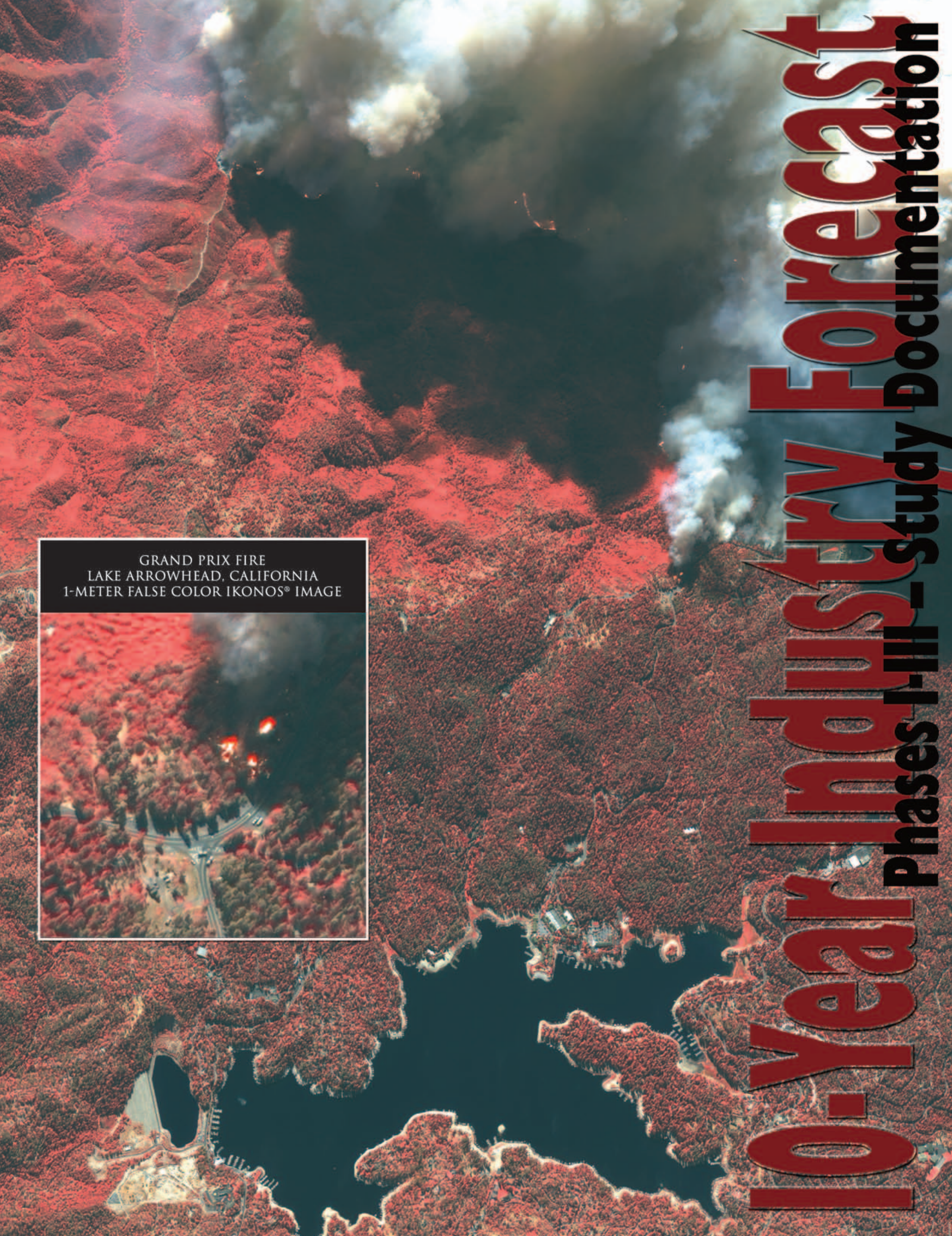
10-Year Industry Forecast

Phases I-III – Study Documentation



GRAND PRIX FIRE
LAKE ARROWHEAD, CALIFORNIA
1-METER FALSE COLOR IKONOS® IMAGE

Acknowledgements

ASPRS and the authors are deeply indebted to NASA and NOAA, who provided significant financial support to the first three phases, and to all of the many volunteers from throughout the imaging and geospatial information community who contributed their time and energy to the successful completion of this project. In particular, special thanks are due to Ronald Rabin and his staff at NASA Stennis Space Center, Tim Stryker and Katy Vincent at NOAA, and to James Plasker and his staff at the American Society for Photogrammetry and Remote Sensing (ASPRS) in Bethesda, Maryland. In addition, thanks goes to the innumerable respondents to the many survey questions, focus group participants, and interviewees, for without the information and opinion freely shared, there would be no real information available upon which to base these findings. Thank you to all in the community for making this project a reality.

Forecast Cover Image

The image provided by Space Imaging on the Forecast cover is a 1-meter IKONOS satellite image of the Grand Prix fire in the Lake Arrowhead region of California. Of particular interest are the cloud plumes and hot spots heading up-ridge from the area of San Bernardino (note that North is down in this image) on October 28, 2003. The image inset, showing several hot-spots near homes and roads, illustrates the detail available in a high-resolution satellite image. Once the fire is contained, the perimeter and severity of the fire can also be mapped using satellite imagery. The pan-sharpened image was created by blending the 1-meter panchromatic band with 4-meter multispectral bands. The image is displayed as a false color composite, thereby rendering the vegetation in red-tones and water in black. Roads, residential areas, docks, and other man-made structures are clearly identifiable in the image, as well as land cover type. To see more satellite images of the California wildfires, go to our Gallery on www.spaceimaging.com.

10-Year Industry Forecast

Phases I-III – Study Documentation

Prepared for

The American Society for Photogrammetry and Remote Sensing

Submitted by Mr. Charles Mondello, Dr. George F. Hepner, and Dr. Ray A. Williamson

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For more information on the 10-Year Industry Forecast, visit
http://www.asprs.org/asprs/news/forecast.html

Disclaimer

1 Executive Summary of the NOAA/NASA/ ASPRS 10-Year Industry Forecast

In August of 1999, the National Aeronautics and Space Administration (NASA) and The American Society for Photogrammetry and Remote Sensing (ASPRS) agreed to undertake a comprehensive study of the remote sensing and geospatial information industry in the United States. Their ultimate goal was to develop a continuing forecast of the remote sensing industry. In 2002, the National Oceanic and Atmospheric Administration (NOAA) formally joined NASA and ASPRS to support the documentation and analysis of the forecast and to provide further information to the private sector and government agencies.

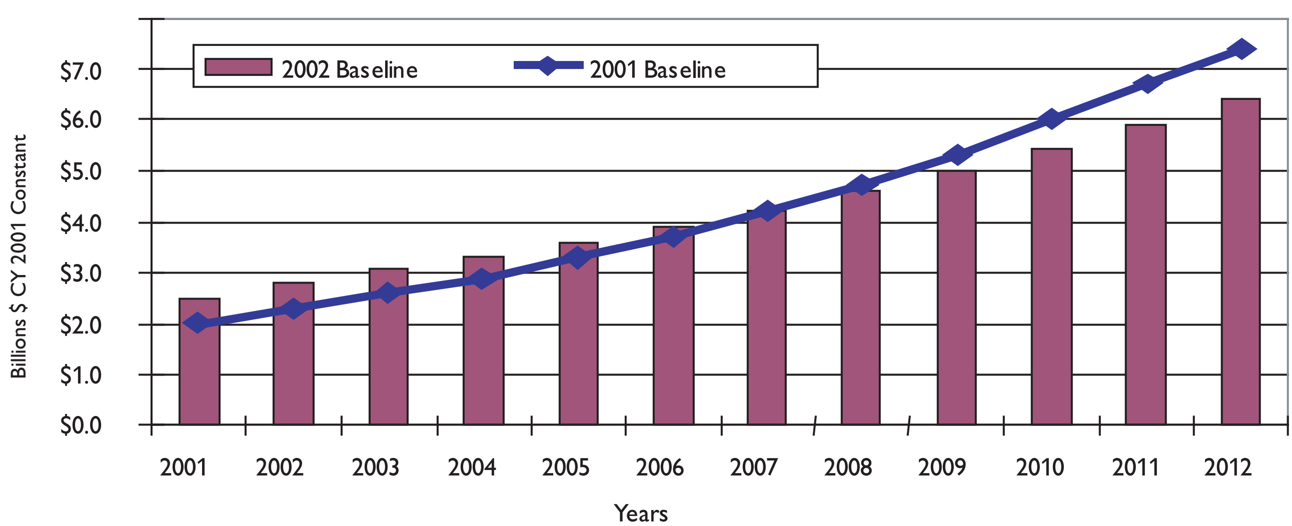
An estimated 175,000 people are employed in the U.S. remote sensing and geospatial information industry, which includes those commercial firms, not-for-profit organizations, governmental agencies, and academic institutions involved in the capture, production, distribution, and application of remotely sensed geospatial data and information, primarily for the civilian sector. It is a rapidly growing segment of the much larger information industry.

New technological advancements facilitate the application of remote sensing to a wide range of disciplines, from the sciences to myriad practical applications. Prior to this study, few comprehensive data about the industry, and no reliable, unbiased assessments of the industry's future existed. This study is an attempt to remedy these limitations by combining the experience of the talented volunteers of the membership of ASPRS with the knowledge, experience and resources of NASA, NOAA and the U.S. Geological Survey (USGS) in a continuing forecast of the industry and the key factors that affect it. This report provides historical, technical and policy context about the nucleus of the research project, the recently completed Ten-Year Industry Forecast Phases I-III. This document summarizes the Forecast's methodology, analyzes its results, and assesses their implications for the industry and for government policy.

The forecast is composed of three phases to date. Phase I, which was completed in December 2000, characterized the industry, and developed a financial and activity baseline and an initial forecast. Phase II, completed in 2002, centered on the identification and assessment of the end users of remote sensing and geospatial information products. Phase III focused on validating the results of Phase I and II and delivering an updated technology and market assessment, especially given the potential impacts on the industry following the terrible events of September 11, 2001. Post-Phase III (Phases IV and on) activities will center on developing a revised market forecast and standardizing methods for continuing the rolling forecast.

> ***"Industry members hold an optimistic view of future industry growth, estimating that it will increase by 9 to 14 percent per year."***

The industry is undergoing rapid change as technology improves and potential clients realize the benefits of using geospatial data and analytical technologies for their information needs. In 2001, the industry gained estimated revenues totaling $2.4 billion, not including sales of satellite systems and aircraft platforms. Based on the 2000 and 2001 surveys of gross revenue, the industry currently appears to be growing at rates of between 9 and 14 percent per annum. Phase III of the forecast assessed the effects of September 11, 2001 on industry growth. Consistent with the contraction of the U.S. economy since 2001, study respondents reduced their growth projections in Phase II to 9% over the next few years (from 14% in Phase I).



Survey responses revealed that most firms in the industry are relatively small (< 100 employees) and focused on providing specific, narrowly defined services or data. By contrast, the few large firms (greater than 500 employees) generally provide a wide range of services. Most of the civilian remote sensing industry involves the provision of mapping and engineering applications needed by governments at all levels. The many smaller firms that under gird the industry are less inclined to support internal R&D and workforce development, are more affected by governmental competition with their services, and are less able to meet foreign competition force-

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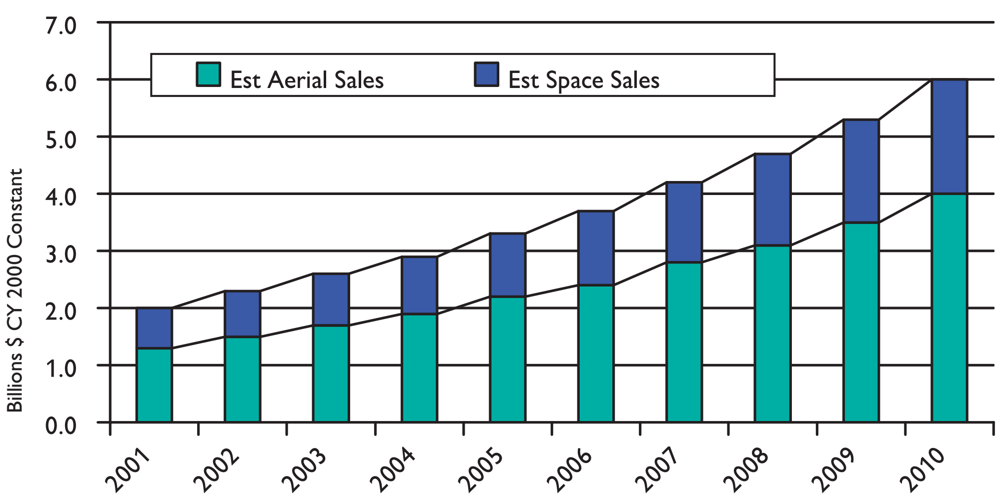
fully. Because of their size, smaller firms generally do not have the financial resources to support a significant amount of R&D.

> ***"...the introduction to the market of high-resolution satellite imagery has enhanced, rather than undercut, sales of data..."***

Over the past decade the commercial remote sensing industry has experienced significant technological change and improved market penetration. New sensor technologies, both in aerial and space systems offer myriad new information capabilities.

The development of high-resolution commercial satellites (better than 1 meter black and white and 2.5 meter multispectral) has opened new data and new collection methodologies to the ultimate information customer. In response, in part, to competition from satellite remote sensing, the aerial industry has also developed new methods of capturing geospatial data in computer-friendly digital form. Initially, some analysts believed that satellites would usurp aerial's market share, but this survey shows that both segments are growing and augmenting each other. In several cases, satellite and aerial data producers have formed strategic partnerships to enhance each others' market opportunities.



> ***"...opportunities for private firms and academia are tightly coupled with the information needs of all levels of government."***

Federal, state, and local governments participate in the remote sensing marketplace by purchasing data and services and by providing research and development (R&D) funding. Government agencies constitute the largest single class of customers for data and services. They also hire analysts with skills in RS/GIS. Industry interactions occur primarily business-to-business and business to government, with minimal direct interaction with citizen consumers. As a result, the private sector is heavily influenced by governmental involvement in the marketplace.

Much of the civilian R&D for both government and private sector takes place in academic institutions. The future workforce for the industry depends on the viability and responsiveness of the academic community to the rapidly changing technological developments and skill needs of the industry.

> ***"Federal government policies...have had a major influence over the development of the market for remote sensing data, new technologies and other applications within the geospatial industry."***

Federal government policies, developed and refined over the years, have had a major influence over the development of the market for remote sensing data, new technologies and other applications within the geospatial industry. Conversely, inconsistency in governmental policy has introduced extra uncertainty and risk for the industry.

Federal funding has developed the basic technologies for all forms of satellite remote sensing and contributed markedly to the development of advanced airborne instruments, such as light detection and ranging (LIDAR), interferometric synthetic aperture radar (IFSAR, INSAR), and hyperspectral digital sensors. For stated reasons of national security, the federal government has limited the development of high-resolution civilian satellite sensors and maintained sharp boundaries between the technology developed for national security and civilian uses.

In the early 1990s, more liberal federal policies began to promote the use of satellite data for a wide variety of uses. As government at all levels is the primary purchaser of data, the price and licensing of data are key issues evolving in the private sector, especially in the satellite domain. Inconsistent, or highly variable, governmental policies are particularly worrisome because they introduce an extra element of risk for industry, especially for satellite data firms. In order to stay in business, these firms need supportive governmental policies that allow them to recoup the massive investments they have made in modern satellite technology. By comparison to the satellite segment of the industry, the aerial market is very large, and has a profitable, more assured business model. On April 25, 2003, the White House issued a new commercial remote sensing policy that further eased previous restrictions on the commercial collection and sale of satellite remotely sensed data. Among other things, the new policy provides guidance for establishing a "long-term, sustainable relationship between the United States Government and the U.S. commercial remote sensing space industry".[1]

Phase III results regarding the real and potential effects of the attacks of September 11, 2001 on governmental policy indicate that increased restrictions on the public availability of geospatial information have had a negative effect on organizations producing geospatial data and information, especially in data export, airspace restrictions and data purveyance to the public. The user community, primarily civilian government and private sector, cited little change in 2002 and anticipated minimal impacts in the future.

Many recognize that keeping data prices low and eliminating data-use restrictions for government-supplied, low and moderate resolution satellite data, has helped to stimulate the commercial market while providing a public geospatial infrastructure meeting many data needs. The prices charged for commercial satellite data products must recover the costs of developing, building, and operating the satellite system, just as they must for aerial data services. Increased resolution, position accuracy, and other capabilities increase the utility and value of data to the customer. Nevertheless, many educators expressed considerable anxiety about future access to data, not only with respect to funds to acquire data, but also the right to use and share new, advanced data with few restrictions. The federal government could assist the academic community to improve its research capacity and the development of more efficient ways to apply improved data by underwriting more of the data costs for research and education.

In some disciplines, government agencies may compete with commercial entities in the provision of data and services. Some commercial suppliers of data and value-added services voiced strong concern about perceived government competition with these suppliers. In order to foster industry development and growth for the benefit of the United States, it will be important for government at all levels to avoid unnecessary competition with the private sector.

"The development of a capable workforce is of major concern for continued industry growth...Lack of retention of entry level workers is hampering the long term health of the industry."

Governmental and private sector leaders declared a strong need for properly educated and trained entry-level employees. This need has become more pronounced as market growth has increased and much of the workload has shifted from the government to the private sector.

In interviews, corporate officers cited the shortage of trained workers emerging from educational programs and the lack of the required skill sets among many of the graduates. All sectors agree that an educated workforce is critical to the continued growth of the industry and increased utility of geospatial information to the economy.

[1] White House, "U.S. Commercial Remote Sensing Policy," Fact Sheet, April 25, 2003.

Most RS/GIS programs in the U.S. are offered in departments or colleges of geography, natural resource management, forestry, and civil engineering. Other disciplines offer individual courses in RS/GIS, but these three disciplines provide the homes for most instructional programs of multiple, integrated courses. These academic programs are small and cannot adjust rapidly to new advancements taking place in the industry. Further, as noted earlier, the smaller firms generally have limited resources for additional on-the-job training to compensate for any educational deficiencies in new staff.
As the industry expands and changes, meeting industry needs will require increased funding for RS/GIS educational programs, in order to modernize curricula and instructional and research infrastructure (equipment, software, labs) and to retrain faculty in newer sub-disciplines and technologies. Educators must themselves deliver new, integrated curriculum programs to meet future needs.

Certificate programs (non degree, supplemental programs) are gaining increased acceptance in the educational community. These programs provide a means for disciplinary specialists to retool their knowledge and skills to take advantage of the geospatial information revolution in their disciplinary areas without committing to a multi-year degree program.

It will be necessary to raise the status of the field of geospatial information in the larger educational framework in order to achieve continual support within university administrations. Such support is required to meet future information demands, to have properly prepared K-12 students who have knowledge of RS/GIS upon entering college, and to attract and support quality graduate students.

The study also revealed concerns over the retention of qualified employees. Phase II showed that the age structure of workers in the industry follows a bi-modal distribution, with most either older, experienced workers or younger employees, new to the industry. There are relatively few in the mid career range. These data suggest that many younger employees are leaving the industry for better opportunities, potentially creating a shortage of mid-level personnel. The reasons for this trend are not clear. However, because many industry employees earned degrees outside of remote sensing and GIS, they may feel drawn to accept positions in their original fields of interest in the broader information industry (such as computer science) when such positions become available, thus contributing to the exodus.

"The development of new analytic methods and new geospatial technologies will lead to future growth,... Data customers especially desire higher resolution and improved positional accuracy."

Phase I of the study revealed ample opportunities for growth in diverse market segments. Although mapping, civil government, national defense and global security applications of geospatial data/information currently dominate the market, the needs of local and state government for homeland security, environmental assessment, and infrastructure applications are substantial and are likely to increase.

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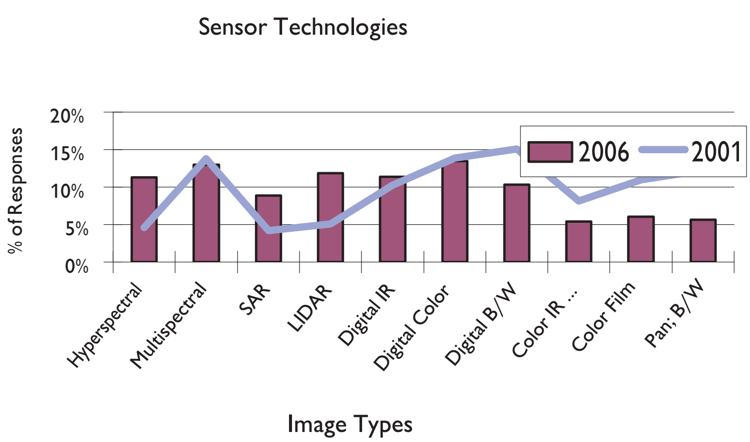
Smaller firms are attempting to provide specialized value-added services on both satellite and aerial products to meet customer needs. Further, the use of both aerial and satellite data is increasing. Hence, the industry appears to have opportunities both for a greater number of firms and continued growth among diverse markets. For example, industry gains only a small portion of revenues from certain business activities with strong geospatial requirements, such as real estate and insurance. These businesses could bring future market opportunities if geospatial information can be tailored to their special needs and potential customers are educated in using such information effectively.

In aerial remote sensing, the transition to digital sensor technologies, some capable of direct geo-registration and elevation collection has opened up new markets for urban mapping and infrastructure inventory and analysis. In general, sensor technologies have increased in diversity and improved in capability during the past two decades. Digital aerial cameras coupled with inertial measurement and onboard GPS enable the low cost acquisition of geopositioned information, which will assist in opening new markets, especially where pricing has limited acceptance of remotely sensed information.



Data users are evaluating the replacement of multispectral data with hyperspectral data. Growth will be seen in the key areas of hyperspectral, SAR (IFSAR), and LIDAR for aircraft, especially as sensor systems evolve that provide low cost, broad area coverage. Hyperspectral sensor systems in development will offer automated feature detection, identification and classification. Markets as diverse as defense, precision agriculture and forestry all benefit from change detection technology. The elevation component of remote sensing from IFSAR and LIDAR sensors also provides high growth potential. These systems can provide data to create highly accurate digital elevation models (DEMs) to markets in need of superior geopositioning and terrain information.

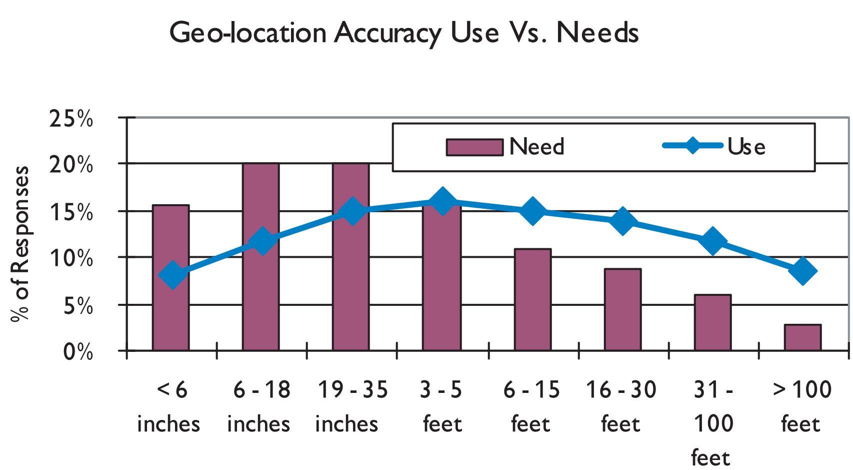
Factors beyond the remote sensing industry further play into data utilization, which affects industry capabilities. While computers have kept pace with increases in resolution and data processing, not all levels of users can keep up with these advances. Improvements in resolution often require users to invest in costly improvements both in data storage and data networking.

Further, issues of high data cost, delays in acquisition, and licensing of data sales may inhibit adoption of these data by users. Continued industry growth will only occur with the implementation of improved technology and government policies that support geospatial research and development in a number of disciplines.

Phase II evaluated the customer's data needs by undertaking a detailed requirements analysis of "use versus need" as a function of multiple user types. Data characteristics included Ground Sample Distance (GSD), Geopositional accuracy, data layers, elevation accuracy and data timeliness. While all are important to the remote sensing industry, small GSD and high geopositional accuracy are critical. Neither the needs of the academic data customers nor those of governmental data customers are being met at sufficiently high levels of accuracy.

Forecast data imply that data users desire resolutions smaller than three feet (0.9 m). GSDs such as these provide key details of object content and characterization. Data sets may be used to assess urban infrastructure or for high accuracy mapping. Further, they can be used to delineate details in the environmental, forestry and agriculture segments. High-resolution imagery over broad areas requires high levels of data storage, which will require improvements in computer storage capacity and access speed. Geospatial data and information users desire improved geopositional accuracy, signifying market opportunities for firms interested in achieving more stringent geo-positioning. Direct geo-registration techniques have increased data collection firms' ability to achieve improved positioning, but additional R&D will be required to reduce costs and improve market penetration of high accuracy techniques.

Overall, the remote sensing industry is growing, though supportive government policies will be needed to foster continuing growth. There is a tight coupling between the commercial, government and academia in this highly fragmented industry. New technologies, data and sensors from air and space are fostering growth. However, limited workforce availability, as well as inconsistent federal policy on data holdings, technical restrictions and exports, limit industry growth.



2 Introduction to the Remote Sensing Industry Forecast

2.1 Forecasting the Size and Growth of the Civilian Remote Sensing Industry

In August of 1999, the National Aeronautics and Space Administration (NASA) and The American Society for Photogrammetry and Remote Sensing (ASPRS) agreed to undertake a comprehensive study of the remote sensing and geospatial information industry in the United States. Their ultimate goal was to develop a continuing forecast of the remote sensing industry. In 2002, the National Oceanic and Atmospheric Administration (NOAA) formally joined NASA and ASPRS to support the documentation and analysis of the forecast. NOAA's goal in the sponsorship of this document is to provide a narrative analysis of the study in order to disseminate information on the state of the industry to its stake holders, the industry and the public at large.

For purposes of this effort, the remote sensing industry is viewed 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. Some 175,000 people are employed in the U.S. remote sensing and geospatial information industry, a rapidly growing segment of the much larger information industry. New technological advancements facilitate the application of remote sensing to many previously unrealized disciplines, from the sciences to myriad practical applications. Prior to this study, few comprehensive data about the industry, and no reliable, unbiased assessments of the industry's future existed. This study is an attempt to remedy these limitations by combining the experience of the talented volunteers of the membership of ASPRS with the knowledge, experience and resources of NASA and NOAA. These organizations are carrying out a continuing forecast of the industry by analyzing and quantifying the key factors affecting it. This report summarizes the study's methodology, analyzes its results, and assesses their implications for the industry's participants.

2.1.1 Introduction To the Industry

A. Industry Components

This industry forecast centers on the use of remotely sensed data in three major components: image-based geographic information systems (GIS), photogrammetry, and remote sensing: Definitions for these components used in the forecast are:

- ***Image-Based GIS:*** A system for capturing, storing, checking, manipulating, analyzing, and displaying raster data from imagery, with vector, textual and attribute data that are spatially referenced to the Earth.
- ***Photogrammetry:*** The uses of image data sets to make measurements of the size, height and location of objects or landforms. As such it includes the science of mapping the topography of the Earth's surface and of locating and measuring the dimensions of objects on the surface.
- ***Remote Sensing:*** Remote sensing is the field of study associated with the extraction of information about an object without coming into physical contact with it. This forecast limits the term to overhead observation of the Earth, with a major emphasis on aerospace-based data acquisition.

This report generally uses the term "remote sensing industry" to refer to any or all three of these image-based components. Throughout this report, the authors have provided historical, technical, and policy context for the remote sensing industry and the forecast.

2.1.1.1 Evolution of Airborne Platforms and Sensors

The market for remotely sensed data began nearly a century ago, shortly after the development of the airplane, when photographers first began to collect aerial photographs acquired from aircraft. The development of precision aerial cameras during World War I made it possible for a number of small companies to offer aerial services for mapping, planning, and general survey. The view from above was unique, giving people an unprecedented overview of the land and water below, and adding another aspect to their ability to plan for development. Government agencies like the Soil Conservation Service and the U.S. Geological Survey (USGS) assisted that development by contracting with firms to provide survey photographs of the earth. The USGS, especially, assisted the further development of precision cameras, using them to generate accurate topographic maps of the entire United States.

World War II led to additional technological developments. Film-based cameras generated thousands of frames of aerial images of enemy installations, which were used by the Army Air Force to gather intelligence and to plan attack strategies. After the war, a number of small companies developed to serve local or regional needs, often staffed by individuals who had learned their craft in World War II. The development of this data market continued to grow slowly but surely. Since World War II aerial photography has become a staple of the remote sensing industry. Hundreds of aerial flying firms currently support commercial, government and educational remote sensing needs worldwide.

Today, the aerial industry as a whole is in the midst of a technological revolution, with large, sophisticated digital sensors flown on a variety of aircraft platforms augmenting the use of photographic cameras (table 1, page 16). The remote sensing industry has never experienced greater diversity in the delivery of useful geospatial data to a broad variety of customers with many different geospatial applications. The evolution in digital technology has led to a suite of sensor options, including: panchromatic, color, color IR, multispectral, hyperspectral, LIDAR, and synthetic aperture radar (SAR and related technologies IFSAR). In this era, companies still use the twin-engine aircraft platform to perform most data collection.

Light aircraft are nevertheless used increasingly as small format digital imaging gains in favor. They are often cheaper and more flexible to operate than the twin-engine aircraft. Helicopter platforms are also used, as they are ideal for detailed evaluation of point targets or for corridor data collection that is difficult for fixed wing aircraft.

Some sensors are better suited to light jet aircraft. Small jets provide benefits of weight capacity, power, and broad area coverage not feasible with their slower propeller-based brethren. Synthetic Aperture Radar (SAR) sensors, capable of broad area coverage, may be flown cost-effectively on light jets. Finally, Unpiloted Airborne Vehicles (UAVs) now under development for military and civilian use may soon provide alternative means of carrying some cameras, especially in areas where access is denied or where pilot risk is especially high.

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Table 1 Matrix of Primary Aircraft Sensors and Platforms

Aircraft Platforms	Sensors
Single Engine Fixed Wing	Aerial Film (Color/Pan/Extended Red/Near IR)
Twin Engine Fixed Wing	Framing/Scanning/Linear Digital (Color/Pan/Extended Red/Near IR/Thermal IR)
Short Take Off & Landing Fixed Wing	Multispectral (greater than 4 channels)
Rotary Wing	Hyperspectral (hundreds of channels)
Jet	Light Data and Ranging (LIDAR)
Unmanned Airborne Vehicle (UAV)	• Synthetic Aperture RADAR • Passive Microwave • Other (Magnetometer, Short & Mid Wave IR, etc)

2.1.1.2 Satellite Sensors and Platforms

In contrast to the multiplicity of sensors and platforms of the aerial marketplace, only relatively few satellites yet offer data on a commercial or cost of distribution basis (table 2). These have nevertheless made significant inroads into the market for remotely sensed data. Satellites began delivering digital data for civil use in July 1972 when the National Aeronautics and Space Administration (NASA) launched the first of the series of Landsat satellites. Landsat 1[2] carried the 80-meter resolution multispectral scanner (MSS) and a television camera. NASA had prepared ahead of time by extensively testing a prototype instrument aboard aircraft. It also funded the development of image processing software and the laboratories necessary to turn the raw imagery into useful information about land cover and land cover change

The MSS delivered data in digital format, suitable for direct analysis in computers. Thus, these data had a clear advantage over photographic imagery, as they could be immediately ingested into computers and analyzed directly. MSS imagery proved enormously useful for large-scale, regional studies of surface conditions, and for scientific and applied studies of agriculture, forestry, mineral exploration, and rangeland management.

As part of U.S. outreach to other countries, NASA and the Department of State promoted the development of receiving stations around the world. By 1982, 11 countries were collecting Landsat imagery and distributing it to local customers. NASA and the U.S. Agency for International Development (USAID) sent delegations of scientists to developing countries to promote the use of Landsat imagery for resource development and management. Most embassies were given Landsat images of the country to promote the technology abroad. The two agencies also instituted programs focused on training non-U.S. personnel in the analysis of Landsat imagery.

Table 2 Primary Current Satellite Sensors and Platforms

Sensors	Satellite Platforms	Operator
Enhanced Thematic Mapper (One 15 m pan band, five 30 m multispectral, one 60 m thermal)	Landsat 7	U.S. Geological Survey
Thematic Mapper (Five 30 m multispectral, one 120 m thermal)	Landsat 5	U.S. Geological Survey
10 m pan band, 20 m multispectral	SPOT 4	Spot Image, SA.
2.5 or 5 m pan band, 10 m multispectral; 1 km multispectral	SPOT 5	Spot Image, SA
One 6 m pan, 23 m multispectral	Indian IRS	Indian Space Agency
Synthetic Aperture Radar (variable resolution)	Radarsat I	Radarsat, Int.
SeaWiFS (Eight 1.1 km multispectral bands)	Orbview-2	Orbimage, Inc.
One 0.8 m pan band, four 4 m multispectral	Ikonos	Space Imaging, Inc.
One 0.6 m pan band, 2.5 multispectral	Quickbird	DigitalGlobe, Inc.
One 1.8 m pan band	EROS-A, B	ImageSat International
One 1.0 m pan band, four 4 m multispectral	Orbview 3	Orbimage, Inc.

Within the United States, NASA worked with other federal agencies to develop a variety of programs to encourage the use of Landsat data in analyzing U.S. and foreign agricultural production, forestry, and rangeland management. The relatively coarse resolution of the imagery limited such studies to large, relatively uniform land areas. Thus, for example, the U.S. Foreign Agricultural Service (FAS) found enormous use for the data in estimating Soviet wheat production.

Buoyed by the low cost of MSS data (many agencies received data directly for free), the Landsat data market grew steadily throughout the 1970s. However, when NOAA took charge of Landsat operation in the early 1980s in preparation for transfer to private sector operation, in accordance with federal policy concerning the transition, it instituted sharp data price increases, which resulted in a precipitous drop in data sales.[3] A later additional price increase by the private operator, EOSAT, led to a steeper drop in data sales. The data were priced beyond the ability of most science users to pay and commercial use of the data was growing only slowly. Yet the launch of the first French SPOT satellite in 1986 stimulated the data market.

Further, the SPOT satellite was capable of collecting imagery off-nadir, which meant that it could create quasi-stereo images of some regions. Some analysts had predicted that the sales of data from the commercially-operated SPOT satellite[4] would cause Landsat sales to decline even more. However, the interest in SPOT data also sparked an upturn in sales of Landsat imagery.

After deciding that the commercial arrangement for Landsat threatened the continuity of data supply, and that the commercial sector needed policy changes to make it more viable,[5] Congress passed the Land Remote Sensing Policy Act of 1992. The Act brought the future Landsat 7 under government operation and control and promoted the commercial development and operation of remote sensing satellites.

This development led to major changes in the way in which Landsat 7 data were acquired and sold after the satellite was launched in April 1999. Officials of NASA and USGS, which operate the satellite, developed a plan to gather as much data as possible and to make processed scenes available quickly after acquisition. USGS is now able to capture scenes in each of the four seasons over most of the globe's land surface and coastal regions, developing an unprecedented data set capable, among other things, of revealing regional and global patterns of land use and land change.

During the late 1990s, enabled and promoted by licensing regulations developed by the Clinton administration, high-resolution U.S. commercial satellites began to come into their own. At the present time, both Space Imaging and Digital Globe are operating polar orbiting satellite systems, capable of collecting panchromatic images of 1-meter resolution or better. On June 26, 2003 Orbimage also launched a similar system.

The beginnings of a nascent market for satellite data and digital sensors also supported the creation of airborne multispectral scanners and synthetic aperture radar sensors. These developments have assisted the aircraft data market in growing along with the market for remotely sensed satellite data, competing in some markets, but generally complementing the growing use of satellite data and providing greater flexibility for the data customer.

Two other streams that influenced the development of the remote sensing market were the concurrent development of geographic information systems (GIS) software and the use of small, powerful computer workstations, and eventually, the personal computer. The operational deployment of the Global Positioning System (GPS) in the early 1990s, added another important element in the utility of remotely sensed data by making possible the accurate measurement of geographic positions quickly and easily in the field.

2.1.2 Forecast Mission and Method

The ASPRS/NASA/NOAA 10 Year Industry Forecast is designed to determine the future of the remote sensing industry as a function of core industry sectors, supporting technologies, and industry practices.

Mission Statement

> Within 5 years, the joint ASPRS/NASA/NOAA team will produce a cohesive, comprehensive remote sensing industry analysis to serve as the planning standard both for the U.S. Government and private industry and to facilitate continued U.S. strength in this highly competitive international market.

The forecast uses a model similar to industry forecasts by the Government Electronics and Information Technology Association (GEIA). In the electronics industry, which is composed of many large aerospace and defense firms, corporate donations of funds and individuals provide the resources needed to characterize the current state of the industry and forecast the industry's growth/change over a ten-year period. This model was adapted to the remote sensing industry by a forecast team led by NASA and ASPRS. Initially, an Integrated Product Team (IPT) team of volunteers from ASPRS and staff from Stennis Space Center met to develop the study approach outlined below. Volunteers from many private firms, governmental agencies and universities were enlisted to carry out the plan (table 3, page 18).

Beyond the ASPRS, NASA and NOAA, other professional organizations, over 20 private firms, several governmental agencies and academic institutions have actively participated in the study (table 4, page 18). All of these groups have donated their support in the belief that the forecast will benefit the industry.

The team soon learned that the remote sensing industry did not correspond to the electronics industry in several key areas, necessitating changes in the implementation of the plan. Unlike the electronics industry which has several large firms, the remote sensing industry is composed of numerous small firms unable to provide voluntary funding and personnel to undertake the forecast project. Further, the governmental and academic sectors represent a much greater influence in the direction of the remote sensing industry

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[2] Landsat 1 was originally called Earth Resources Test Satellite (ERTS-1). The name was later changed to Landsat.

[3] See Ray A. Williamson, "The Landsat Legacy: Remote Sensing Policy and the Development of Commercial Remote Sensing," *Photogrammetric Engineering and Remote Sensing*, Vol. 63, No. 7, July 1997, pp. 877-885.

[4] The development of the SPOT system has been funded by CNES, but the system is operated by the private company SPOT, SA, incorporated in France. CNES is a major stockholder in the company.

[5] Ray A. Williamson, op. cit.

continued from page 17

Table 3 Components of the Forecast Plan

I: Preparation	• Decide on Mission for Forecast Project • Assemble & Organize Study Integrated Product Teams (IPT) • Define RS Industry, Determine Purpose and Focus of Analysis • Select Market and Business Segments for Analysis • Formulate Study Objectives
II: Planning	• Activate Area of Interest IPTs-Develop Report and Presentation Outlines • Develop Study Plan • Identify Data Needs and Develop Collection Methodology
III: Execution of Plan in Phases I-IV	• Collect & Analyze Data • Identify Opportunities • Develop Conclusions & Recommendations
IV: Reporting and Dissemination of Results	

Table 4 Forecast Participants

NASA	Pictometry	University of Utah
NOAA	LMSO	George Washington University
ASPRS	Space Imaging	University of Arizona
NSGIC	Kodak	University of Missouri
MAPPS	SPOT Image	Rochester Institute of Technology
USGS	EarthData	
	PAR	
	Autometrics	
	Spencer-Gross	
	American Forests	
	RAND	
	Leading Edge	
	Geomatics	
	Eaglescan	
	Landcare Avn.	

than in the electronics industry. Therefore, rather than being able to rely primarily on support from a consortium of large commercial firms, the project relied on direct financial support from NASA and NOAA and significant volunteer support from the membership of ASPRS and other organizations to complete the project. [6] USGS recently joined the project to assist in Phase IV.

By the end of fiscal year 2004, ASPRS, NASA, NOAA, and the USGS expect to have jointly developed a process that:

- Enables a Continuing Broad-based Analysis of the Remote Sensing Industry
- Creates a Financial and Activity Baseline of the Industry
- Presents a 10-year Business Forecast
- Disseminates the Forecast Information

Components III and IV of the forecast plan involve the creation of the baseline and the forecast and are composed of multiple phases, I-IV. Phase I, which was completed in December 2000, characterized the industry, developed a financial and activity baseline and an initial forecast. Phase II, completed in 2002, focused on the identification and assessment of the end users of remote sensing and geospatial information products and their needs. Phase III centered on validating the results of Phase I and II and delivering an updated technology and market assessment, especially given the potential impacts on the industry following the terrible events of September 11, 2001. Post-Phase III activities will concentrate on developing a revised market forecast and standardizing methods for continuing the rolling forecast.

3 Phase I – Baseline Forecast

3.1 Phase I: Objectives

Phase I of the Forecast attempts to:

- Define commercial market projections
- Project educational and workforce demands
- Define R&D trends and opportunities
- Ascertain policy, standards, and certification issues affecting market growth
- Define influences of new business models (e-commerce and internet access)

In addition, the Forecast attempts to probe issues of cause and effect:

- By sector, what customer requirements are not being fulfilled?
- How can the remote sensing industry better meet the needs of a given sector?
- By disciplinary area, how can colleges better prepare students for employment?

The Phase I information collection used four approaches to meet the forecast objectives (figure 1):

- Research and assessment of existing literature and studies of the remote sensing industry;
- An internet survey polling membership of ASPRS (sustaining and general) and other groups;

[6] For more information, review the ASPRS website, www.asprs.org/news.html or contact the authors.

- Direct interviews at annual meetings of ASPRS and other large gatherings of professionals in the geospatial industry; and
- A "closed envelope" gross revenue survey administered to corporate CEO's and CFO's.

Each of the collection approaches was conducted independently to provide information that could be cross-validated. The surveys and interviews were conducted in a non-attributable manner to achieve accurate and reliable results. The Phase II forecast added a focus group to the strategy in order to diversify further and to verify the validity of the information gathered.

The survey was administered via the internet to over 3700 individual private sector, government, and academic members of ASPRS and other organizations. A total of 437 respondents provided data. Project volunteers conducted a series of direct interviews (total of 48) with primary corporate officers and government managers using a prescribed methodology and list of questions.

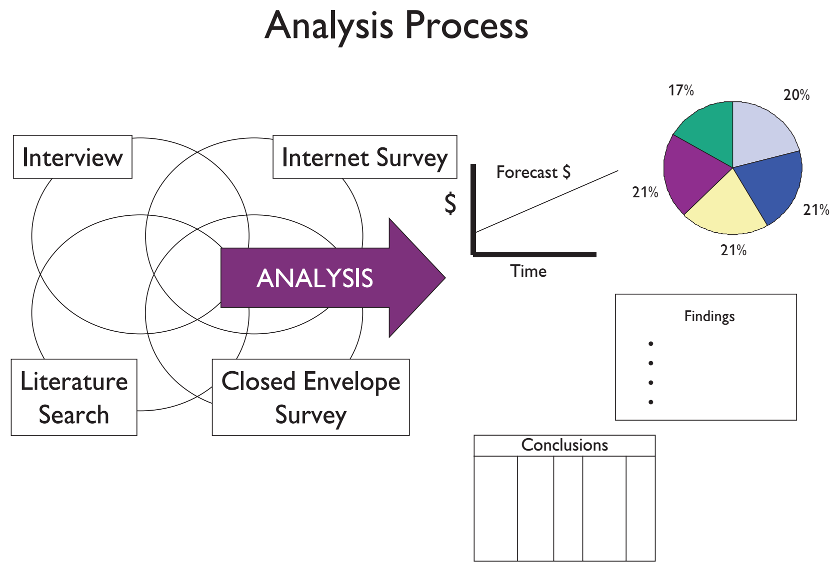

Figure 1 Forecast Process

Finally, volunteers conducted a closed-envelope gross revenue survey of financial information by querying financial officers in 45 private firms, ranging in annual sales of $400,000 to $120,000,000. This survey asked this sample group of firms to estimate the sales of their companies in the two years past (1998, 1999), the current year (2000), the next year (2001) and two out-years (2005 and 2010). This gave the survey a solid base of two and one-half years of recent financial history.

The key step in this process is that the information derived from the research and literature survey, interviews, electronic survey and closed envelope survey was analyzed by industry professionals to develop an interpretation of these data and information within the context and dynamics of the remote sensing industry. This penetrating and informed look at a broad set of data in this manner is the basis for the outputs of this study that support decision making and policy.

3.2 Phase I Implementation

The first task of Phase I was to define the entities, activities, and relationships to be analyzed within the remote sensing industry (figure 2).

- ***Data Collection:*** Providers of a service generating raw or level 0 unprocessed data sets in either analog or digital form.
- ***Data Processing:*** Providers of services generating processed or "value-added" data sets. This included, but was not limited to, correction of radiometric, spatial, dead channel errors, geo-positioning, rectification, and photogrammetric interpretation (analog and digital).
- ***Support hardware and systems:*** Providers of hardware components or systems utilized in the processing of remotely sensed data. Vendors here provide hardware or systems employed by the data processing services. Functions may include data recording, manipulation, viewing, and distribution. Hardware and hardware systems for data scanning, vectorization or rasterization are included under this heading.
- ***Software:*** Providers of software components employed in processing, analysis, or adding value to remotely sensed data. Vendors here provide software utilized by the data processing services. Functions may include data recording, manipulation, viewing, and distribution. Software for data scanning, vectorization or rasterization are included under this heading.
- ***Industry Intermediary***: Value Added Resellers (VARs) add additional value to data sets prior to resale. This may come in the form of addition or modification of data layers from data collection and processing providers. VARs do not simply pass data

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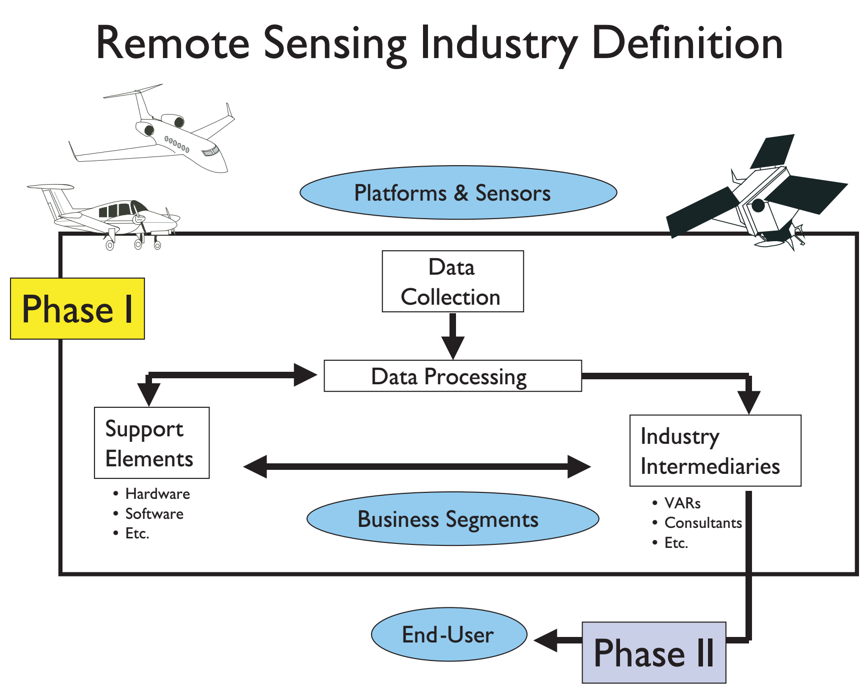

Figure 2 Remote Sensing Industry Definitions

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through from collector to user but add value to the product through data analysis or incorporating additional information.

- ***Consultants***: Consultants add value to data sets by linking provider to end-user. They may provide guidance to clients in optimizing remotely sensed data use. They may help specify data sets for projects. Consultants generally do not provide extensive data reprocessing.

The Integrated Product Team (IPT) excluded satellite systems and aircraft platforms from the Phase I study because their high cost would skew analysis of industry sizing. Phase I therefore *excluded*:

- Platforms and Sensors
- Manufacturers of aerial or space data collection platforms and sensors.

3.3 Phase I Forecast Framework

For the Phase I, the IPT further segmented the industry into large, yet manageable components. These components form the cube defined by market sectors, market segments, and business segments, and their respective sub-elements as shown in Figure 3.

By segmenting the industry in this manner the team hoped to develop a useful baseline that could be queried to answer many of the users' questions regarding:

- Research Requirements & Opportunities
- Training, Education & Employment
- Industry Trends & Influences and Market Growth & Projections
- Supporting Technologies
- Core Technologies (GIS, R/S, Photogrammetry)
- Integration Opportunities
- Advancing Industry Practices

The Forecast framework allows individuals to assess the status of their unique areas of interest and includes market segments chosen on the basis of both historical and projected future areas of interest. Market sectors include: government, commercial/not-for-profit organizations, and academia. The categories of business segments provide for the possibility of extracting further detailed information about the industry.

4 Phase I results (Commercial, Government, Academic Sectors)

4.1 Phase I Survey Population and Response Size

As noted above, the forecast included four independent data collection elements: literature research, survey, interviews, and closed-envelope survey. The literature research focused on review of existing materials, annual commercial surveys and publications.

The membership of ASPRS reflects a broad spectrum of geospatial industry professionals, distributed among government, academia and the commercial sector. Therefore, the Society's membership was selected as the primary target for the survey sample. The internet survey was administered to an ASPRS membership of 3708 potential respondents (table 5).

As shown in columns 1 and 3 of Table 6, 437 or approximately 12% of the ASPRS membership responded to the Phase I online survey. This is considered a reasonable and statistically significant sample. Of these responses, 13% work in commercial and government sectors and 7% in academia. In assessing the responses of Phase I governmental employee respondents, the reader should consider the fact that the response from federal sector employees is much larger than the number of state, local, and regional governmental users.

4.2 Phase I Commercial Sector Results Phase I

4.2.1 Commercial Segment

The commercial focus of Phase I of the forecast was on the imaging and geospatial components within the industry. Online survey respondents were asked to identify the geospatial activity representing the primary business of their organization, whether image based GIS, photogrammetry, or remote sensing.

Figure 4 shows that 44% of the respondents considered photogrammetry as their core activity within the industry, followed by remote sensing (31%), and image-based GIS (25%). In addition, based

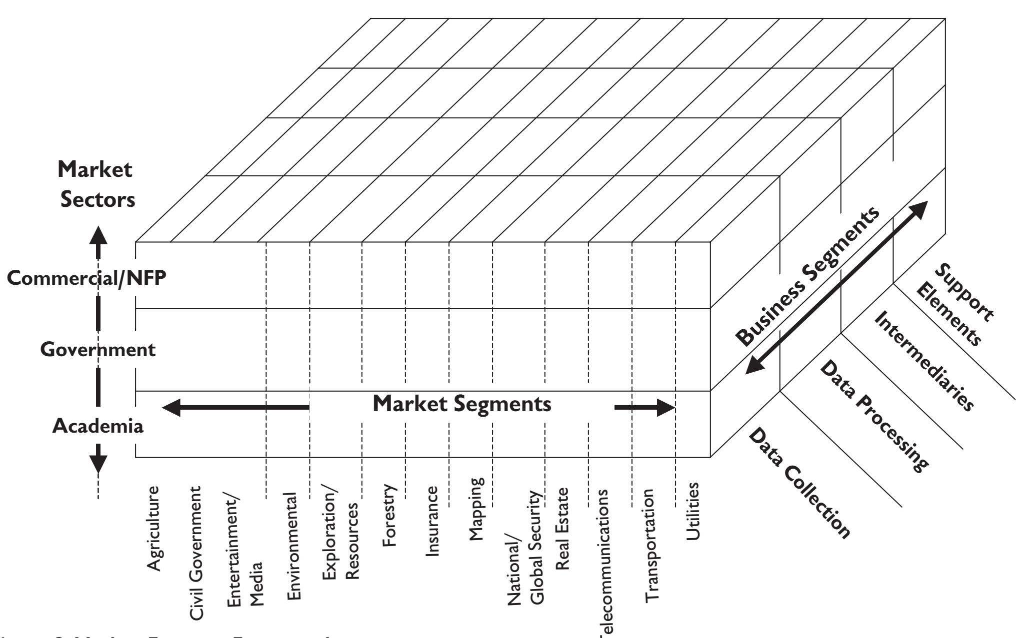

Figure 3 Market Forecast Framework

Table 5 Internet Survey Respondents

Academia		**370 (23%)**
‣ Education and Academia		
Government		**489 (31%)**
‣ City, Town, and Local	18	
‣ County/Regional	38	
State/Province	89	
Federal/Civil	290	
Federal/Defense, Intelligence	54	
Commercial		**724 (46%)**
‣ Private Industries	306	
‣ Private Practice/Consulting	406	
‣ Public Utilities	12	
		1583
The sample also included:		
Other	155	
Retired	44	
Employment (not specified)	1926	
Miscellaneous		2125
Total		**3708**

on other results, approximately 20% of respondents stated that their operations covered all three activities.

4.2.2 Markets Served by Segment

Using a question that provided 14 options, respondents were asked in which market segments (up to 3) their firms participated. Of these segments, four (mapping, civil government, environmental, and national/global security) consistently ranked as the most served regardless of the activity (image based GIS (figure 5, page 22), photogrammetry (figure 6, page 22), and remote sensing (figure 7, page 22)). Interestingly, these same market segments were cited as the most relevant in the cross-validating process using the CEO Closed Envelope Survey and the Phase I interviews.

Each market segment is further known to have unique data needs. Environmental, Agriculture, Forestry, and Exploration require imaging on a seasonal basis, especially in the extended red and infrared portions of the spectrum. They may further require multispectral or hyperspectral band segmentation for detailed target classification and identification.

The remaining market segments are likely opportunities for industry growth. As digital data proliferates and becomes easier to use, so does access to remotely sensed data. If an effort is made to determine the unique data needs within the smaller market segments, cost effective solutions to needs within these segments will provide a basis for growth. Coupled with continued integration with GIS, growth of image-based GIS, photogrammetry, and remote sensing in all market segments is likely.

Market segments experiencing previous high use have recently benefited from the introduction of high-resolution satellite data sources, as well as GPS/Inertial Measurement Unit (IMU)-based aerial collection systems. Both have increased access to data and reduced end user costs. The use of remotely sensed data in the real estate and entertainment segments, which already employ some of these data, will potentially grow as data prices drop and data types proliferate. Improving market penetration will depend, in part, on improving resolution and providing geospatially corrected data.

Phase III of the industry forecast is used to validate previous findings and to provide a detailed needs assessment by market segment. These details on market segments will be discussed later in the Phase III discussion of this report.

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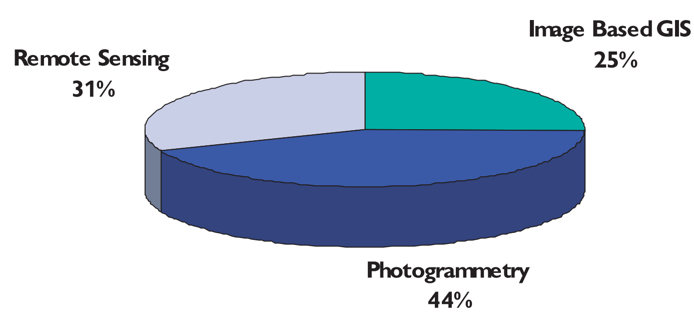

Figure 4 Commercial Segment Focus

Table 6 Phase 1 Internet Percent Member Surveyed

Sector	ASPRS Members Surveyed	% of Total ASPRS' Membership Surveyed	Sample Size (Respondents)	% of Total Sample Size	Sample Size as % of ASPRS Members Surveyed
Commercial/NFP	1701	46%	227	52%	13%
Government	1148	31%	149	34%	13%
Academia	859	23%	62	14%	7%
Totals	3708	100%	437	100%	12%

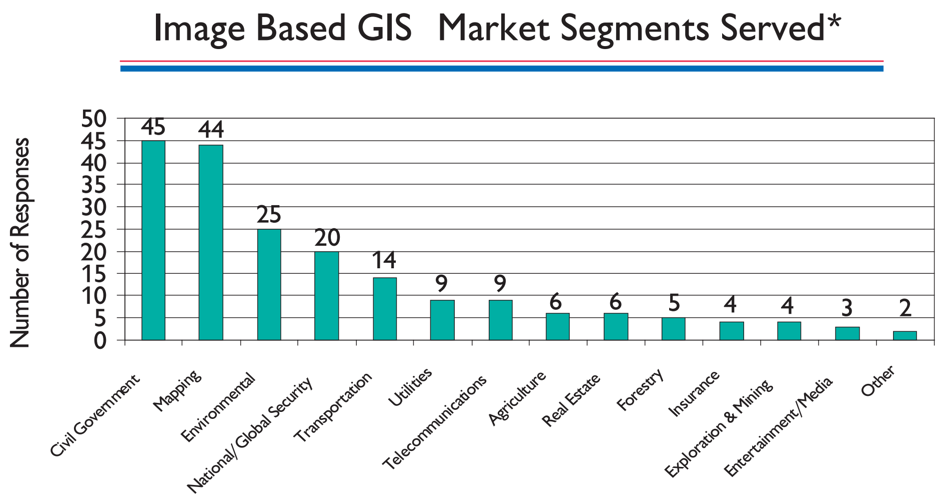

Figure 5 Image Based GIS Markets Served

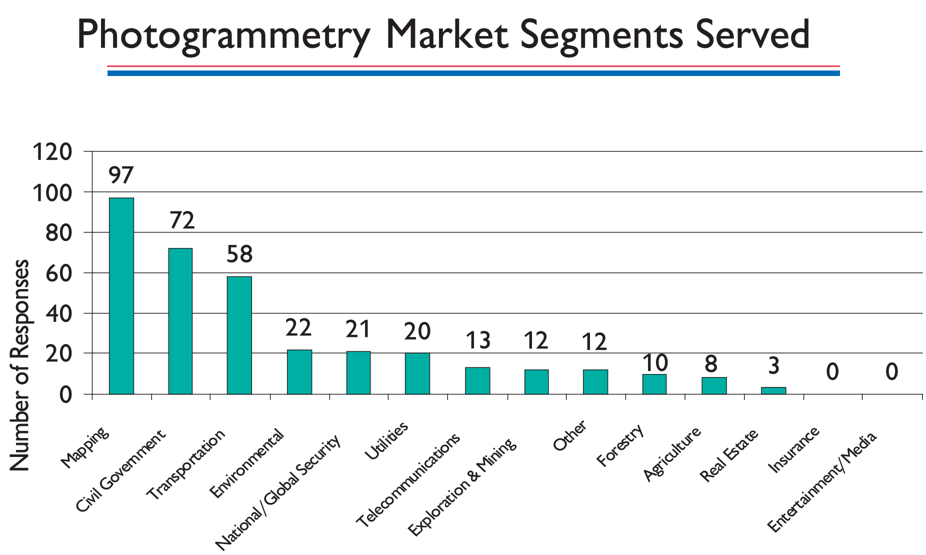

Figure 6 Photogrammetry Markets Served

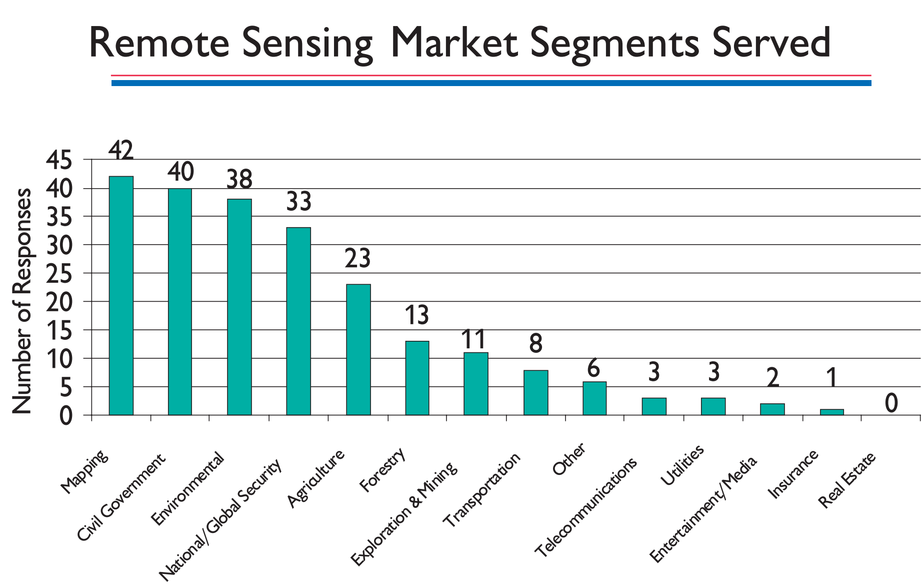

Figure 7 Remote Sensing Markets Served

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4.2.3 Geospatial Sales Projections

Credible projections of market size and growth are critical to understanding the direction of the industry (figure 8). Hence, the team initiated the closed envelope survey to support the online internet survey and interview activities. In addition to 48 Phase I interviews, 150 non-attributable closed envelope surveys were sent to CEO/CFO's within the industry, of which 45 responded.

Electronic survey and interview respondents were asked to estimate sales from 1998 to 2001 in (year 2000 dollars) Since the data collection took place in 2000, it can be assumed that the 1998-2001 estimates are a very solid baseline for the forecast.

In addition, respondents were asked to estimate the percentage growth expected in sales between 2000 and 2005, then again to 2010. From these data points the team constructed the graph in figure 8, using the average annual growth rates to fill the gap years.

The closed envelope sample of 45 CEO/CFOs were used to verify the sales projection estimates. These values along with other forecast results from the literature compared to our estimates within a range of 10% plus or minus. Such a range is acceptable given the variations in approaches used for the estimates.

4.2.4 Sales of Data Acquired Through Aerial and Space Platforms

With the development of high-resolution commercial remote sensing satellites, some industry observers believed that satellite data suppliers might substantially erode the market share captured by companies that specialize in aerial data collection. However, the analysis reveals that both segments are growing and augmenting each other (figure 9). Key to understanding this trend comes in the evaluation of user data needs in Phase II of survey, which performed a detailed requirements analysis of "use versus need" as a function of user types (see the later Phase II sections).

4.2.5 Employees by Geospatial Activity

The internet survey and interviews indicate that geo-spatial industry in the United States is composed of numerous firms, ranging in size from a few employees to hundreds. As shown in Table 7 (page 24), about 85% of the firms 100 employees or less, of which an average of 20-25 employees are geo-spatial professional or technical personnel. This reveals a strong fragmentation within the industry.

Smaller firms often foster relationships with state and local customers, while the larger firms are more closely associated with meeting the needs of larger federal governmental customers. Small firms often focus on a single market segment. These firms support unique vertical markets or specific functions within data capture, processing, and information production. They often provide value added engineering services for data sets targeted at a vertical application, which ties them closely to economic fluctuations in a particular market and makes these small firms more vulnerable than their larger, more diverse brethren.

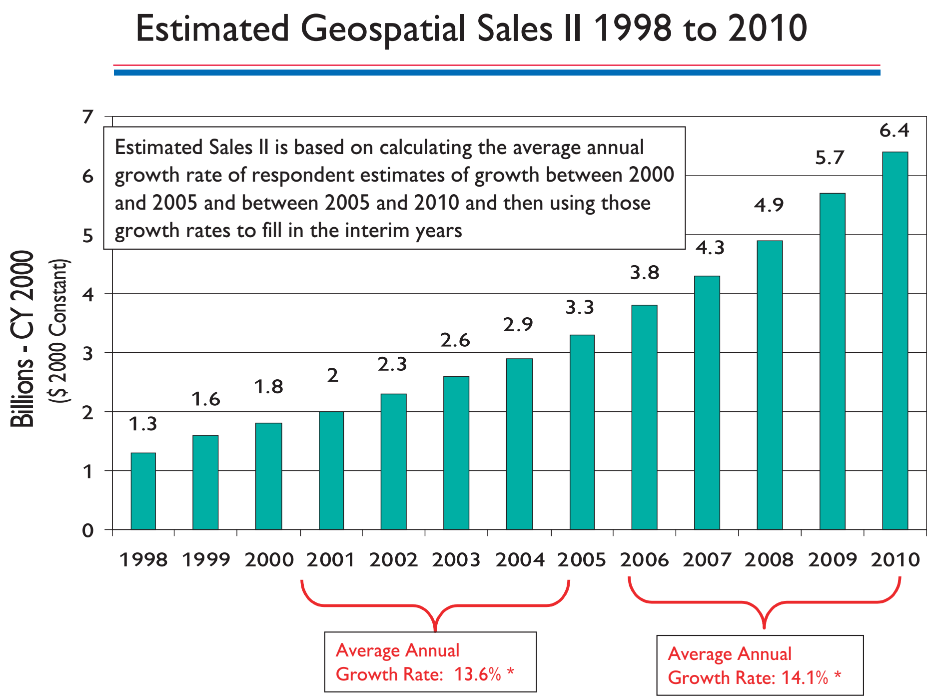

Figure 8 Geospatial Sales 1998 to 2010

4.2.6 Academic Output versus Industry Needs

The upper left portion of Figure 10 (page 24) indicates the estimated number of degrees granted and expected by discipline by the academic respondents to the internet survey. The lower right graphic displays the job titles most sought after by private sector respondents as of 2000.

As a result of the size and mix of skills required, challenges clearly exist in hiring in certain areas. Academic programs in photogrammetry, imaged based GIS, and remote sensing are not commonplace. This causes a difficulty in hiring employees with these skills. Individuals trained in applications development, GIS, cartography and software development are clearly at a premium. Many firms within the industry, regardless of market sector, require these skills. In most cases, firms can find staff with a subset of these capabilities. Rarely, however, does the academic community train individuals to fulfill the entire skill set required. Firms must train employees to meet rapidly changing corporate needs.

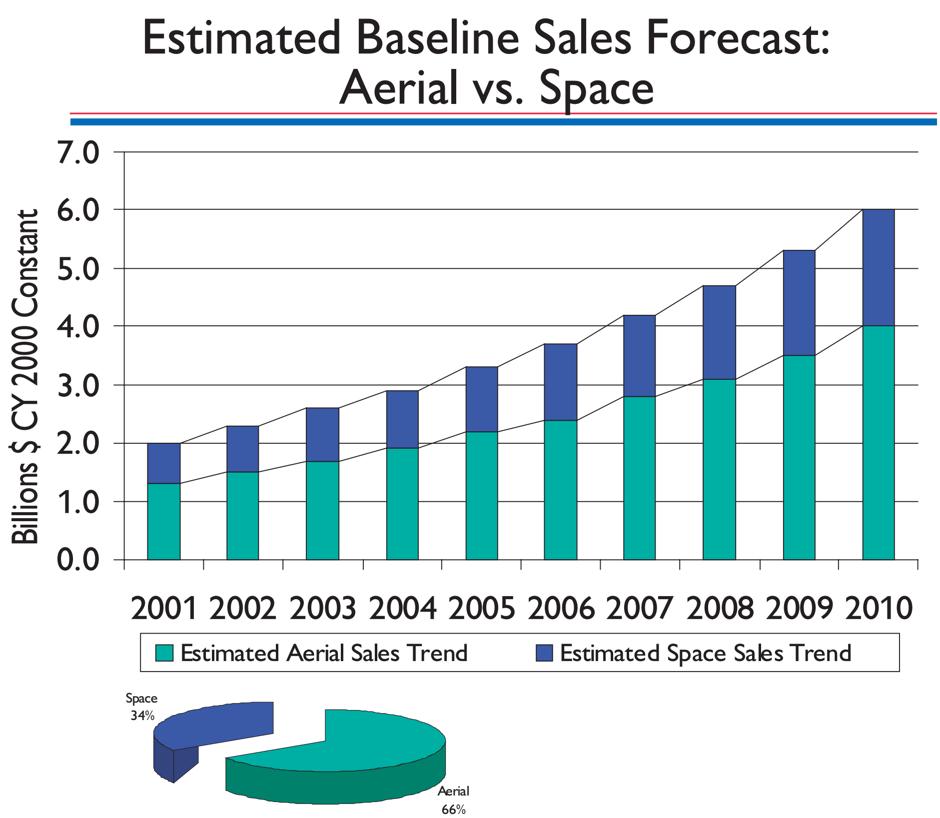

Figure 9 Sales Forecast Aerial vs. Space

4.2.7 Commercial Research and Development

Figure 11 (page 25) indicates that only about 40% of the industry respondents conduct research and development (R&D). This indicates that the remaining 60% depend on providers of systems, hardware, and software, and academic and governmental institutions for new capabilities. If one presumes that larger firms in general perform R&D then only about 27% of the smaller firms work to develop new commercial capabilities for the industry. Phase II showed that the bulk of R&D is performed in the academic and/or the defense communities. These results indicate a fragile R&D base upon which to support future industry innovations and growth.

Therefore, firms often combine commer-

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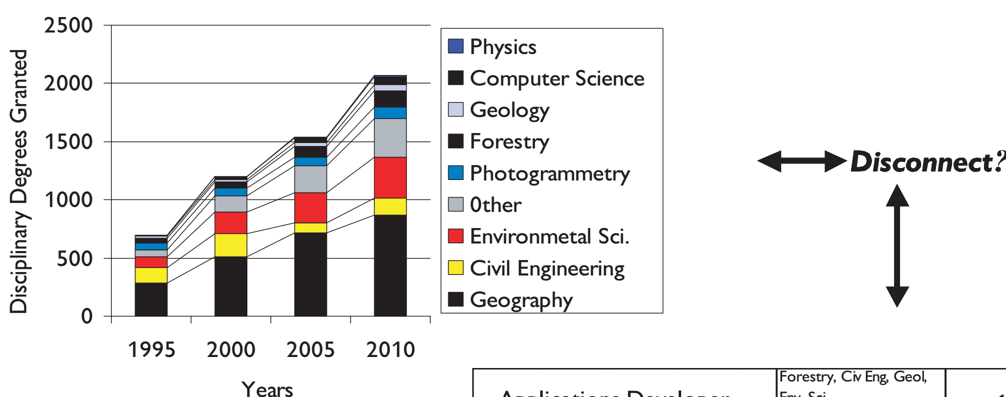
Table 7 Numbers of Employees by Geospatial Activity

Number of Employees	Mean	Geo-Spatial Activity/Business Area					
		Remote Sensing		Image Based GIS		Photogrammetry	
		Number Responses	Employees	Number Responses	Employees	Number Responses	Employees
1-10	5	36	180	36	180	46	230
11-40	25	23	575	20	500	40	1000
41-60	50	5	250	7	350	10	500
61-100	80	9	720	1	80	14	1120
101-200	150	5	750	4	600	8	1200
201-500	350	7	2450	3	1050	5	1750
over 500	500	4	2000	2	1000	2	1000

Most Difficult Job Skills to Hire



Applications Developer	Forestry, Civ Eng, Geol, Env. Sci.	1	MOST
Cartographer	Photog., Geol	2	
Software Developer	Comp. Sci.	3	
Cartographic Technician	photogr, Geol	4	
GIS Applications Analyst	Appl. Dev.	5	
GIS Technician	Appl. Dev.	5	
Database Administrator	Other	7	
Manager	Other	8	
Sales Executive	Other	9	
Geostatistical Analysis	Comp Sci.	10	LEAST

Figure 10 Most Difficult Job Skills to Hire

cially available capabilities into unique systems to meet end user needs. For example, some firms combine digital sensors with LIDAR. This provides the sort of market differentiation needed for firms to maintain commercial uniqueness and profitability.

4.2.8 Aerial and Space Based Sensors Utilized

Growth within the industry is predicated on the development of new systems, data, or new uses for information collected to meet customer demand. Hence, the industry survey included an examination of the types of sensors used at present and expectations of directions for future development. Figure 12 combines two sets of Phase I data concerning platform use combined with media type used by organizations.

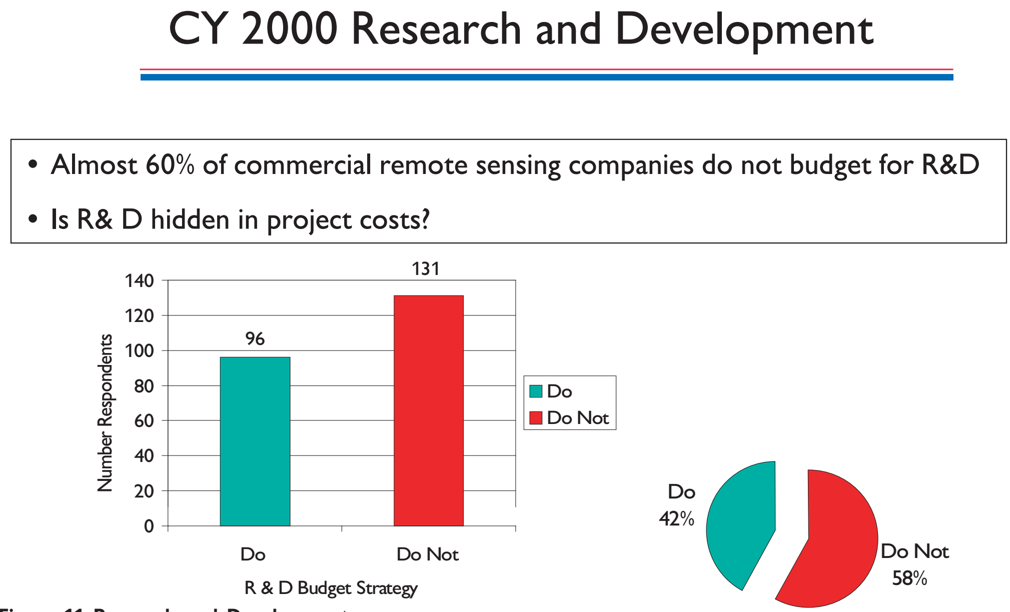


Figure 11 Research and Development

Sensor technologies are diverse and continually evolving. The oldest ones rely on film. Films, or silver halide emulsions coated on a dimensionally stable base, have served the industry for decades. Given its high resolution and area coverage capabilities, film is still very viable, and can be scanned for use in digital systems. Digital aerial sensors have evolved from two unique heritages. Aerial digital cameras have been developed from professional studio equipment. Here as the pixel count grows for the larger consumer and portrait market, so does the technology base for aerial digital photogrammetric equipment. Geospatial vendors have also entered the direct digital acquisition segment with larger format linear and staring array systems. In space based systems linear arrays are somewhat more common because of the stability of the sensor platform. In all cases linear arrays offer the ability to add more bands along the direction of scan. Linear arrays lend themselves to the development of higher frame rate, time delay integration. The format also simplifies the addition of spectral bands for extracting radiometric information.

4.2.9 Phase I Commercial Sector Interviews

While many issues were covered in the internet survey and sealed envelopes process many other issues emerged during the interviews with commercial CEO and executives. Although the issues cited were quite diverse, three concerns were most pervasive: 1) the availability of a trained workforce from which to hire staff, 2) government influence on the market, and 3) and the issue of subsidized international competition.

Training and Education

Many commercial firms focus on selling to unique vertical market segments. This requires a staff educated in a diverse suite of skills, not often available from academic institutions. Staff often come with a single primary skill and require additional training on the job to meet the needs of the organization.

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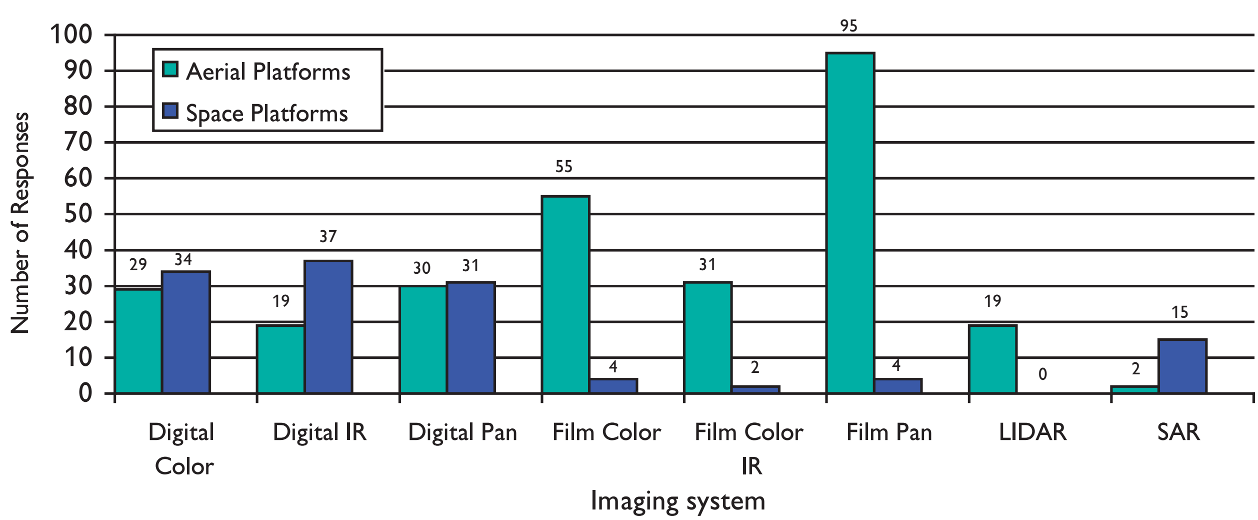

Figure 12 Aerial and Space Based Sensors Utilized

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Government Influence on the Market

Commercial firms often resell or license data, imposing significant restrictions on distribution to third parties. The firms do so in order to achieve and maintain profitability. Federal government policy[7] however, requires most data acquired by the government to be distributed at cost of reproduction and distribution and imposes no restrictions on additional sharing of data so purchased. Often firms cannot price data according to this model and survive. Even if they can cover operational costs of their system using this business model, they cannot recover their initial investment.

International Competition

Internationally, the line between commercial firms and government agencies is blurred in many cases, compared to the United States, which attempts to maintain a sharp separation between the two entities. U.S. firms see this lack of separation as giving non-U.S. firms a non-market advantage over U.S. firms.[8] Many survey respondents perceive that U.S. legislation and export control policies restrict U.S. firms from selling abroad, but do not hinder the sales of products from foreign companies in the United States.

4.2.10 The following paragraphs, taken from one interview, highlight a subset of industry concerns. All interviews were held on a non-attributable basis.

Interview Questions

- What are your company's major business activities? What are your major Market Segments?
  Answer: Remote sensing vertical market segments
- What factors most affect your industry?
  Answer: Government competition [in data sales with commercial data providers]
- What factors most affect your firm/business?
  Answer: Need for additional industry data processing tools
- What do you see as the barriers to industry growth?
  Answer: Educational outreach, spectral libraries for a variety of objects, high resolution DEMs
- How can these barriers be overcome?
  Answer: Government should stimulate industry not compete with it. Government should seed new high-risk technology development. Establishment of a government archive as "futures" for use in image change detection.
- How do you see the future of the Remote Sensing Industry unfolding?
  Answer: Significant growth will be seen
- How do you visualize the Industry five years from now?
  Answer: Better information products will be available and may be more efficiently used across market segments.

4.3 Phase I Government Sector Results

4.3.1 Government Respondent Profile

Phase I utilized a unique question set for each major segment of the remote sensing industry: Commercial, Academic and Government. A government-based team developed the question set to examine general and specific issues across the government segment. Many challenges exist across the forecast through all components of the government. While federal users often participate in professional society annual meetings and trade events, it is far less common for regional and local users to attend. This is seen in the bias of the results toward the views of federal and state users. Phase II of the forecast attempted to remove part of this bias by using information gained from regional and local focus groups.

Phase I centered on the qualification and quantification of major government missions within federal, state, regional, and local levels (table 8). This separation helps all segments to understand the level of government needs most commonly voiced. It helps to answer the question: Are the needs of the local or regional levels captured by the state, federal and commercial users and providers?

Governmental influence is pervasive within all market segments. The federal government, for example, is the largest single customer for data. This influences the industry in terms of data procurements as well as future direction. The federal government's research funding further fosters industry growth.

Table 8 Internet Survey Government Respondent Level

Government Level	Respondents (Sample)	% of Respondents
Federal	89	60%
State	37	25%
Regional	1	>1%
Local	18	12%
Other	4	3%
Total	149	100%

Eighty percent of the government respondents suggested that the industry would grow over the next five years. Thirty percent further suggested that such growth would be significant.

[7] Federal government policy toward data dissemination is guided by the principle that government information is a valuable national resource whose economic benefits are maximized when the information is available in a timely and equitable manner to all. Hence, with few exceptions, customers are accorded open and unrestricted access to government data and information at no more than the ***cost of dissemination***, per Office of Management and Budget Circular A-130. Further, the costs of collection or original processing are not to be included.

[8] In response, foreign data providers note that the large national security market in the United States provides an indirect subsidy to U.S. firms that is not enjoyed by foreign firms.

4.3.2 Government Mission Activities

Based on the approach used previously regarding data collection in sectors, an analogous approach relative to government was employed. This approach collected governmental data in sectors according to "Mission Activities." The federal sector has interests in most mission activities. Data users in the states are most focused on utilities and natural resource management (table 9).

As a major sponsor of technology development, the federal sector was the sole respondent in this mission activity. This agrees with the fact that the federal government has historically provided funds for remote sensing technology development through various grant and contract vehicles (areas of greater significance noted in white).

The federal government has a continued critical role in stimulating existing sectors and the growth of new commercial markets. With the current focus on homeland security it is critical that the federal sector continue to support technology development in remote sensing.

4.3.3 Factors Affecting Governmental Missions

The survey polled the government respondents to assess the factors most critical to their mission success (table 10).

Government respondents cited governmental funding and the effects of changes in departmental budgets as major factors affecting their ability to achieve success in using remotely sensed data. Technology evolution and customer needs are important, but to a lesser degree.

4.3.4 Federal Policies on Data Holdings

As table 11 (page 28) illustrates, most government respondents believe that data should be provided to the users at the cost of distribution. By contrast, as noted earlier, most commercial vendors require the sale of data at prices that allow them to recover their system investment costs their commercial viability. Many have expanded their market penetration by developing creative licensing arrangements in an effort to reduce costs to large volume customers. Key to the growth of the commercial remote sensing sector is the resolution of the potential conflict between data supplied by government and the private sector. This was an area of **critical** concern established during the CEO interviews of Phase I (see Phase I commercial).

4.3.5 Phase I Government Sector Interviews

As with the commercial sector the survey team conducted a series of interviews with participants within different levels of government. While the federal and state sectors were well covered by the internet survey, only four government leaders were interviewed.

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Table 9 Government Mission versus Type of Government

Mission Activities	Federal	State	Regional	Local	Other	Totals
Mapping	16	3	0	6	0	25
Earth/Natural Science	20	2	0	0	0	22
Natural Resource Management	10	10	0	1	0	21
Utilities	1	13	0	1	3	18
Government Services	5	0	1	6	1	13
Technology Development	10	0	0	0	0	10

Table 10 Factors Affecting Governmental Missions

External Factors	Federal	State	Regional	Local	Other	Totals
Funding/Budget Changes	73	30	1	12	1	117
Technology Evolution	39	19	1	12	2	73
Changing Customer Needs	30	8	0	10	2	50
Commercialization/ Privatization of Government Functions	36	10	0	0	0	46
Politics/External Lobbying	24	9	1	6	2	42
New Legislation	21	13	0	6	2	42
Impact of Climate/Hazards/Disasters	19	5	0	0	1	25
Data Access/Supply/Cost	4	5	0	4	0	13
Media/Public Opinion	7	2	0	2	2	13
Agency History/Credibility	4	2	0	1	0	7

continued from page 27

Given this small number, analysis and conclusions are taken from these interviews. The results of these interviews are noted in parts of the documentation.

4.4 Academic Component – Phase I

The academic community surveyed in Phase I included ASPRS members who are employed at universities, colleges, and organizations offering education and training in remote sensing, geospatial information science and technology, or the mapping sciences. Sixty-two individuals from the academic sector responded to the internet survey of Phase I. This amounts to over 7 % of the 859 academic members of ASPRS and 14% of the total survey response group. No direct interviews were conducted with academic respondents.

The internet survey profiled this community in terms of current operations, average program size, and future expectations for program orientation. It also documented the primary research and instructional markets they serve and estimated the trends, directions, and needs of the academic community in supplying an educated workforce in the future.

Table 11 Data Holding Policies

Policy Choices	Response
Public Domain Data Distribution at Cost of Distribution	83
Public Domain Data Distribution at Prices Above Cost of Distribution	6
Public Domain Data Distribution With Some Restricted Data	29
Restricted Data with Some Public Domain Data Distribution	19
Restricted Data Only (No Distribution)	12

4.4.1 Objectives of the academic survey include:

1. Estimation of the changes in the 1995-2000 period in the academic community in students, faculty and programs in response to the needs for remote sensing and GIS (RS/GIS) instruction.
2. Estimation of the changes in the 2000-2010 period in the academic community in students, faculty and programs in response to remote sensing and GIS instruction.
3. Determination of the outside forces that most affect the RS/GIS academic community, for example, business-university partnerships, commercialization efforts, research funding, equipment funds, and accreditation
4. Determination of the internal university forces that most affect the academic RS/GIS community, for example, training vs. education, disciplinary control of resources, program development needs, institutional administrative support.
5. Determination of the community's perception of the four primary internal and external factors that will influence RS/GIS growth between 2000 and 2010.
6. Determination of the three specific areas of critical program needs for each segment of the academic community:

Table 12 Positions of Academic Respondents

Position	Number
Academic Administrator	0
Professor	22
Associate Professor	12
Assistant Professor	11
Instructor	1
Adjunct Faculty Member	1
Laboratory Director	4
Other	2
Research Staff	9
	62

The majority of the respondents are academic faculty (table 12) located at larger institutions, averaging 17,000 students. All were from 4-year colleges/universities and none were from community colleges. Respondents' disciplinary backgrounds included computer science, geology and engineering, but were concentrated in geography and forestry.

Because of the high cost of suitable technology and expertise to develop a program, only the larger universities are likely to have programs in remote sensing. The sample, while not comprehensive of the educational spectrum, does appear to be representative of the type and size of institutions that have instructional and research programs in remote sensing.

Based on the survey estimates of numbers of students in the programs, the average program size is 140 students (undergraduate and graduate), accounting for less that 1% of the student body of the average university (17,000 students). This small size limits the visibility and administrative consideration during the budgeting process. This dilemma of high per student cost for instruction and small, diffuse program visibility inhibits program growth. A larger role of commercial entities and governmental agencies in advocating for programs or augmenting program resources is needed.

The respondents expect to see a rise in the number of degrees granted in the next 10 years. This rise is most pronounced in geography and environmental sciences, in part because these disciplines are most likely to grant Masters and Doctors degrees in remote sensing. The other disciplines, such as computer science or geology, may have a course or two in remote sensing, but do not have degree program concentrations.

Figure 13 indicates that educator respondents anticipate a significant increase in geospatial degrees awarded in their programs over the next eight years. The expansion will take place in both undergraduate and graduate degrees, with a slight increase at the master's degree level.

Certificate programs are usually composed of multidisciplinary courses, which provide a certificate credential to the student upon completion to supplement their disciplinary degree. . For example a student might take a one year concentrated remote sensing course sequence organized by three separate departments to earn a certificate. These programs are expected to be growth areas at the respondent institutions.

The issues related to foreign students in science and engineering programs in the U.S. including academic remote sensing/GIS programs is complex. As reported in a recent RAND Institute study,[9] the number of science and engineering (S&E) Ph.D. degrees awarded to U.S. citizens was 16,390 compared to 13, 438 degrees in 1980. However, the NSF statistics on graduate programs show that non-citizens receiving Ph.D.s in science, engineering and health has increased from 22% to 37% since 1980. Currently, foreign born students comprise about 50% of the graduate students in computer science and engineering.

The question of the supply of educated professionals in the RS/GIS fields to meet future demand cannot ignore the presence of foreign students in both educational programs and the derivative workforce. The electronic survey results (figure 14) indicate that the numbers of foreign students (shown in blue) has been increasing and will likely continue to increase in the future.

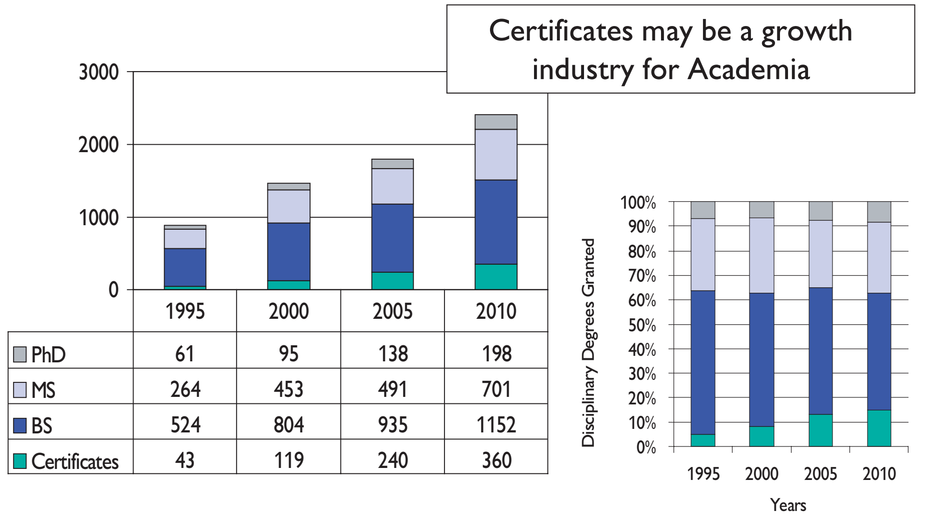
There may not sufficient numbers of adequately prepared U.S. high school and undergraduate students motivated to enter the programs at this time or in the foreseeable future. Also, many U.S. students obtain good jobs with undergraduate or masters' degrees. Foreign students cannot obtain jobs as easily because of federal restrictions on employment of foreign students. Hence, they often continue on to advanced graduate education, resulting in a disproportionate share of the graduate population compared to U.S. citizens.

Respondents were asked which topics students had the greatest interest in at present and how they perceived levels of demand might change between 2000 and 2004 (table 13, page 30).

As shown in Table 13, respondents felt that the highest demand was in applications science in remote sensing using GIS, spatial database development and spatial statistics/analysis. They estimated that the narrower technological areas of hyperspectral sensing and multi-sensor fusion would likely to be in high demand in the future.

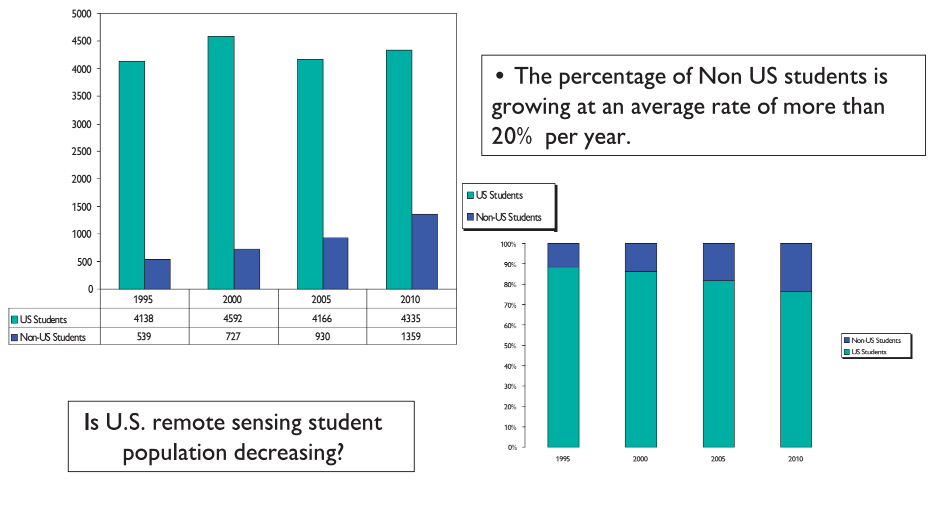
Significant is their opinion that the demand for photogrammetry would decrease. This tends to support the earlier data that private firms were devoting less R&D spending to photogrammetry.

The academic respondents were asked to select factors they felt would most affect their institutions in the next five years. As shown in Table 14 (page 30), the availability of funding to support instructional programs and laboratory infrastructure led the list of important factors. These were closely followed by the need for qualified graduate student applicants and graduate student support.



	1995	2000	2005	2010
PhD	61	95	138	198
MS	264	453	491	701
BS	524	804	935	1152
Certificates	43	119	240	360

Figure 13 Estimate of Number of Degrees and Certificates 1995-2010



	1995	2000	2005	2010
US Students	4138	4592	4166	4335
Non-US Students	539	727	930	1359

Figure 14 U.S. vs. Non-US Remote Sensing Students 1995 - 2010

4.4.2 Response to the Open-ended Questions

In an attempt to develop responses beyond the structured questions, the last questions of the survey asked for open-ended responses. In Question A 13, each respondent was asked to, "List in priority order three actions most needed by government and/or the private sector to advance educational programs in RS/GIS in the United States". The free form answers covered an extensive range of suggestions for action. Only those responses listed as first priority are evaluated in this analysis. These results tend to validate the earlier responses provided in the structured question format of the survey. The analysis reveals four primary areas where academic respondents felt that the government and commercial sectors could assist the academic remote sensing effort.

1. Increased Funding for University RS/GIS Programs.
2. Greater Access to Affordable Data for Educational Purposes.
3. Enhanced Educational Partnerships with the Private Sector
4. Improved K-12 RS/GIS Education.

continued on page 30

[9] William P. Butz, Gabrielle A. Bloom, Mihal E. Gross, Terrence K. Kelly, Aaron Kofner, and Helga E. Rippen, "Is There a Shortage of Scientists and Engineers? How Would We Know?" RAND Issue Paper 241, 2003. (http://www.rand.org/publications/IP/IP241/).

Table 13 Respondent-Perceived Changes in Demand for Selected RS/GIS Areas 2000-2004

<table>
<tr><th rowspan="2">RS/GIS Demand Areas</th><th colspan="3">Level of Demand</th></tr>
<tr><th>High</th><th>Average</th><th>Lower</th></tr>
<tr><td>Applications Science</td><td bgcolor="#333399"></td><td></td><td></td></tr>
<tr><td>Hyperspectral</td><td bgcolor="#333399"></td><td></td><td></td></tr>
<tr><td>Applications Science Using GIS Tools</td><td bgcolor="#333399"></td><td></td><td></td></tr>
<tr><td>Spatial Data Base Development</td><td bgcolor="#333399"></td><td></td><td></td></tr>
<tr><td>Spatial Statistics/Analysis</td><td bgcolor="#333399"></td><td></td><td></td></tr>
<tr><td>Multisensor Fusion</td><td bgcolor="#333399"></td><td></td><td></td></tr>
<tr><td>Algorithms</td><td></td><td bgcolor="#ee2a2e"></td><td></td></tr>
<tr><td>Sensor</td><td></td><td bgcolor="#ee2a2e"></td><td></td></tr>
<tr><td>Basic Phenomenology</td><td></td><td bgcolor="#ee2a2e"></td><td></td></tr>
<tr><td>Cartography/Visualization</td><td></td><td bgcolor="#ee2a2e"></td><td></td></tr>
<tr><td>Multispectral</td><td></td><td bgcolor="#ee2a2e"></td><td></td></tr>
<tr><td>Photogrammetry</td><td></td><td></td><td bgcolor="#f7e92a"></td></tr>
</table>

continued from page 29

The last question of the survey, asked: "List in priority order three actions most needed in the educational community to advance RS/GIS educational programs in the United States." The team analyzed only those responses listed as the number one priority. Three pri-mary, related categories were cited by academics for improvement within the educational community:

1. Improved RS/GIS Curriculum Development
2. Increased Funding for Facilities and Equipment
3. Elevation of the Status of Remote Sensing and GIS in the University Community

5 Phase I Conclusions and Implications

Phase I generated findings and issues that have major implications regarding the remote sensing and geospatial information industry. This research is informed by respondents in all three industry sectors (government, commercial and academic), each of which may have differing perspectives on the issues and their resolution. The analysis and interpretation of the data/information collected in Phase I provides significant insights into the nature and potential resolution of several relevant industry issues.

Industry Growth

The data/information yielded by all collection means (internet survey, interviews, research of literature and revenue survey) lead to the conclusion that the remote sensing industry will experience positive growth of 8 to 10%, and becoming a $5.0 to $6.0 Billion per year industry by 2010. Several factors are capable of enhancing this trend, such as initiatives to increase user and potential user knowledge as to the potential of remote sensing applications, increased attention to under-attended market segments, and actions by the U.S. government to provide consistent policy, which minimizes business investment uncertainty and "levels the playing field" with foreign competition

Interaction of Commercial Sector with Government and Academia

Much of character of the industry is related to the tightly coupled interdependency of the three sectors and the predominance of smaller firms relative to larger ones. The result is that the many smaller firms which

Table 14 Factors that will affect RS/GIS programs in the Next 5 years

Rank	Factor	Group
1	Availability of Funding to Support Program Development	I
2	Availability of Funding for Lab and Technology Development	I
3	Availability of Government Funding for Educational/Equipment Programs	I
4	Availability of Government Funding for Research	I
5	Availability of Qualified Graduate Students	II
6	Level of Support for Graduate Students	II
7	Availability of Jobs for Graduates	II
8	Salaries for Remote Sensing/GIS faculty and Staff in your Institution	II
9	Administrators Understanding of the RS/GIS Industry	III
10	Public Understanding of the Remote Sensing/GIS Field and Educational Needs	III
11	Ability to Fill Vacant Positions	III
12	Business/University Partnerships	III
13	Availability of Qualified High School Students	III
14	Department/Discipline Control of Resources "Protection of Turf" Issues	IV
15	Competition for Research Funds with Private Sector Firms	IV
16	Acreditation/Certification Issues	IV

form the foundation of the industry are less able to support internal R&D and workforce development activities, are more susceptible to competition with government agencies, and are less able to meet foreign competition forcefully.

More than in most other industrial and business areas, the three sectors are interdependent. Industry interactions occur primarily business-to-business and business to government, with minimal direct interaction with individual consumers. The private sector depends on government for a large portion of its sales. As a result, the private sector is heavily influenced by governmental policies. Inconsistent governmental policies are particularly worrisome because they introduce an extra element of risk for industry.

Much of the civilian research and development for both government and private sector takes place in academic institutions. The future workforce for the industry depends on the viability and responsiveness of the academic community to the rapidly changing technological developments and skill needs of the industry. These complex relationships are known to most industry participants, but seldom are made explicit. They became very apparent in Phase I and need to be continually monitored to assist in developing sound policies and insure competitiveness within the industry.

5.1 Potential government agency / commercial competition for data and services

As the survey data illustrate, federal, state, and local governmental agencies participate in the remote sensing marketplace by purchasing data and services. In fact, government agencies constitute the largest single class of customers for data and services.[10] Government agencies also hire analysts with skills in RS/GIS, as well as produce and disseminate RS/GIS data and products. In some cases, government agencies may be competing with commercial entities for data and services. The survey revealed a strong concern among some commercial suppliers of data and value-added services about perceived government competition with these suppliers.

Although government assistance in research and development of systems and new data products has been generally welcomed by the industry, some industry members have stated that some government agencies at federal, state, and local levels tend to fund their in-house expertise at the expense of hiring external contractors to handle the analytic effort. Some level of in-house expertise is desirable in order for the agencies to be "smart buyers" of remote sensing goods and services. Nevertheless, preserving an appropriate and defendable balance between the maintenance of in-house expertise and external contracting will continue to be an important task for all levels of government.

[10] The actual influence of government over the industry is even greater than direct sales of data and services indicate because private firms may purchase data and value-added services to fulfill contracts with government agencies.

5.2 Federal Policy Influence Over Remote Sensing Market Development

Federal government policies, developed and refined over the years, have had an overwhelming influence over the development of the market for remote sensing data (table 15) and other parts of the geospatial market (table 16, page 32). On the one hand, federal funding has developed the basic technologies for all forms of satellite remote sensing and contributed markedly to the development of advanced airborne instruments, such as LIDAR, interferometric SAR, and hyperspectral digital sensors. On the other, generally for stated reasons of national security, the federal government has limited the development of high-resolution civilian satellite sensors and maintained sharp boundaries between the technology developed for national security and civilian uses. Further, experiments with privatization of the Landsat system and inconsistent policies toward the application of remote sensing techniques to practical problems

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Table 15 Federal Government Policy: Areas of Influence On the Remote Sensing and Geospatial Industry

● Encouragement and licensing of commercial providers of satellite data	
● Government research and development of new systems	
	‣ Airborne
	‣ Satellite
● Support of research	
	‣ Universities
	‣ Private sector partnerships
● Support for education and training	
● Creation and maintenance of remotely sensed data archives	
	‣ Distribution of archived data
● Purchases of commercially supplied data and value-added services	
● NASA, NOAA, USGS outreach to other government agencies	
	‣ Federal
	‣ State
	‣ Local
● Creation of data policies for government systems (EOS, Landsat, Metsats, archived data)	
	‣ Price
	‣ Licensing of data use
● International outreach, trainin	
● Lack of an operational U.S. synthetic aperture radar system	
● Potential government agency competition with commercial sector for data and services	

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slowed the development of the market until the end of the Cold War (Appendix I). In the early 1990s, more liberal federal policies began to promote the use of satellite data for a wide variety of uses. The following paragraphs review the key policy decisions since the early 1970s that either enhanced or slowed the development of the global market for remotely sensed data.

5.3 Data prices and licensing

The price of data and the licensing of data are key issues evolving in the private sector, especially in the satellite domain. Private firms find it essential to repay the massive investments made in modern satellite technology. Specifically, data prices for commercial satellite data products must sustain the cost of developing, building, and operating the satellite and data processing systems, just as they must for aerial data services. As a result, satellite data prices reflect this business requirement. Only by comparison to government supplied data do satellite data prices seem high. Per area covered, they are generally competitive with the data prices of the aerial data market, which is very large, and has a profitable business model.

Many recognize that keeping data prices low and eliminating data-use restrictions for government-supplied, low and moderate resolution satellite data, has helped to stimulate the commercial market while providing a public geospatial infrastructure meeting many needs for the data. For example, as noted by Lillisand[11], because of their broad geographic coverage in seven wavelength bands, Landsat data provide an excellent tool for pinpointing where more detailed geospatial studies of an area might be needed, which can spur the use of commercially-supplied data of higher resolution, stereo view, and other capabilities.

Many educators expressed considerable anxiety about future access to data, not only with respect to funds to acquire data, but also the right to use and share new, advanced data with limited restrictions. As the market for commercial satellite develops, firms are likely to be able to offer fewer data sharing restrictions, especially for older, less current data, which has less commercial value.

5.4 Research support

Primarily through grants from NASA, NOAA, the National Science Foundation (NSF), the Department of Transportation (DOT), and the USGS, scientists in universities and private research have made significant progress in learning how to use remotely sensed data acquired from aerial and satellite platforms to analyze a broad set of environmental and planning concerns. Many of the techniques and methods developed for these applications will also contribute to improved preparation for homeland security. Cooperative research agreements with private companies have provided stimulus for the commercial development of a wide range of products to serve the value added community.

Table 16 Related Government Policies

● Maintenance, regulation and use of GPS	
● Governmental use of GIS, geospatial data	
	‣ Sharing of data with state and local users
● Standards setting through FGDC	
● OMB Circular A-130	
	‣ Governs distribution of data developed at taxpayer expense
● International agreements affecting domestic industry	
● Workforce training in GIS, GPS	

Such research has formed the foundation for the development of a remote sensing market, and contributed to the development of analytical tools.[12] Future development of the remote sensing data market will continue to depend in part on federal research funding in the exploration of analytical algorithms, new data products, and geospatial tools. Although the commercial marketplace has made significant strides in developing new tools, the federal government's special needs for advanced remote sensing data and analytical tools, particularly for homeland security and national defense, will continue to influence government research and development of advanced airborne and satellite systems.

The RS/GIS educational field is growing, but the educational basis of the field needs to be more flexible and dynamic to service a changing industry. Phase I results indicate the need for more private sector partnerships that recognize the need for guidance, as well as support, from the private sector to meet this challenge. In the academic science arena it is not just a question of more of the same faculty, faculty skills, course offerings and research infrastructure, but of meeting the need for a continually changing set of faculty skills, course offerings and infrastructure. These needs will place greater demands upon all concerned: educators, government and private sector educational partners.

Phase I respondents cited the future potential and therefore the need for additional research support for synthetic aperture radar (SAR) and for hyperspectral systems. This portends growth in these areas and the need for additional research and development.

SAR Systems. Although the market for SAR data is currently very small, the fact that SAR instruments can operate through most clouds and through the night makes them especially useful for responding to natural disasters and in providing imagery for areas that are often covered by low-lying clouds. Recent interest has increased in geometric measurement of the earth and surface features using interferometric SAR (INSAR, IFSAR).

In the satellite realm, NASA has focused on the development of the successful but limited capacity Shuttle Imaging Radar (SIR-A,B,C), which, among other capabilities has provided highly accurate, comprehensive global digital terrain data sets.[13] However, the U.S. has no current plans to orbit an operational civilian SAR system.

For civilian operations, the United States has essentially ceded primacy to Canada and Europe, which now operate SAR satellites

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[11] Tom Lillisand, Landsat Data Continuity Mission Workshop, Reston, VA, January 2001; accessed at: http://ldcm.usgs.gov/documents/ldcmworkshop2-8-01/.

[12] See, for example, Ray A. Williamson, Stanley Morain, Amelia Budge, and George Hepner, *Remote Sensing for Transportation Security,* National Consortium for Safety, Hazards, and Disaster Assessment, July 2002.

[13] See http://www.jpl.nasa.gov/srtm/.

[14] Orbimage's Orbview 4 carried an experimental hyperspectral sensor provided by the U.S. Air Force. However, the launch failed and no replacement has been launched.

routinely and are planning successor systems for the future. The complexities of processing SAR data currently make these data less attractive to many customers. Hence, there is a need to continue to develop processing algorithms and to experiment with new SAR data sets. Although U.S. data customers can purchase data from non-U.S. systems, the lack of an operational U.S. civilian system generally limits experimentation with SAR data and their use in U.S. applications, because there are few government incentives to do so.

Hyperspectral sensors. Hyperspectral sensors hold great promise for detailed surface studies, especially examinations of the type and character of land use and land cover change. Nevertheless, they are primarily in the research stage. NASA and the Department of Defense have experimented with the use of hyperspectral sensors and several companies operate them mounted on aircraft. To date, no US civilian or commercial satellites carry hyperspectral sensors.[14]

5.5 Support for education and training

In their interviews, corporate officers emphasized the workforce issue, citing the shortage of trained workers emerging from educational programs and the lack of the required skill sets among many of the graduates. All sectors agree that an educated workforce is critical to the continued growth of the marketplace to support the increased utility of geospatial information to the economy.

Most RS/GIS programs in the U.S. are offered in departments or colleges of geography, natural resource management, forestry, and civil engineering. Other disciplines offer individual courses in RS/GIS, but these three disciplines are the homes for most instructional programs of multiple, integrated courses.

The results indicate the need for increased funding for RS/GIS educational programs as the industry expands and changes in the future, in large part because the newer sub-disciplines and technologies will require changes in curriculum programs, faculty specializations, and instructional and research infrastructure (equipment, software, labs). In addition, educators must themselves deliver new integrated curriculum programs to meet future needs.

Certificate programs are gaining in acceptance in the educational community. These programs provide a means for disciplinary specialists to retool their knowledge and skills to take advantage of the geospatial information revolution in their disciplinary areas without committing to a multi-year degree program.

Educators recognize the need to elevate the status of the geospatial information field both on campus and in the larger educational framework within the United States. Improved status of the field of geospatial information will be necessary to achieve continual support within the university administration to meet the demands of the future, to have properly prepared K-12 students who have knowledge of RS/GIS upon entering college, and to attract and support quality graduate students.

The federal government has supported remote sensing education and training directly through funding of academic programs in K-12, undergraduate, and graduate schools, and indirectly through funding of university research. However, as noted in the survey, educators feel that the federal government needs to do more to support the development of the necessary skills to make use of the wealth of data that is increasingly becoming available, by providing:

1) ***focused support*** for graduate level RS/GIS students;
2) ***greater access to affordable*** *data* for educational purposes. The NASA "Data Buy" program, in which NASA purchased commercially-supplied data for research projects was of consider-

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able assistance to undergraduate and graduate education. However, this program has been terminated.

3) ***enhanced educational partnerships*** with federal, state, and local agencies;
4) ***improved RS/GIS education in K-12***, linked directly with math-science education. Remote sensing and GIS provide powerful tools for developing critical reasoning tools and for educating students in aspects of science and mathematics.

5.6 Creation and maintenance of remotely sensed data archives

The data records from Landsat and other satellite systems provide an important record of continuity and change over the globe, forming the basis for a detailed understanding of short and long term changes induced both by natural and human causes. The scientific and applied value of these data increases with time. In the early 1970s, the federal government created the U.S. Geological Survey's Earth Resources Observation Systems Data Center (EROS Data Center) in Sioux Falls, South Dakota, in order to have a facility in which to store and distribute the nation's valuable collection of land remote sensing data. This collection has become an indispensable resource in support of the continued growth of the Earth observations marketplace. It will be important for the United States to continue to archive and protect these data and make them available at the cost of reproduction and distribution for future data customers.

5.7 International cooperation, competition, outreach, and training

Although the survey does not deal explicitly with issues of international cooperation, outreach, and training, it is clear that a variety of cooperative programs funded by NASA, NOAA, and the USGS, among other federal agencies, have assisted in the international proliferation of data sources and data customers in the United States and abroad. By bringing the benefits of geospatial data and analytical tools to other countries, these programs have assisted in creating market opportunities for U.S. firms.

Global competition is increasing as well. Among other things, the development of new satellite systems throughout the world will provide new sources of satellite data, increasing the competitive pressure on U.S. companies. Non-U.S. suppliers of aerial data have improved their cameras and expanded their market services globally. Government programs in many countries are designed to foster the development of innovative indigenous geospatial solutions. The most ambitious of these programs is Europe's Global Monitoring for Environmental Security (GMES),[15] but India and Japan are pursuing major development efforts that will provide both additional markets for U.S. geospatial information providers and additional competition.

U.S. geospatial companies market software, satellite and aerial imaging, and value-added services to a global marketplace. The global geospatial information marketplace is growing and changing with the introduction of new geospatial technologies. Policies at all levels need to be more dynamic in several respects to meet a changing industry, within government, academia, and the private sector. The April 25, 2003 federal policy on commercial satellite remote sensing[16] and NIMA's NextView contract with DigitalGlobe are generally seen within the industry as highly supportive of the U.S. remote sensing industry. However, the industry views export control laws as overly restrictive, especially with respect to the export of remote sensing technologies and in the use of advanced technology aerial cameras abroad. Such restrictions need to be reviewed often with respect to the availability of competing technologies abroad to be sure that they do not unduly restrict the competitive stance of the U.S. geospatial industry. U.S. academic institutions and U.S. firms need to be more nimble in keeping up with technological developments. In order to gain a broader understanding the of U.S. marketplace in the context of global competition, it may be advisable to extend the U.S. forecast survey to the international community.

[15] GMES is a joint undertaking of the European Union and the European Space Agency designed to develop a range of geospatial products in support of sustainable development and European security needs.

[16] White House, "U.S. Commercial Remote Sensing Policy," Fact Sheet, April 25, 2003.

6 Phase II Implementation

6.1 Phase II – Understanding the end user and manager

During Phase II, the team added the use of focus groups to the interviews conducted during various professional meetings around the United States. This allowed the team to target data users in a variety of occupations. Also, the team continued to explore the literature, use the internet survey, and the closed envelope revenue survey as means to collect data. Phase II also reached out to additional professional organizations and interest groups.

Phase II focused on the operational manager and end-user of remote sensing and geospatial information by:

1. Identifying and profiling the managers (purchasers) and end-users whom use/need remote sensing data, information and software products;
2. Identifying and baselining the on-the-job needs (in non-technical terms) of these managers and end-users;
3. Determining needs-driven applications requirements as they derive from the managers and end-user needs baseline;
4. Determining if current applications provide cost effective solutions to needs-driven applications requirements;
5. Assessing current, emergent and future technology capabilities to meet needs-driven applications requirements.

These goals were met by collecting data to meet goals 1 and 2 and then, through analysis, use that information to meet goals 3-5. This led to the development of a coordinated and integrated data collection plan using an internet survey, interviews, focus group sessions at conferences and literature searches. During Phase II, the National States Geographic Information Council (NSGIC) and the Management Association for Private Photogrammetric Surveyors (MAPPS) became active participants, fostering the collection of information from additional private firms and state and local governmental agencies.

Phase II of the forecast assessed the requirements of the end user by quantifying the needs of the end user as a function of market segment. The survey asked a series of questions about "use versus need" from which metrics quantifying specific systems and performance could be derived. Comparison of these responses with data collected in Phase I served to assess possible industry shortfalls in meeting the requirements of the end user.

6.2 Phase II results (Commercial, Government, Academic)

The changes in respondent profile for Phase II (figure 15) reflect the inclusion of NSGIC and MAPPS membership into the direct data collection pool of respondents. In Phase II sampling, the number of commercial respondents is constant between Phase I & II. The numbers of both the government and academic sector respondents were significantly increased.

6.3 Experience by Sector

The survey data shown in Figure 16 indicate a bi-modal distribution in workforce longevity The bulk of the employees in the industry have either less than 4 years or greater than 11 years experience within the industry. Approximately one third of the workforce has remained longer than 11 years. This affects the remote sensing industry in multiple ways. The workforce is aging and the bulk of newer staff, posed to replace retiring staff, often leave the remote sensing industry for other career opportunities. While a younger staff may be attracted out of academia, the data indicate that many will be unlikely to remain. The shortfall of trained staff from higher education further exacerbates this problem.

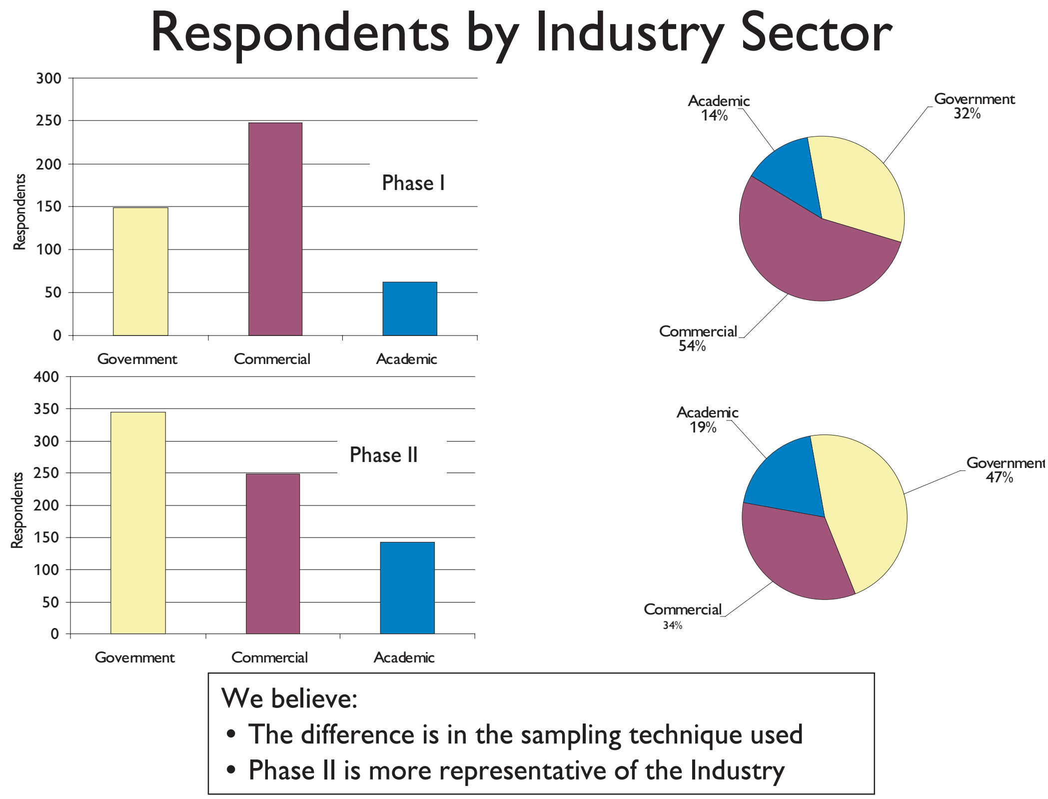

Figure 15 Respondents by Sector

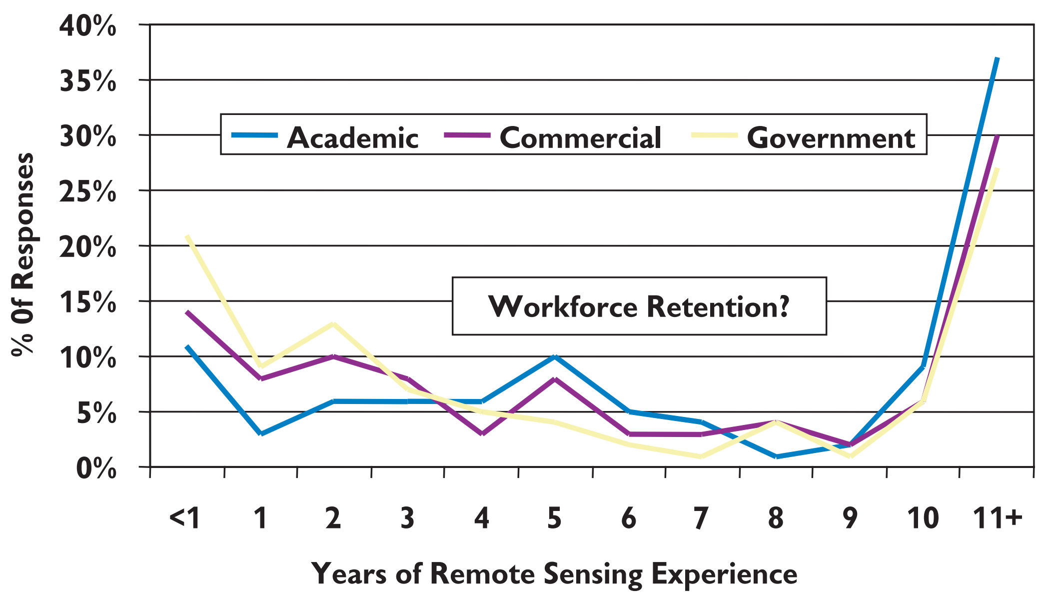

Figure 16 Experience by Sector

6.4 Respondents' Work Areas

The bulk of the respondents in Phase II work within the first three application areas: General Mapping, Environmental, and Civil Government. By contrast, in Phase I, these three application areas were joined by Transportation and National/Global Security/Defense to form the top five. In Phase II, a smaller percentage of respondents identified themselves as fitting predominately within National and Global Defense activities than in Phase I. In any case, it is important to note that the important market segments-application areas remained consistent for both phases of the study.

These work areas confirm the inculcation of remotely sensed data into the decision making process. This trend follows that revealed by a plot of revenue by market segment. National/Global Security/Defense appears to be an outlier compared to the revenue data. This may be the result of differences in the mix of contractor versus actual government employees who responded in the two phases. The change will be explored in future phases.

Figure 17 and table 17 (page 36) show the respondents' affiliations with professional organizations. Their choices of affiliation seem dependent on their disciplinary background and their situation in either the government, commercial or academic sectors.

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7 Phase II Commercial Sector

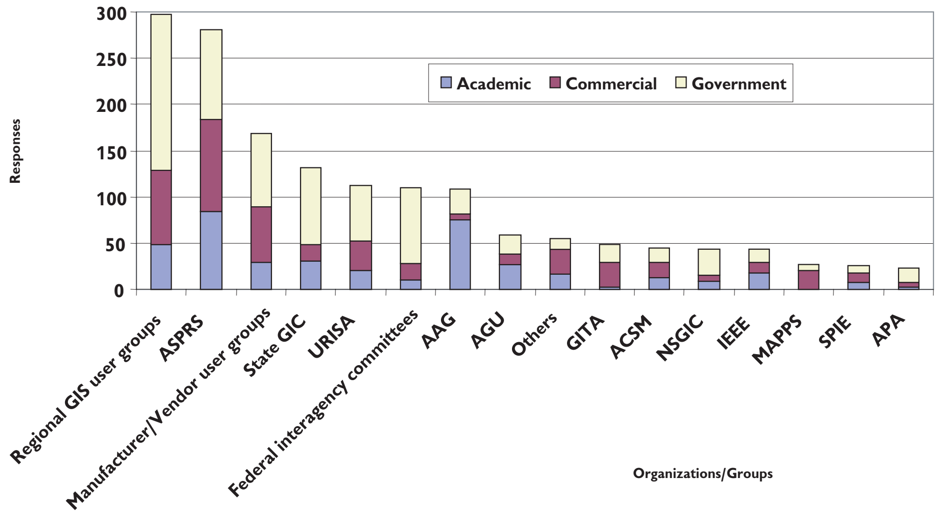


Figure 17 Professional membership across the geospatial industry

The Phase II market forecast depicted in Figure 18 was calculated based on the 1) Phase I 2001 baseline, 2) the results of the Phase I and II CEO/CFO closed envelope surveys, 3) extrapolations of similar market forecasts from the literature and 4) calculations involving the combined average growth rates of 2001-2003.

In general, the 2002 baseline indicates a slightly higher expectation of growth in 2002-2006 and lowered expectations of growth in the outer years compared to the expectations of 2001. However, the difference is insignificant and does not fully reflect uncertainties in the market following the events of September 11, 2001. In spite of the uncertainty, the industry displays a continuing positive trend, indicating an industry of growth; this is especially significant considering it came in a period of general downturn in the U.S. economy.

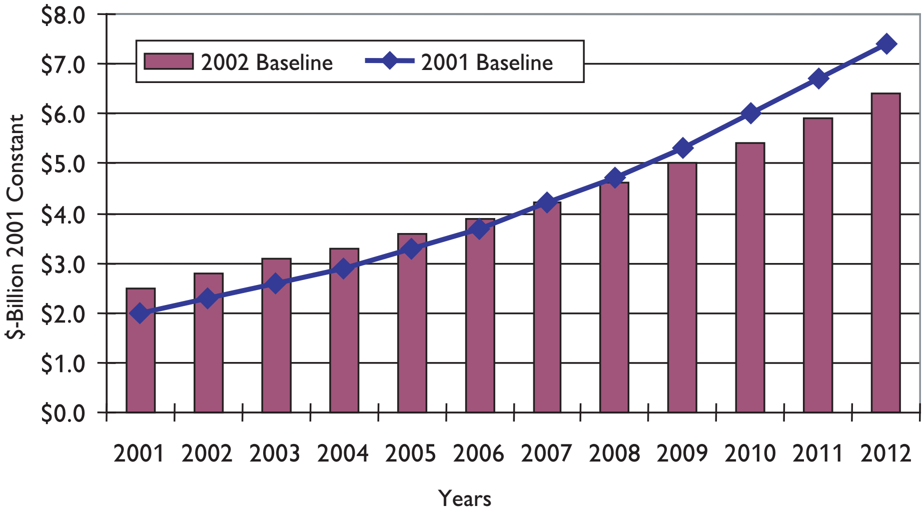
Table 17 Professional membership across the geospatial industry

Survey Respondents Participate in a Wide Range of Professional Societies
ASPRS, The American Society for Photogrammetry and Remote Sensing
URISA, The Urban and Regional Information Systems Association
AAG, The American Association of Geographers
AGU, The American Geophysical Union
GITA, The Geospatial Information and Technology Association
ACSM, The American Congress on Surveying and Mapping
NSGIC, The National States Geographic Information Council
IEEE, The Institute for Electrical and Electronic Engineers
MAPPS, The Management Association for Private Photogrammetric Surveyors
SPIE, The International Society for Optical Engineering (the Society for Photographic Instrument Engineers)
APA, The American Planning Association

Figure 19 depicts data collected via the closed envelope revenue survey. CEO/CFOs were asked to estimate the percent of their revenues derived from each of the 13 market segments used in the forecast. The results indicate the three most important segments of the current market are national and global security, civil government, and mapping, which account for about 65% of the commercial sector revenues. However, photogrammetry, remote sensing and image-based GIS have considerable promise to meet emerging requirements and opportunities, in transportation, environmental resource protection, and utility planning. The federal government can continue to assist by providing research funding in several critical areas. Here again, survey respondents considered continued federal, state and local funding as critical to industry growth.

As noted earlier, the industry (figure 20) has a substantial number of smaller firms (less than 100 employees), many of which perform more than one activity within their market segment. Phase II reinforces that the data collection and processing segments are the most common types of firms; value-added resellers and hardware/software/systems providers are secondary. These smaller firms participate in unique areas of the market and may specialize in the collection or creation of unique data sets or value added products. The larger firms tend to work across market segments and are more visible to federal policy makers than the smaller ones. Because federal policies are levied on the industry as a whole, the impact of these policies on smaller firms with unique capabilities should be considered.

Because satellite sensors and platforms, especially, are extremely expensive, satellite developers have tried to construct sensor and platform characteristics that will serve a wider range of customers. Hence, it is difficult to serve the specialized needs of all potential data customers. In response, smaller firms are attempting to provide aerial photography and imagery or specialized value added services on both satellite and aerial products to meet the diversity of needs within the customer base. This diffuseness tends to limit the poten-



- Average 2001 and 2002 CEO/CFO Expected Revenue estimates. Use to plot 2001-2006
- Apply AAGR associated with those estimates to forecast 2007-2112

Figure 18 Comparison of 2001 and 2002 baselines

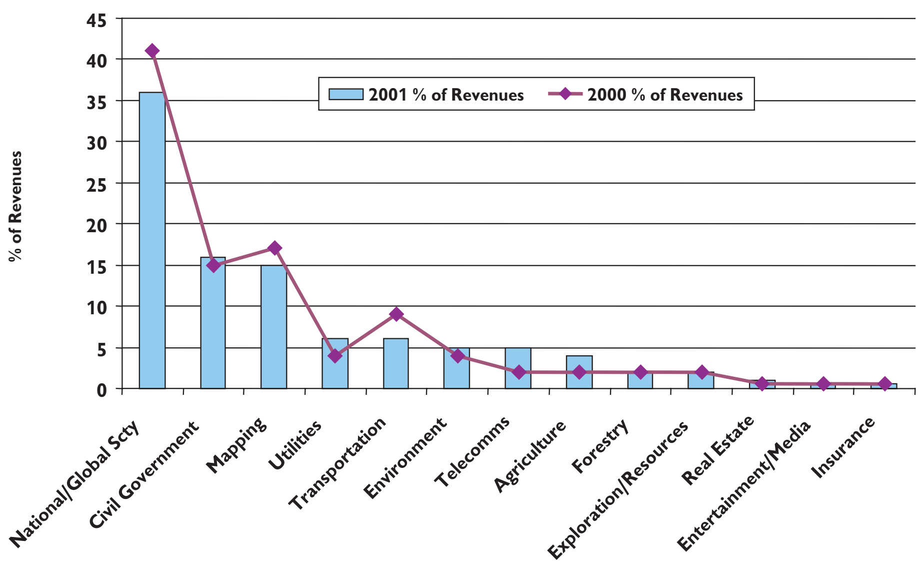


Figure 19 Revenue versus Market Segment

Figure 20 Commercial Company Size

tial for one or two firms to capture a disproportionate portion of the market. As Phase I results indicated, the aerial firms and the satellite firms were not in substantial direct competition. For these reasons, the industry appears to have opportunities for more firms and additional growth among diverse markets.

8 Phase II Government Sector

Figure 21 (page 38) illustrates the current major market segments within the industry. The government workforce at all levels follows in parallel those same application areas. The lowered response in National/Global Security/Defense is attributable to the fact that the data collection process tended to exclude the non-public Department of Defense programs. It is further important to note that this work was done prior to reorganizing many of the Government agencies into the Department of Homeland Security. Because the government is a key driver in industry funding, these data can be used to suggest future market segment size and development. Areas of high geospatial use follow a higher degree of government participation.

Given the importance of government spending on the geospatial industry the survey posed a series of questions to define the government profile in terms of constituents, mission and spending.

Figure 22 (page 38) illustrates that the federal government is the largest single level of government involved in the remote sensing market. However, state, local, and tribal governments, taken together form a larger and potentially more diverse market segment. Regional focus groups raised concerns about the lack of sharing of data between Federal agencies and state/local agencies or between state and local agencies. The smaller agencies often do not have the resources to purchase data on their own and could benefit from receiving data from the larger ones. However, often the data licensing arrangements prevent broad sharing of data. To meet this need, data providers have attempted to develop license arrangements that will allow such sharing for an extra fee, making possible broader use of the data than would otherwise be possible and relieving in part the burden of costs to the state and local governments.

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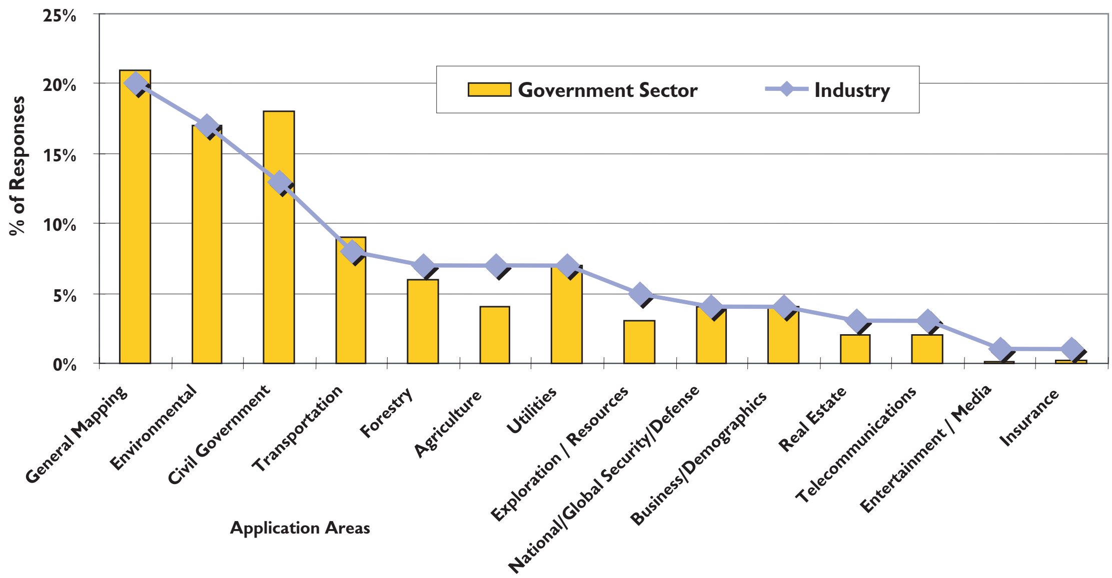

Figure 21 Comparison of Application Areas in which Government Respondents Work

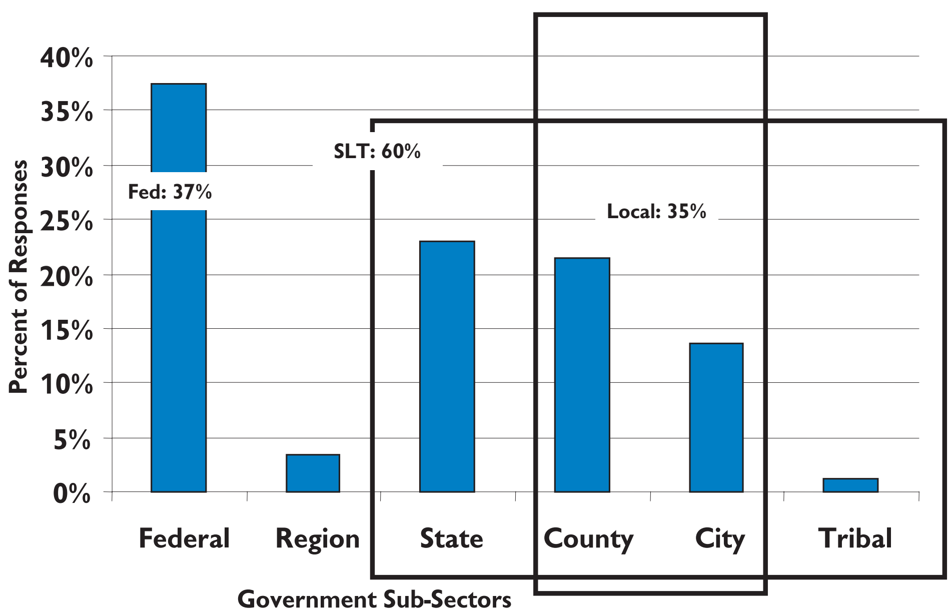

Figure 22 Government Sub-Sectors of Employment

Table 18 Most Important Mission by Level of Government

Mission Activities	Federal	State	Regional	Local	Other	Totals
Mapping	16	3	0	6	0	25
Earth/Natural Science	20	2	0	0	0	22
Natural Resource Management	10	10	0	1	0	21
Utilities	1	13	0	1	3	18
Government Services	5	0	1	6	1	13
Technology Development	10	0	0	0	0	10

For government-employed respondents to the Phase II internet survey, table 18 lists the single most important mission by level of government for which they work. The federal government is active in all mission types, though it places little emphasis on utilities. State governments, by contrast, focus most heavily on natural resource management and utilities planning and regulation. Only the federal government regards technology development as an important focus of its remote sensing efforts.

- Timeliness of data delivery How much time it takes a customer to receive data after an order.

The ground sample distance of a sensor system defines spatial resolution in most cases. In the past, line pairs per millimeter were used to characterize analog film systems. Given the increasing importance of digital capture, this study used ground sample distance (GSD) to define sharpness of resolution. In general, the demand exceeds current use for data of 1 meter or better resolution. With the advent of higher resolution satellite systems, this component of the industry has received considerable attention. It is apparent that the users in all three sectors often use products of a spatial resolution coarser than the level needed (figure 23, page 40). This indicates that significant sales opportunities exist in the sub-meter resolution products, and that recent deployments of high spatial resolution satellites for civilian use have a significant market for their imagery, though data price and licensing arrangements will continue to affect data sales.

Table 19 External Factors Most Likely to Affect Government Mission Activities 2000-2004

External Factors	Federal	State	Regional	Local	Other	Total
Funding/Budget Changes	73	30	1	12	1	117
Technology Evolution	39	19	1	12	2	73
Changing Customer Needs	30	8	0	10	2	50
Commercialization/Privatization of Government Functions	36	10	0	0	0	46
Politics/External Lobbying	24	9	1	6	2	42
New Legislation	21	13	0	6	2	42
Impact of Hazards/Disaster	19	5	0	0	1	25
Data Access/Supply Cost	4	5	0	4	0	13
Media/Public	7	2	0	2	2	13
Agency history/Credibility	4	2	0	1	0	7

Factors external to the government agency employing remote sensing data and technologies may affect the agency's ability to use them effectively. The surveys revealed that external factors could be quite diverse and vary according to level of government (Table 19). Respondents were able to pick up to three external factors. They cited changes in funding level as having the greatest effect on government missions at the federal, state, and local levels. Despite extra constraints on budgets during the current economic downturn, the industry is still experiencing limited growth. This suggests that other factors, including technological evolution and continued growth in customer needs, are at work to buoy the industry.

9 Geospatial Data Characteristics

Phase II compared the characteristics of geospatial data used and needed by each sector of the industry. Each survey question probed product performance as currently used versus the level of performance desired by the end user to meet their needs.

- **Spatial Resolution** The level of detailed information you can gather from an image. Ground Sample Distance (GSD) or modulation transfer functions (MTF) are measurements to characterize resolution.
- **Geo-Location Accuracy** The degree to which the coordinates of points determined from a geospatially referenced image or dataset agree with the coordinates determined by ground survey or other independent higher-accuracy means.
- **Temporal resolution** The frequency with which an imaging system can capture repeat imagery of a particular target area.

Geo-locational accuracy is another critical characteristic in the geospatial industry. It provides a measure of the accuracy with which a pixel can be located within a known surface. Together with GSD, the utility of a data set for mapping depends on the accuracy with which a pixel on the earth can be georeferenced. More accurate direct georegistration of remotely sensed images, with and without photo identifiable control, would spur industry growth. Data with geopositioning accuracy of three feet or better are in highest demand (figure 24, page 40), in large part because they reduce the costs to the users of establishing their own control points.

In many cases, accurate geo-locations depend on having accurate elevation data. The survey results for elevation accuracy indicate that academic and government customers need much better elevation data than they currently use (figure 25, page 41). The gap results from the fact that affordable elevation data are not broadly available in the marketplace. The provision of more accurate elevation data would apparently encourage remote sensing market growth.

Figure 26 (page 41) shows the responses to questions regarding

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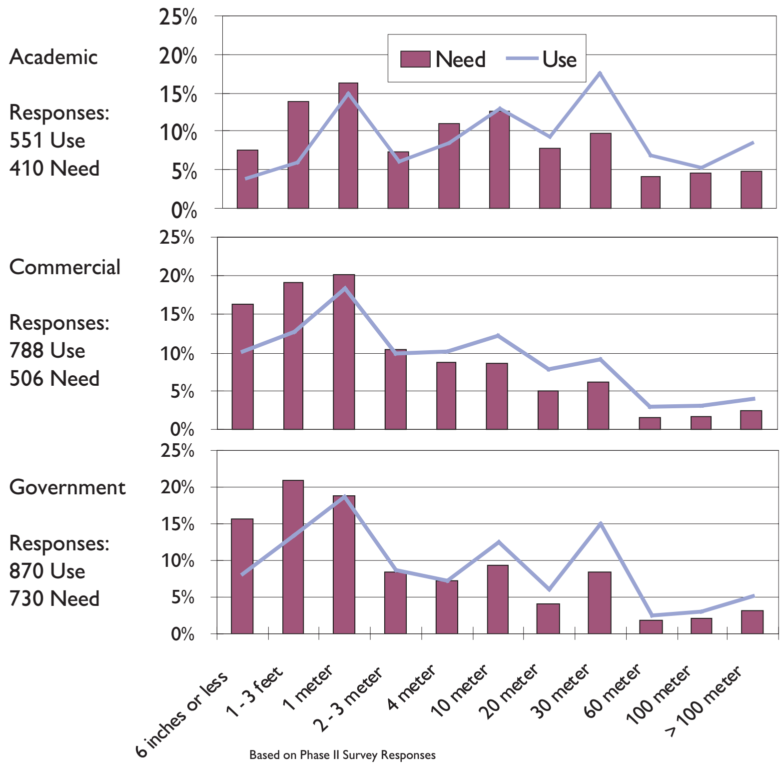
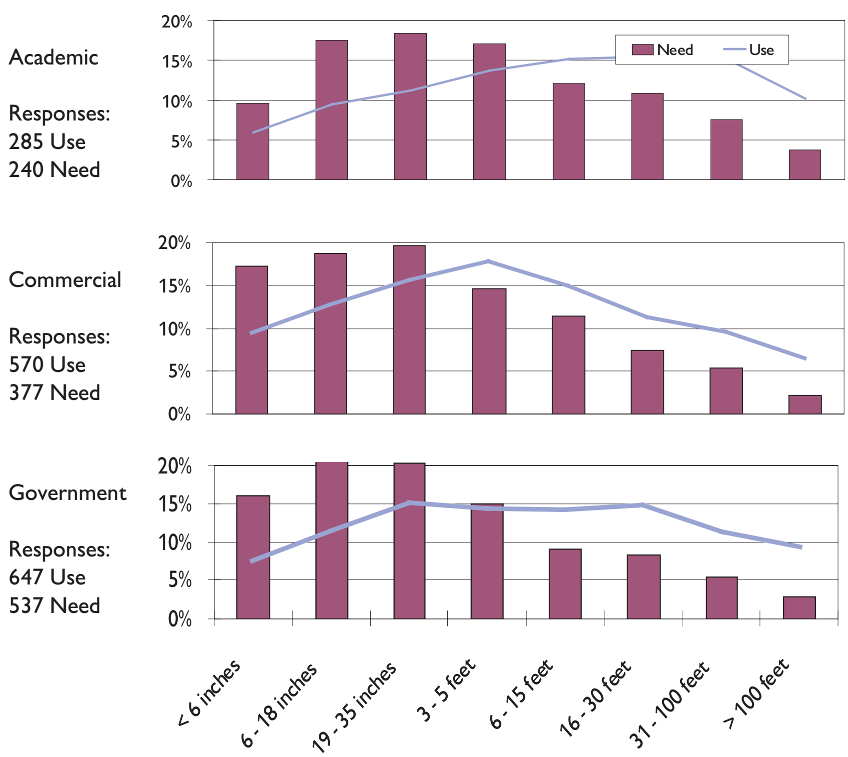
Spatial Resolution: Comparison of Use vs. Need (All Sectors)



- Academic and Government Sectors have similar profiles
- There is a distinct difference in the 30 meter range between Commercial and the Academic/Government sectors
- Commercial has the largest fall-off at 1 meter resolution (from Use to Need)
- Commercial Use and Needs tend toward higher resolutions, and are potentially less price sensitive. Academia and Government toward lower.
- Government Needs lean toward the 1-3 feet range

Figure 23 Spatial Resolution: Use vs. Need

Geo-location Accuracy: Use vs. Need (All Sectors)



- All sectors show a mismatch in what is Needed versus what is in Use.
- All sectors indicate an unfilled Need for Geo-Location Accuracy at levels of less than three feet.
- The Commercial and Government sectors have pronounced Needs for Geo-Location accuracy at levels of less than six inches.
- Academic and Government sectors indicate a Need for increased accuracy at three feet and less.

Figure 24 Geo-location Accuracy: Use vs. Need

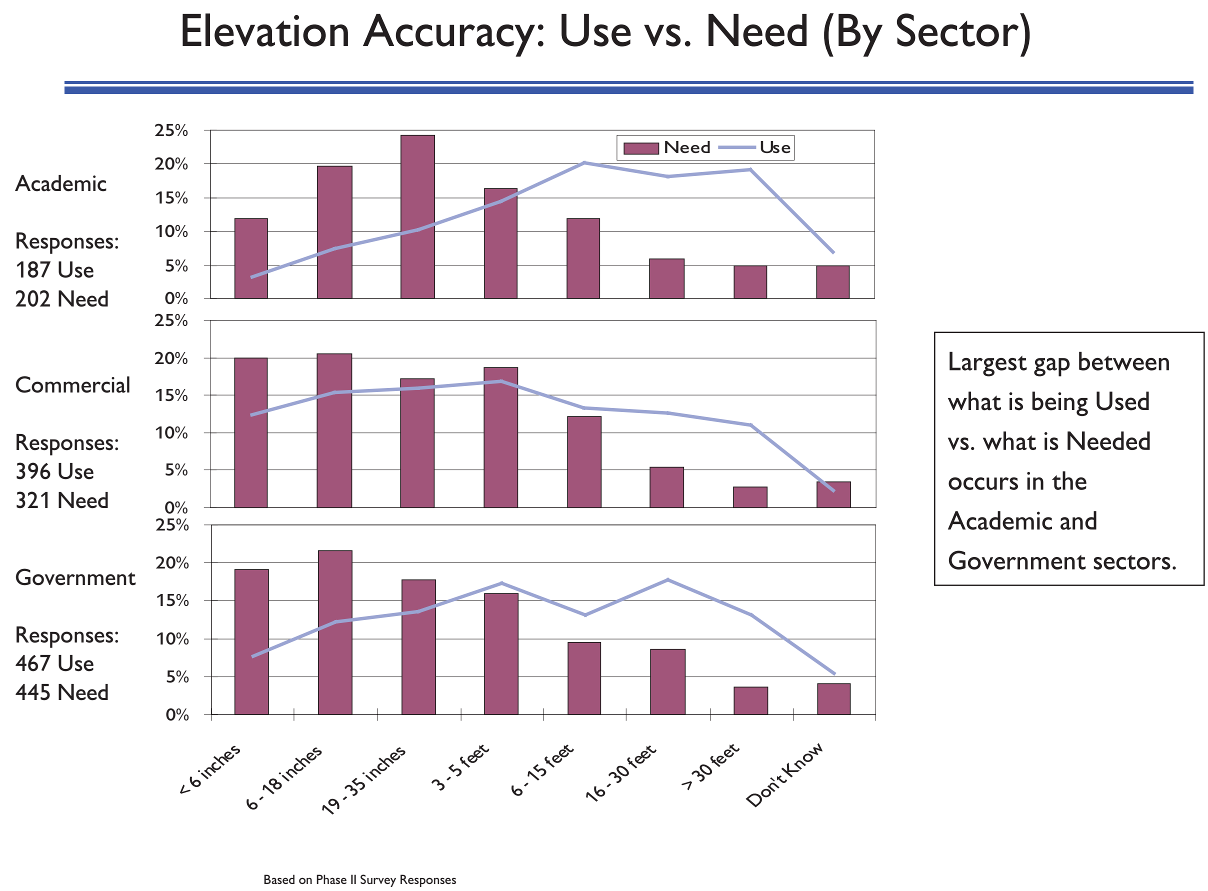


Figure 25 Elevation Accuracy: Use vs. Need

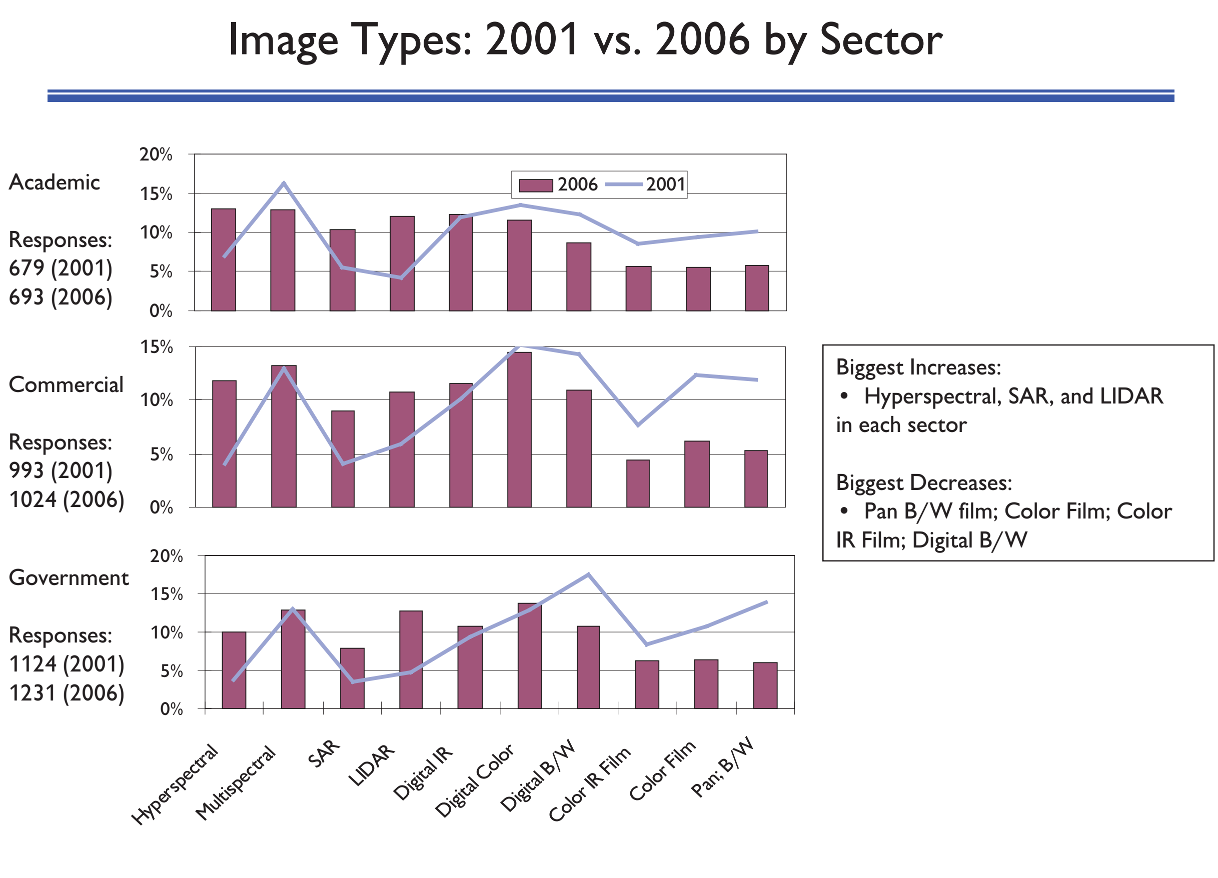


Figure 26 Image Types

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current and anticipated use of various types of imagery from 2001-2006. The results indicate an increasing shift to sensors that can provide the accuracy levels for geo-location and elevation shown in the previous figures. As high spatial resolution satellite imagery becomes more available and more affordable, customers will place less reliance on aerial photographic products. Providers of aerial data may in turn shift to using sensors operating in non-visible parts of the spectrum, such as LIDAR or to airborne Hyperspectral and SAR, which will provide higher spatial resolution than satellite counterparts for the foreseeable future.

10 Phase II Conclusions and Implications

Phase II results of the internet survey, focus groups and the closed envelope revenue survey reinforced the results of Phase I, but also provided new insights and greater specificity towards understanding the user community. Analysis of the data indicates a more comprehensive belief that the remote sensing and geospatial information industries are emerging as increasingly important constituents of the U.S. and global information economy. They also believe that providing increased policy attention to the many important details of the industry will assist the industry to grow and prosper.

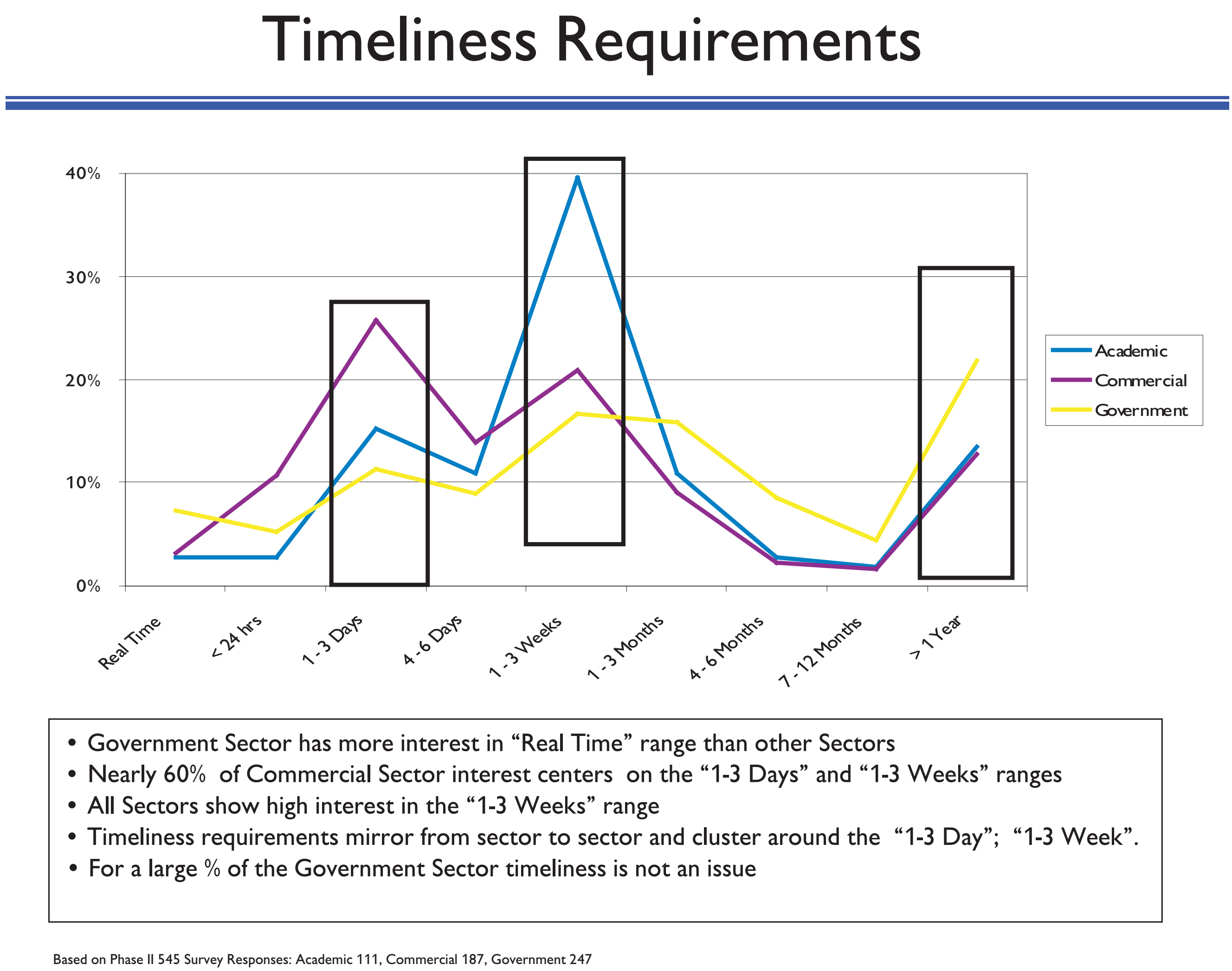

Figure 27 Timeliness Requirements

The peaks of figure 27 indicate the industry's desire for data timeliness, as defined as the time between data acquisition and delivery to the customer. As government agencies at all levels adjust to potential new demands for remotely sensed data to support homeland security, more timely data delivery may be of greater interest. This trend will likely encourage deployment of processing capabilities during the airborne data collection and autonomous processing on satellites.

10.1 Character of the Industry

This is an industry undergoing rapid change as potential clients realize the benefits of using geospatial data and analytical technologies. Respondents continued to hold an optimistic view of the growth of the industry, though they reduced their growth projections compared to Phase I to 9% over the next few years (from 14% in Phase I). Phase II responses also revealed the fact that most firms in the industry are relatively small (< 100 employees) and focused on providing specific, narrowly defined services or data. By contrast, the few large firms (500-1000 employees) generally provide a wide range of services. Most of the civilian remote sensing industry involves the provision of mapping and engineering applications needed by governments at all levels.

Phase II also highlights the prominence of the federal government in direct procurement, support for other levels of government, and as a source of research and development. The focus and evolution of the industry is highly influenced by government requirements at all levels of government. Hence, much of character of the industry is defined by a tightly coupled interdependency of the three sectors—government, private firms, and academia. Further, the many different applications for geospatial information within governmental institutions have led to the development of many small firms devoted to a few geospatial information products. As a result, the many smaller firms that under gird the industry are less inclined to support internal R&D and workforce development activities, are more affected by governmental competition with their services, and are less able to meet foreign competition forcefully.

10.2 Workforce Issues

Phase II demonstrates that the age structure of workers in the industry follows a bi-modal distribution, with most either older, experienced workers or younger employees, new to the industry. There are relatively few in the mid range. These data suggest that many younger employees are leaving the industry for better opportunities, potentially creating a shortage of mid-level personnel. The reasons for this trend are not clear. However, because many industry employees earned degrees outside of remote sensing and GIS, they may feel drawn to accept positions in their original fields of interest in the broader information industry (such as computer science) when such positions become available, thus contributing to the exodus.

It is unrealistic to assume that academia can produce sufficient numbers of qualified, entry level workers with all of the education and skills to meet every RS/GIS job requirement. The data suggests that just at the time of full integration to a job (usually 3-4 years), many employees are exiting their jobs and even the RS/GIS profession. This situation, along with the shortage of remote sensing professionals graduating from the educational systems, results in a chronic shortage of qualified employees. Private firms and government agencies must take initiatives to retain those early career employees to address this shortage.

The results of Phase II reemphasizes the discomfort that respondents in the private sector and government have about the relatively low numbers of geospatially-prepared graduates and the relevancy of their education and training. Graduates are simply not entering the workforce in sufficient numbers and with sufficient training in the latest technologies and techniques. This is a very difficult problem, since most academic programs are small and cannot adjust rapidly to new advancements taking place in the industry. Further, as noted earlier, the smaller firms generally have limited resources for additional on-the-job training to compensate for any deficiencies in the educational programs of their new hires.

This is clearly a key shortfall in supporting the future growth of the industry. The burden of training skilled individuals rests within the commercial sector or the relatively few schools offering remote sensing or GIS degree programs.

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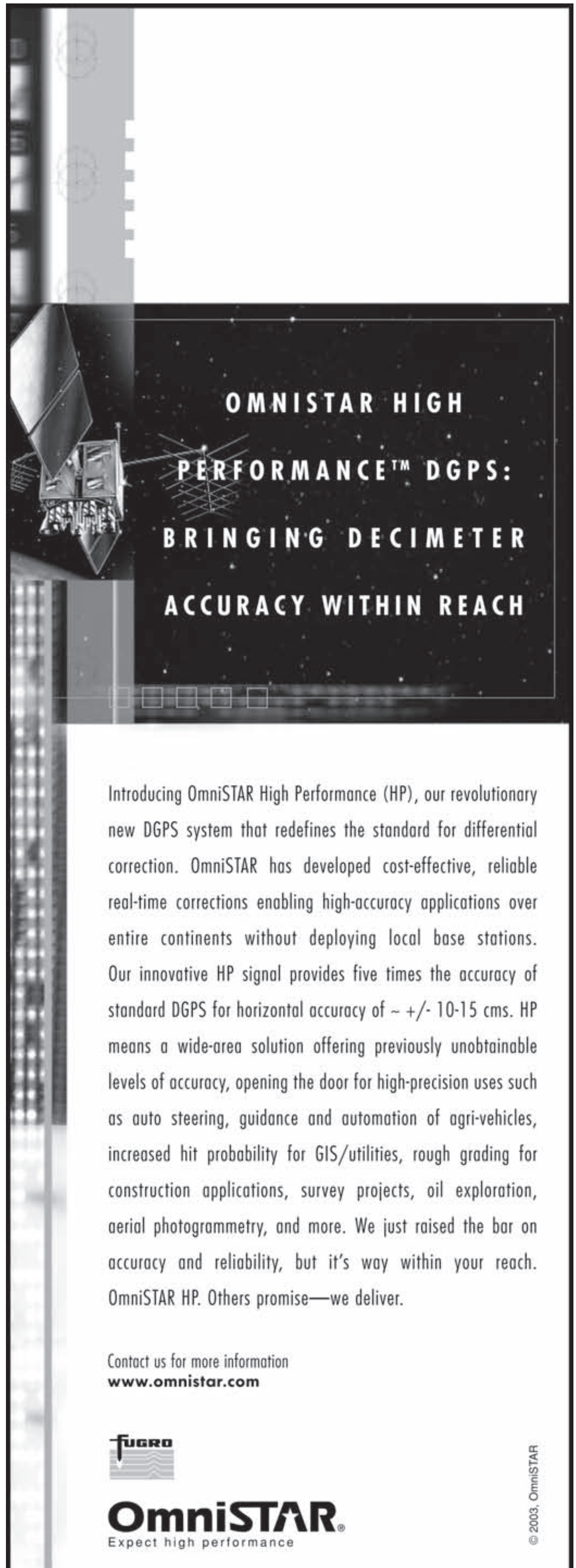

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10.3 Adoption of New Sensors

The results indicate that geospatial users are embracing the new data sources and imagery. Respondents see higher spatial resolution data, LIDAR, and SAR (IFSAR) as important industry advancements.

Each of these technologies offers its own potential for growth. Digital aerial sensors provide potential new vendors with relatively low entry barriers of cost and technology to remote sensing compared to satellite sensors. Other technologies such as hyper or high spatial-resolution multispectral sensors offer new market potential to the industry.

Digital aerial cameras coupled with inertial measurement and onboard GPS enable the low cost proliferation of geopositioned information. Lower cost systems may be used to capture data aerially and in turn these cost savings may open new markets where pricing has limited acceptance of remotely sensed information.

Hyperspectral sensor systems in development will offer automated feature detection, identification and classification. The ability to discern change and apply appropriate corrective measures affects many markets. Markets as diverse as defense, precision agriculture and forestry all benefit from change detection technology.

The elevation component of remote sensing also provides high growth potential. As sensors are developed many serve markets requiring geopositioned content. Both IFSAR and LIDAR offer the wide range of imaging sensors an elevation layer of high accuracy. Such elevation data open DEM-limited systems to markets in need of superior geopositioning and terrain information.

10.4 Market Opportunities

The results of Phase II indicate that there are ample opportunities for growth in diverse market segments. Although national defense and global security still dominate the data uses, the needs of local and state government for mapping, homeland security, environmental assessment, and infrastructure applications are substantial and are likely to increase.

The industry gains a very small portion of revenues from certain business activities with strong geospatial requirements, such as real estate and insurance. These businesses could bring future market opportunities if geospatial information is provided to them in attractive and appropriate configurations and potential customers are educated in its use. Insurance applications require specific timing, rapid deployment and high spatial resolution. Real estate often requires lower cost pricing, as well as collections other than nadir. Future forecast efforts should focus on understanding more deeply which fields are likely to likely to pose growth opportunities and how market penetration might be assisted.

Smaller firms are attempting to provide specialized value added services on both satellite and aerial products to meet the diversity of needs within the customer base. The diversity of analytical needs tends to limit the potential for one or two firms to capture a disproportionate portion of the market. Further, the aerial firms and the satellite firms do not appear to be in substantial direct competition. On the contrary, for many applications, they complement each other. Thus, for these reasons, the industry appears to have opportunities both for a greater number of firms and continued additional growth among diverse markets.

10.5 Data Access by Levels of Government

As indicated in Phase I, issues of data access are of concern, especially to federal government data users, while data rights and licensing are of concern to the commercial producers. Phase II focused greater attention on lower levels of government. Federal data users express concerns about finding sufficient funding to support data acquisition for their missions. Further, they worry about the uncertainty of data access and about private sector licensing policies that may limit interagency and intra-agency sharing of raw data and derived data products. Since civilian federal agencies increasingly collaborate with state and local governments, the ability of the different levels of government to share data and products among themselves is a growing concern. Focus groups reiterated the lack of sharing between the federal and local governmental users. The geospatial demands of responding to homeland security improvements are likely to add to this concern. To gain sufficient income to remain in business, commercial firms must generally resell data to different levels of government. Nevertheless, some innovative pricing structures involving several levels of government together (federal, state and local) have appeared recently.

10.6 Data Specifications – Need Versus Use

In recent years, the industry has provided data to civilian users with higher spatial resolution, and higher geo-locational and vertical accuracy. All sectors of the user community welcome these trends. However, Phase II results indicate that the current data resolutions and geospatial accuracies generally do not meet the needs of data users. In particular, many data customers require levels of spatial resolution and geo-locational and vertical accuracy of .5 – 3.0 feet, but do not use them because of barriers of cost or availability. Hence, there is ample scope for improvements both in the quality of data offered and in the costs of the data.

Factors beyond the remote sensing industry further play into data utilization, which affects industry capabilities. While computers have kept pace with increases in resolution and data processing, not all levels of users can keep up with these advances. Improvements in resolution often require users to invest in costly improvements both in data storage and data networking.

For example, hyperspectral data to support the analysis of urban surface materials, such as road surfaces, or for non-point pollution applications would be highly desirable, but not generally available. Further, the results indicate that issues of high cost, delays in acquisition, and licensing may inhibit adoption of these data by users. Neither the needs of the academic data customers nor those of governmental data customers are being met at high levels of accuracy. Continued industry growth will only happen with the necessary implementation of improved technology and policy.

11 Phase III Analysis and Conclusions

Phase III of the Ten-Year Forecast project was designed to capture the most recent information for those organizations that primarily use and/or produce data and information from image based GIS, photogrammetry and remote sensing and to validate the information and trends extracted from Phases I and II. It also attempted to gauge the impacts on the industry of the September 11, 2001 terrorist attacks. Phase III primarily used an internet survey to collect data, contacting individual and sustaining corporate membership of ASPRS during the

Autumn-Winter of 2002. The organizations targeted and respondent samples of each phase of the survey differ. It is further critical to note that many of Phase III's subsegment analyses have a limited sample size.

11.1 Profile of Respondents

A total of 333 respondents completed the survey. As shown in figure 28, a total of 133 respondents, or approximately 40% of the sample work in the commercial sector. About 41% (134 respondents) work in government at all levels and 19% (66) for academic organizations. As is indicated in the following, this sample represents a good cross section of the industry.

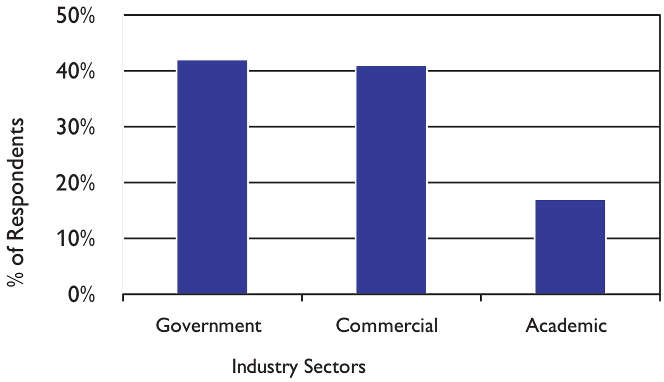

Figure 28 Respondent Distribution by Remote Sensing Industry Sector

Figure 29 shows that about 45% of government respondents work for the federal government. Slightly less than 40% are from local governments and the smallest group (18%) works for state government. This response profile tends to confirm that most of the interest and activity within the industry is concentrated at the federal and local levels.

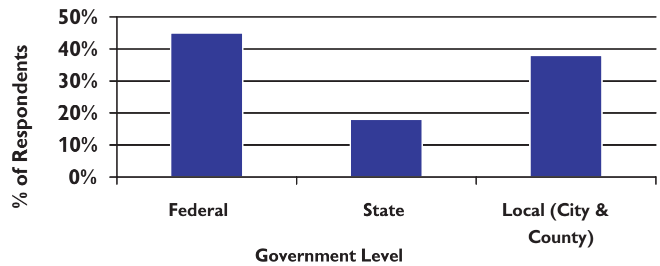

Figure 29 Government Respondent by Level

Figure 30 reflects the geographic pattern of respondents to the Phase III survey, with the majority coming from states with high levels of activity in the remote sensing industry. Most respondents live in California, Colorado, Florida, New York, Virginia and Washington D.C.

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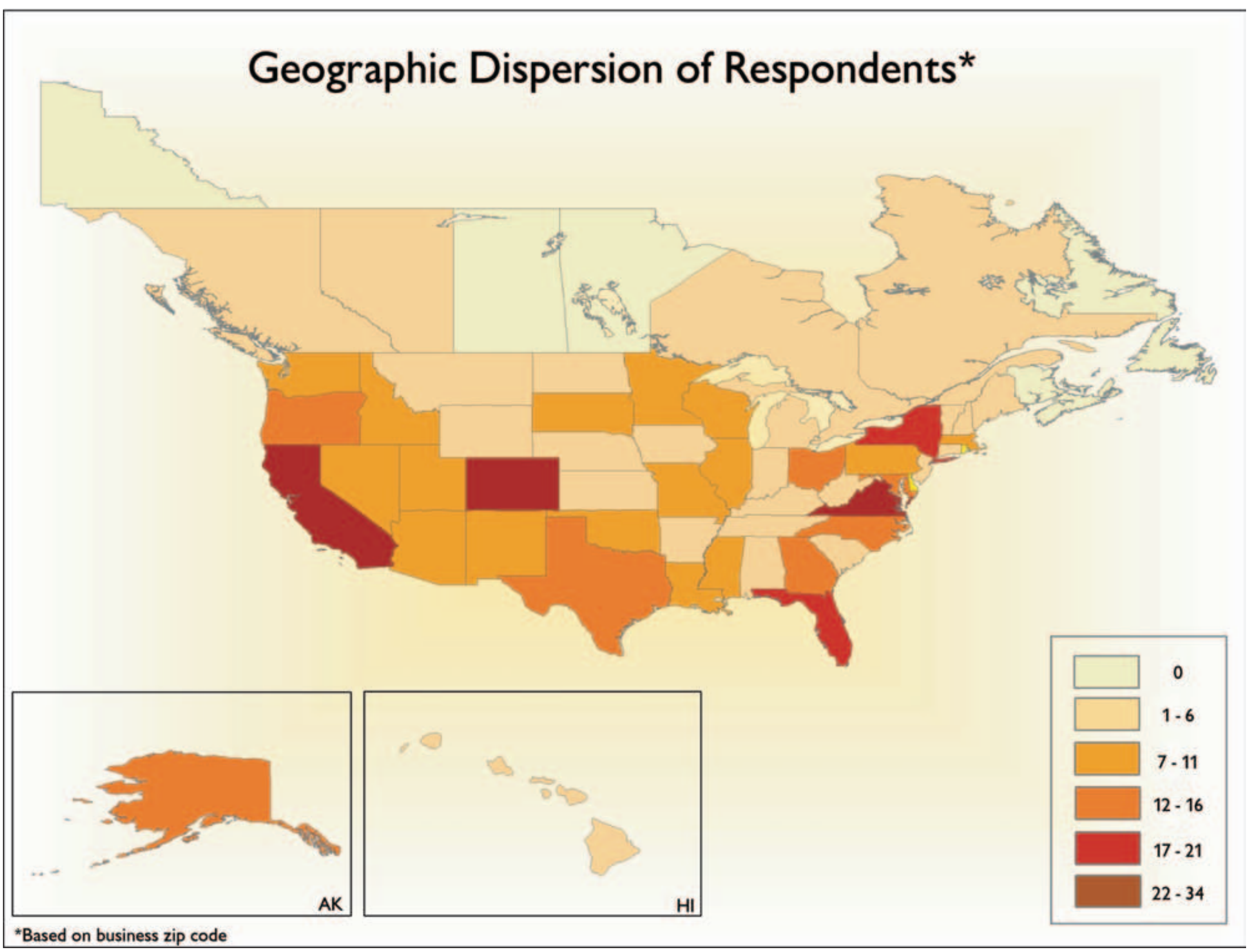

Figure 30 Geographic Dispersion of Respondents

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The respondents reflect the spectrum of levels and job titles within their organizations (table 20). The senior management of commercial firms was strongly represented with 43 responses from owners or presidents. In the governmental organizations, the majority of the respondents are on the professional and technical staff. Academic respondents are comprised of approximately equal numbers of teaching faculty and research staff and administrators.

The sector balance of Phase III respondents appears to reflect the relative proportion of employees in the commercial and government sectors, each of which comprise about 40% of the total industry population. Employees of the academic sector make up the remaining 20%. Within the government sector, federal and local level sector responses dominate, which reflects the relative proportion of persons involved in Geospatial activities in the government sub-sector.

Phase III shows a nearly even distribution among the basic activities: (photogrammetry: 32%; remote sensing: 34%; image-based GIS: 34%). Slightly more producers than users responded, especially in photogrammetry and remote sensing. However, the survey received a significant response from the user community. Overall, the sample is large enough in all categorical breakdowns to form the basis for reliable analysis of the present status of the industry and informed forecasting.

Table 20 Respondents organizational job title

Government			
Title	**Responses**	**Title**	**Responses**
Executive Director/Senior Manager	40	Professional Technical Staff	67
Research Scientist	14	Technician	5
Program Staff	8		
Commercial			
Title	**Responses**	**Title**	**Responses**
Owner	35	R&D Manager	2
President	8	Marketing Manager	5
Top Level Manager	15	Product Manager	7
Senior Manager	18	Manager	15
Sales Manager	4	Analyst	14
Engineer	4	Technician	6
Academic			
Title	**Responses**	**Title**	**Responses**
Academic Administrator	5	Adjunct Faculty Member	1
Professor	15	Laboratory Director	6
Associate Professor	6	Research Staff	10
Assistant Professor	6	Student	2
Instructor	2	Other	13

11.2 Characterization of Data Producer and User

The internet survey asked a series of questions on market segmentation, activity, and producer and user interaction to understand how image-based geospatial data are being used. As illustrated in figure 31, the five most common industry segments are General Mapping, Environmental and Civil Government, National/Global Security/Defense and Transportation. The focus of geospatial activities differs according to market subdi-

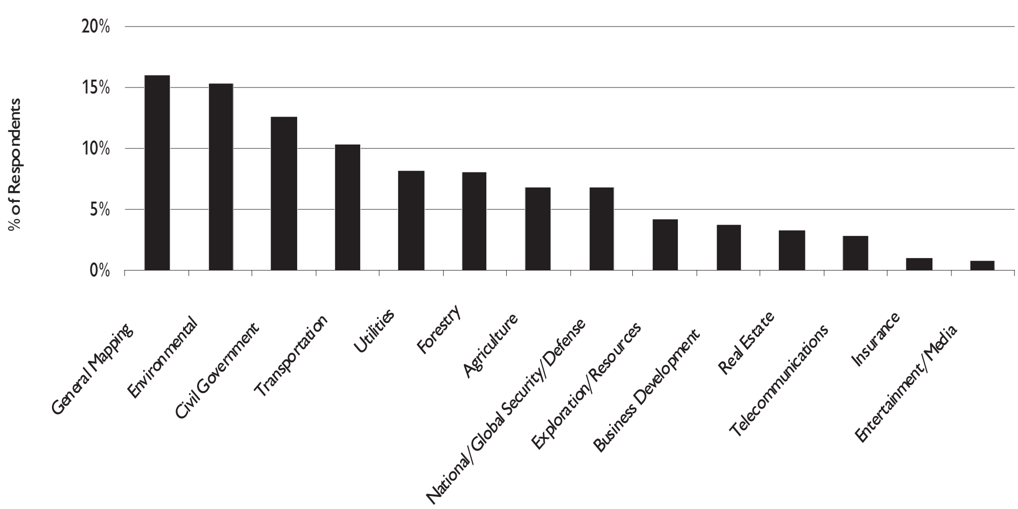

Figure 31 Organizational Focus on Market Segments

vision; Image based GIS, while not largest subdivision in terms of respondents, has the most even distribution across the market segments. Photogrammetry has the greatest presence (about 30% or more) in General Mapping, Civil Government, Transportation, Forestry, Utilities, Exploration, Real Estate and Insurance. Remote Sensing primarily supports the Environmental, National/Global Security, and Agriculture segments.

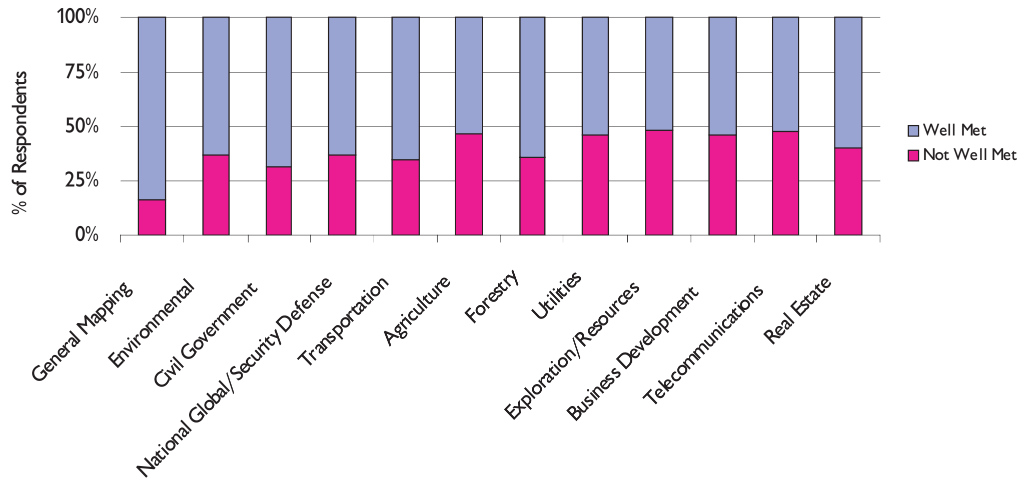

Figure 32 Extent of Producer and User Needs Met by Market Segment

Producers and data/information users in most market segments (figure 32) indicated that their geospatial needs are reasonably well met. Environmental and Civil Government user needs are met slightly more effectively than those of producers. However, the geospatial information needs of Agriculture, Utilities, Exploration/Resources, Telecommunications, and Real Estate are less well met than the others, which is likely because these sectors have had less experience with geospatial information than the other categories.

As indicated in figure 33, approximately 40% of the firms in the industry have been using or developing geospatial data and information for less than a decade. This highlights the relatively youthful and innovative nature of the geospatial market. It is also changing rapidly. Over the last decade, many new technologies have been developed into industry staples: softcopy photogrammetry, position orientation systems, geographic information systems, LIDAR and other technologies. Many of the newer firms have been critical in introducing these technologies into the marketplace. As noted earlier, these firms generally are small and are engaged in value-added deployment of technologies developed by federal government laboratories and larger firms.

Delivery of data in electronic form is the method of choice for firms today (table 21, page 48), though they still deliver a few paper products (7%). for certain needs Although digital data and information are easier to use in most applications, hard copy is still very viable for its ease of access and use in the field.

The forecast allows a comparison of user and producer perspectives. Given the technological focus of geospatial markets it is critical for growth that users and producers successfully convey an understanding of products and features to each other. User awareness of

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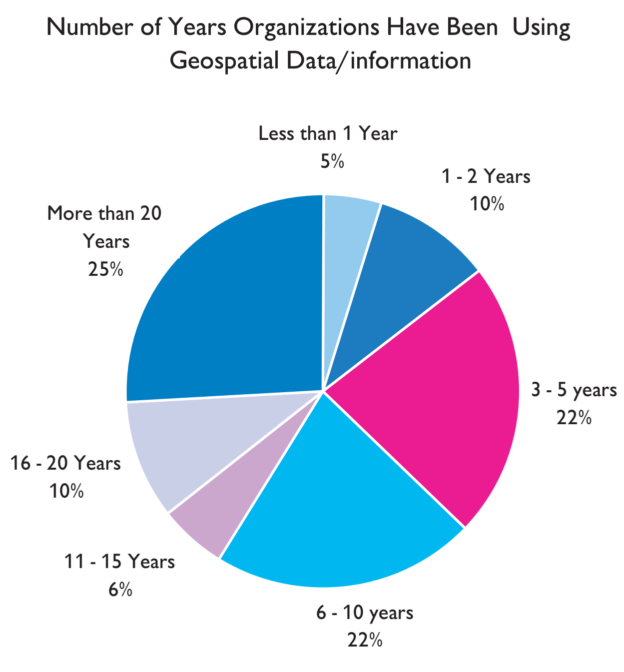

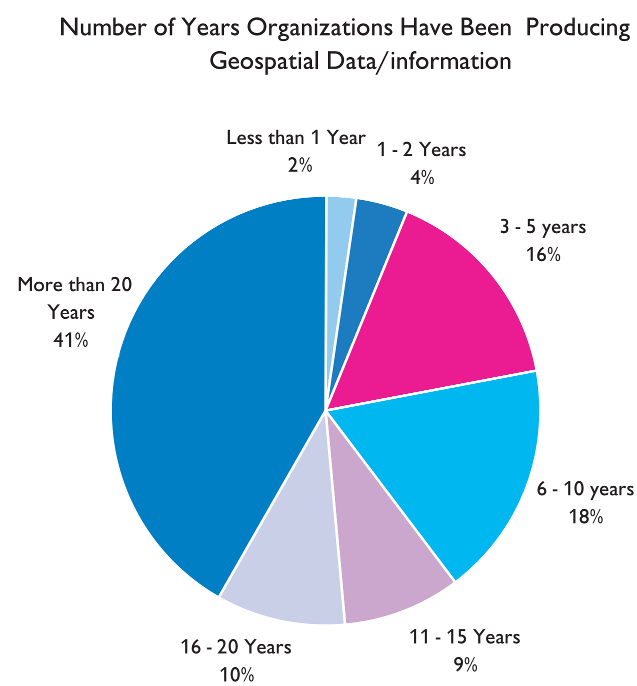

Figure 33 Number of Years Organizations Have Been Using and Producing Geospatial Data & Information

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Table 21 Data Delivery Methods

Method of Data Delivery	% of Respondents
Compact Disk	56%
Electronic Transmission	18%
World Wide Web / Internet	10%
Paper/Hardcopy	7%
Digital Video Disk	4%
Magnetic Tape	3%
Hard Drive	1%

technological capabilities and benefits is critical in user decisions to purchase technologies and data. Approximately 75% of data producers believe that customer/user technology awareness is a critical issue for the industry as a whole (table 22).

Table 22 Producer View of Customer Technology Awareness

Importance in Data Delivery

Level of Importance	Percent of Producers
Somewhat Important	9%
Important	25%
Very Important	40%
Extremely Important	26%

Importance in Purchase Decisions

Level of Importance	Percent of Producers
Somewhat Important	8%
Important	20%
Very Important	48%
Extremely Important	25%

Earlier phases of the forecast noted that users often failed to understand the benefits likely to accrue from the adoption of new geospatial technology. While producers are often required to develop and incorporate new technologies in their products, the higher costs often incurred are seen as impediments to the user. It is critical for producers to provide users a cost benefit analysis and a clear understanding of what can be gleaned from new technologies and data. This minimizes the separation in understanding and training between the two groups. Successful firms will give greater attention to customer training in order to close this potential gap in understanding.

Phase II of the forecast developed the use versus needs matrix for data and information characteristics. This matrix helps developers and data providers define which characteristics are most important to their prospective markets. Phase III found the characteristics of greatest importance to be those metrics that define how the data can be evaluated: geolocation accuracy, timeliness, cost, currentness, and spatial resolution (figure 34). Of secondary importance are components defining the documentation or processes associated with the content: color/spectral/radiometric quality, documentation/metadata, format, and accuracy statement.

Though data users found documentation, metadata and accuracy less critical than other characteristics, these often define the interoperability of data sets. Formatting permits the user to correctly register and read data sets, to further enhance data sharing. So while these fields may not appear to the user to be of primary concern, they will clearly drive the overall user satisfaction with a product suite.

11.3 Phase III-Geospatial Data Use by Market Segment/Application

11.3.1 Environmental Applications

In the environmental segment, land use and resource planning and watershed analysis are the most important market sub segments (figure 35). More producers than users responded to the survey. Most have been producing data/information for either 6-10 years or more than 20 years. Civil government producers cite currentness and spatial resolution as the most important data characteristics. As in other segments, civil government data producers feel that data users need to be knowledgeable about data characteristics and the technologies used to collect and analyze the data in order for the producers to serve them adequately.

In environmental analysis, color infra-red, multispectral, or hyperspectral systems may benefit the user by making it possible to sharpen analysis or more fully classify regional types. Yet, surprisingly, radiometric integrity was not noted as a key issue in this market segment. No users in the environmental segment reported using photogrammetry services or data.

Most users have been working with environmental data/information for 3 - 10 years and receive data/information primarily on CD or in paper/hard copy format, which they find of particular utility in fieldwork. Many affirm that knowledge of product characteristics and utility is important to very important when it comes to increasing the use of geospatial information in their work. About half of the users are dissatisfied with the data providers' explanations of how best to use data/information products. Hence, better information and training about data and information products could well assist additional growth within the environmental segment. Geolocation accuracy and cost of data are the most important data/information characteristics to environmental users.

11.3.2 Civil Government

Most organizations supporting civil government have been producing data/information for either 3 –5 years or more than 20 years. This bi-modal distribution apparently results from the entry of new firms that introduce new technologies to the marketplace. Image-based geographic information systems accounts for 50% of the type of data used in this sector, which exemplifies the growth of systems delivering geopositionally accurate data. This trend also illuminates the importance of data sharing and including accurate meta data. While this was a secondary issue for producers, it may be considered of greater importance to users of the data. As in other segments, producers believe that the technological awareness of the users is im-

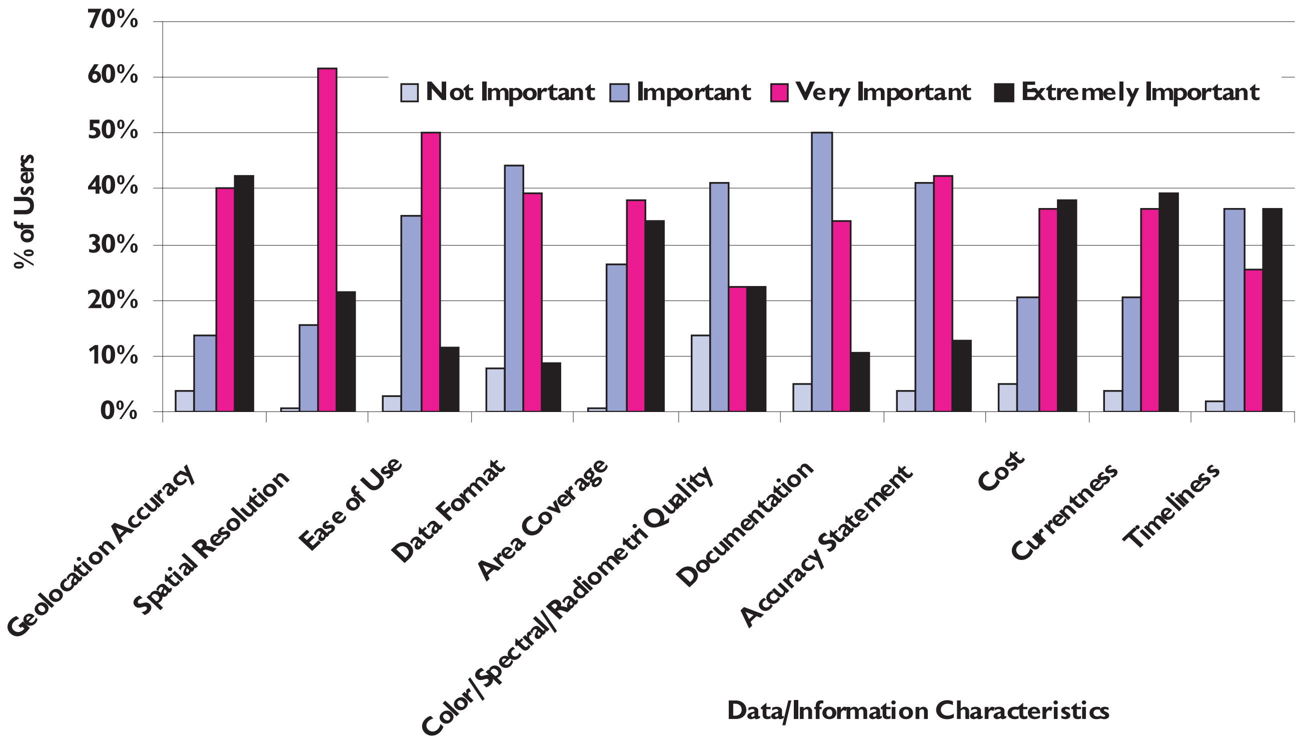
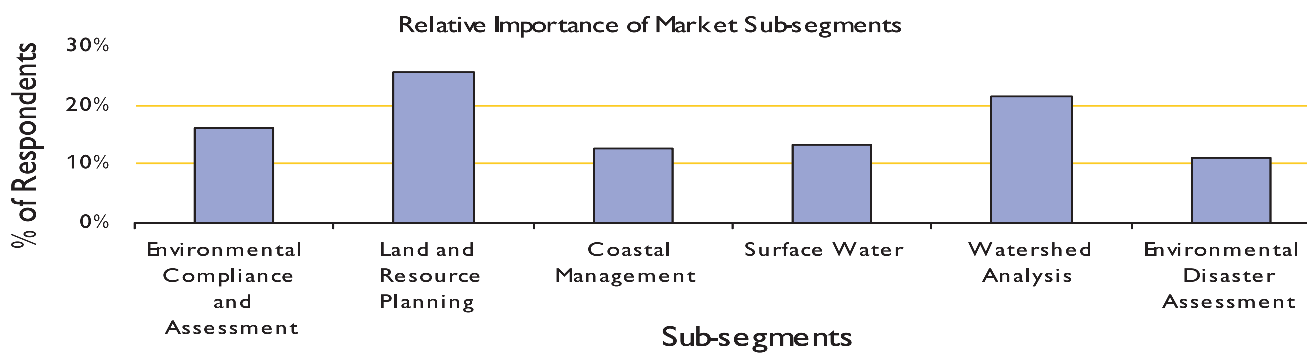


Figure 34 Importance of Data/Information Characteristics to Users



Type of Geospatial Data Used	
Image Based GIS	35%
Photogrammetry	0%
Remote Sensing	65%

Producer or User?	
Producer	73%
User	27%

Environmental Respondents Sectors	
Academic	38%
Commercial	24%
Government	38%

Figure 35 Environmental Segments

portant to very important in terms of being able to deliver their data products successfully.

Producers found cost and geolocation accuracy to be the most important data characteristics (Figure 36, page 50). Producers must focus on cost to insure their ability to sell or produce a product. Geolocation accuracy is also important to producers because achieving geolocation accuracy and validation often requires significant attention to quality data capture and production, thus requiring significant investment in time and resources.

11.3.3 National Defense and Global Security

Understandably, in this category all of the respondents work for the federal government (figure 37, page 50). The majority of organizations in this market segment have been producing data for more than 20 years. Many workers in this segment have previously worked directly the federal government supporting tactical and strategic reconnaissance missions.

Here again, producers cite users' technological awareness as very/extremely important in being able to deliver data and information effectively. This segment has often led the industry in pushing the boundaries of requirements and improving both the analytical state of the art and the research and development of future systems. Historically, spatial resolution has been the most important data/

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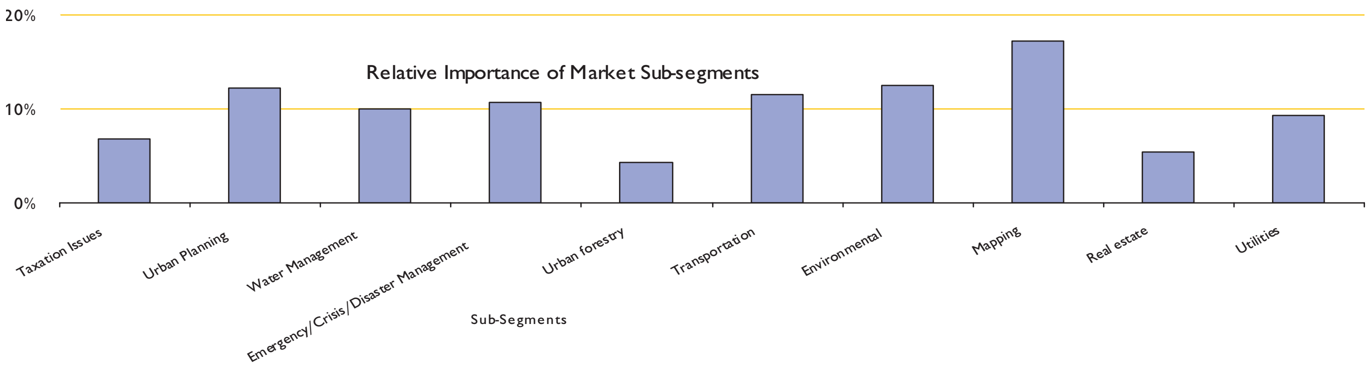
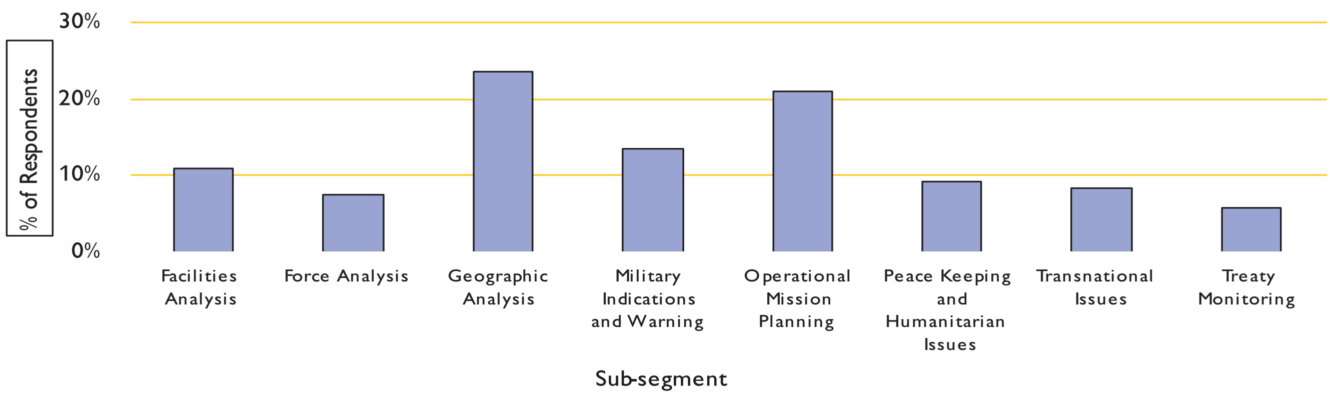


Type of Geospatial Data Used	
Image Based GIS	50%
Photogrammetry	27%
Remote Sensing	23%

Producer or User?	
Producer	63%
User	37%

Civil Government Respondents Sectors	
Academic	4%
Commercial	46%
Government	50%

Figure 36 Civil Government Segment



Type of Geospatial Data Used	
Image Based GIS	35%
Photogrammetry	12%
Remote Sensing	53%

Producer or User?	
Producer	79%
User	21%

National /Global Security/Defense Sectors	
Academic	3%
Commercial	53%
Government	44%

Figure 37 National/Global Security/Defense Segment

information characteristic in this segment. What can be seen in imagery is critical. Thus, ground sample distance is more important than other metrics (i.e. color/radiometric content) to imagery analysts.

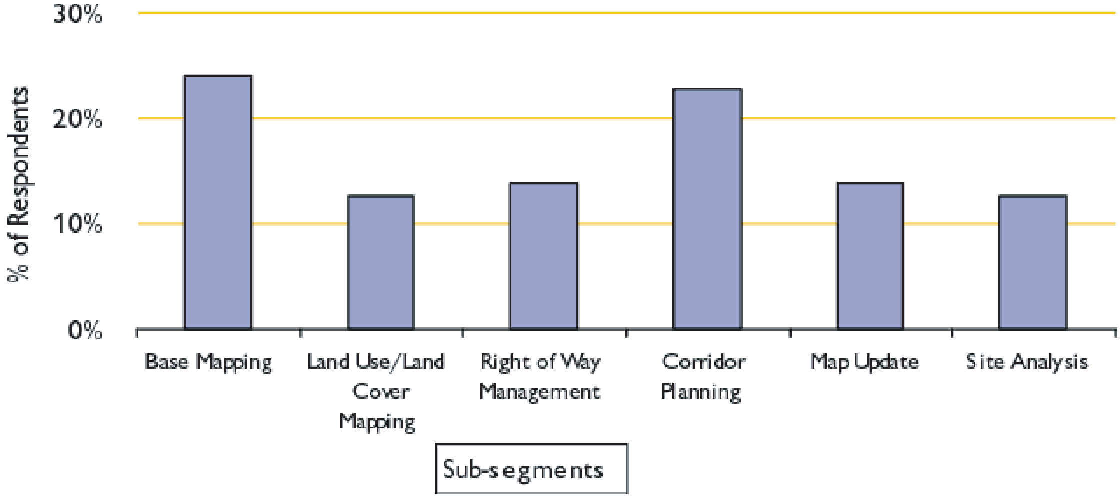
When examining user needs for data characteristics, too few data users in this market segment responded to produce statistically significant results. Further, the line between users and producers of data is blurred by the fact that the government or its contractors often produce content for internal consumption.

11.3.4 Transportation

The transportation segment has long needed detailed, highly accurate maps for transportation planning, construction and maintenance. Hence it is not surprising that geolocation accuracy is the most important data/information characteristic for this market segment. As is evident by the low use of remotely sensed data (Figure 38), the segment has fewer identified requirements for detailed color, multispectral, or radiometric information.[17] Historically, state agencies have led in the production and use of geospatial data for transportation, a reflection of the primacy of state responsibilities for transportation. Some 68% of the respondents citing transportation as their primary responsibility are government data producers. Overall user needs were not as well met in corridor planning as in other subsegments, suggesting an opportunity for industry growth in supplying these data/information needs. The use versus needs section of phase II supports this observation.

As a result of the number of transportation sub segments (figure 17), the survey achieved an insufficient sample to provide statisti-

[17] The Department of Transportation has funded the National Consortium for Remote Sensing in Transportation (http://www.ncrst.org) to promote research and development in this field.



Type of Geospatial Data Used		Producer or User?		Transportation Respondents Sectors	
Image Based GIS	20%	Producer	64%	Academic	4%
Photogrammetry	76%	User	36%	Commercial	28%
Remote Sensing	4%			Government	68%

Figure 38 Transportation Segment

cally significant results for users of transportation data/information. Further, the line between users and producers of data is also blurred in transportation because governments produce much data and information for internal consumption.

11.3.5 Forestry

The majority of forestry data producers have been in the industry for more than 20 years. Most respondents work in forestry management and timber inventory (Figure 39).

Some 67% of respondents in forestry data production and use work in government, with 60% of these in the federal government. Producers of forestry data products feel that the technological awareness of the users is very important in terms of being able to deliver appropriate data. Respondents cite ease of use/integration, color/spectral/radiometric quality, and currentness of data as the most important characteristics, metrics that define the foresters' ability to assess and characterize a forest stand. A much more uniform distribution of skills is required in this segment. In contrast to transportation or defense, no one type of geospatial data type stands out in forestry, though respondents emphasized remotely sensed data, likely because these data help to differentiate tree type, extent of stands, and potential stress on forests. The ability to review remotely sensed forestry data sets in a timely manner makes it possible to respond quickly to forestry needs or concerns.

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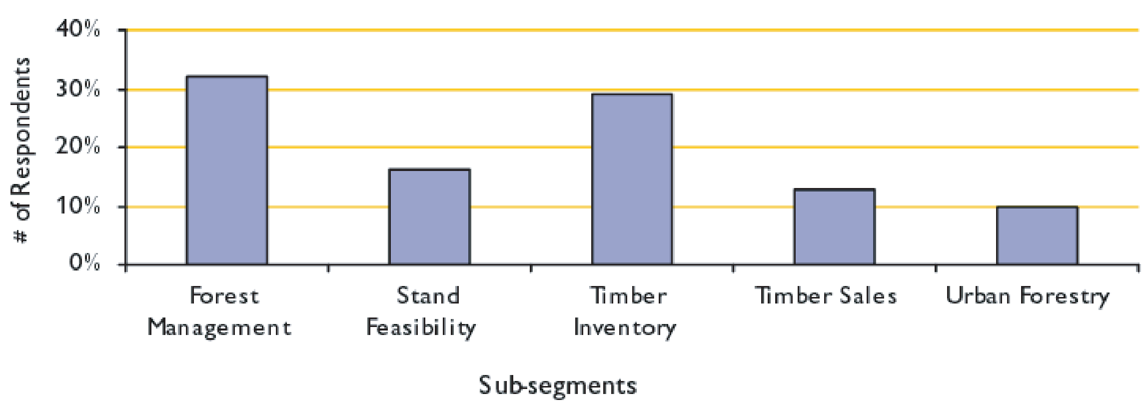

Type of Geospatial Data Used		Producer or User?		Forestry Respondents Sectors	
Image Based GIS	25%	Producer	58%	Academic	17%
Photogrammetry	33%	User	42%	Commercial	17%
Remote Sensing	42%			Government	67%

Figure 39 Forestry Segment

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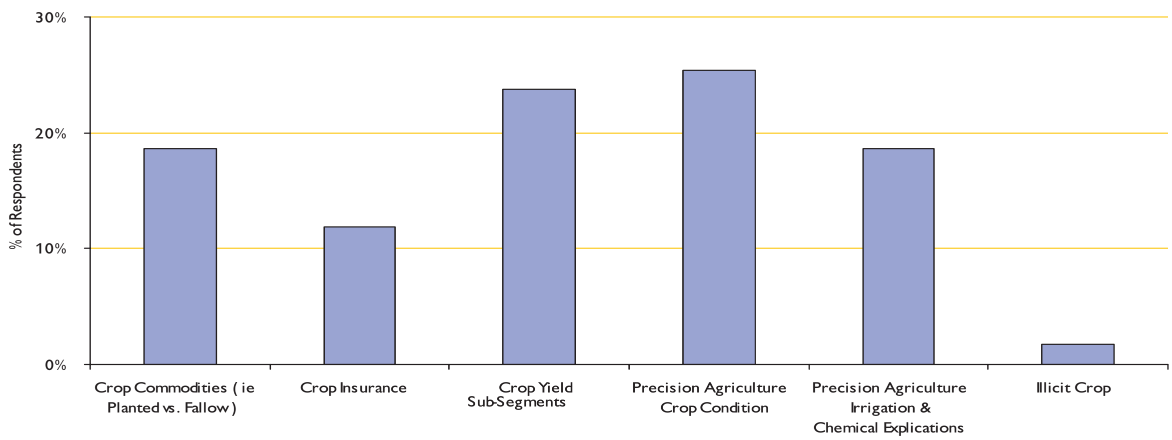
11.3.6 Agriculture

Most data providers in the agricultural sector have been producing data/information for either 3 –5 years or more than 16 years (a bi-modal distribution). Agricultural data/information producers believe that the technology awareness of the users is important to very important in terms of being able to deliver data.

Most use remotely sensed data (Figure 40). Cost and timeliness are the most important data characteristics to agricultural producers. Remotely sensed data provided in a timely manner allow farmers to characterize the needs of a field quickly and apply appropriate corrective measures. Successful precision agriculture in turn necessitates that these measures be applied often within hours or a day or two in order to produce a crop while minimizing the environmental impacts and costs of chemicals required.



Type of Geospatial Data Used	
Image Based GIS	17%
Photogrammetry	0%
Remote Sensing	83%

Producer or User?	
Producer	83%
User	17%

Agricultural Respondents Sectors	
Academic	39%
Commercial	33%
Government	28%

Figure 40 Agricultural Segment

Most user organizations have been working with agricultural data/information from 3 - 10 years. Agricultural respondents think that additional product knowledge would increase their use of geospatial data/information and were satisfied that providers did an adequate job of explaining how to best use it. Cost and currentness of data are the most important data/information characteristics. Their primary methods for receiving data/information are both CD and paper/hard copy.

11.4 Effects of the Attacks of September 11, 2001 on the Geospatial Industry

As the depressed state of the travel industry demonstrates, the attacks of September 11, 2001 have had a strong negative effect on some industries. As an information industry that supports many other governmental and industrial activities in the global marketplace, the geospatial market has likely experienced some negative effects of September 11.

Because the Phase I survey had been completed prior to September 11 and Phase II survey was completed only a few months afterwards, Phase III was the first opportunity to assess the effects of the attacks on the size and growth of the geospatial marketplace. The Phase III survey instrument asked both producers and users of geospatial data and information to rate the effects of the events of September 11 on key aspects of the industry.

11.4.1 Producers

Employment

The survey asked what changes in employment were expected (no change, positive, negative). On average in 2002, 50 percent of respondents anticipated no change, 20 percent anticipated a positive change, and 30 percent anticipated a negative change. Producers of photogrammetric data and information expressed the greatest pessimism about future employment opportunities and producers of image-based GIS the greatest optimism. Overall, data and information producers anticipated a slightly negative effect on employment for the near term. For 2003 and beyond, the projections of all categories for employment opportunities were less negative, but uncertainty about future employment opportunities increased markedly.

Product Prices

In 2002, only 20 percent of producers thought prices would increase as a result of September 11; most of these were companies that identified themselves as producers of photogrammetric data and information. The vast majority saw little or no change. From 2003 on, producers primarily expressed uncertainty over future prices as a result of September 11. In fact, from 2003-2005, there was a marked shift toward increasing uncertainty, with the response category “Don’t Know” increasing by 500 percent. In the breakdown among the three primary groupings of the Forecast for 2002 estimates, producers of photogrammetric data and information anticipated price rises more than the two other groups, but their uncertainty about the future (2003-2005) increased markedly right along with the other two groups.

Product Sales

Some 30 percent of producers anticipated a down turn in sales for 2002, vs. 20 percent that expected an increase in sales (Figure 41). Most (38 percent) anticipated no change, while 12 percent were not sure whether sales would rise or fall. For 2003 and beyond, producers were more positive about sales (18% negative, 24% positive, 28% no change, and 30% uncertain for 2003). For 2005, producers grew increasingly uncertain, with about 52 percent in that category. Here again, photogrammetry producers had the most negative outlook for sales from 2002 to 2005, but beyond 2002, uncertainty led both negative and positive outlooks.

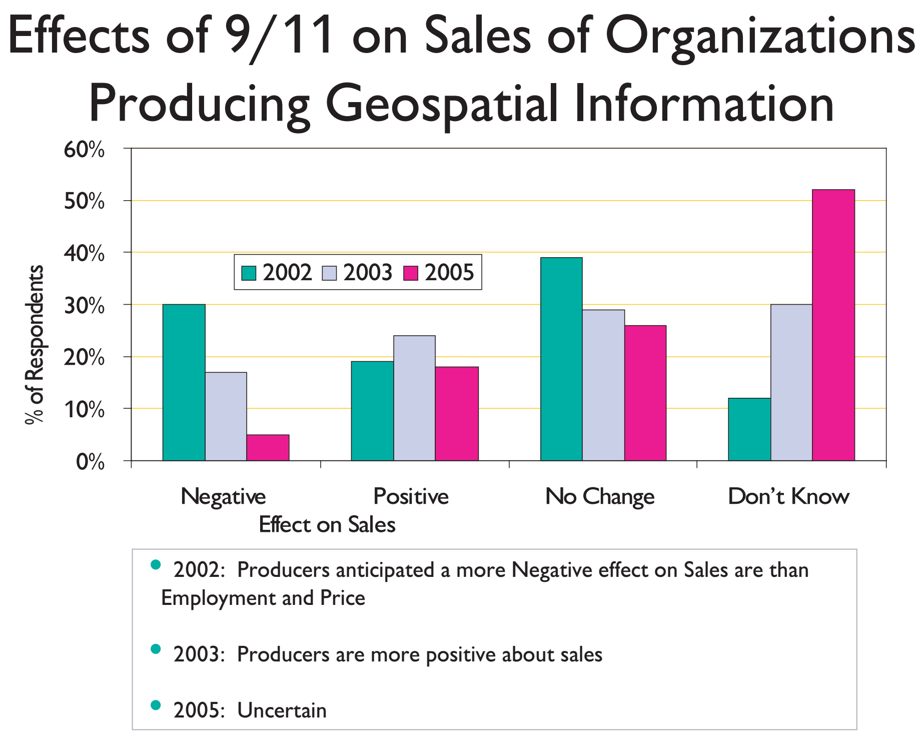


Figure 41 Effects of 9/11 on Sales

Overall Effect of Government Restrictions Implemented Since September 11

When asked, "Do new government restrictions implemented since September 11, affect or impact your business?" 55 percent of respondents answered yes, with 45 percent answering no. Of those who responded yes, 80 percent experienced a negative affect on their businesses, with only 20 percent experiencing a positive effect. Overall, the data reveal that government restrictions implemented since September 11 have had a negative effect on about 44% of the organizations producing geospatial data and information.

Should the Federal Government Change the Restrictions Implemented Since September 11?

When asked whether current restrictions placed on the distribution of geospatial data and information should be increased, decreased or stay about the same, most producers (an average of about 60 percent) felt that current restrictions were about right. The replies were collected under the following categories:

- Sale of imagery
- Geolocation accuracy
- Aerial collection
- Satellite collection
- Spatial resolution
- Geographic location restrictions.

Within these groupings, responses to the question varied slightly, but not significantly. Some 20 percent were of the opinion that additional restrictions would be in order, while about 12 percent felt that restrictions should be reduced.

2002 Impact of September 11 on Selected Data Dissemination-Related Activities

The Phase III survey also separated the activities related to data collection and dissemination into the following categories:

- Export of data/information
- U.S. sales of data/information
- Offshore data production
- Internet data exchange
- Data availability to the industry user
- Data availability to the public
- High technology hardware
- Government policies.

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Nearly 50 percent of survey respondents in all categories except high technology hardware experienced negative effects on data distribution. Only 25 percent of respondents involved in high technology hardware production and sales signaled negative effects on their businesses. Those companies needing access to airspace for their business, however, experienced significant effects, as a result of the many limitations imposed on general aviation in the months following September 11.

Future (2005) Impact of September 11 on Selected Data Dissemination-Related Activities

When asked about the future, producers opined that the events of September 11 would continue to have an effect on their businesses, but a diminishing one. They believe that the greatest negative effects will continue to be felt in the categories of Export of Data/information, Data Available to the Public, and Access to Airspace. September 11 will have the least impact on Sales of High Tech Hardware, U.S. Data Sales, and Offshore Data Production.

11.4.2 Users Of Geospatial Data And Information

Impact of September 11 on the Use of Geospatial Data and Information

September 11 affected data and information users relatively little. Some 61 percent of respondents cited no change for 2002, with about 25 percent citing a positive effect and only five percent citing a negative one (Figure 42). Responses change very little for 2003 and 2005, though uncertainty increased steadily.

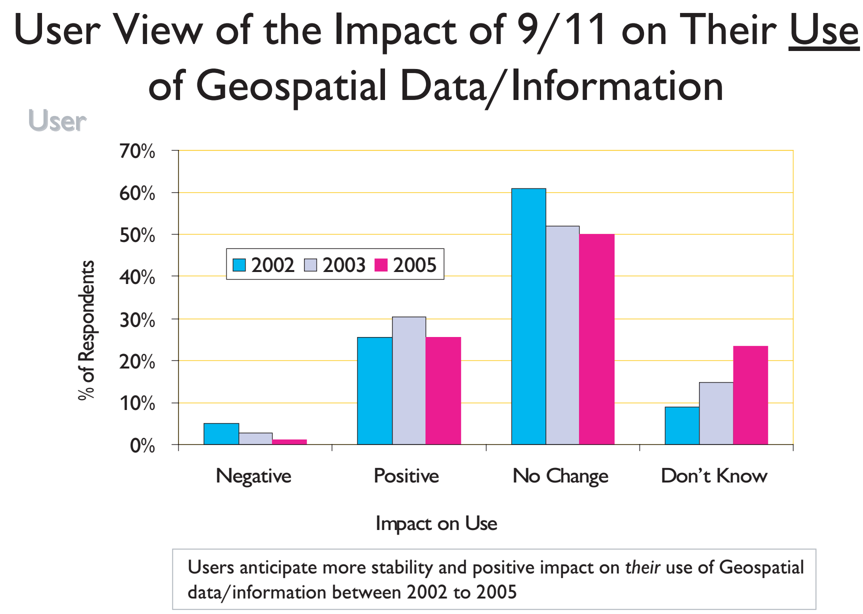

Figure 42 Impact of 9/11 on Users of Geospatial Data and Information

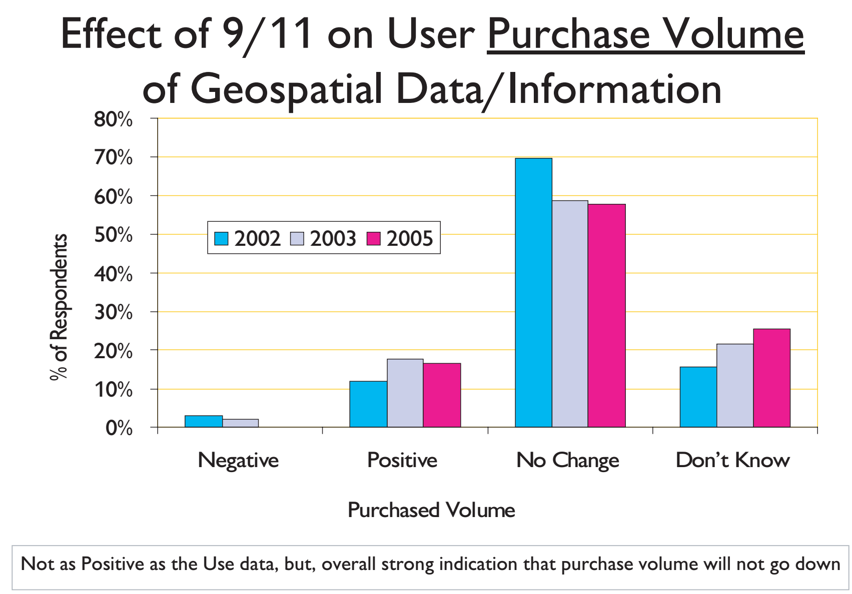

Figure 43 Effect of 9/11 on User Purchase Volume

Effects of September 11 on User Purchase Volume of Geospatial Data and Information

About 70 percent of data and information users cited no change in their purchases of geospatial of geospatial data and information for 2002, while about 11 percent noted an increase in volume and 16 percent indicated that they did not know what effect the events had had (Figure 43). Only about three percent experienced a negative effect.

Should Government Policy Place More or Less Restrictions On Selected Specific Remote Sensing Industry Activities?

Overall, when asked whether the current restrictions should be increased or lessened, most (about 65 percent) felt that they were about right. With the exception of the two last categories (Geographic Location Restrictions and Availability of Selected Themes), the survey revealed very little variation in responses among users in the following:

- Sale of imagery
- Geolocation accuracy
- Aerial collection
- Satellite collection
- Spatial resolution
- Geographic location restrictions
- Availability of selected themes.

Those who felt that more restrictions were in order nearly balanced those who thought restrictions should be reduced at 12 to 20 percent. However, those who favored greater restrictions were somewhat higher than the average in the categories of Geographic Location Restrictions and Availability of Selected Themes (24 percent and 27 percent, respectively).

Impact of September 11 on Selected Remote Sensing Industry Activities

When queried about their views of the current impact of September 11 on different categories of the remote sensing industry, respondents generally noted far more negative effects in the following areas:

- Export of data/information
- U.S. sales of data/information
- Offshore data production
- Internet data exchange
- Data availability to the industry user
- Data availability to the public
- Airspace access
- High technology hardware
- Government policies

The greatest negative effects were experienced in Airspace Access, Export of Data/information, Government Policies, and Data Availability to the Public. The form of the survey did not allow for greater detail in respondent's answers. Future phases of the survey should probe these issues more fully to see if any negative effects continue over time.

11.5 Conclusions

Phase III results support the conclusions of the earlier Phase I and II. There is strong correspondence between the results of all three phases with increased uncertainties due to effects of September 11, 2001 and the slow economy at present. For example, Phase III results indicate a degree of uncertainty in the estimates of the amount of growth in the industry, but no decrease in the optimism that the field will grow in the future. Phase III shows that the industry is embracing new technologies. A number of producers and users are beginning to use new sensors in their work. Data users are asking for data with sharper resolutions and higher geospatial accuracy. Phase III also confirms the recognition by both government and commercial users of the need to educate current and potential users as part of their ongoing mission.

12 Appendix I Policy History of Satellite Remote Sensing

12.1 Development of Modern Airborne Systems

NASA's development of airborne sensors generally preceded the development of satellite sensors because these airborne examples were used to validate the technologies needed on the satellites. Because such sensors proved useful not only as precursors to satellite applications, but also as airborne sensors, NASA continued to fund their development and use for a wide variety of airborne applications. However, as the utility of these sensors was proven by NASA research and development, commercial interest grew and private companies began to offer airborne services. Thus, while NASA continues to fly a few airborne sensors for research purposes, LIDAR, interferometric SAR, and Hyperspectral sensors are now flown by commercial companies who contract to gather a wide variety of data for scientific and applied customers. These systems contribute to the marketplace for remote sensing data and analytical services.

12.2 Development of Landsat and Commercial Satellite Systems

As noted earlier, satellite remote sensing for civil land applications began in the late 1960s, when NASA developed precursor sensors flown on aircraft. During the late 1970s, when it became clear that Landsat data had economic value in a wide variety of applications, after a detailed study, the Carter Administration decided that control of Landsat operations and data distribution should be transferred to the private sector. It proposed a phased transfer from NASA, first to NOAA, an agency with considerable experience operating both the Polar-orbiting Operational Environmental Satellite (POES) system and the Geostationary Operational Environmental Satellite (GOES) system, and then to a commercial entity. According to this plan, in a series of steps, NOAA would establish prices for the data that would begin to represent the prices that a private owner-operator would have to charge in order to earn a profit and provide the capital to build follow-on satellites and ground stations. NOAA took operational control of Landsat 3 in 1981. Landsat 4, carrying the new Thematic Mapper sensor, was launched in 1982.

Shortly after the Reagan Administration took office in 1981, it decided that the transfer process should be accelerated, in order to relieve the government of the continued operational burden of Landsat 4&5. Administration officials believed the market had grown sufficiently to make the transfer feasible. Most analysts, however, were much more pessimistic, fearing that the probable high costs of commercial data would dampen interest in using the data.[18] Academic users, in particular, were fearful that the high cost of Landsat data would undercut their ability to pursue research and teaching with Landsat data.

Nevertheless, the Administration promoted legislation that would make the transfer possible, and in July 1984, after several hearings and study,[19] Congress passed the Land Remote Sensing Commercialization Act (Public Law 98-365). Basically, the politics of privatization overrode expert opinion on the feasibility of privatizing the Landsat system. The Act established the basic steps for the transfer, a licensing procedure for the private operation of remote sensing satellites, and general framework for providing an initial subsidy for the operator of Landsat 4&5.

NOAA took operational charge of Landsat 4 following its launch in 1982 and established prices for the new 30-meter TM data and the 80-meter MSS data (Table XY). Data sales plummeted, the direct result of the increased prices.

During deliberations over the proposed bill, NOAA issued a request for proposal (RFP) for operation of Landsat 4&5 and any follow-on system. After competitive bidding, Eosat, a private corporation formed for the purpose by RCA and Hughes Space and Communications Group, won the operational contract, according to which the government would continue to subsidize the operation of Landsat 4&5 at a decreasing rate, as the company established the market, and also provide a subsidy for the development of Landsat 6 and 7, which Eosat would also operate.

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[18] See, for example, U.S. Congress, Congressional Budget Office, *Encouraging Private Sector Investment in Space Activities* (Washington, DC: U.S. Government Printing Office, February 1991), ch. 3.

[19] U.S. Congress, Office of Technology Assessment, *Remote Sensing and the Private Sector*, Technical Memorandum (Washington, DC: U.S. Congress, March 1984).

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In an effort to develop a profitable business and accumulate some of the capital needed to build Landsat 6 and its receiving station in Norman, Oklahoma, Eosat raised prices to about $4,000 per scene. Sales dropped again (figure X). Further, in order to prevent customers from sharing data with other users, thus undercutting sales, Eosat established fairly restrictive licenses, similar to the practice of licensing software. While normal practice in the business world, this had the effect of reducing the ability of scientific users to share data with colleagues working on similar regions. The pricing and licensing policies had the combined effect of lessening sales still further, and reducing the flexibility of university departments and research institutes in their research and teaching programs. Government data users also found the practice restrictive.

During the late 1980s, opinion within the Bush Administration and Congress began to shift toward the realization that Landsat privatization was not working very well and that the nation was in danger of losing the valuable resource that the Landsat system represented. Continuity in the provision of Landsat data was certainly in doubt. Nevertheless, data continuity became one of the cornerstones of the Land Remote Sensing Policy Act of 1992, which brought Landsat back under government operation.

The Act also relaxed one of the provisions of the 1984 Act, which called for private sector operators to "make un-enhanced data available to all potential users on a nondiscriminatory basis."[20] This was an attempt to mollify those nations who might have objected to the private operation of remote sensing satellites by making sure they would have access to data collected by the company. The new provision called only for the operator to "make available to the government of any country (including the United States) un-enhanced data collected by the system concerning the territory under the jurisdiction of such government as soon as such data are available and *on reasonable terms and conditions*;" This provision made clear that the company was required to sell data only to the governments of sensed countries and that it could use normal business practices in setting the prices for data. This and other small changes set the stage for the private sector to develop its own satellite systems.

Customers, both within the government and in the private sector were asking for data of higher resolution than the 30 meters of the Landsat system. The market had shown increasing interest in the10 meter panchromatic data from the SPOT system, but many potential data customers needed data of even higher resolution.

In an effort to promote the development of commercial remote sensing systems, the Bush Administration relaxed the previous restriction of a 10-meter lower limit on the sensor resolution and approved an operating license for the WorldView Corporation in the closing days of the Administration (January 1993). The license allowed WorldView to operate a polar-orbiting sensor capable of 3 meters panchromatic and 10 meters multispectral.

In July 1993, the Lockheed Corporation requested a license to operate a system of even higher resolution system, capable of resolving details as sharp as 1 meter panchromatic and 4 meters multispectral. In March 1994, after a thorough policy review by an interagency committee, the Clinton Administration issued PDD-23, a policy document to guide the licensing of commercially owned and operated systems. This policy led to a license for Space Imaging, a Lockheed Martin subsidiary, and then to other companies, including DigitalGlobe and Orbimage, to operate systems capable of high resolution. In April 2003, this policy was replaced by a new U.S. policy[21] that encourages private firms to develop their competitive capabilities by advancing satellite remote sensing technology developments. The policy also directs government agencies to purchase and use commercial satellite imagery to carry out their missions where possible.

U.S. policy, which has led the world in allowing the commercial sale of high resolution, has emboldened other countries to develop their own high-resolution optical systems. Some countries, such as Russia, India, and Israel, are selling data from their systems commercially. Canada, which operates the synthetic aperture radar satellite, Radarsat-1, building a 3-meter system called Radarsat-2 and plans to market these data globally. We are truly in a world of increased competition in remote sensing capabilities and of increasing global transparency, where even smaller countries are developing their own systems for analyzing trends in their own and their neighbors' lands.

[20] Land Remote-Sensing Commercialization Act of 1984, 15 USC 4242 Sec. 402 (b) (2).

[21] White House, "U.S. Commercial Remote Sensing Policy," Fact Sheet, April 25, 2003.

13 Appendix II Common Definitions and Terms

Common Definitions and Terms used during data gathering activities of the Ten-Year Industry Forecast

3D modeling Development of digital elevation models (DEM), development of stereo models, and use of these in 3D modeling such as fly through.

3D Viewing Viewing data in three dimensions.

Aero Triangulation The process for the extension of horizontal and/or vertical control whereby the measurements of angles and/or distances on overlapping photographs are related into a spatial solution using the perspective principles of photography.

Area Coverage/Theme size The amount of landmass covered by an image usually measured in square miles or square kilometers.

Band-to-band registration To register one image band to another.

Bathymetry The art or science of sounding, or measuring the depth of bodies of water.

Break Line Extraction The extraction of data where the terrain changes abruptly.

Cadastral Of or pertaining to landed property. Cadastral Surveying is surveying having to do with determining and defining land ownership and boundaries.

Camera Self-Calibration The calibration of a camera system to assess its focal length, principle points and radial distortions

Certified Data parameters compared against standards in the laboratory or field by an independent sanctioning agency.

Change detection The comparison of two images over a specific period of time to detect changes.

Characterized Data parameters compared against standards in the laboratory or field.

Civil Government Includes applications such as urban planning, taxation, redistricting, water management, etc.

Classification The process of sorting or arranging image data into different classes, groups or categories.

Color/Spectral/Radiometric Quality The recording of the targets brightness or intensity by the sensor. Color refers to an image of more than one channel segmenting the electromagnetic (EM) spectrum into bands (i.e. RGB (red-green-blue) or IRRG (infrared-red-green)). Spectral band is a descriptor denoting a segment of the EM spectrum. Radiometric quality is the quantification of the systems ability to accurately record the brightness of the target despite atmospheric, sensor and target unknowns.

Community Growth Focuses on land use, transportation, infrastructure, cultural and recreational resource and issues of quality of life in our communities, i.e., business and business demographics.

Contour Generation Mapping of lines of equal parametric value, usually of common elevation or height.

Contrast The difference in brightness between the light and dark areas of an image.

Convolution A technique used to enhance an image. Can be used to sharpen, smooth, or detect edges in an input image.

Cost Amount of money that a purchaser pays for remote sensing (data)(information).

Create / Edit tabular data To create or edit descriptive information, including locations, that is stored in rows and columns and can be linked to map features.

Create / Edit thematic layers To create or edit layers of related geographic features, such as streets, parcels, or rivers, and the attributes (characteristics) of those features.

Crop To subset the extents of an image.

Currentness of data How recently the data was collected.

DATA The analog and/or digital raster imagery collected by active and/or passive remote sensors. The vector content is manually or automatically digitized or in analog form. Includes textual content as well.

Data Format Common formats such as .tif, .jpg, .bil, and .hdf. Data format is particularly significant when considering the compatibility of software and the format of data products.

Data Licensing Contractual rights outlining who can possess or use a product, as well as how that product can be distributed.

Data Provider A vendor who provides RS/GIS data, or the analog and/or digital imagery collected by active and/or passive remote sensors. The data is in relatively raw form with minor geometric and/or radiometric corrections.

Data Source/Heritage Is the provider of the data and its associated metadata. Heritage specifically refers to what checks are preformed by the data provider prior to and during collection (calibrations in example prior, Photogrammetry or radiometric control during collection during. It should also refer to what has been done to the data prior to receipt by the client.

Delivery Media Format The configuration of or the way data is written upon a medium (CD, zip disk, magnetic tape, etc).

DEM Extraction Using software techniques to extract DEM's (digital elevation models) from imagery using stereo photogrammetry techniques.

Disaster Management Encompasses natural disasters, such as volcanic eruptions, earthquakes, severe weather and floods, as well as ecological issues related to the health of human, plant and animal communities.

Display themes The displaying of a set of related geographic features, such as streets, parcels, or rivers, and the attributes (characteristics) of those features.

Dynamic Range The ratio of the maximum to minimum signal levels that introduce no more than acceptable levels of signal amplitude distortions.

Edge Matching The process of eliminating locational and content discrepancies in the representation of features at the edges of adjacent map sheets or tiles when joining them into one coverage.

Elevation The height of the terrain or man-made feature above the Earth's surface.

End-User A person whose job would entail working with remote sensing data, information and/or software.

Enhancement tools Tools used to enhance features in an image to make it more readable.

Environmental Quality Covers both air and water quality, and the effect of natural and man-made changes in the landscape on the environment.

Error Quantification Determination of sum total of errors in a data set.

Feather The brightness and spatial smoothing of features associated with the gradual transition boundary between two images.

Flythrough creation Using data (i.e. terrain and image data) to create a virtual 3D flyover.

Geocoding The process of assigning (x, y) coordinates to data that is not in a spatial data format.

Geodetic Control The control with which geographic position and elevation of features on the Earth's surface are mapped. This control incorporates information in which the size and shape of the Earth has been taken into account. The control points are often those whose geographic coordinates are known to significant accuracy.

Geo-Location Accuracy The degree to which the coordinates of points determined from a geospatially referenced image or dataset agree with the coordinates determined by ground survey or other independent higher-accuracy means.

Geometric correction The process of tying an image to ground coordinates.

GIS analysis tools For example, the importing of GIS layers and overlaying onto registered imagery. Also, the use of GIS data layers for resolving solutions from analysis of matrices of the layers.

Grab To select an area of an image for manipulation.

Ground Sample Distance (GSD) The representation of a pixel as projected on the ground.

Histories Undo / Redo The ability to retract or protract processes that have been run during data manipulation.

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Hydrography The scientific description and analysis of the physical conditions, boundaries, flow, and related characteristics of the earth's surface waters. The mapping of bodies of water.

Hyperspectral Remote sensing imagery defined as the collection of reflected, emitted, or backscattered energy from an object or area of interest in hundreds of bands (regions) of the electromagnetic spectrum.

Image Filters Filters used to obtain image information or to reduce noise.

Image reprojection Changing the projection of an image.

Image-based GIS A system for capturing, storing, checking, manipulating, analyzing, and displaying raster, textual and vector data which are spatially referenced to the Earth.

Imaging Working with data in a raster format, typically produced by an optical or electronic device. Satellite data, scanned data, and photographs are common forms of image data.

INFORMATION Textual, vector or imagery-based data that has been fully processed, combined, analyzed and interpreted into a geospatial product such as a GIS.

Interior Orientation The relative spatial position and orientation properties of the lens and camera/sensor systems used in acquiring data.

Layer manipulation Analyzing layers of data to obtain information.

MANAGER/SUPERVISOR A person who can (influence) (spend) (allocate) (authorize) dollars to purchase/acquire remote sensing data, information and/or software.

Manager/User A person who can (influence) (spend) (allocate) (authorize) dollars to purchase/acquire remote sensing data, information and/or software and works with said data, information and/or software.

Map composition Generation of hard copy output from virtual composition including imagery, annotation, legends, charts, scale bars, and logos. The putting together of information into a map format for printing.

Miscellaneous Land Use - Land Cover (Polygonal), Map Reference, Biological, Cultural, Environmental, Economic, Geophysical, Infrastructure (Points & Lines).

Mosaicing The process of creating a large image by merging several smaller images. Involves blending the seam lines in the geometric sense (warping to eliminate discontinuities) as well as in the radiometric sense (to eliminate sudden shifts in brightness) (i.e. edge matching, feather).

National/Global Security/Defense Covers security and defense issues on a national and global scale.

Online internet processing Capability of image analysis using distant processing tools on the Internet.

Orthoimagery Units Every pixel is made to appear as if nadir (directly beneath) from the camera. It is made by the development and integration of a detailed camera, sensor and target model.

Other geo-spatial (Georegistered: Vector, Textual)

Outline The determination of specific edges within an image (i.e. a coastline).

Pan To move the view of the image back and forth across the image.

Photogrammetry The uses of image data sets, vector layers, and sensor models to make measurements of the size, height and location of objects or landforms. As such it included the science of mapping the topography of the Earth's surface and of locating and measuring the dimensions of objects on the surface.

Querying / analyzing thematic layers (proximity analysis) To use a question or request to select geographic features or records, and to study these features and the relationships between them.

RADAR [Radio Detection and Ranging] An active microwave remote sensing system used for Earth resource observations. It is based on the transmission of long-wavelength (e.g. 3-25 cm) microwaves through the atmosphere and then recording the amount of energy backscattered from the terrain.

Raster Input The input process for raster based data.

Remote Sensing Remote Sensing is associated with the extraction of information about an object without coming into physical contact with it. For the purposes of this forecast we are restricting the definition to overhead observation of the Earth with a major emphasis on aerospace based data acquisition.

Resize Sample To increase or decrease the size of an image.

Resource Management Includes natural resources as well as renewable economic resources such as agriculture, forestry, and fisheries.

Revisit Rate How often sensor passes over the same target.

Routing The creation of themes using routes, or linear features with a user-defined measurement system.

Software Utility Compatibility The ability of a software package to be easily shared.

Spatial modeling Image processing algorithms used to extract specific information from image data (i.e. principle component analysis, filtering, Fourier Transforms, and so forth).

Spatial Resolution The level of detailed information you can gather from an image. Ground Sample Distance (GSD) or modulation transfer function (MTF) are measurements to characterize resolution.

Temporal resolution The frequency with which an imaging system can capture repeat imagery of a particular target area.

Textual Input The input process for adding text to a project.

Timeliness of data delivery How much time it takes you to get your data from order to delivery.

Transportation Roads, Airports, Railroads, Navigation.

Vector Input The input process for vector based data.

Views Multiple, usually simultaneous instances of looking at data from varying angles or using varying combinations of parameters.

Windows Common Tools Basic Windows interface functionality such as file management, subset or crop, grab, copy/paste, pan, zoom, undo, redo, etc.

Zoom To move the view of the image into and out of the image.