service plan, often provided through a value-added reseller. The service does have limitations, such as the need for a clear view of the sky. However, more than 86 percent of the Earth's surface is not serviced by terrestrial telephony and, consequently, satellite phones are a vital part of the remote infrastructure.[364]

Even the ground-based wireless devices we use require satellites to operate fully. Mobile phone services use information from navigation satellites to provide accurate timing for their networks, and paging companies use satellites to distribute paging signals for transmission throughout the country. In 1998, the Galaxy 4 satellite onboard control system malfunctioned, instantly silencing 80 percent of American pagers.[365] In response to the 1997 FCC mandate for Enhanced 911, cell phone companies are adding GPS chipsets in cell phones so emergency responders can locate the origin of 911 calls.[366]

The Future

As we move into the future, space and the lifestyle media sector will become more closely linked. In the near future, movie companies may rely on satellites to distribute digital copies of newly released movies to theaters instead of mailing large reels of film around the country. The same satellite radio signal could provide software and data updates to your car while refreshing your music list on your MP3 player. Networks might begin to integrate satellite, wireless, and fiber infrastructure to provide seamless Internet and data services to rural and urban areas alike. As tele-media shifts to high bandwidth applications, such as high definition television (HDTV), satellite demand increases significantly. This change in the nature of satellite services could become the driving factor in future transponder demand.

Imagery from cameras mounted on launch vehicles, the space shuttle, and remote sensing satellites have been incorporated into blockbusters and documentaries. Further down the line, possibilities exist for on-orbit movie filming or planetary missions using in-space equipment, controlled by an audience of virtual space explorers back on Earth, as they voyage to the final frontier.

5.7 | Retail, Finance, and Management

Very small aperture terminal (VSAT) networks are commonly used to connect distributed retail locations to a centralized location. Common uses for VSAT communications include gas stations (currently more than 100,000 in the United States),[367] toll booths, retail locations, and ATMs. Banco de Brasil has nearly 7,600 branches throughout Brazil and other countries in South and Central America, as well as in the United States, Europe, and Asia, serving more than 13 million customers. With the assistance of VSAT manufacturer Hughes, Banco de Brasil has connected 4,600 of these branches to a broadband network.[368] State Bank Group (SBI), a large Indian banking firm, used BASE24 switching software and VSATs to grow from 250 to 5,000 ATMs in five years.[369]

The Retail, Finance, and Management section covers many common business concerns. The retail area is defined as those establishments that sell merchandise in small quantities directly to consumers, either in a store, over the Internet, by mail, through infomercials, or any number of methods. Finance consists of industries that are primarily engaged in financial transactions, including the creation, liquidation, or change in ownership of financial assets. This area also encompasses the insurance industry. The management area comprises the in-house establishment concerned with strategic and organizational planning and decision making of the company or enterprise.

Icon image credit: Intermec Technologies

ATMs use GPS precise timing capabilities to interact with their financial institutions' network. ATMs are connected by VSAT, fiber, and wireless infrastructure to complex interbank networks, such as Cirrus, Maestro, and Plus. These networks are responsible for a large number of transactions, more than 100 million daily transactions for VISA card holders alone,[370] so, the timing and sequence of transactions is critical. GPS receivers synchronize ATM transactions, allowing a precise and universal time stamp on each transaction.

Time stamping transactions are even more essential to brokerage institutions. The National Association of Securities Dealers (NASD) requires all trade transactions to be stamped with a three-second accuracy or better. However, institutions normally have more stringent requirements, on the order of 5-20 milliseconds, to accommodate thousands or millions of daily transactions. An objective and accurate mechanism for recording the time of a transaction preempts disputes over the value of a transaction, a common occurrence. The World Bank and the New York Stock Exchange, for example, both use GPS precise timing mechanisms by Symmetricom Corporation.[371] Even greater accuracy (10 nanoseconds) is possible by using the military signal code and an advanced receiver.[372]

An employee uses a cordless RFID Reader/Programmer to inventory his stock. RFID data can then be put into a satellite-enabled real-time database containing all the stores, allowing for automatic re-ordering. *Image credit: Intermec Technologies*

The management of large corporations requires dedicated networks to support a number of communications applications, from the financial transactions discussed above to video conferencing, local network interconnection, wide area wireless networking, multicasting, virtual private networks, Internet applications, and voice-over-IP. In some cases, especially for companies with many locations, it is economical to use satellite communications to fulfill these roles rather than dedicated terrestrial leased lines. More often, satellite communications supplement terrestrial connections. Wal-Mart, for instance, uses lease lines for inventory tracking and credit card transactions, but still maintains VSAT connections as backups in 1,523 stores.[373]

Inventory management is a crucial element to the profitability of retail stores, and this process has come to incorporate satellite capabilities at critical moments. The most sophisticated retail outlets collaborate closely with their suppliers; for instance, when a Proctor & Gamble item is scanned for purchase at a retail store, a message is sent via satellite uplink to the factory.[374] Proctor & Gamble obtains real-time updated information of when to make and ship more products. The manufacturer can coordinate with a delivery system, such as FedEx, to provide tracking data to the retail outlet and ensure inventory remains relatively constant.[375] This process allows the retail outlet to minimize the capital tied up in inventory. 7-Eleven of Japan takes this practice a step further. Each of its 8,500 stores are connected by a flexible adaptive network using satellite dishes, redundant phone lines, and independent mainframe hubs.[376] In addition to inventory management, this network tracks and analyzes customer preferences on a daily basis to give their products an edge over the competition. 7-Eleven stores also rely on weather satellites for local weather reports that allow the inventory to be adjusted according to environmental conditions.

2005 HIGHLIGHTS

- Wal-Mart announced in January 2005 a requirement that vendors place RFID tags on all shipments.
- Hughes Network System Inc. announced an agreement with SignStorey and two grocery chains to distribute point-of-decision advertising via satellite to 250 store locations.

Retail stores themselves have been increasing the use of "digital signage,"[377] in-store TV or radio content that features programming and advertisements produced exclusively for viewing in the store. These networks can be seen at Albertson's, Target, Kroger, and Wal-Mart. This content is distributed from corporate headquarters to individual stores via satellite connections. Similarly, Starbucks and XM Satellite Radio's alliance created the "Starbucks Hear Music" channel, played in more than 4,000 Starbucks retail locations in the United States and available to all XM subscribers.[378]

The Future

According to OECD's *Space 2030*, satellites have the ability to reduce the digital divide and provide telecommunication infrastructure, opening markets for e-commerce. E-commerce applications are well established and expanding broadband networks via satellites is likely to have a strong effect on the economy and electronic trade in the near future.[379]

Satellite communications and GPS timing have become integral in the retail and finance sector, with their use and importance likely to grow. Precise timing is a critical component in banking and finance, particularly in large, international markets. In the retail trade, satellite networks are finding novel applications, as distributed retail outlets communicate with corporate headquarters with increasing sophistication. Firms continually work to the point where "information will replace inventory."[380] Satellite links will continue to enable this transition.

Space Applications

- Data communications
- E-commerce
- Corporate networks
- Financial transactions including ATM and credit cards
- Retail information
- Video conferencing
- Video surveillance
- In-store radio/video
- Enterprise telephony
- Financial network timing
- On-orbit advertising

5.8 | Science and Academia

Access to space has enabled unique scientific endeavors using space-based platforms and sensors to enhance our understanding of the universe and the Earth. Satellite systems provide infrastructure for science and academia through tele-education and remote communication with scientific outposts.

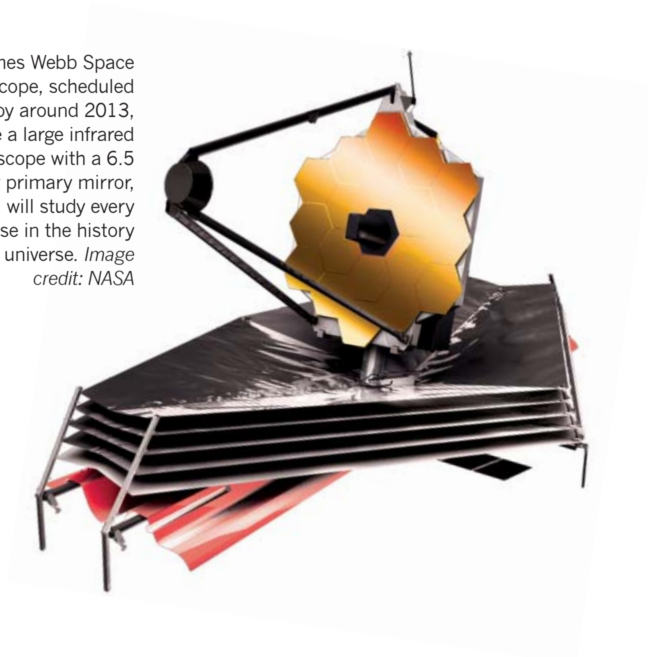
The Science and Academia section encompasses research, development, and educational programs. Science establishments are those primarily engaged in research and experimental development in the physical, engineering, and life sciences. Academia refers to knowledge-based programs of all levels/types and the organizational systems that bind them together.

Icon image credit: MEMS-Nanotechnology Exchange

Tele-education has proven itself valuable for bridging great distances. In Canada and the United States, more than 100 different satellite tele-education systems are now in operation, including regionally owned and operated networks and commercial networks that range from primary schooling to graduate level programming. Virtual universities, such as the U.S. National Technological University (NTU), combine college courses produced by dozens of universities to provide specialized short courses and corporate training.[381] The European Union (EU), as part of a strategic effort, is designing a virtual university that will tie all of Europe's best science and engineering departments together.

An Atlas V lifts off in January 2006, carrying NASA's New Horizons spacecraft, that will journey to Pluto and Charon. *Image credit: NASA*

More than 170 missions carrying scientific instruments, in the form of probes and rovers, have been launched into the solar system to study planets, comets, asteroids, and other phenomena.[382] These instruments return valuable scientific data on the history and nature of the solar system. Recently, NASA launched the New Horizons probe in January 2006 to study Pluto. Internationally, China, Europe, India, Japan, and the United States have plans to develop lunar exploration probes that will launch before the end of the decade.[383] A goal of these precursor missions is to identify the precise location of lunar ice deposits, which, when processed into sustenance and fuel, could enable long-duration, human-tended bases.

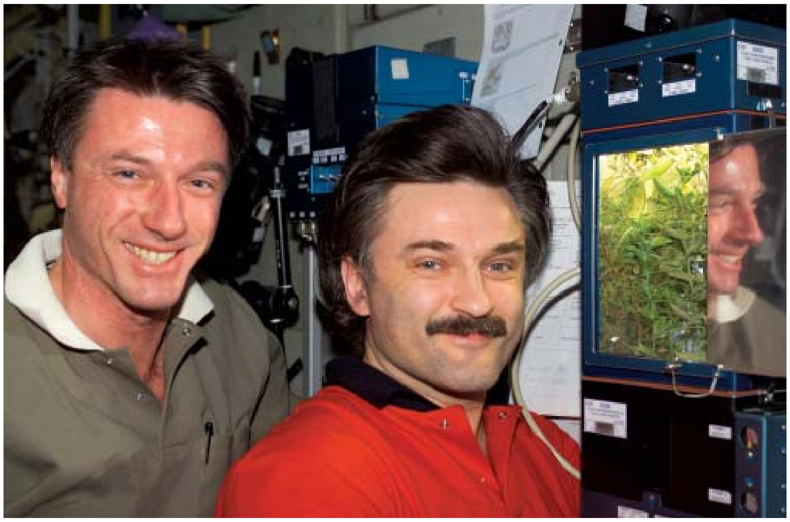


The James Webb Space Telescope, scheduled to deploy around 2013, will be a large infrared telescope with a 6.5 meter primary mirror, and will study every phase in the history of our universe. *Image credit: NASA*

Telescopes placed in space have greater capabilities than those located on the ground. Light received by telescopes in Earth orbit does not travel through the atmosphere (which causes the characteristic "twinkle" in stars). Orbital telescopes are protected from vibrations and weather. The Hubble Space Telescope (HST) has revolutionized scientists' understanding of our own solar system and the origins of the universe. An even larger successor, the James Webb Space Telescope (JWST), is scheduled to deploy around 2013.[384]

In 2005, NOAA requested $360 million for scientific research to provide funding for internal research laboratories and partnerships with academia.[385] In addition to gathering data through Earth observation satellites, NOAA research projects use space systems for communication and navigation such as the joint NOAA/NASA Altair Unmanned Aircraft System.[386] Earthscope, a National Science Foundation (NSF) project to investigate the structure and evolution of the North American continent, gathers data from satellite radar imagery and GPS receivers to measure shifts and displacements in the Earth's crust.[387] Satellite imagery can detect geological events on very large scales, like the Yellowstone caldera, which was discovered through field work and satellite imagery in the 1970s.[388] More recently, satellite radar interferometry has been used to detect bulging over geological hot spots, a potential prediction of a future eruption.[389]

Space-based platforms provide unique opportunities for microgravity research and international scientific cooperation. The ISS, the space shuttles, Skylab, Russia's Mir Space Station and *Soyuz*, and the Chinese *Shenzhou* have enabled microgravity research in fields such as protein crystals, tissue and bacteria growth, convection currents and their effects on flames, fluids and metals, Earth observation, and humans living in space. Earth resources have capabilities that may never be understood or used without thorough experimentation in microgravity. Studying microgravity's effect on flames onboard the space shuttle in the 1980s and early 1990s led Lawrence Berkeley National Laboratory researchers to patent a ring-flame stabilizer, which, when retrofitted to residential heating furnaces, reduced atmospheric polluting nitrogen oxide emissions by a factor of ten.[390] Enhanced control over crystal growth in space resulted in significantly larger and higher quality zeolites on-board the space shuttle than possible on Earth. Zeolites, a class of crystalline materials used in petroleum refinement, make possible $90 billion in annual exports by the United States and, according to the National Research Council, even a tiny improvement in their composition and size would save hundreds of millions of dollars.[391]



C. Michael Foale (left) and Alexander Kaleri pose beside pea plants growing in the ISS's Lada greenhouse. *Image credit: NASA*

Low cost launchers, like SpaceX's Falcon family, could have a significant impact on scientific missions, which typically rely on scarce public funds. Payloads from universities and research labs often "piggy back" on the launch of commercial satellites. Currently, the Falcon is scheduled to launch research and technology demonstration satellites for the Naval Research Laboratory and the Malaysia government.[392] The failed March 24, 2006, launch of Falcon 1 was carrying a FalconSat 2 research satellite for the Air Force Academy.[393]

2005 HIGHLIGHTS

- The Mars Reconnaissance Orbiter (MRO) was successfully launched on August 12, 2005, on a mission to study Mars' atmosphere and seek out new potential landing sites for the explorers that follow.
- The Venus Express, Europe's first probe dedicated to studying Venus, launched on November 9, 2005, and carried a suite of tools designed to peer close at the planet's thick atmosphere.
- Huygens successfully descended through Titan's atmosphere, providing atmospheric and surface data.
- NASA's Deep Impact successfully slammed into the comet Tempel 1.
- Hubble celebrated 15 years in space.

Civil space programs have major science directorates that guide programmatic decisions. Divisions for Solar System Exploration, Structure & Evolution of the Universe, and Astronomical Search for Origins are all found in NASA's $4 billion 2005 space science budget.[394] ESA allocated much of its $4 billion budget to astronomy and remote sensing; JAXA's 2004 budget of 272.4 billion yen ($2.5 billion)[395] was concentrated on solar and weather applications. India's Indian Space Research organization (ISRO)'s 30 billion INR ($700 million)[396] funds a significant education directorate. Roscosmos allocated 18.3 billion rubles ($663 million) to science in 2005,[397] focused on microgravity's effect on the human condition.

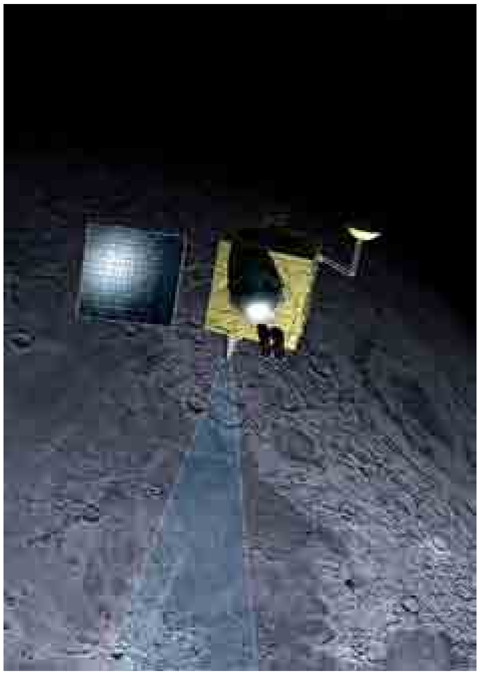
Space Applications

- Tele-education
- Corporate training
- Solar astronomy
- Gamma-ray burst astronomy
- Meteorite observation/tracking
- Orbital debris monitoring
- Upper atmosphere tracking
- Space test bed
- Station/shuttle platforms
- Hazardous waste disposal

The Future

World-class education services to rural and remote locations will continue to proliferate and stimulate economic development in those locations. The OECD's *Space 2030* recommends governments use satellites to provide services such as distance learning to rural and remote areas. India's EDUSAT satellite, launched in 2005 with the goal of developing rural states like West Bengal by 2020, is a prime example of governments using distance learning in remote and undeveloped areas.[398] Major multinational corporations are likely to drive distance learning to improve employees' skills and reduce training costs.

Several civil space agencies have plans to study our solar system with robotic probes to the Moon, Mars, and other neighborly bodies. In 2007-08, ISRO intends to launch its first lunar mission, CHANDRAYAAN-1, a high resolution lunar mapping satellite that will provide both topological and compositional images of the Moon. In addition to the Indian payload, CHANDRAYAAN will carry American and European instruments.[399] In November 2005, ESA launched Venus Express, which entered orbit in May 2006. Venus Express carries a magnometer, radio sounder, and an infrared/thermal spectrometer for studying the Venusian atmosphere and surface in great detail.[400] NASA's Mars Science Laboratory (MSL) builds on the success of *Spirit* and *Opportunity* and, if successful, this rover will carry the most advanced scientific payload ever used on Mars.[401] MSL will be able to collect and crush rock for analysis, vaporize small surfaces in order to determine chemical composition, and detect and identify organic compounds that might remain from microbial life on Mars.[402] Looking ahead a decade, ESA recently released its *Cosmic Vision: Space Science for Europe 2015-2025*, describing the future direction of European space science, including potential missions like a Europa lander, Mars sample return, and a deep space gravity probe.[403]



CHANDRAYAAN-1 is an Indian Space Research Organization (ISRO) mission designed to orbit the Moon over a two-year period. Packed with an international suite of science instruments designed for, among other things, high resolution imaging and the search for water ice, CHANDRAYAAN-1 is on schedule for a late 2007-2008 launch. *Image credit: Dan Roam*

5.9 | Transportation, Warehousing, and Manufacturing

Satellite data communications and GPS play a crucial role in logistics. GPS and fleet tracking enable timely and dependable deliveries to reduce the amount of capital manufacturers have tied up in inventory. While this "lean" thinking is not new, the technologies that support these business methods are evolving and continue to leverage space assets. In all, these efficiencies have had an enormous impact on the economy, reducing logistics costs as a percent of GDP, from 14.5 percent in 1982 to slightly more than eight percent in 2006.[404]

The Transportation, Warehousing, and Manufacturing section includes those segments of the economy involved in the transport and housing/storage of passengers, supplies, and cargo. This area also includes enterprises engaged with creating new products through mechanical, physical, or chemical transformation of materials, substances, or components.

GPS technology makes it easy to track whole fleets of trucks in real time.

One of the most visible uses of GPS tracking is in fleet management systems used on trucks. Trucking companies use GPS receivers, such as the Comtech Mobile Datacom transceivers (a small white box antenna often seen atop trucks and military vehicles), to track their fleets, estimate delivery times, locate stolen vehicles, and enforce regulations on hours.[405] For regular suppliers and delivery services like FedEx, fleet tracking is used to reduce costs, fuel expended, and run times. Fleet management systems services like those offered by GPS Fleet Solutions integrate truck mounted GPS receivers with the General Packet Radio Service (GPRS), an extension of the mobile cellular network, and a Web interface to provide real-time updates to dispatching centers.[406] Other areas that can use this data are landscaping, construction, taxis, police cars, tow trucks, rental vehicles, plumbing, emergency responders, and limousine services. Today, more than 1.3 million fleet vehicles are equipped with GPS location capabilities. These systems cost approximately $500-700 per vehicle and can provide a 10 percent reduction in fuel while reducing transit times and increasing productivity.[407]

In-dash GPS units help drivers locate the best routes to their destinations by identifying shorter trips and closer locations, and by taking into account traffic conditions.

Trains can be tracked with GPS to improve scheduling, efficiency, and safety. With further advances in technology, trains and other forms of transportation could become mostly automated.

Additionally, personal navigation systems are a quickly growing application of GPS for the consumer market. In-vehicle navigation systems can be purchased as an integral component of the car's systems or an autonomous dashboard navigation unit. These receivers use GPS data to pinpoint the location of the vehicle and cross reference that data with an internal database of maps and information. In 2004, GPS systems came standard

EXHIBIT 5b. Product Launches of Leading Private Manned Spaceships

NAME	STATUS	FINANCE	SEATS	LAUNCH METHOD	PROPELLANT
SpaceShipOne	Completed	Paul Allen	3	Air	Hybrid
SpaceShipTwo	In development	Virgin Galactic	8	Air	Hybrid
Rocketplane XP	In development	Private/state	4	Ground	Liquid
Xerus	In development	Private investors	2	Ground	Liquid
Explorer	Design	Ansari family	6	Air	*
New Shepard	In development	Jeff Bezos	*	Ground (VTOL)†	Liquid

Source: The Economist
*Not Known
†Vertical take-off and landing

on more than 100 car models from among 25 manufacturers.[408] According to ABI Research, 11 million original equipment manufacturers (OEM) and aftermarket in-vehicle navigation systems were sold in 2004.[409] In-vehicle navigation systems account for half of the $22 billion commercial GPS market.[410] According to Research and Consultancy Outsourcing Services (RNCOS) report, *Worldwide Global Positioning Systems Market Forecast*, the worldwide GPS equipment and devices market will reach a value of more than $30 billion by 2008.[411]

Software advances in GPS tracking and navigation systems allow vehicles to make automatic adjustments or supply the driver with supplemental information about off-road conditions and location. For passenger vehicles, navigation units can be linked to satellite radio to provide local traffic updates for certain municipalities, allowing the navigation systems to responsively reroute to avoid delays. In the trucking industry, logging trucks in Alaska and British Columbia use satellite feeds to onboard computers to adjust tire pressure and other variables in response to weather and road conditions.[412] In Europe and Japan, Dynamic Route Guidance systems send traffic information via radio waves to automotive navigation computers that update routes and travel times accordingly. This system began operation in 1997.[413]

Satellite systems also are essential for communication between management and remote manufacturing facilities. By outsourcing part of the manufacturing process, companies can reduce labor costs but often must cope with limited terrestrial infrastructure. Satellites provide a cost-effective method of retaining communications infrastructure without running fiber from the nearest population center.[414]

Applications of GPS technology have revolutionized air traffic control, shifting it from radar-based tools to more accurate and cost-effective systems using satellite technologies. In the United States, the airspace tracking system is called the Automatic Dependent Surveillance-Broadcast (ADS-B) system. Location, speed,

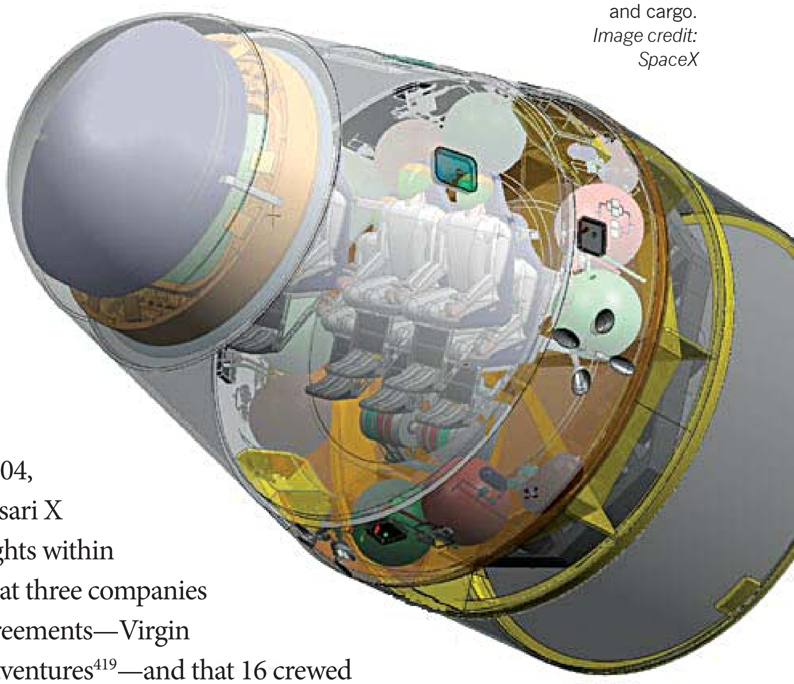
2005 HIGHLIGHTS

- Virgin Galactic announced the formation of The Spaceship Company, a joint venture with Scaled Composites, to build suborbital launch vehicles based on SpaceShipOne.
- A contract between the FAA and Lockheed Martin for the WAAS Geostationary Satellite Communications Control Segment system was finalized.
- ESA sponsored the first successful Trans-African flight using the EGNOS GPS augmentation system.
- New Mexico Space Authority begins plans for the X PRIZE Cup.

Space Applications

- Manufacturing plant inventory control
- Manufacturing plant communications
- Warehouse inventory management
- Fleet communications
- Air traffic control
- Automobile navigation
- Fleet management
- RFID tracking/data relay
- Differential navigation
- Package tracking
- Shipping container tracking
- Warehouse shipment/ management
- On-orbit servicing
- On-orbit refueling
- On-orbit materials manufacturing
- Cargo hauling
- Orbital maneuvering
- Earth-to-orbit transport
- Space burial
- Space tourism
- Travel agencies
- Crystal growth
- Bacteria growth
- Mass production of micro-electric-mechanical systems (MEMS)

and direction information, acquired via GPS signals, is broadcast between aircraft and ground stations. As a result, each aircraft and all ground stations have a precise, continuously-updated image of all airborne vehicles. The precision and accuracy of the GPS data in the system is increased approximately five-fold using the Wide Area Augmentation System (WAAS), which uses geostationary satellites and fixed ground stations at known locations throughout the United States to send correction signals to GPS receivers. Without this system, GPS signals are accurate from 1-10 meters. Using WAAS to correct for ionosphere disturbances, clock drift, and orbital errors, the system achieves an accuracy within three meters 95 percent of the time, enabling more precise applications. This system was activated in 2003.[415] In 2006, the WAAS system coverage will be expanded from 95 percent of the United States to 99 percent.[416] The European equivalent to WAAS is the European Geostationary Navigation Overlay Service (EGNOS). It is being tested and should be ready for basic operations in 2006 and Safety-of-Life Services in 2007.[417]



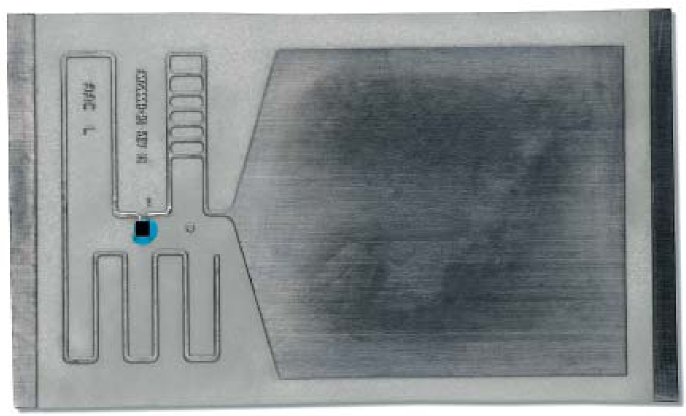
SpaceX's Dragon was one of two COTS finalists selected to develop launch services for the ISS. Dragon will be launched on SpaceX's Falcon 9 rocket, capable of carrying seven passengers or a mix of passengers and cargo. *Image credit: SpaceX*

The market for human transportation into space is beginning to develop in the private sector. Three tourists, Dennis Tito, Mark Shuttleworth, and Greg Olsen have flown aboard Russian spacecraft at a price of approximately $20 million each. The deal was brokered by Space Adventures of Alexandria, Va. A relatively larger market for suborbital tourism is developing as well. More than 150 people have made deposits to Virgin Galactic for suborbital flight.[418] In 2004, Scaled Composites won the $10 million Ansari X PRIZE by demonstrating two suborbital flights within one week. Since that time, the FAA notes that three companies have existing Suborbital Space Tourism Agreements—Virgin Galactic, Rocketplane Kistler, and Space Adventures[419]—and that 16 crewed suborbital vehicles are in various stages of development.[420] The FAA reports that "the birth of this market is expected to begin around 2007."[421] Highlights of a suborbital flight include several minutes of weightlessness, views of the Earth below, a clear glimpse of the stars, and astronaut wings.[422]

The Future

Radio Frequency Identification (RFID) tags, in combination with GPS tracking, are slowly beginning to be used more in logistics. Because RFID tags can be read at small distances, their use would greatly simplify and automate much of the tracking work. According to *The Economist*, "Combining RFID technology with GPS tracking would mean that nothing need ever get lost in the supply chain again." However, the technology is "promising, but still needs to become cheaper and more reliable." [423]

A longer-term (20-30 years) market for manufacturing in space has attracted some interest. For the most part, attention has focused on the innovative materials that can be produced on orbit. As demonstrated on the space shuttle and ISS, microgravity environment in space allows for the homogenous mixing of metals, the growth of pure crystals, and contamination-free processing in general. Though orbiting, manufacturing facilities are currently beyond technological and economic capabilities; the potential economic payoff is driving investment in research and technological development today.[424]



By using RFID readers along shipping routes, it is possible to track individual items as they travel to a destination. *Image credit: Intermec Technologies*

NASA's Commercial Orbital Transportation Services (COTS) is designed to encourage private investment in space transportation. Currently, no privately developed rocket is capable of meeting NASA's needs, but the agency is pursuing agreements for capability demonstrations and hopes to find a contractor for ISS resupply by 2010.[425] These vehicles could be used for additional markets, including space tourism, on-orbit servicing, on-orbit refueling, space burial, and satellite launching.

As GPS systems and mapping databases progress, the versatility of navigation systems increases. By incorporating data about individual locations, these systems can become search tools for finding local restaurants or even a caffeine fix (Caffeine Finder, an application for the hand-held BlackBerry, already allows users to search for the coffee shops nearest to their location).[426] Soon, navigation systems will not only be able to tell you how to get from point A to point B but also where the cheapest gas on your route is and how far out of your way you will have to go for a great steak.

EXHIBIT 5c.
Overview of Space Activity 2005

SPACE ACTIVITIES

HOW SPACE PRODUCTS AND SERVICES ARE USED

		Accommodations	Energy & Earth Resources	Governance & The Public Good	Healthcare & Biotechnology	Homeland Security, Defense & Intelligence	Lifestyle Media	Retail, Finance & Management	Science & Academia	Transportation, Warehousing & Manufacturing	Revenues to Industry	Government Budgets
SATELLITE PRODUCTS AND SERVICES *Communications, Remote Sensing, Positioning*	Converged Media	• Travel Reservation Services • Television content distribution to hotels • Hospitality communications	• Environmental risk assessment	• E-voting • Disaster management • Post-disaster communication • Emergency response • Law enforcement	• Internet to health clinics • Telemedicine (data) • Telemedicine (interactive)	• Digital battlefield terminals • Sensor monitoring • Signal tracking • Vehicle command and control • Signal jamming • Military communications • On-orbit and Earth telemetry, tracking, and control systems	• Internet backbone • Internet-to-end user residential • Internet-to-end user small business • Paging backbone • Voice over IP telephone • Long distance telephone trunking • Remote telephony • In-flight Internet • Digital content to cell phones • Internet entertainment (hot spots/public/ Internet café) • Tourism tele-exploration • Satellite television • Broadcast and cable television distribution • Digital movie distribution to theaters • News gathering • Satellite radio	• Data communications • E-commerce • Corporate networks • Financial transactions including ATM and credit cards • Retail information • Video conferencing • Video surveillance • In-store radio/video • Enterprise telephony	• Tele-education • Corporate training	• Manufacturing plant inventory control • Manufacturing plant communications • Warehouse inventory management • Fleet communications		
	Geoinformatics	• Hotel guest GPS services	• Monitoring (agricultural, well and pipelines) • Resource exploration • Mineral exploration • Oil finding/assessing • Weather tracking • Emergency mapping • Treaty verification • Ecological monitoring • Ozone monitoring • Land use monitoring • Pollution monitoring • GPS controlled tractors • Wild animal tracking	• Population forecasting • Search and rescue • Natural disaster tracking/monitoring • Civil planning (pipelines)	• Disease tracking	• Battle damage assessment • Battlespace awareness • Launch event monitoring • Weather forecasting • Targeting/ atmosphere monitoring • Real-time sensor to hand held • Arms control treaty verification • Space catalog • Border protection • UAV navigation and control • Logistics tracking • Munitions guidance	• Location-based community networks • GPS games • Cell phone network timing	• Financial network timing	• Solar astronomy • Gamma-ray burst astronomy • Meteorite observation/tracking • Orbital debris monitoring • Upper atmosphere tracking	• Fleet management • Radio Frequency ID tracking/data relay • Travel agencies • Differential navigation • Package tracking • Shipping container tracking • Warehouse shipment management • Air traffic control • Automobile navigation	$80.21 B	
IN-SPACE ACTIVITIES *Platforms, Transportation*		• Space hotels	• Orbital debris remediation		• Orbital bioresearch • Gene transfer among plants • Crystal growth • Bacteria growth	• On-orbit sparing • On-orbit servicing • Suborbital force application	• On-orbit filmmaking	• On-orbit advertising	• Space test bed • Station/shuttle platforms • Hazardous waste disposal	• On-orbit servicing • On-orbit refueling • On-orbit materials manufacturing • Mass production of micro-electrical-mechanical systems • Cargo hauling • Orbital maneuvering • Earth-to-orbit transport • Space burial • Space tourism	$.03 B	U.S. $57.24 B International $12.09 B
										Space Products and Services Revenues	$80.24 B	
										Space Infrastructure and Support Industry Revenues	$30.08 B	
										Totals	$110.32 B	$69.33 B

Budgets & Revenues — Grand Total $179.65 B

Totals: $179.65 B

Revenue numbers referenced from Exhibit 4t on page 77.

SPACE FOUNDATION THE TAURI GROUP

IMPACTS

6.0

6.0

Impacts | 6.0

The impacts of space activities are frequently characterized through documentation of specific instances of technology transfer and through analyses of resulting economic activities and impacts. This section of *The Space Report* summarizes transfer of space technology documented by space agencies in the United States and Europe in 2005. It also identifies a dozen recent space-related economic impact assessments of varying degrees of complexity and rigor, and reports on their findings. While this type of information is useful, it does not capture the full range of societal impacts of space activities. Two major research and analysis efforts seek to better understand how space activities have affected the course of history and how they will help shape the future. Together, these projects take a sweeping, rigorous look at past impacts and future applications of space activities, products, and services. The two projects, one recently completed and one that is approaching a major milestone, are described in section 6.3, *Broader Societal Impacts of Space Activities*. Exhibit 6a details the structure of this section.

EXHIBIT 6a. Topics Covered in Impacts

6.0 Impacts
6.1 2005 Technology Transfer
6.1.1 NASA Spinoffs
6.1.2 Space Technology Hall of Fame®
6.1.3 ESA Technology Transfer
6.2 Recent Estimates of Economic Impact
6.2.1 Kennedy Space Center
6.2.2 Goddard Space Flight Center
6.2.3 Johnson Space Center
6.2.4 Stennis Space Center
6.2.5 NASA Field Centers in California
6.2.6 Patrick Air Force Base
6.2.7 Vandenberg Air Force Base
6.2.8 Offutt Air Force Base
6.2.9 State of Colorado
6.2.10 Feasibility of a Florida Commercial Spaceport
6.2.11 New Mexico Commercial Spaceport Economic Impact Studies
6.2.12 The Economic Impact of Commercial Space Transportation on the U.S. Economy: 2004
6.3 Broader Societal Impacts of Space Activities
6.3.1 Societal Impact of Spaceflight (NASA and National Air and Space Museum)
6.3.2 Space 2030 (OECD)

6.1 2005 Technology Transfer

Technology developed in association with space activities is used in many industries and non-space applications. Technology is transferred through intentional efforts by governments to identify new applications, as well as through organic adaptation of technologies, via connections among researchers, labs, and companies.

One of the 2006 inductees to the Space Foundation's Space Technology Hall of Fame,® Novariant AutoFarm's systems link farm vehicles with GPS tracking, enabling accurate hands-free navigation of fields. This increases efficiency and allows crews to work longer—even in the dark. *Image credit: AutoFarm*

Space technology enabled the creation of the ubiquitous, rechargeable, powered toothbrush. *Image credit: Phillips Electronics*

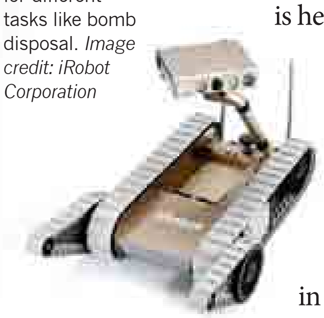
6.1.1 NASA Spinoffs

It is part of NASA's charter to "research, develop, verify, and transfer advanced aeronautics, space, and related technologies."[427] A compelling example is cordless power tools and appliances, originally developed for *Apollo* astronauts. Black & Decker was chosen to develop a drill for gathering samples from the Moon's surface, part of the *Apollo* program. Through the course of development, Black & Decker created a unique, battery-powered device supported by computer software—technology it later refined for consumer and professional spinoff products. This industry continues to expand with worldwide sales of these cordless, rechargeable products from Black & Decker alone generating approximately $400 million annually[428] at the turn of the millennium. Spinoffs continue to create new opportunities. Just recently, scientists from the George Washington University and Cornell University announced that, with assistance from NASA, they have successfully modified NASA's imaging technology for increasing the speed of their diabetes research.[429]

NASA maintains a database of spinoff applications from space technologies, which can be found at http://www.sti.nasa.gov/tto. NASA's annual publication, *Spinoff,* describes some of the non-space uses to which space technologies have been applied. NASA also maintains a bibliography of information on spinoffs and technology transfer, described as resources "on how NASA has made the world a better place." See http://www.hq.nasa.gov/office/hqlibrary/pathfinders/spinoff.htm.

In 2005, NASA highlights technologies in multiple fields. Exhibit 6b lists the 2005 spinoffs in NASA's database. Just a few examples are described here.

Biolog, Inc., is helping NASA study the impact of decreased gravity and space-borne bacteria on plants being grown for food in space. With help from NASA, this company also is creating new cell and bacteria analysis tools to help discover and develop new drugs on Earth, and their technology is helping scientists detect changes in levels of proteins or genes that direct cellular functions on large scales in microbial and mammalian cells. The technology is being used in private and federal laboratories, like the Food and Drug Administration (FDA) and the Department of Agriculture.



Adapted from JPL technology used in creating the Mars Rovers, the iRobot PackBot Explorer Tactical Mobile Robot allows soldiers to stay at safe stand-off distances while the robot relays real-time video, audio, and sensor readings. Other models are available for different tasks like bomb disposal. *Image credit: iRobot Corporation*

Ford Motors put hydrogen-powered technology to work in a shuttle bus engine that made its debut at the 2005 North American International Auto Show. A vehicle powered in such a way emits only water as exhaust. Technology developed by NASA to detect hydrogen leaking also is being used by auto manufacturers in vehicles that use hydrogen power for monitoring safety.

EXHIBIT 6b. NASA 2005 Spinoffs
Advanced Joining Technology
Anthrax Smoke Detector
AWARE Intelligent Software
Big Results From a Smaller Gearbox
Celestial Software
Cooking Dinner at Home–From the Office
Crystal-Clear Communication
Discovering New Drugs on Cellular Level
Dolphin
Fault-Detection Tool
Forty-Year-Old Foam Springs Back
Global Anglers Fish Finding Service
Going End to End to Deliver High-Speed Data
Hutch Hugger
Hydrogen Sensors Boost Hybrids
Inertial Motion Tracking
Intelligent Robot Braves Battlefront
Lighting the Way for Quicker Healing
Lightning Switch
Low Differential Transducer
LUCIDOC Document Management
Making a Reliable Actuator Faster
Making the Most of Waste Energy
Monitoring Wake Vortices
Nanoscale Materials
NVISION Satellite Tracking
PC Squid
Pesticide-Free Device for Mosquitoes
Popping a Hole in High-Speed Pursuits
PS300 Powdered Lubricant
Pulsed Phase Locked Loop
PureSense
Ready and Able to Inspect Those Cables
Satellite and Ground System Solutions
Secure Networks for First Responders
Software of Seismic Proportions
Solar Panels A-300
Space Garden
Space Suit Spins
STC Catalysts
Structural Analysis Made 'NESSUSary'
Synthetic Vision
Taking the Risk Out of Risk Assessment
The Space Laser Business Model
Valiant 'Zero-Valent' Effort
Washing Away the Worries About Germs

Public safety and homeland security have received intense scrutiny in recent years. After September 11, 2001, it became clear that technology developed with NASA's Jet Propulsion Laboratory (JPL) to detect bacterial spores when preparing and cleaning spacecraft to go to Mars could be applied in the commercial sector for a so-called anthrax "smoke" detector. A portable unit is now sold worldwide in partnership with NASA and JPL and has the potential for use for mass transportation, sports and recreation centers, or hotels.

Applying the same remote command and control concepts that NASA uses to run experiments on the International Space Station (ISS), *ConnectIO* allows its owners to cook dinner from the road via a cell phone, personal digital assistant, or Internet connection. *Image credit: TMIO, LLC*

NanoSolve, a carbon nanotube-composite material, exploits technology NASA uses to reduce spacecraft weight dramatically in creating lighter and stronger bicycle components and hockey sticks, as well as more flexible and responsive baseball bats. Pursing partnerships that have resulted in the materials used in professional and recreational applications, the company that developed NanoSolve, Zyvex Corp., anticipates growth of $400 to $800 million ten years after commercialization.

Another example is a Plantronics headset system that uses Bluetooth technology. Plantronics started designing headsets for airlines and NASA astronauts. The system was recognized at the 2005 International Consumer Electronics Show for innovation in design and technological advances.

PureSense Environmental, Inc., through increased partnership with NASA and the Department of Defense (DoD) since September 11, 2001, has developed a combination of hardware and software applications to assess, manage, and analyze data for water and air quality. It also finds solutions for poor quality and other problems arising from poor ventilation or filtration that cost the United States billions of dollars each year.

Plum Brook Station's test facilities (which perform ground tests for the U.S. Government, the international aerospace community, and the private sector) and NASA's engineering experience were combined to improve a family of tire deflating devices that help law enforcement agents safely, simply, and successfully stop fleeing vehicles in high-speed pursuits. *Image credit: Phoenix International, Ltd.*

Southwest Research Institute (SwRI)'s NESSUS software, originally designed for NASA for the probabilistic structural analysis of components of the shuttle, can have performance models for stress, strain, vibration, displacement, fracture, and so on, and can do a reliability analysis and identify critical variables and failure modes. The latest version of NESSUS was made available to the public in 2005 and is being used in such diverse fields as health and medicine, automotives, biomechanics, and weapon systems. It also was used to solve a critical space shuttle problem in NASA's effort to return to flight and was crowned as one of the 100 most significant technological achievements of 2005.

Work at NASA's Langley Research Center led to a self-bonding solder that enabled high connectivity and the metallic joining of carbon and ceramic materials to various metals. This technology found use in a thermal management package for battery compartments on satellites, among other things. Commercial development by Materials Resources International (MRi) of the commercial technology, called S-Bond, is emerging in electrical packaging or general industrial applications, but market potential is strongest, according to NASA, as a metallic-joining compound, which could be applied in thermal management devices. There is growing market demand, with MRi sales from 1997-2004, greater than $1 million, and emerging markets for its electrical packaging have the potential for sales of more than $10 million in the next three years.

6.1.2 Space Technology Hall of Fame®

The Space Foundation, in cooperation with NASA, maintains the "Space Technology Hall of Fame®." The Space Foundation annually identifies technologies, institutions, and individuals whose innovations have applied technologies originally developed for space to other applications. See http://www.SpaceTechHallofFame.org.

EXHIBIT 6c. Space Foundation Space Technology Hall of Fame® Inductees

Active Pixel Sensor	Liquid-Cooled Garments
Advanced Communications Technology	MedStar Monitoring System
Advanced Lubricants	Miniature Accelerometer
Anti-Corrosion Coatings	Monolithic Microwave Integrated Circuit Technology (MMIC)
Anti-Shock Trousers	Multi-Junction (MJ) Space Solar Cells
Automatic Implantable Cardiovertor Defibrillator	NanoCeram Superfilters
Cochlear Implant	NASA Structural Analysis Computer Software - NASTRAN
Cordless Tools	Novariant RTK AutoFarm AutoSteer
Data Matrix Symbology	Outlast Smart Fabric Technology
DeBakey Blood Pump	Parawings or Hang Gliders
Digital Image Processing - Medical Applications	Physiological Monitoring Instrumentation
Digital Latching Valve	PMR-15 Polymide Resin
Direct Readout Satellite System	Portable Hyperspectral Imaging Systems
DirecTV	Power Factor Controller
Earth Resources Laboratory Applications Software - ELAS	Precision Global Positioning System (GPS) Software System
Excimer Laser Angioplasty System	Programmable Implantable Medication System
Fabric Roof Structures	Quantum Well Infrared Photodetectors (QWIP)
Fire-Resistant Aircraft Seats	Radiant Barrier
Global Positioning System (GPS)	Safety Grooving
Heart Defibrillator Energy Source	Satellite Radio Technology
Heat Pipe Systems	Scratch Resistant Lenses
Humanitarian Demining Device	Sewage Treatment With Water Hyacinths
Improved Firefighter's Breathing System	Stereotactic Breast Biopsy Technology
InnerVue Diagnostic Scope System	Tempur Foam
iROBOT PackBOT Tactical Mobile Robot	Video Image Stabilization and Registration (VISAR)
LADARVision 4000	Virtual Window
Light Emitting Diodes - Medical Applications	VisiScreen (Ocular Screening System)

Technologies inducted in 2005:

- **Hyperspectral Imaging Systems:** Hyperspectral imagery provides hundreds of "spectra," or measurements of energy, making it possible to distinguish between natural and man-made objects. Working with NASA, the Institute for Technology Development (ITD) has radically reduced sensor size and eliminated the need for sensor or target motion to obtain images. These innovations have led to a portable device that has opened a range of new diagnostic applications in the biomedical, forensics, counter terrorism, food safety, and Earth imaging markets.

Hyperspectral imaging offers new ways to observe patients by looking beyond the light that we see and finding differences in the composition of the body. Unseen skin damage and subsurface features are rendered visible, allowing doctors to make more accurate diagnoses.
Image credit: Institute for Technology Development

Narrower than traditional endoscopes at 1.2mm, InnerVue uses space technology to offer quicker, safer, and more accurate views inside the body. *Image credit: Arthrotek, Inc.*

- **InnerVue™ Diagnostic Scope Systems:** The InnerVue™ Diagnostic Scope System uses space image enhancement technology and a disposable micro-invasive endoscope to enable doctors to see clearly inside joints with minimum patient discomfort. With this new technology, patients are able to walk immediately after a knee examination and also receive a quick and accurate medical diagnosis.

- **Outlast Technologies, Inc., Smart Fabric Technology:** Derived from research on materials to protect astronauts against extreme temperature fluctuations in space, Outlast Smart Fabric Technology contains micro-encapsulated phase change materials called Thermocules that can absorb, store, and release heat. This patented technology is used in a range of consumer products, such as active wear, to create a comfort zone next to the body.

Using the heat storage property of its Thermocules, Smart Fabric warms the skin in a cold environment and cools it in the heat, resulting in a constant microclimate. *Image credit: Outlast Europe*

EXHIBIT 6d. Technology Transfer Successes Reported by ESA in 2005

21 Nov 2005	Imaging industrial products
03 Nov 2005	Space tech onboard transatlantic racer
20 Oct 2005	Space concepts improve life in the desert
13 Oct 2005	Bat inspires space tech for airport security
26 Sep 2005	Gourmet space dinner on Greenland icecap
22 Sep 2005	Motorcyclists keep their cool
10 Aug 2005	Fastnet yacht runs faster with space technology
06 Jul 2005	Sun-powered aircraft to support sustainable development
21 Jun 2005	Pescarolo team makes fastest lap at Le Mans
13 Jun 2005	Ready for dinner on Mars?
24 May 2005	€50 000 for good satellite navigation ideas
28 Apr 2005	Space tech comes down to Earth
21 Apr 2005	Space technology on winners' podium
17 Mar 2005	Test-drive ESA technology
21 Feb 2005	Ariane 5 technology turns the lights on
15 Feb 2005	Space 'eye' for textiles
15 Feb 2005	Space 'eye' gives cloth quality colour control
27 Jan 2005	Telemedicine is healthcare's new frontier
12 Jan 2005	Giant robot helps prevent landslides

6.1.3 ESA Technology Transfer

ESA reports on non-space uses of space technologies, noting in Web articles on technology transfer successes. See http://www.esa.int/SPECIALS/Technology_Transfer/index.html and http://www.esa.int/esaCP/Improving.html. ESA's discussion of the benefits of technology transfer is shown in the sidebar. The non-space uses of space technology ESA highlighted in 2005 are listed in Exhibit 6d.

The Solar Impulse single-pilot aircraft will be designed to fly around the world powered only by solar energy. It will be constructed using ultra-light materials and be able to fly during the night on batteries charged during the day. *Image credit: Oxyde de-Sapristi/EPFL–Solar Impulse*

By using high-tech materials originally developed for satellites, the Pescarolo C60 Hybrid Judd racecar shed weight and improved performance, allowing the team to amass several wins and top-five finishes at Europe's premier endurance races in 2005. *Image credit: Speedpics.nl*

6.2 Recent Estimates of Economic Impact

Many attempts have been made to quantify the economic impact of space activities. Often, studies focus on the impact to a state or region of a particular facility. Characterizations of direct economic impacts estimate total expenditures such as salaries, contracts, facility construction, and operations. Characterizations of secondary economic impacts include the additional economic activity of associated industries and increased earning and spending by affected households. Important assumptions in economic impact analyses address the question of whether expenditure "leaks out" of a region, via spending on products and services not produced in the region, and whether the activity truly is new, rather than supplanting an existing activity. Estimates of indirect economic effects sometimes suffer from questionable results and require evaluation of whether the analytic methodology was appropriate and correctly applied. The selected space-related economic impact assessments summarized here should be subject to the same scrutiny. The studies summarized address the economic impact on the U.S. of seven of NASA's ten field centers, two proposed United States spaceports, space-related military facilities in Nebraska, Florida, California, and Colorado, and the commercial space transportation industry.

A virtual keyboard that can be applied to a variety of materials is being developed with technology previously used on accelerometers in the inertial postioning system onboard Ariane launches. Vibration sensors are mounted on the product to detect which area is touched. It is easy to maintain and has no moving parts. *Image credit: Sensitive Object*

6.2.1 Kennedy Space Center

The NASA Kennedy Space Center (KSC)'s Office of the Chief Financial Officer (OCFO) released a report on the economic impact of NASA on Florida's economy for the period October 1, 2004, through September 30, 2005. The report, *Economic Impact of NASA in Florida,*[430] calculates NASA/KSC's direct expenditures in Florida at $1.67 billion. It notes that, in addition, KSC's Visitor Center attracted 865,000 out-of-state tourists who collectively spent $48 million at KSC during FY 2005. The

Kennedy Space Center's vehicle assembly building as seen from an aerial view. Launch pads 39a and 39b, where the shuttles launch from, can be seen in the background *Image credit: NASA*

Benefits of Technology Transfer
(European Space Agency Web site)

Space technologies can enhance the life and well-being of ordinary citizens through, for example, healthcare products, improved waste management and water recovery or landmine detection.

Space technologies can also be used by manufacturers to create, modify or improve new and existing components and products which, in turn, provide industry, commercial users and ultimately the general public with a wider choice of robust and reliable goods.

While some spinoffs and projects do not necessarily and immediately result in tangible social and health benefits, they may still result in safety benefits, albeit to a specialized sector. Some segments of the population gain in perhaps a less obvious way. Space technologies are used by the motor racing, sailing and skiing communities, and sports fans can see their favourite teams and competitors gain an edge through the improvements resulting from space-based technologies. The transfer of space technology to motor racing is not just pandering to the elite, however, because such space technologies and materials are already seeing their way into mass-produced cars. In fact, competition motor racing is believed to be the best way to raise public awareness about alternative "green" energy fuels that are more efficient and less polluting. The space technologies being applied in such activities show the commitment to sustainable development as well as safety and reliability.

Technology transfer has other less obvious benefits. For instance, in the context of European space activities, technology transfer:

- Eases the burden imposed on public resources through research and development by adapting technologies, systems and know-how developed in one sector (space) to another (non-space users and applications)
- Maximises the return on investment in space research conducted by ESA for the benefit of its Member States
- Minimises the duplication of research between the space and non-space sectors
- Provides cross-disciplinary opportunities for researchers to collaborate with other organisations
- Allows the possibility for two-way transfer – both in spin off from space to non-space sectors and spin-in of technologies developed in non-space sectors which might be relevant for space
- Provides economic potential and motivation for both technology donors and technology receivers where the social impact is high and the potential market is large

Another benefit is economic, with revenues accruing to both technology donors as well as technology receivers. Indeed, it is calculated that the revenues of ESA Member States generated by transfers of space technologies exceeds its related expenditure by 15-20 times.

Source: http://www.esa.int/SPECIALS/Technology_Transfer/SEMY2TRMDGE_0.html reported indirect economic impact of NASA expenditures in-Florida funds included $3.7 billion in state-wide output and 35,000 jobs. The report also said that $187 million in federal taxes and $85 million state and local taxes were generated from this economic activity.

6.2.2 Goddard Space Flight Center

The Goddard Space Flight Center is home to the nation's largest organization of combined scientists and engineers dedicated to learning and sharing their knowledge of the Earth, solar system, and universe. The Greenbelt, Md. facility, seen here, is comprised of 50 buildings spread across 1121 acres. *Image credit: NASA*

The NASA Goddard Space Flight Center (GSFC)'s publication, *Economic Impacts FY04,*[431] shows that GSFC obligated more than $2.96 billion in FY 2004 to contractors nationwide, as well as outside the United States, with commercial firms receiving about 55 percent, educational institutions about 25 percent, nonprofit organizations about 10 percent, other government agencies about 10 percent, and organizations geographically outside the United States receiving less than 1 percent. Of the total, $1.34 billion went to organizations in Maryland. GSFC defined its workforce, inclusive of facilities in Greenbelt, Md.; Wallops Island, Va.; N.Y.; Fairmont, W. Va.; and White Sands, N.M., as totalling 10,005 (3,129 civil servants and 6,876 contractor personnel). The publication provided additional detailed information about the breakdown of funds by state, Maryland by county, and type of recipient. It noted that GSFC expenditures enhance business development, create jobs, and increase the tax base but did not estimate indirect economic impacts.

Astronaut Philippe Perrin, STS-111 mission specialist, trains in the Johnson Space Center's Neutral Buoyancy Laboratory, which is the world's largest indoor pool. *Image credit: NASA*

6.2.3 Johnson Space Center

The Bay Area Houston Partnership addresses the economic impact of Johnson Space Center (JSC) on its Web site: "The economic impact data supplied by NASA Johnson Space Center and the University of Houston-Clear Lake's Center for Economic Development & Research was compiled using a widely accepted impact methodology with official Bureau of Economic Analysis multipliers." It characterizes the combined workforce in Bay Area Houston at 16,844 jobs, made up of 3,076 civil employees and 13,768 NASA contractors. It says, "When the economic multiplier effect of these jobs is considered, the total impact from JSC on Houston and Texas exceeds more than 26,435 employees with personal incomes of more than $2.5 billion and total spending [that] exceeds $3.5 billion."

A rocket is seen test firing at the John C. Stennis Space Center. *Image credit: NASA*

6.2.4 Stennis Space Center

In a March 2006 brief, NASA released findings of Dr. Charles Campbell, professor of economics at Mississippi State University, on the local economic impact of the Stennis Space Center (SSC).[432] According to the brief, the total impact of SSC's operation includes at least 19,706 jobs, $819 million in personal income, $328 million retail sales, and an estimated $88 million of tax revenue. In addition, direct impacts are reported showing that, of the $691 million direct funding from SSC, $503 million remained in the local area.

6.2.5 NASA Field Centers in California

A California Space Authority produced document titled "Economic Impact of NASA on State Economy of California," dated May 2006,[433] notes that California is the only state with three NASA Centers: Jet Propulsion Laboratory (JPL), Ames Research Center (ARC), and Dryden Flight Research Center (DFRC). It states that NASA contracts contribute directly to the state's economy, with a total of $3.55 billion in direct contracts in FY 2004, and an annual payroll of $800 million for more than 6,500 jobs. It shows indirect economic impacts at $21 billion, based on "aerospace multiplier applied to indirect jobs." It also notes that 920 jobs have been lost at the three NASA field centers in California since 2004.

Patrick Air Force Base's 45th Space Wing provides support for launches at Cape Canaveral Air Force Station, like this Delta IV rocket taking off from Launch Complex 37B. *Image credit: The Boeing Company*

6.2.6 Patrick Air Force Base

Patrick Air Force Base (PAFB), Fla., home of the 45th Space Wing and Cape Canaveral Air Force Station, published annual economic analyses for 2004 evaluating its impact on Brevard County, Fla. PAFB personnel included 3,745 military and 9,083 civilians. In addition, the report noted 3,142 military dependents and 14,296 military retirees received pensions in Brevard County. For 2004, the total direct impact of PAFB including payroll and expenditures was $980 million. The indirect impact from jobs created was calculated at $22 million by applying a multiplier. The total economic impact calculated was $1.2 billion, including wages and salaries, the estimated dollar value of the indirect jobs, and expenditures including local contracts and construction, educational aid, health payments, commissary, and Base Exchange contracts.[434]

Vandenberg Air Force Base, home of the 30th Space Wing, is responsible for the DoD's space and missile testing, placing satellites into orbit, and missile defense for the west coast of the U.S. *Image credit: 30th Space Wing, VAFB*

6.2.7 Vandenberg Air Force Base

The California Space Authority, in testimony to the Governor's Council on Base Support and Retention, characterized Vandenberg Air Force Base (VAFB), Calif., as having a significant impact on the economies of the County of Santa Barbara and the State of California, directly contributing "more than $500 million each year to those economies through its hiring and its purchasing."[435] The testimony said, "VAFB is the second largest employer in Santa Barbara County with a current employment level of more than 7,000 people. This number includes 3,500 military personnel, almost 1,100 civil servants, and about 2,750 government contractors. In addition, VAFB is a military installation that includes more than 99,000 acres on the Central Coast of California. The installation has more than 42 miles of coastline and 771 miles of roads." The Space Authority noted that the base includes almost 2,000 homes and another 1,800 business-oriented buildings, with replacement value of VAFB estimated at $14.5 billion, and that VAFB is the largest provider of housing in Santa Barbara County, with active duty personnel, as well as 3,700 family members, inhabiting its 2,000 homes. It noted VAFB also provides medical and logistics services to more than 6,000 local retirees.

U.S. Strategic Command (USSTRATCOM) Headquarters at Offutt Air Force Base. USSTRATCOM is a global integrator charged with the missions of Space Operations; Information Operations; Integrated Missile Defense; Global Command & Control; Intelligence, Surveillance and Reconnaissance; Global Strike; and Strategic Deterrence. *Image credit: USSTRATCOM*

6.2.8 Offutt Air Force Base

Offutt Air Force Base (AFB), Omaha, Neb., is the home of the United States Strategic Command (USSTRATCOM), which includes space operations and support missions, among its many activities. A 2005 report, *Economic Impact Analysis*,[436] prepared

EXHIBIT 6e. Florida Commercial Spaceport and New Mexico Spaceport America: Estimated Economic Impacts Through 2015

SPACEPORT	LAUNCHES	COST OF SPACEPORT	ADDITIONAL ECONOMIC ACTIVITY	NEW JOBS
Florida Commercial Spaceport (constrained scenario)	169	$11 M	$7 M	50
Florida Commercial Spaceport (robust scenario)	574	$28 M	$25 M	165
New Mexico Spaceport America	756	$170 to $230 M	$460 M	3,460

Data and analysis shown were selected to provide comparable data and time periods. Additional data and analysis are reported in sources cited. Sources: Futron. (2005, September). Feasibility Study of a Florida Commercial Spaceport (2006-2015). Retrieved July 31, 2006, from http://www.futron.com/pdf/FSA_SpaceportFeasibility.pdf; Futron (2005, December 30). New Mexico Commercial Spaceport Economic Impact Study for State of New Mexico Economic Development Department (2010-2020). Retrieved July 20, 2006, from http://ww1.edd.state.nm.us/images/uploads/Futron_Report.pdf. Also, source for spaceport cost estimate referenced in Futron report, http://ww1.edd.state.nm.us/images/uploads/Futron_Report.pdf. The Arrowhead Center (AHC), New Mexico State University. (n.d.). Business Plan For The Southwest Regional Spaceport. Pg. 25. Retrieved July 20, 2006, from http://ww1.edd.state.nm.us/images/uploads/NMSU_Report.pdf.

by the Financial Analysis office of the 55th Comptroller Squadron, estimated direct expenditures on payroll, construction and services, and materials, equipment, and supplies in 2005 of approximately $770 million. The report also showed indirect economic impacts (calculated using a gross income multiplier of 3.1644 that was not explained) of approximately $2.8 billion. Finally, the report showed Offutt AFB as responsible for more than 25,000 jobs, including an excess of 11,500 direct jobs and 13,000 indirect jobs.

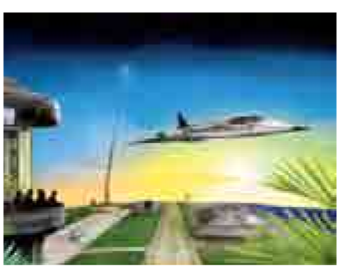
6.2.9 State of Colorado

The *Colorado Data Book*,[437] prepared by the Colorado Office of Economic Development, states:

COLORADO SPACE COALITION
A MILE CLOSER TO SPACE

The Colorado Space Coalition (CSC) is a group of stakeholders in Colorado's space industry whose volunteer efforts support and promote the industry regionally and nationally. *Image credit: CSC*

> *Colorado has a strong aerospace, satellite and space industry. Colorado is home to the third largest space economy, behind California and Texas. There are more than 100 companies in the space business in Colorado. The industry provides an estimated 115,000–130,000 direct and industry support jobs and between $4 and $5 billion a year in revenues. Industry leaders include Ball Aerospace & Technologies, Inc., Lockheed Martin, The Boeing Company, Raytheon Company, Northrop Grumman, GeoEye, and EchoStar. These companies are engaged in satellite manufacturing, launch and ground equipment, and space communications. It is anticipated that this industry will be an economic generator as commercialization of space becomes more widespread in the future. By the year 2010, it is estimated that revenues will increase to $7 billion and employment to 232,000.*



The subject of a Futron study, a commercial spaceport in Florida, located separately from the federal lands at the Cape, would initially target the horizontal launch market. *Image credit: Florida Space Authority*

6.2.10 Feasibility of a Florida Commercial Spaceport

In September 2005, The Futron Corporation completed a study conducted for the Florida Space Authority on the feasibility and potential economic impact of a commercial spaceport at Cape Canaveral or an offsite facility.[438] Futron used the DOC's Regional Input-Output Modeling System (RIMS II) (an input-output model developed by the Bureau of Economic Analysis of the Department of Commerce), along with data from a launch forecast, to estimate the economic impact from spaceport operations. The report recommended a split-site model for a new spaceport separate from Cape Canaveral that would share resources with an existing airport and build additional facilities for a vertical launch platform. The cost of the split-site spaceport was estimated at between $10.5 and $28 million. The economic impact of a split site commercial spaceport was reported for two principal time periods, 2010 and 2015. The spaceport was projected to capture 15 percent under a constrained scenario and 50 percent under a robust scenario of addressable suborbital launches in addition to a small number of orbital launches, resulting in a total of 169 (constrained) to 574 (robust) orbital and suborbital launches during the period 2006 to 2015. Florida's economic benefit from a commercial spaceport was estimated at between $6.3 and $17.5 million for 2010 and between $7.4 and $25.4 million for 2015, with additional jobs as a result of spaceport operations ranging from 35 to 115 for 2010 and 50 to 165 for 2015 (See Exhibit 6e for a comparison with estimates for a New Mexico commercial spaceport).

December 2005—New Mexico Governor Bill Richardson and Sir Richard Branson announce New Mexico will be the world headquarters for Virgin Galactic. *Image credit: New Mexico Economic Development Department*

6.2.11 New Mexico Commercial Spaceport Economic Impact Studies

In December 2005, the State of New Mexico's Economic Development Department released a report on the feasibility and economic impact of a New Mexico spaceport,[439] Spaceport America, conducted by The Futron Corporation. Futron used the DOC's RIMS II launch forecasts to estimate the economic impact from spaceport operations. The report used "Governor Bill Richardson's vision for creating a new commercial space transportation and manufacturing cluster in southern New Mexico" as a baseline. The cost of the spaceport was estimated at between $170 and $230 million between 2006 and 2007.[440] The spaceport was projected to capture initially 75 percent of addressable suborbital launches and dropping to 50 percent in later years. In addition, the spaceport could expect a small number of orbital launches, resulting in 756 launches in the period 2010 to 2015, and an additional 1,647 in the period 2016 to 2020. Futron estimated the spaceport could result in $460 million of economic activity and 3,460 jobs by 2015, potentially increasing to $552 million and 4,320 jobs by 2020. These impacts included $347 million in revenues due to space transportation and manufacturing firms moving to New Mexico, a NASCAR-style rocket racing league, and the X PRIZE cup. Futron cited several advantages to a New Mexico spaceport, including year-round launch windows, low real estate prices, and the absence of conflicting launch and air traffic (see Exhibit 6e for a comparison with estimates for a Florida commercial spaceport). The New Mexico State University developed a business plan for Spaceport America; it may be found on the Web site of the State of New Mexico's Economic Development Department at http://www.edd.state.nm.us/.[441]

Space-Themed Tourism

Space programs and activities interest the public.
The Smithsonian's National Air and Space Museum is recognized as the world's most visited museum. For 2005, a total of 6,100,871 people visited the museum building on the Mall, which on average attracts more than nine million people annually, and 1,169,951 visited the affiliated Udvar-Hazy Center.

A United Kingdom firm publishes a guidebook on space locations that lists more than 400 space-related places to visit in North America. Visitor centers at NASA field centers, as well as programs like Space Camp, attract millions of visitors annually (KSC's Visitor Complex drew about 1.5 million visitors in 2005, JSC's more than 0.7 million, and together they generated about $100 million).

The appeal of space extends to adventure tourism. Two firms, Space Adventures and Zero G, offer space-themed adventure experiences. Space Adventure's revenue for 2004 was anecdotally reported as $15 million, with profitability of about 10 percent, in the N.M. Spaceport Business Plan. Zero G sells zero-gravity flights aboard a modified Boeing 727-200 at a fare of $3,000; its first flight was in 2000. Space Adventures, in business since 1998, has flown customers for $19,000 in a MiG-25 Foxbat, as well as booked them on other space-themed adventure and cruise vacations. (Space Adventures also sells *in-space* adventure experiences—see the discussion of space tourism in section 3.0, *Space Products and Services.*)

A woman tries to catch a glob of liquid in her mouth while floating in zero-gravity aboard a plane flying on a special parabolic path. Zero-gravity flights are a relatively inexpensive form of space-themed tourism. *Image credit: Zero-G*

EXHIBIT 6f. Total Impacts on the U.S. Economy Generated by Commercial Space Transportation and Enabled Industries, 2004

INDUSTRY	ECONOMIC ACTIVITY ($000)	EARNINGS ($000)	EMPLOYMENT (JOBS)
Launch vehicle manufacturing	$1,658,384	$437,674	8,870
Satellite manufacturing	$3,466,111	$846,843	17,820
Ground equipment manufacturing	$31,668,782	$7,737,343	162,820
Direct-to-Home (DTH) TV Services	$49,920,750	$12,868,350	288,850
VSAT services	$2,307,690	$592,290	13,450
Data services	$769,230	$197,430	4,490
Transponder leasing	$2,717,946	$697,586	15,840
Mobile satellite telephony	$743,589	$190,849	4,330
Remote sensing	$681,199	$237,705	5,700
Distribution industries	$4,153,278	$1,239,817	29,180
Total Impacts	**$98,086,960**	**$25,045,888**	**551,350**

Source: FAA AST. See endnote 442.

6.2.12 The Economic Impact of Commercial Space Transportation on the U.S. Economy: 2004

The FAA released its third report on the economic impact of the commercial space transportation market on the United States in 2006, reporting 2004 impacts.[442] The report estimates direct, indirect, and induced economic activity using an adaptation of DOC's RIMS II.

The report estimates the total economic activity generated by commercial space transportation and enabled industries at $98.1 billion for 2004, composed of $16.7 billion in direct expenditures, $46.4 billion in indirect impacts, and $35 billion in induced impacts. This is a slight increase from the 2002 data, which reports $95 billion in total economic impact. In addition, the report attributes 551,350 jobs to the commercial space transportation industry in 2004.

It should be noted that the industry revenues used as source data for the analysis were drawn from the Satellite Industry Association's *Satellite Industry Indicators 2004*.[443] This data has recently changed; the 2006 SIA *Industry Indicators* report revised its 2004 estimate for global revenues of direct broadcast television (DBS), indicating that 2004 global DBS revenues were overstated by approximately 39 percent, or $13.7 billion. Note that the FAA analysis used only U.S. revenues, not global, and also that some industries were recategorized[444] to work with RIMS II, so that the magnitude of the relevant change in the source data is not clear. However, the question is significant because approximately half of the total economic impacts, earnings, and employment reported in the FAA report derives from direct-to-home television (see Exhbit 6f).[445]

6.3 Broader Societal Impacts of Space Activities

Anecdotal evidence suggests space activities have affected daily life beyond the products and services that use space hardware. A flow of technologies has entered the commercial and industrial mainstream as well as transformed key niches. Space activities undeniably affect local, regional, and national economies. On a more psychological note, it is clear that people are interested in space. Public interest in space activities—real-world space activities—is so strong that millions of people spend their vacation time learning about space programs, and an increasing number are seeking out vacation experiences that simulate space travel and microgravity (see the sidebar: Space-Themed Tourism on page 127).[446] Many research projects, as well as popular books and articles, have addressed elements of space and society. Some major studies have considered the broad effects of a specific space capability; a significant multi-year study is currently underway, for example, on remote sensing. NASA, NOAA, and the American Society for Photogrammetry and Remote Sensing (ASPRS), have initiated a ten-year forecast study of the remote sensing and geospatial information industry.

Important analysis and insight have come from efforts such as these. However, no definitive, comprehensive, integrated analysis considering the full range of societal impacts of space activities exists. In 2005, two major research and analysis efforts are filling that gap, seeking to understand better how space activities have affected the course of history and how they will help shape the future. Together these projects take a sweeping, rigorous look at past impacts and future applications of space activities, products, and services. The two projects, one recently completed and one that is approaching a major milestone, are described here.

6.3.1 Societal Impact of Spaceflight (NASA and National Air and Space Museum)

The NASA History Division and the Department of Space History at the National Air and Space Museum sponsored a conference, *The Societal Impact of Spaceflight*, "to undertake a broad overview of the societal impact of space exploration, especially as illuminated by historical research. The purpose is not to conduct an exercise in public affairs or a debate over public policy, but to examine with rigorous research what the impact has been, both nationally and internationally. This is an enormous topic, so we cannot be comprehensive, but we can be broadly representative of the major areas of impact."[447] The conference took place September 2006 (as this book went to print) in Washington, D.C. Papers to be presented included characterizations of the impacts of space exploration on education, on industry and the economy, on social roles, and on international relationships.

Gi-TEWS, a German-Indonesian project establishing a Tsunami Early Warning System in the Indian Ocean, aims at a combination of a very rapid yet reliable early warning. The implementation of the technical installation of the sensor networks and data centers phase is scheduled to be concluded in 2008. The image above is from a GPS survey, Sri Lanka, July 28, 2005, after the 2004 Tsunami. *Image credit: The United Nations University, Institute for Environment and Human Security*

6.3.2 Space 2030

The Organisation for Economic Co-operation and Development (OECD) International Futures Programme conducted a scenario-based study to provide an unbiased "non-space" assessment of the opportunities and challenges facing the space sector, particularly in terms of civil applications, and outlines what needs to be done to make its contribution to society at large as effective as possible. The study was conducted over a two-year time period and involved 25 participants from various countries. A 30-year timeline and three future global scenarios (Smooth Sailing, Back to the Future, and Stormy Waters) were used.

This is the Earth as seen with Meteosat-7's water vapor channel. The constellation features four satellites with three spectral channels (visible, infrared, and water vapor) each, and are used primarily in weather forecasts. *Image credit: EUMETSAT*

The study describes itself as having a focus on applications that provide new insight into how space capabilities can affect societies. It notes: "This publication builds on previous work but takes a somewhat different perspective: its broad socio-economic approach and geographical coverage set it apart from earlier reports. Most past studies of the space sector have focused on the supply side: technological advances and the types of new capabilities that can be developed. They assume, often incorrectly, that development eventually follows such advances. This publication explores instead how governments can get the most out of future public and private space investment."[448]

The study describes the current [2003] state of the industry as "depressed" for the "upstream" or hardware manufacturing and launching industry with some recovery evident in the restructuring of manufacturing firms. The "downstream" or service side of the industry is described as "uneven growth" and slightly better than the upstream.

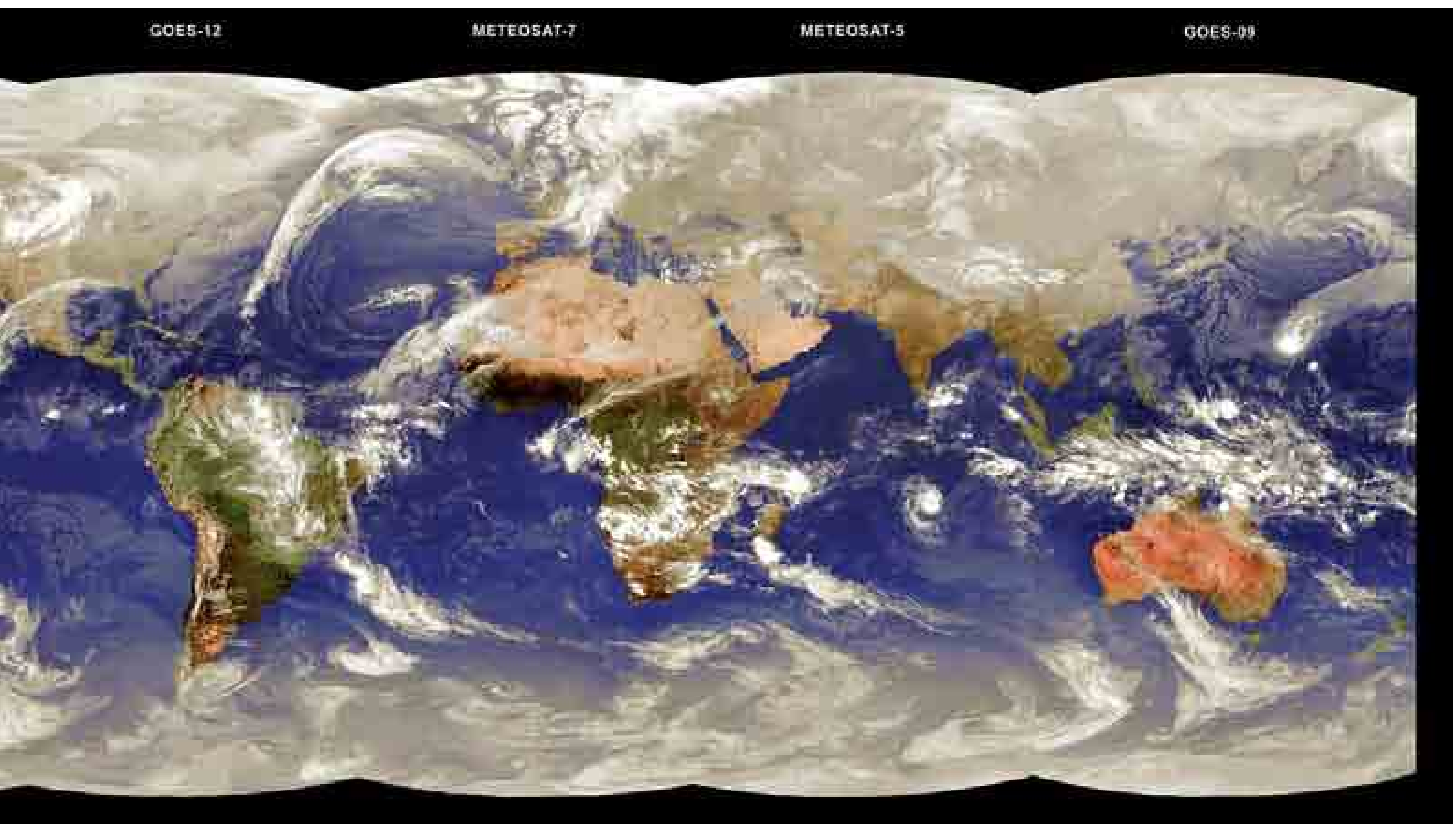
The futures portion study concluded that, in general, the long-term demand for space applications is likely to be substantial, in part due to increased military space across all three scenarios and the use of space applications in the civil and commercial sectors to address societal, technological, and environmental concerns. The major future challenges the study says the world will face, and the roles it says space can play in addressing them, are listed below.[449]

- **Environmental Challenges:** Weather forecasts, monitoring air pollution, detecting potential anthropogenic change, validating climate models, predicting future change, monitoring changes in natural environments such as the evolution of fault lines, subsidence, and volcanoes.
- **Challenges for Managing Natural Resources and Agriculture:** First, providing information on current and future states of the energy system and the environmental context, controlling power and pipeline distribution systems, hydropower dam operation and wind power generation; second, Earth observation data to facilitate the management of water resources, providing information on atmospheric temperature and water vapor, sea surface temperatures, ocean winds, 3D information on rainfall structure and characteristics, soil moisture, and ocean salinity; third, space technology is useful for managing forest resources, mangrove forests, wetlands mapping, determining high and low water line; finally, space systems can be used to appraise the state of crops, identify areas requiring attention, and target treatment automatically.

The Earth is seen here in a composite image from five EUMETSAT satellites on their infrared channels. This picture is a stark contrast to the water vapor channel image seen on the previous page, and shows the variety of data that one satellite is gathering simultaneously. *Image credit: EUMETSAT*

- **Security Challenges:** Provide input to disaster management information systems, pinpoint the scene of an accident, enhance the ability of emergency personnel to treat victims quickly and effectively, assist in tracking and controlling the transport of illegal and hazardous goods, and support monitoring compliance with international treaties and surveillance of international borders.
- **Mobility Challenges:** Enable route guidance (selection of optimum route in real time), management of traffic flows, anticipation of traffic jams, fleet management, advanced driving assistance systems, road-charging schemes, and air traffic control.
- **Challenges Related to the Move to the Knowledge Society:** R&D efforts of space agencies and other space sectors create new knowledge; Earth observation and deep space missions generate data and information on the state of our planet and of the universe; space facilitates the distribution of knowledge.

The study also points out that the long-term demand for space capabilities that these applications drive will be tempered by "severe short-and medium-term fluctuations." This study was published in two volumes: the final report, *Space 2030: Tackling Society's Challenges* and the report of the scenario-based futurist analysis, *Space 2030: Exploring the Future of Space Applications*.[450]



2006

THE SPACE REPORT

OUTLOOK

7.0

Outlook | 7.0

There are few open sources for reliable data on future space activities, revenues, and budgets. Even for-purchase, proprietary publications are generally limited in scope; in addition, only their top-line findings, if any, are released in the press. While these resources provide useful information, particularly for specific applications, decision-makers dealing with space activities would benefit from a comprehensive forecast providing an integrated projection across industry areas with consistent assumptions and multi-year traceability. This is an objective of the Space Foundation.

EXHIBIT 7a. Topics Covered in Outlook

7.0 Outlook
7.1 Selected References, Forecasts, and Projections
7.2 Trends
7.2.1 Technology
7.2.1.1 Katrina
7.2.1.2 SpaceShipOne
7.2.1.3 Launch Vehicle Technology
7.2.1.4 Small Satellites
7.2.1.5 Space-Based Radar
7.2.1.6 Space-Enabled Information Technology
7.2.1.7 Nanotechnology
7.2.1.8 Applications
7.2.2 Policy
7.2.2.1 International Traffic in Arms Regulation (ITAR)
7.2.2.2 Commercial Orbital Transportation System (COTS)
7.2.2.3 Exploration Systems Architecture Study (ESAS)
7.2.2.4 NASA Authorization Bill
7.2.2.5 National Security Space Acquisition
7.2.2.6 China
7.2.3 Business Outlook
7.3 Space Foundation Space Index

The Space Foundation seeks to be the integrator of the best available data and analytical tools, augmenting missing data, deconflicting useful resources in cooperation with their developers, and formulating forecasts and projections. *The Space Report 2006* is the first step in achieving this goal. *The Space Report's* high-resolution snapshot of space activities is the cornerstone for this process. It will aid in identifying missing data, conducting needed research to fill gaps, developing analytical tools, and working with others in the community to build robust and credible integrated forecasts.

The Space Report also characterizes future uses of space products and services across nine broad sectors of economic and other activity. See section 5.0, *How Space Products and Services are Used*.

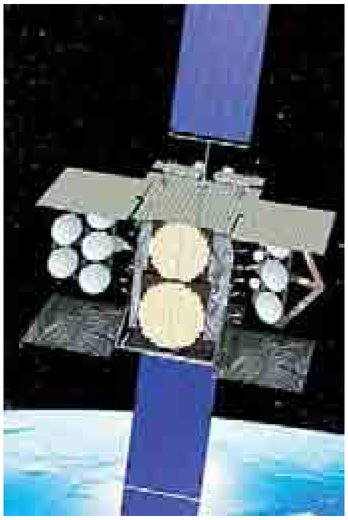
First, throughout the document, *The Space Report* summarizes selected sources of data about future activities. Second, *The Space Report* shares the insights of more than 50 leaders in the space industry about future trends and directions in technology, policy, and business. This information is unique and timely; it crosses sectors of space activity to depict the views about the future of those who are helping to shape it.

The world's first privately developed space launch vehicle, Pegasus is an air-launched, three-stage ELV, which is initially powered by the "Stargazer" L-1011 aircraft. The rocket is carried to an altitude of 40,000 feet before being dropped and igniting its stage one motor. *Image credit: Orbital Sciences Corporation*

Finally, *The Space Report* delivers a tracking tool that will provide on-going, up-to-date insight into the financial performance of space firms—the newly created Space Foundation Space Index. The Space Index will be updated on the Space Foundation's Web site (www.SpaceFoundation.org). The insight offered into U.S. public equity markets by the Space Index is evidenced by the historical five-year trend that shows—no doubt to the surprise of many—that the index has out-performed both the NASDAQ and the S&P 500.

7.1 Selected References, Forecasts, and Projections

- **Launches:** The Federal Aviation Administration (FAA) publishes 10-year projections of commercial satellite launches, drawing on its Commercial Space Transportation Advisory Committee (COMSTAC); the FAA forecast of 236 launches through 2010 is detailed in section 2.1.1.1, *Orbital Launch Events,* on page 28. A study on the economic impacts of a New Mexico spaceport by Futron Corporation predicts an anual suborbital launch market of 852 flights by 2020 and also projects the relevant orbital market; see Ehibit 6e, on page 126 for more detail and references, including a similar study for Florida.

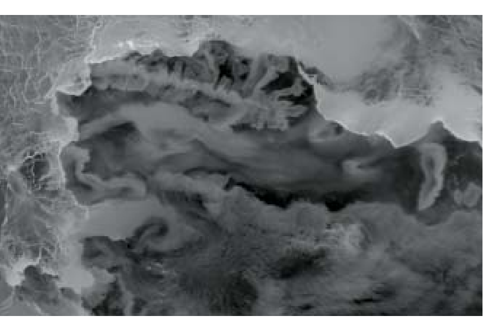


The Wideband Gapfiller Satellites (WGS) are the key elements of a high-capacity satellite communications system that will provide a quantum leap in communications capabilities for the warfighter. WGS will support the DoD's war fighting information exchange requirements, enabling execution of tactical command and control, communications, and computers; intelligence, surveillance, and reconnaissance; battle management; and combat support information. *Image credit: The Boeing Company*

- **Satellites:** As discussed in section 2.2.1, *Communications Satellites,* on page 37. The Teal Group Corporation predicts that a total of 176 geosynchronous commercial satellites worth $28.3 billion will be built and launched from 2006 to 2015. Forecast International has projected 800 satellites, nearly 700 expendable launch vehicles (ELV), and a $46 billion ELV market through 2015; this data is shown in section 2.1.1.1, *Obital Launch Events,* on page 28, and section 4.0, *Budgets and Revenues,* on page 66.
- **Military Programs:** The U.S. Department of Defense (DoD) forecasts budget expenditures using the Future Years Defense Program (FYDP), the official DoD document summarizing forces and resources associated with programs approved by the Secretary of Defense. A Forecast International report, *Western Military Satellites: 2005-2014,* projects that 118 dedicated military satellites are earmarked for production during the next ten years, with an associated revenue of $41 billion. See section 4.3, *Government Space Budgets,* on page 73.
- **NASA:** The NASA Fiscal Year (FY) 2006 Budget Request forecasts relatively small—1.8 percent to 3.1 percent—annual increases in the total NASA budget, bringing the total budget to $18.03 billion by FY 2010. See section 4.3, *Government Space Budgets,* on page 28.
- **Direct-to-Home Television**: In-Stat estimates the market will reach $80 billion in revenue and 100 million subscribers by 2009. See section 4.2.1.1, *Communication,* on page 68.
- **Satellite Radio:** Jupiter Research projects 35 percent compound annual growth in the U.S. digital satellite radio market, growing from 12 million installed units in 2005 to 55 million units in 2010, and Veronis Suhler Stevenson Partners, LLC, says that through 2009, "unprecedented expansion of satellite radio" will drive broadcast and satellite radio's combined revenues to grow at a compound annual rate of 6.2 percent.[451] See section 4.2.1.1, *Communication,* on page 68.
- **Data Communications:** Northern Sky Research (NSR) reports the North American market for satellite broadband will continue to grow, reaching $600 million in service revenue by 2010. In addition, government demand for commercial satellite bandwidth is expected to increase, growing to $4.8 billion by 2012. See section 4.2.1.1, *Communication*, on page 68.

Technicians monitor Sirius Satellite Radio's fleet of three satellites in a control room. Unlike XM, which uses three geostationary satellites, Sirius' satellites are in an elliptical orbit, and only two of the three satellites are in contact at any one time. *Image credit: Sirius Satellite Radio*

The image below depicts Moderate Resolution Imaging Spectro-radiometer (MODIS) satellite data from Antarctic ice sheets. The National Snow and Ice Data Center (NSIDC) uses these to monitor ice shelves considered susceptible to rapid change due to climatic warming. *Image credit: NSIDC*



- **Remote Sensing:** Forecast International predicts an additional 170 remote sensing satellites will be built between 2004 and 2013. The American Society for Photogrammetry and Remote Sensing (ASPRS)'s Ten-year Industry Forecast for the American remote sensing industry has released preliminary data from the first three phases of the study. See section 4.2.1.2, *Remote Sensing,* on page 70.
- **Satellite Positioning:** The worldwide market for GPS equipment and devices is predicted by Research and Consultancy Outsourcing Services (RNCOS) in its Worldwide Global Positioning Systems Market Forecast to reach about $30 billion by 2008. See section 4.2.1.3, *Satellite Positioning,* on page 71.
- **Long-Term Demand:** The Organisation for Economic Co-operation and Development (OECD)'s *Space 2030* study describes the role of space applications in the next 25 years and predicts long-term growth in demand for space capabilities with fluctuations on the way. See section 6.3.2, *Space 2030,* on page 129.

The Space Report also characterizes future uses of space products and services across nine broad sectors of economic and other activity. See section 5.0, *How Space Products and Services Are Used,* on page 80.

7.2 Trends

What drives innovation, investment, and change in the global space economy is people. To gain the insights of some of the key leaders in the global space economy, *The Space Report* talked with more than 50 people who are "moving and shaking" the space economy. These leaders range from senior military officers to policymakers, entrepreneurs, business leaders, and financiers. Among their numbers are scientists, engineers, and academics. The full list of key leaders is included at the back of *The Space Report* (pages 166-167). All were asked to identify what they thought was the most significant space-related event of the past year and what they saw on the horizon.

A damaged oil refinery as seen by NOAA satellites in the aftermath of Hurricane Katrina. *Image credit: NOAA*

7.2.1 Technology

All of the space sector leaders with whom we spoke were asked what they saw as the key technology developments of the past year, what they saw on the horizon, and what applications of space capabilities they viewed as most significant. Among these were SpaceShipOne, launch vehicle technology, small satellites, space-based radar, and nanotechnology.

7.2.1.1 Katrina

A majority of the senior leaders focused on the importance of space technology in dealing with natural disasters, in general, and Hurricane Katrina in particular. Space technology provided overhead Earth observation and imagery capabilities that played a fundamental role in tracking these storms and effectively issuing warnings. These warnings helped minimize some of the potential damage. **Nancy Colleton**, President of the Institute for

Global Environmental Strategies, summarized the value provided by overhead systems: "In the case of Hurricane Katrina, the 56-hour early warning enabled the evacuation of more than 90 percent of Louisiana's southeast coastal area. In the energy sector, the advance warning afforded by satellite systems helped to protect the off-shore workforce. It is amazing to realize that no lives were lost or injuries reported for the off-shore workforce, estimated at 25,000-30,000 people. Although Katrina and Rita combined destroyed more than 100 production platforms and five drilling rigs, there were no off-shore environmental catastrophes. Our observations, modeling, and prediction capabilities worked. Industry had enough time to prepare, secure, and shut down its production facilities."

Colleton

Following the storm, most of the terrestrial communication infrastructure was damaged or destroyed. Space-based communications systems such as GlobalStar, Inmarsat, and Iridium remained intact and helped fill the void, enabling emergency rescue and relief operations to be coordinated and executed. XM Satellite Radio also made its contribution by broadcasting emergency information to the Red Cross over a dedicated channel. The navigational capabilities of GPS enabled the rescue and relief operations that proved especially important, since many landmarks were either flooded or blown away. The fundamental role of space in helping contain the damage and assist in the recovery of this natural disaster is just one example of how important space technology proved to be in the past year.

The White Knight is a manned twin-turbojet aircraft designed to provide a high-altitude airborne launch of SpaceShipOne. *Image credit: Scaled Composites*

7.2.1.2 SpaceShipOne

Perhaps the most frequently mentioned single technology was SpaceShipOne. Although SpaceShipOne's initial flight occurred in 2004, many key leaders in the space sector still saw its influence as the most significant technology development, or one of the most significant, during the past year. The reasons given for this prominence range from how the flight of the first manned private spacecraft raised the profile of commercial space markets to its potential for opening up the space tourism industry. Also frequently mentioned was the innovative technology used on the vehicle. **Pierre Chao,** Senior Fellow and Director of Defense-Industrial Initiatives, the Center for Strategic & International Studies (CSIS), saw Burt Rutan, Paul Allen, and those associated with SpaceShipOne as the Wilbur and Orville Wrights of this century. He noted that their win of the Ansari X PRIZE demonstrated a space economy beyond the standard government and commercial launch markets.

Higginbotham

John Higginbotham, Former Chief Executive Officer, SpaceVest, highlighted the folding wing technology that is at the heart of the "care-free reentry" system and the "cantilevered-hybrid" rocket motor technology as particularly significant. The wing can be folded to provide a "feather" effect to create extremely high drag for reentry, permitting reentry deceleration

Based on a long heritage of space proven engines, Merlin is the highest performance gas generator cycle kerosene engine ever built. Nine Merlin engines will power the first stage of SpaceX's Falcon 9 rocket. *Image credit: SpaceX*

at a higher altitude, greatly reducing the effects of heat on the structure. This also allows the ship to orient itself automatically to a belly-first attitude without pilot input. Following reentry, SpaceShipOne can extend the wings and glide for up to 60 miles. The engine containing both solid and liquid motors was highlighted as a significant step forward in the area of safety.

Musk

From the responses, it is apparent that the progress of Richard Branson and Burt Rutan's SpaceShip Company's SpaceShipTwo will be among the most watched technologies on the near horizon. The eight-person suborbital spacecraft is scheduled for its inaugural flight in 2008.

7.2.1.3 Launch Vehicle Technology

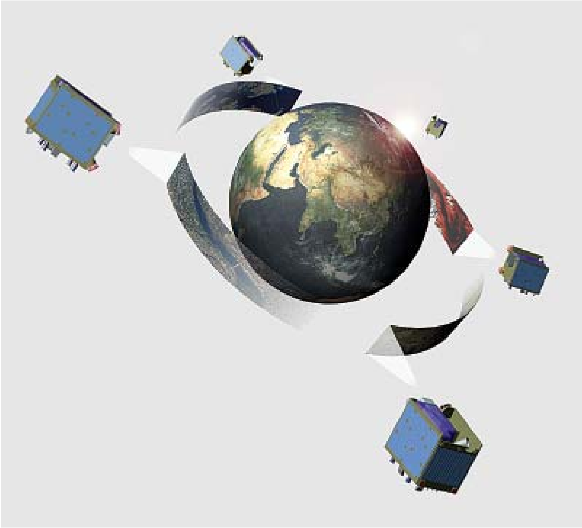
The importance of reducing the cost of launch or solving propulsion challenges associated with long-distance exploration received prominent mention from a significant number of the space leaders. The key to both of these challenges requires developments in launch vehicle and propulsion technology. Many leaders saw some encouraging signs in this area during the past year. In terms of technological developments, Space Exploration Technologies (SpaceX) and its work on Falcon 1 received the most mentions. Falcon 1 is a member of a new category of low-cost rockets designed to revolutionize the space launch industry by dramatically lowering the cost of launch. According to SpaceX Chairman and Chief Executive Officer **Elon Musk**, its main engine (Merlin) is the first all-new American hydrocarbon booster engine to be flown in 40 years and only the second new American booster of any kind in almost three decades.

Even though an engine fire cut through a critical pneumatic line at approximately 30 seconds into flight, which shut down the engine, and the launch vehicle then entered unpowered flight and crash-landed downrange during the first Falcon 1 rocket, Musk considered the March 2006 launch a success. Most of the leaders we talked with were not discouraged by this incident either and remain optimistic about the future prospects of SpaceX. On the horizon, several note they are watching SpaceX's work on its new vehicle, the Falcon 9, currently under conceptual design. This booster is being designed to have a sizeable thrust upgrade from the

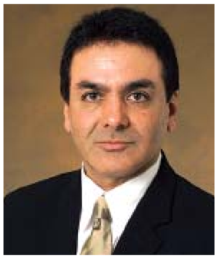
The canceled Jupiter Icy Moons Orbiter (JIMO) project was created to explore the use of a nuclear powered spacecraft. Using nuclear power, spacecraft could travel further and operate longer than ever before. *Image credit: NASA*

Falcon 1 and also to be considerably less expensive per pound of thrust than Falcon 1.

Also mentioned as significant is the emergence of Hybrid Space Launch Vehicles (HLV). Currently, the Air Force has awarded four study contracts to develop concepts for future space launch vehicles with a reusable fly-back first stage and an expendable second stage booster. The HLV system is intended to be capable of lifting 10,000-15,000 pounds into Low Earth Orbit (LEO) at one-third the cost of using an expendable launch vehicle. Potentially, it will be able to take off vertically and land horizontally. The program is managed by the Air Force's Space and Missile Systems Center in cooperation with the Air Force Research Laboratory. Contracts to develop the HLV concept have currently been awarded to Lockheed Martin and Northrop Grumman. Two other contracts are expected to be awarded in the near future. The Air Force hopes to have this capability available by 2020.



The RapidEye constellation will consist of five microsatellites capable of observing the entire world in high resolution every 24 hours. *Image credit: RapidEye AG*



Naderi

Looking further into the future, a number of space leaders note the need to develop some form of nuclear propulsion for long distance space flight. The Jet Propulsion Laboratory (JPL)'s Associate Director, **Dr. Firouz Naderi**, notes that one such initiative was JPL's Prometheus Jupiter Icy Moon Orbiter (JIMO) project. The initial $400 million co-design project was part of an $8 billion effort involving Northrop Grumman, JPL, and various government partners to build the first electric propulsion spacecraft powered by a nuclear fission reactor. However, because this project was terminated last year, **Naderi**, along with a number of other space leaders, sees the need for some other project to take its place eventually.

7.2.1.4 Small Satellites

An area that many of the space leaders see as particularly promising is the progress made in developing small, or micro, satellites. Major advances in microelectronics, particularly microprocessors, have made small satellites a cost-effective solution to traditional problems at a time when government space budgets are decreasing. Small, responsive, and less expensive, these satellites are designed to work either independently with narrowly defined capabilities or in clusters. They are being designed for defense, civil, and commercial applications.

Armor

Small satellites are a key component of the Operationally Responsive Space (ORS) concept being pursued by the Department of Defense. **Maj Gen James B. Armor, Jr., USAF**, Director of the National Security Space Office, notes that the investments in small satellites are starting to bear fruit and sees a major shift in the work right now. So important does Congress view the potential for these systems and the ORS concept, that in 2006 the House passed legislation directing the creation of a Systems Program Office to manage ORS initiatives, notes House Defense Appropriations Committee staffer, **Josh Hartman**. Currently, the DoD has four small satellites either developed or under development.

Great promise is seen for these smaller systems on the commercial side, too. Some, such as Consultant **Wolfgang Demisch**, Demisch Associates, see the potential for small satellites to emulate the capability of larger ones and even gain added capabilities by functioning as "swarms." He sees this as part of the trend toward making every gram launched into space count for as much capability as possible.

One particular cluster of microsatellites, Rapid Eye, was singled out as one to watch. **Nancy Colleton** remarked that "all eyes are on Rapid Eye." The Rapid Eye constellation of five 380 kg microsatellites is a public-private partnership with the German Space Agency (DLR). This Earth observation system is largely aimed at the commercial market for agricultural imaging and mapping. However, it also has military applications. It will be capable of proving wide-swath, multi-spectral imaging in six bands, with daily revisits over Europe. In fact, the Rapid Eye orbital formation ensures that every possible area of the world can be covered in one day. Rapid Eye will provide a 6.5-meter resolution and a 78-meter swath width.

Another potential area where small satellites may make a significant contribution is in education. Teal Group Corporation's Senior Analyst and Director of Space Studies, **Marco Caceres,** sees that the lower costs of small satellites may expand the total number of players, particularly in the small but growing university market.

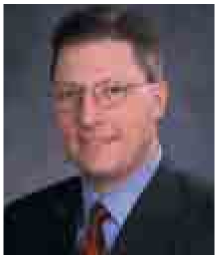
7.2.1.5 Space-Based Radar

The space-based radar system being fielded by the DoD is seen by many of the leaders as a technology with tremendous future potential. This system is designed to provide worldwide, on-demand, near continuous surveillance and reconnaissance. It will be able to gather information of a type and under conditions that cannot be duplicated by other types of reconnaissance satellite systems because its ability to see through clouds, operate at night, operate independently of energy emitted or reflected from a target. **Maj Gen James Armor** is among those who compare the potential of space-based radar to GPS. While acknowledging that the technology is challenging, he notes this is something that we know how to do and that we just need to get it into space. Once we get it into orbit, he expects we will wonder how we ever lived without it.

Analytical Graphics, Inc. (AGI)'s President and Chief Executive Officer, and Space Foundation Board Member, **Paul Graziani**, is another who sees parallels between space-based radar and GPS. He sees us now in approximately the same place with space-based radar as we were with GPS in the 1960s. At that time, GPS was denounced as a technology that would never work and was much too costly. Now, space-based radar is the subject of similar criticism. But, just as in the 1960s and 1970s, when no one anticipated the whole host of applications for GPS, many of which have virtually transformed both our economy and our society, space-based radar offers similar potential. He sees the potential that in 10 to 15 years, space-based radar could be providing a whole host of unanticipated applications such as real-time traffic management.

Graziani

Pace



Sanford

7.2.1.6 Space-Enabled Information Technology

Many, like NASA's Associate Administrator for Program Analysis and Evaluation, **Dr. Scott Pace**, see the growth of information technology that allows for more efficient connectivity and the exploitation of the space environment as among the most significant recent technology developments. A key feature he identifies is the ability to establish networks in space. **Rick Sanford,** Director, Space and Intelligence Initiatives, Cisco Systems, Inc., sees the future in Internet Protocol (IP) networking in space. His company is developing on-board processor and router technology to link space and terrestrial services through a simple IP network that can carry other communications services more efficiently, securely, and cost effectively than competing services, and in a way that will prove transparent to the users. He sees this merging of terrestrial and space systems driving the development of new applications and generating consumer demand that will, in turn, spur the development of other new technologies with further new applications.

Don Brown, President of Swe-Dish Satellite Systems, views the development of IP router technology for space applications as the single most significant recent space technology development. This, in his view, is the beginning of an IP backbone in space, a trend he envisions will have a major impact.

Courtney Stadd, President of Capitol Solutions and Former NASA Chief of Staff, expects IP based on merged satellite and terrestrial communications networks to have a profound impact on next generation mobile, voice, data, and video capabilities. He sees ancillary terrestrial component (ATC) technology as potentially revolutionary. This technology, in his view, is leading to major investments in IP-based networks, seamless interoperability, and the ability of space-based communications to provide uninterrupted communications even in the event of total loss of ground-based cell towers.

Stadd

Levin

Lon C. Levin, Chief Strategic Officer of Transformational Space Corporation (t/Space), member of the Space Foundation Board of Directors, and a co-founder of XM Satellite Radio, was instrumental in obtaining the first ATC license granted by the FCC (to Mobile Satellite Ventures). He has called ATC "the technology of the future," and sees a new playing field emerging for satellite providers to compete robustly with terrestrial competitors. ATC enables satellite communication to achieve its full potential. In his view, ATC will enable satellite communication to deliver true ubiquitous access in the same way that the network of repeaters in major cities did for satellite radio.

Ballhaus

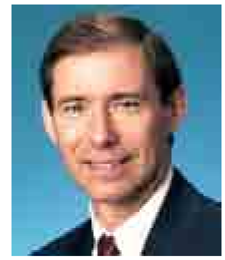
7.2.1.7 Nanotechnology

Looking further out on the horizon, many see great promise for nanotechnology to transform the space sector. As The Aerospace Corporation's President and Chief Executive Officer, and Space Foundation Executive Committee Member, **Dr. William F. Ballhaus, Jr.,** notes, everything in space is underpinned by launch costs. The advances now taking place in nanotechnology are offering great prospects for miniaturization that will enable more capabilities per weight and size.

Hubbard

In addition, he sees the potential for nanotechnology to help advance materials development. **G. Scott Hubbard,** Visiting Scholar, Stanford University; Carl Sagan Chair, SETI Institute; and Former Director, NASA Ames Research Center, sees nanotechnology as having the potential to yield materials and devices that could have a tremendous impact due to their ability to reduce mass. Even more promising, in his view, is the convergence of biotechnology, nanotechnology, and information technology. This convergence holds the potential to yield advances that he predicts will be truly transformational. Vice President and General Manager, Boeing Space Exploration, The Boeing Company; Space Foundation Board Member; and Former Astronaut, **Brewster Shaw,** also anticipates great potential for nanotechnology to provide low mass, low volume, and low energy consumption, all leading to greater space capabilities. He sees particular promise in the potential for the reduced mass to enable robotic precursors for long-distance space travel.

Domino's Pizza allowed viewers to order pizza for delivery while watching television through WebTV. *Image credit: Domino's Pizza / RespondTV*



Shaw

7.2.1.8 Applications

Among the applications identified as most influential are those that feature the convergence of data derived from space with information from terrestrial databases. Most prominently mentioned was Google Earth. This application features an interactive 3D map of the Earth constructed from satellite images matched with terrestrial databases that provide driving directions and maps as well as the ability to search for a wide variety of consumer services. Transformational Space Corporation,Vice President, **Brett Alexander,** sees Google Earth as doing more for remote sensing than anything in the past decade. In his assessment, the technology is secondary, and the application is key. He views applications like this as bringing space to the personal or individual level. **Dr. Neil deGrasse Tyson**, Director of the Hayden Planetarium and Rose Center for Earth and Space at the American Museum of Natural History, and Space Foundation Board Member, notes that applications like Google Earth and Google Mars bring space to our backyards. For the next generation, space just becomes part of life.

Alexander

Tyson

The National Space Society's Executive Director, **George Whitesides,** points to OnStar, a subscription-based communications monitoring and tracking service provided by General Motors. It consists of both communication through mobile phone networks and tracking by GPS technology. He sees this bundled, packaged set of applications as an example of an emerging trend that takes advantage of existing space-based capacity and, by remixing it with terrestrial systems, provides value to consumers and great opportunities for entrepreneurs.

Wild Blue offers broadband Internet access virtually anywhere in the contiguous United States. *Image credit: WildBlue Communications, Inc.*

Whitesides

Technology does not matter so much anymore; services are what is most important, according to **Evie Haskell**, Vice-Chairwoman and Editor-in-Chief of Media Business Corp., whose publications include *SkyREPORT*, *SkyRETAILER*, *The Evening BRIDGE*, and *The Bridge*. In her assessment, the greatest promise for the application of space technologies is in the convergence of technologies and services that make it simple for consumers. She highlights Direct Broadcast Satellite (DBS) systems that contain interactive TV options such as Open TV. She notes that

Haskell

Domino's Pizza has experienced great success in the United Kingdom, deriving eight percent of its revenues from interactive TV orders.

DalBello

Intelsat Vice President for Government Relations, **Richard DalBello,** is among those who identify satellite broadband access as significant. For the military users, new airborne intelligence and surveillance platforms are creating demand for extremely robust satellite links. To satisfy the need for mobile Internet, he points to Inmarsat BGAN—a voice and broadband data mobile communications service accessible anywhere on the planet via satellite. Another similar example he sees is WildBlue, which uses Ka-band satellites to provide two-way wireless high-speed Internet access to rural customers across the United States.

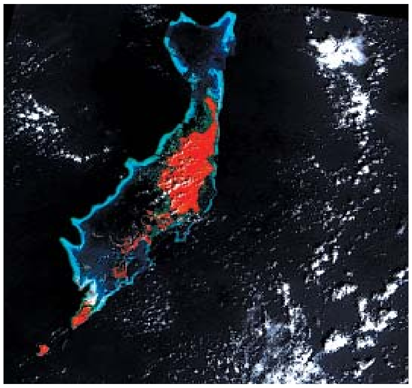
Certain Garmin GPS units receive traffic, weather, and road work information from XM satellites, which the unit then uses to reroute the driver onto a quicker path. *Image credit: Garmin*

Second only to Google Earth was the success of Digital Audio Radio Satellite (DARS) services such as XM and Sirius. **Paul Graziani** perhaps summed up the sentiment best. "I'd have to say that DARS would be the most significant. Particularly, the new service that XM has rolled out delivering traffic updates digitally to certain GPS receivers. This is really amazing that your car's navigation system can receive near real-time traffic updates and reroute you to take the best path. Then, just in general, the primary mission of providing high-quality radio to people's cars, with highly specialized content, is really big," said **Grazani**.

Lautenbacher

Also receiving significant mention were applications associated with Earth observation. National Oceanic and Atmospheric Administration (NOAA) Administrator, **VADM Conrad C. Lautenbacher Jr., (Retired),** stresses that Earth observation is enormously beneficial and may be the most productive use of space. He sees applications for continuously monitoring the Earth as having the potential to benefit humanity across the entire spectrum of human activities. He forecasts particular benefits from long-term climate monitoring and expects these capabilities significantly to increase once National Polar-orbiting Operational Environment Satellite System (NPOESS) and Geostationary Operational Environmental Satellite (GOES-R) are fielded. He is also among those predicting great benefits from the combination of space and terrestrial information. One unique area where this is having a significant positive impact is in monitoring the world's threatened coral reefs. Current applications are permitting managers to monitor these reefs and are enabling them to reduce stress on the reefs by diverting factors that are stressing them. It also allows them to transplant resilient strains of coral to reefs under stress.

The image below features a coral reef (in blue), off the coast of an island in the South Pacific (in red). By using a consistent dataset of high-resolution multispectral Landsat 7 images acquired between 1999 and 2003, the Institute for Marine Remote Sensing at the University of South Florida is developing the first global uniform map of shallow coral reef ecosystems. *Image credit: Institute for Marine Remote Sensing*



7.2.2 Policy

There was generally wide agreement among the space leaders with whom we spoke regarding what the most significant policy initiatives of the past year were and what needs to be addressed in the near future. Dominating the discussions were initiatives associated with NASA, including the need to update the International Traffic in Arms Regulation (ITAR), the Commercial Orbital Transportation System (COTS), the release of the Exploration Systems Architecture Study (ESAS), and the passage of the NASA Authorization Bill. Also prominently mentioned were initiatives to address national security space

Rocketplane's K-1, one of two recipients of COTS funding, is a fully reusable aerospace vehicle designed to accommodate a wide range of missions including LEO payload delivery, microgravity missions, and reboost services for the ISS. *Image credit: Rocketplane Limited, Inc.*

acquisition. A number of leaders also mentioned the need for a coherent national approach to the space initiatives of other nations such as China.

7.2.2.1 International Traffic in Arms Regulation

The top policy issue that needs to be addressed, according to a majority of the space leaders, is ITAR. As Computer Sciences Corporation's Vice President, **Maj Gen Bob Parker, USAF (Retired),** put it, "The first thing we need to do is change the entire technology transfer regime to make it more realistic and make us competitive in the global economy." **Dr. Scott Pace** noted that U.S. ITAR regulations were an inartful response to globalization that created the risk of losing manufacturing capability and influence. They also have proven a wonderful stimulator of international cooperation without U.S. participation. **Rick Sanford** pointed out that the world has changed since ITAR was first implemented, and the current application of it has not kept up with a changing world. He termed the concept of anything space-based being protected as "ostrich like," and potentially damaging to U.S. interests and competitiveness. An example he pointed to was the fielding this year of the first "ITAR-free" satellite in Europe made entirely without U.S. parts.

Weldon

University of North Dakota Assistant Professor, **Dr. Eligar Sadeh,** underscored ITAR's impact, stating, "Evidence is beginning to emerge that it harms the sector and undercuts and erodes our economic competitiveness and forces international partners to go it alone." He explained that space is a global multinational sector and that ITAR is very problematic for furthering global cooperative ties. Ultimately, he concluded, "ITAR was set out to protect national security—but, in my opinion, it is harming our national security. It harms economic competitiveness, cooperation, innovation. Just dealing with that issue will allow for a lot of problems to be solved."

Lepore

7.2.2.2 Commercial Orbital Transportation System

Representative Dave Weldon (R-FL) is typical of the many leaders who see COTS as among the most significant policy initiatives of the past year. In his view, the entrepreneurial involvement of commercial suppliers is very significant because it has the potential to have a great ripple effect. He compares it to the transition of aviation in the early decades of the 20th century from primarily government programs to those dominated by the commercial sector. **Debra Facktor Lepore**, President of AirLaunch LLC, notes that the big deal in 2005 was that NASA announced a need, saw that commercial suppliers could help meet that need, and then put the policies and contracting tools in place to achieve that. She sees the program itself as important, but thinks that far more important is the change in philosophy that now has government working with entrepreneurs and small businesses. **Brett Alexander** argues that NASA cannot execute its exploration mission with "business as usual." He sees COTS as a pivotal future trend and views the inclusion of human spaceflight in this program as especially significant. This approach, in his assessment, has the potential to make spaceflight accessible to people beyond those exceptionally few government employees that have dedicated their lives to

Jennings

spaceflight, eventually even to the average person. **Florida's Lieutenant Governor, Toni Jennings,** adds her voice to those seeing COTS as the single most significant event of the past year. She views the movement of space transportation from overwhelmingly government and military operations to the commercial sector having the potential to revolutionize how we conduct the space business and thinks that the idea of "FedEx-type" businesses in space is now conceivable.

7.2.2.3 Exploration Systems Architecture Study

Kennedy

Many leaders agreed with NASA's Kennedy Space Center Director **Jim Kennedy** that the watershed event of the past year was NASA's release of the ESAS. He views that release as an indicator that the NASA exploration initiative of 2004 is developing traction, and this is a key step in the transition "from the view graphs to reality." The next step, in his opinion, is the release of the contracts for the Crew Exploration Vehicle (Orion) and Crew Launch Vehicle (Ares I). **Tom Koshut**, Associate Vice President for Research at the University of Alabama, Huntsville, and former congressional staffer, explains that his rationale for choosing the release of ESAS as the most significant policy event of the past year is that, prior to this, industry did not know in which direction NASA was moving. The ESAS provided direction across the spectrum of industry as well as for the NASA centers.

NASA expects to use the Ares I Crew Launch Vehicle to send its Orion spacecraft to and from the ISS, the Moon, Mars and other destinations. *Image credit: NASA*

Pryke

Ian Pryke, Senior Fellow, Center for Aerospace Policy Research, George Mason University, finds especially significant NASA's approach described in the transportation portion of ESAS of not going for revolutionary breakthroughs in technology but rather relying on the proven technology derivatives of previous programs such as *Apollo* and the space shuttle. **Dr. Neil deGrasse Tyson** elaborates on this by noting that solid rocket boosters are relatively simple and robust. As for the rest of the shuttle system, Tyson recalls that the space shuttle was boastfully introduced as the most complex space vehicle ever devised, and asks, "Is this a good fact or a bad fact?" His assessment is that complexity is not necessarily an asset and is often a liability. In light of this, he sees the Orion design as conceptually simpler and, therefore, superior.

Chase

7.2.2.4 NASA Authorization Bill

Congress' fully funding of NASA is seen by many, including NASA Assistant Administrator for Legislative Affairs, **Brian Chase**, as particularly significant. In his view, this is indicative that the agency has strong bipartisan support and that it is transitioning from the

President's vision, or the administration's vision, to the nation's vision. **Juliane Sullivan**, Akin Gump Straus Hauer & Feld LLP, and former congressional staffer, also thinks the passage of the Authorization Bill is one of the most significant policy actions of the past year. She says it is particularly noteworthy that passage of this bill got the Congress on record as supporting exploration, but she also has some concerns for the future. She credits the full funding for the President's Vision for Space Exploration to the efforts of former House Majority Leader Tom DeLay (R-TX), who recently resigned. She notes that he was committed to NASA from the outset and would not accept anything less than full funding. He refused to let the FY 2005 Appropriations Bill move without full funding and went so far as to secure a veto threat from the President if the bill moved forward with anything less than full funding for space exploration. **Sullivan's** concern is that, although there is broad bipartisan support for the vision, no one is left with the clout or power base to assume the role Rep. DeLay played in ensuring funding.

7.2.2.5 National Security Space Acquisition

According to many of the space sector leaders, this past year saw some significant action to address problems that have plagued national security space acquisition programs for more than a decade. **Josh Hartman** observed, parties in the various sectors of space acquisition were unwilling to face the problems. In the past year, at least in part due to the number of Nunn-McCurdy breaches that occurred in space acquisition programs, the community came to the conclusion that something had to be done to address these issues, and now he sees a concerted effort to tackle them. **Robie Samanta Roy**, Assistant Director for Space and Aeronautics at the White House Office of Science and Technology Policy, observes that the root cause of these problems is not due to policy today but to policies of the past. He sees concrete legislative and executive branch action being taken now to get space acquisition on the right track.

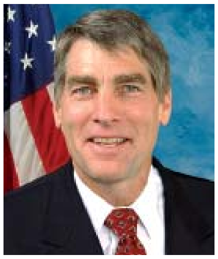
Hamel

Among those charged with devising and implementing solutions to these problems is **Lt Gen Michael A. Hamel, USAF**, Commander of the Space and Missile Systems Center, Air Force Space Commmand, in Los Angeles. He acknowledges that significant program problems have existed but that the Air Force is coming to grips with them and seeing progress. Key to addressing the problems is implementing a "back to basics" approach to acquisition. **Lt Gen Hamel** says they will accelerate delivery of new capabilities to the warfighter and allow for subsequent blocks to capture lessons learned from the user community and new technologies from the laboratory. It also will result in a constant rhythm of research, design, build, launch, and operate—building up momentum with shorter acquisition cycles for smaller systems and, hopefully, increasing confidence in cost and schedule estimates over the long run.

7.2.2.6 China

Another area of international policy that received significant mention from the space leaders was the United States' dealings with China. **Vincent Sabathier,** Senior Fellow and Director, Human Space Initiatives, The Center for Strategic & International Studies, sees hope that the U.S. Administration may be adopting a more cooperative approach to dealing with the Chinese on space issues and a growing realization that China is a global space presence.

Representative Mark Udall (D-CO) stresses the need for adopting a constructive policy toward China. A healthy competition with countries such as China can be beneficial for both countries, he notes. However, he warns that framing this competition in terms of an adversarial relationship could prove very harmful.



Udall

Walker

7.2.3 Business Outlook

The assessment of the space leaders on the prospects for the business environment ranged from mixed to quite optimistic. Former Congressman and Chairman of the House Science Committee, and current Chairman, Wexler & Walker Public Policy Associates, **Robert S. Walker,** describes the space business climate as mixed. He notes that the costs to orbit are high, but successful launches have been creating confidence for large ventures. While he thinks the potential for real growth has not yet emerged, he does see healthy activity. **Marco Caceres** sees a return of investors who lost money in the sector in the 1990s. He notes that those investors are starting to return but doing so cautiously.

John Higginbotham views the environment as improving in all sectors of the space economy. He also sees increasing availability of capital for space ventures. Space ventures are on the cusp of coming into vogue, according to **Rick Sanford**. He sees great promise in space tourism and in SpaceX's Falcon 1. As space systems become more accessible, they create more value than intended. He sees particular potential for growth in the commercial consumer space marketplace, especially in the international market. **Richard DalBello's** assessment is that there is a viable satellite communication industry, a robust satellite entertainment industry, and "everything else is a ward of the state." He expects the market to be robust for communication services and that DoD demand will remain strong. He also expects capital to be readily available for those with proven business models. **Jill Smith,** President and Chief Executive Officer of DigitalGlobe, notes that the market for Commercial Remote Sensing (CRS) is growing at about 40 percent per year, and that this is occurring not only in the United States, but also at an even greater rate in the international marketplace. She expects this growth to continue at a rapid pace as many more applications for satellite imagery emerge. In her assessment, the growth in the capacity to serve the applications and access the data are the most important factors in the continued double-digit growth of the industry.

Smith

The QuickBird satellite offers highly accurate, commercial high-resolution imagery of Earth. QuickBird's global collection of panchromatic and multispectral imagery is designed to support applications ranging from map publishing to land and asset management to insurance risk assessment. *Image credit: DigitalGlobe Inc.*

Cavossa

David Cavossa, Executive Director of the Satellite Industry Association, notes that the business climate in the satellite industry is very positive now, much like it was 10 years ago. He cites the mergers and consolidations that have occurred in the industry during 2005, as well as the companies seeking new sources of funding, as indicators that the climate is good and growing. **Don Brown** sees the "fantastic" consolidation occurring in the commercial satellite industry as among the most significant trends. He expects some positive benefits from this trend as consolidation will allow the satellite industry to rationalize fleets and ditch excess capacity. **Evie Haskell** also sees a shift away from the government sector and toward the commercial sector. The old flow of space services and technologies was from the defense sector to the commercial. She explains the new way is from the commercial sector to defense. Overall, she assesses the opportunities for the commercial sector as "humongous." However, to take advantage of these "huge opportunities," space companies must be prepared to partner with terrestrial providers. She also sees great potential in the international arena. "The international market looks great," she says. "Satellite services are doing great in Europe and there are still huge swaths of the world without terrestrial providers."

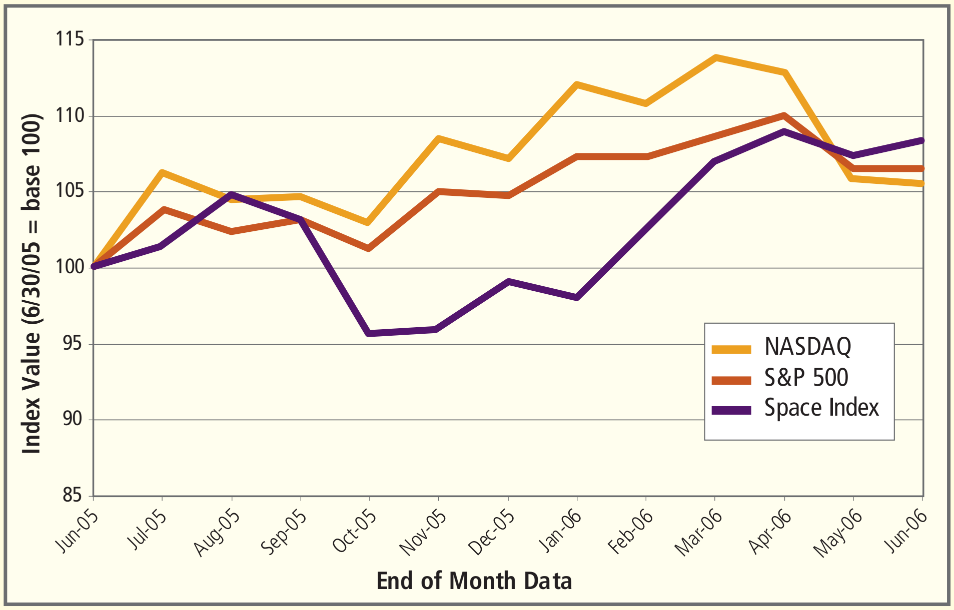
Perhaps the most positive assessment was offered by **Courtney Stadd**. He said, "Overall, I think the business climate is as positive for space investments as I have seen it in 30 years. The chief executive officers of the nascent space ventures are more sophisticated, the financial institutions (high net worth angels, venture capitalists, investment bankers, economic development agencies) are more literate and experienced, and there is a great wealth to be tapped—from hedge funds to large amounts of venture capital looking for opportunities. The success of Burt Rutan's SpaceShipOne and Richard Branson's willingness to associate his worldwide brand with building a commercial passenger-carrying suborbital vehicle has given the entrepreneurial space sector enhanced and positive standing."

Another example is Robert Bigelow who has publicly stated that he has invested $75 million (and is prepared to invest significantly more) in the development and production of Earth-orbiting expandable habitats intended for a range of research and commercial pursuits. The first launch of his Genesis inflatable module took place in July 2006, and he anticipates it will be followed by increasingly sophisticated missions in the months and years to come. **Elon Musk's** steadfast commitment to fixing the technical issues that led to the failure of Falcon 1, with the strong support of his customers, also sends a positive signal to the marketplace. The existence of a stable and, comparatively speaking, predictable (if still sometimes inefficient) regulatory regime has also assisted with this sector's credibility vis-a-vis the investment community.

7.3 Space Foundation Space Index

We would like to introduce the Space Foundation's Space Index, which will track the performance of the space industry in the U.S. public equity markets. The index currently tracks 30 companies that derive a significant portion of their revenue from infrastructure and services activities related to the space industry. The accompanying chart tracks the relative performance of the index with respect to the NASDAQ and S&P 500 Indices during a 12-month period starting at June 30, 2005. Over this period, the Space Foundation's Space Index increased more than eight percent and outperformed the NASDAQ and S&P 500 Indices by approximately two to three percent. Leading advancers during this time period included Garmin, SiRF Technology Holdings, Orbital Sciences, and EMS Technologies, while leading decliners included XM Satellite Radio, WorldSpace, and Motient.

EXHIBIT 7b. Space Foundation Space Index vs. Other Market Indices



The Space Foundation's Space Index was prepared by ISDR Consulting, LLC, on behalf of the Space Foundation. This index is a modified market capitalization-weighted index of representative space companies listed on U.S. market exchanges. Companies were selected based upon an evaluation of several criteria, including percentage of revenues attributable to space-related products and services, market capitalization, trading volume, and which U.S. exchange the securities or ADRs were listed on. Some consideration also was given to provide diverse representation across various space-related markets. Space revenues include

EXHIBIT 7c. Space Foundation Space Index Data

CHART INPUT DATA	COMPARATIVE DATA			ACTUAL INDEX VALUES	
	NASDAQ	S&P 500	SPACE INDEX	NASDAQ	S&P 500
Jun-05	100.00	100.00	100.00	2056.96	1191.33
Jul-05	106.22	103.60	101.44	2184.83	1234.18
Aug-05	104.62	102.43	104.78	2152.09	1220.33
Sep-05	104.61	103.15	103.30	2151.69	1228.81
Oct-05	103.08	101.32	95.66	2120.3	1207.01
Nov-05	108.55	104.88	95.95	2232.82	1249.48
Dec-05	107.21	104.78	99.05	2205.32	1248.29
Jan-06	112.10	107.45	98.09	2305.82	1280.08
Feb-06	110.91	107.50	102.62	2281.39	1280.66
Mar-06	113.75	108.69	106.97	2339.79	1294.87
Apr-06	112.91	110.01	108.85	2322.57	1310.61
May-06	105.93	106.61	107.44	2178.88	1270.09
Jun-06	105.60	106.62	108.38	2172.09	1270.2

Launch Vehicle, Satellite, and related Ground Segment Manufacturing of Components and Systems; Satellite Communication 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 Web sites, and SEC filings, as well as internal experience.

EXHIBIT 7d. Space Foundation Space Index Composition

INFRASTRUCTURE COMPANIES			
SPACE SEGMENT SUB-SYSTEM MANUFACTURERS & SYSTEM INTEGRATORS		**GROUND SEGMENT & SATELLITE COMPONENT MANUFACTURERS**	
Ticker	Company	Ticker	Company
BA	The Boeing Company	GRMN	Garmin Ltd.
LMT	Lockheed Martin Corp.	TRMB	Trimble Navigation Ltd.
NOC	Northrop Grumman Corp.	SIRF	SiRF Technology Holdings, Inc.
RTN	Raytheon Company	VSAT*	Viasat, Inc.
HRS	Harris Corp.	CMTL	Comtech Telecommunications Corp.
ATK	Alliant Techsystems, Inc.	ISYS	Integral Systems, Inc.
ORB	Orbital Sciences Corp.	ELMG	EMS Technologies, Inc.
LORL*	Loral Space & Communications, Inc.	CAMP	CalAmp Corp.
GY	GenCorp Inc.	RADN	Radyne Corp.
		KVHI	KVH Industries, Inc.
		GILT*	Gilat Satellite Networks Ltd.
		SYMM	Symmetricom, Inc.
SATELLITE COMMUNICATION SERVICES COMPANIES			
CONSUMER/RETAIL SERVICES		**BUSINESS/GOVERNMENT SERVICES**	
Ticker	Company	Ticker	Company
DTV	DirecTV Group, Inc.	MNCP	Motient Corp.
BSY	British Sky Broadcasting Group plc	VSAT*	Viasat, Inc.
DISH	EchoStar Communications Corp.	SAT	Asia Satellite Telecommunications Holdings Ltd.
SIRI	Sirius Satellite Radio, Inc.	LORL*	Loral Space & Communications, Inc.
XMSR	XM Satellite Radio Holdings, Inc.	GILT*	Gilat Satellite Networks Ltd.
LNET	LodgeNet Entertainment Corp.		
WRSP	Worldspace Corporation		

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

The index was initiated with a level of 100 as of June 30, 2005. Changes in the index value are driven by changes in the market capitalization of the component companies (price multiplied by number of shares outstanding of each company). The contribution of certain component companies' market capitalization to the index has been discounted to adjust for lower percentage of revenues attributable to space-related products and services. The level of the index is not altered by stock splits, stock dividends, or trading halts, nor is it affected by new listings, additional issuances, delistings, or suspensions.

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If you have any questions, comments or suggestions please contact Kevin Leclaire at ISDR Consulting, LLC: isdr@verizon.net or Marty Hauser at the Space Foundation: marty@SpaceFoundation.org.

www.TheSpaceReport.org

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Mr. Jannette is chief of staff of the Space Foundation, responsible for directing the day-to-day business operations, providing leadership in establishing policies and procedures, and acting for the president and chief executive officer in his absence. Jannette joined the Foundation as vice president of marketing and communications after relocating from Florida, where he was president of Watermark Strategic Communications. Jannette also served in the United States Air Force, as a White House appointee under President Ronald Reagan, and as the assistant administrator for public affairs for the Federal Aviation Administration. He earned a Bachelor of Science Degree in Education, graduating Phi Beta Kappa, and a Master's Degree in English, Summa Cum Laude, both from Ohio University. He also earned national accreditation as a Public Relations Counselor (APR).

Carie Mullins

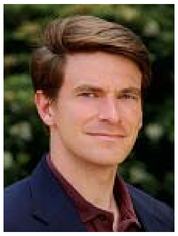
Ms. Mullins is a senior engineer with The Tauri Group. Mullins was the lead analyst for *The Space Report*, managing writing and research efforts. She has more than ten years experience in the space industry applying quantitative analytic techniques (statistics, probability theory, optimization techniques) to advanced technology assessment, forecasting, R&D planning, and risk analysis. She has led major projects including a 10-year forecast of telecommunications demand; technical, financial and risk assessment of alternative architectures for on-orbit power generation; and assessments of technology trends affecting the industrial base (including a current effort analyzing critical technologies for OSD/ Industrial Policy). She has extensive expertise in market forecasting for both GEO and NGSO markets and launches. Mullins earned a Master of Science Degree in Industrial Engineering and has completed all but her dissertation for a Doctorate Degree in Industrial Engineering from the University of Pittsburgh.

Elliot G. Pulham

Mr. Pulham is president and chief executive officer of the Space Foundation. Pulham leads the premier team of space and education professionals providing services to educators and students, government officials, the news media and the space industry around the world. Pulham is widely quoted by national, international and trade media in their coverage of space activities and space-related issues. Before joining the Foundation, he was senior manager of public relations, employee communication and advertising for all space programs of The Boeing Company, serving as spokesperson at the Kennedy Space Center for the Magellan, Galileo and Ulysses interplanetary missions, among others. Pulham is a member of the national board of advisors of the RNASA Foundation, a member of the national board of advisors of the Institute for Space & Security Studies, and a member of the Chief of Staff of the U.S. Air Force's Civic Leader Advisory Group.

Margaret "Ashley" Whelan

Ms. Whelan is a graduate student intern at the Space Foundation's Washington, D.C., office. Whelan provided editorial assistance for *The Case for Space Exploration*, and was researcher and contributing author for the National Security Space Industrial Base White Paper. Ms. Whelan received her Bachelor of Arts in Astronomy/Astrophysics from the University of Colorado, Boulder and is a Master's Candidate in International Science and Technology Policy at The George Washington University's Elliott School of International Affairs in Washington, D.C.



Kevin Leclaire
Mr. Leclaire is the managing partner of ISDR Consulting and provides investment, financial and strategic consulting to clients in the space industry. Prior to ISDR, he was a senior associate at SpaceVest, a venture capital firm that invested in space-related and advanced technology companies. Additionally he co-founded two space industry-focused "virtual think tanks," and founded a navigation software startup. Previously at General Electric, Mr. Leclaire completed GE's Six Sigma Black Belt and Technical Leadership Programs and was part of the GE Corporate audit staff. He earned an M.B.A. from the Harvard Business School and holds Bachelor's degrees in Industrial & Systems Engineering and Economics, with Honors, from Virginia Tech. Mr. Leclaire also serves on the Board of Directors of the Virginia Tech Alumni Association.

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Julie Howell
Ms. Howell is marketing associate, corporate member services, at the Space Foundation. She manages all aspects of the corporate membership program, including internal and external communications, billing and sales, and provides editorial content for all departments. Howell earned a Bachelor of Arts Degree in Journalism and Mass Communications from the University of Northern Colorado, Greeley.

Many Tauri Group staff members contributed to *The Space Report*, including:

- **Bill Wellman**, Program Manager
- **Elaine Gresham**, Senior Technology Analyst
- **John Nelson**, Program Manager/Senior Technology Analyst
- **Kyle Albert**, Senior Technology Analyst

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Additonal contributions were made by the following members of the Space Foundation:

- **Lori Mohr**, Executive Assistant to President/CEO
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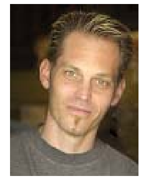

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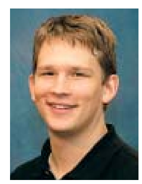

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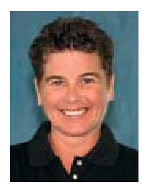

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About The Space Foundation

The independent Space Foundation is a non-partisan, not-for-profit operating foundation with a mission "to vigorously advance civil, commercial and national security space endeavors and to inspire, enable and propel tomorrow's explorers." Founded in 1983, the Space Foundation is incorporated in Colorado as an IRS 501(c)(3) nonprofit company. The Space Foundation has its headquarters in Colorado Springs, Colo., offices in Washington, D.C., and Cape Canaveral, Fla., and professional representation in Houston, Texas. The Foundation is guided by a national board of directors comprised of senior leaders from all sectors of the space community. Its operations are U.S.-focused but international in scope.

The Space Foundation is a hybrid organization that functions primarily as a trade association, with significant complementary enterprises in education and in policy-focused research and analysis.

In its trade association role, the Foundation conducts the major conferences, trade shows and symposia of the space industry. Its National Space Symposium, now in its 23rd year, is the largest annual gathering of the space industry anywhere in the world. Other major events include the national-security-space focused Strategic Space and Defense conference (Omaha, Neb.), the Florida Space conference (Orlando, Fla.) and the Pacific Space Leadership Forum (Honolulu, Hawaii). Internationally, the Foundation is the U.S. industry representative on the U.S. delegation to the United Nations Committee on the Peaceful Uses of Outer Space (UNCOPUOUS); bi-annually, it joins with the Society of British Aerospace Companies and the United Kingdom Industrial Space Committee in presenting the International Space Pavilion at Farnborough International Airshow. The Space Foundation's government affairs professionals are the independent, non-partisan voice of the space community in Washington, D.C., advising policy makers and staff at all levels of government. Its research and analysis team produces *The Space Report* and other reference documents and white papers contributing to informed dialogue concerning the industry.

The Space Foundation is especially proud of its education enterprise, which has trained more than 40,000 teachers across the country on the use of space themes and curriculum to spur improved student performance in the classroom. Its curriculum, indexed to both federal and state education standards by grade level and subject matter, is available online at no cost to teachers, parents and students. The Foundation also offers a unique Summer Institute program, and two unique Masters Degree's, to help teachers inspire and propel our next generation of explorers.

To learn more about the Space Foundation, to contribute, become a corporate member, or attend one of our events, visit the Foundation Web site: **www.SpaceFoundation.org**.

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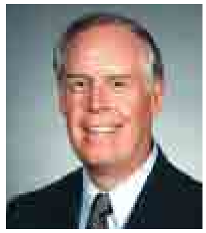

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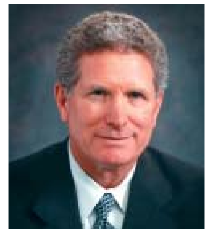

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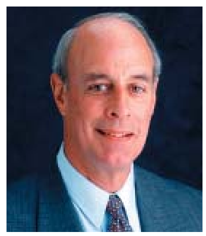

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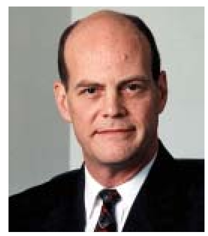

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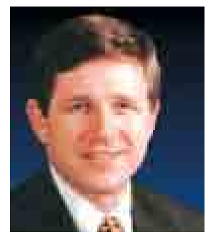

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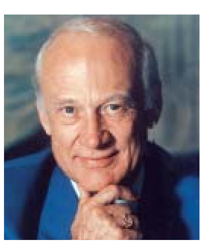

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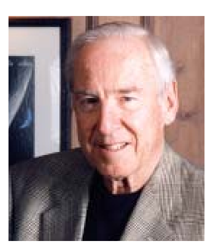

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About The Tauri Group

The Tauri Group, an innovator in analytical consulting, applies creative, responsive problem-solving to homeland security, defense, and space enterprises. Government agencies and multinational contractors trust our objectivity and vision. They know we have the discipline, experience, and expertise to tackle issues with no easy answers.

The Tauri Group's Space and Technology practice delivers decision support that combines in-depth domain expertise with a well-demonstrated commitment to analytic rigor, demonstrated in projects such as *The Space Report*. Because we understand the interplay of national security, civil and commercial space programs, capabilities, and markets, The Tauri Group offers clients unique cross-sector insight. We draw on our military and aerospace expertise and proprietary technology data sets to help clients formulate technology programs, model the benefits of alternative investments, justify research strategies, and evaluate economic impacts. Our principals and senior staff are known nationally and internationally, frequently publishing and speaking about trends in the space industry

Technology Management—The Tauri Group understands how technology integrates into overall programs and delivers uniquely comprehensive R&D planning support and guidance for strategic investments. We've evaluated the latest innovations for security, defense, and space initiatives, helping clients identify the optimum choices for their programs in terms of operations, integration, collaborative partnerships, policy considerations, and future planning.

Strategy & Program Formulation—Our deep strategic planning expertise has supported DoD, NASA, MDA, and intergovernmental initiatives. We understand ConOps development as well, having defined, initiated, and managed complex exercises and pilot programs with multiple stakeholders.

Program Management—The Tauri Group provides full program support. Our experts grasp the big picture as well as offer the in-depth knowledge essential for rigorous, independent analyses and implementation guidance.

Systems Engineering—The Tauri Group uses requirements definition models to identify necessary systems components and test systems longevity. Our integrated trade studies evaluate system performance and cost-effectiveness. Strategists, managers, and technologists work together to design and implement projects and capabilities that integrate diverse elements and achieve clear, measurable results.

Economics & Costing—All initiatives must answer to a bottom line. The Tauri Group goes beyond basic cost estimating and acquisition support to provide a comprehensive economic and financial perspective. We assess a system's economic impact and financial implications, including budgeting, projected cost savings, and resource allocation. We aid future planning through market forecasting, and provide the policy analysis crucial to government and defense projects.

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