10-Year Remote Sensing Industry Forecast

Phase IV – Study Documentation

Prepared for
The American Society for Photogrammetry and Remote Sensing

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10-Year Remote Sensing Industry Forecast

Phase IV

by Charles Mondello, George Hepner, and Ray A. Williamson

Executive Summary

This report summarizes the findings of Phase IV of the ASPRS 10-Year Remote Sensing Industry forecast, which ASPRS carried out in order to assess trends revealed in earlier phases. This phase also attempted to gain additional information about the industry in response to questions elicited by the results of the first three phases. In particular, the Phase IV survey extended its inquiries to the demand for, and use of, medium resolution satellite data. ASRPS expects that the results of this survey will inform and stimulate discussion about the extensive and growing remote sensing component of the geospatial industry.

The on-line survey was made available between August, 2005 and October, 2005 to the approximately 6000 members of ASPRS, which has nearly equal representation from the government, private sector and academia. Members were sent email requests to complete the survey three times throughout this period. Three hundred eighty-six (386) members responded to the Internet survey, about six percent of the target sample population. Of these, 44 percent work for governments, 29 percent for commercial entities, and 27 percent in academic institutions, a sampling that represents the distribution of data users across the industry.

Eighty-four (84) percent of the respondents identified themselves as end users of remotely sensed data and information. Fifty-five (55) percent manage 5 persons or less, compared with 11 percent who manage 20 or more. Most remote sensing organizations are relatively small, which corresponds to the results from earlier phases. Because of the limited nature of the survey, its results cannot be used to predict the future trends. but rather to provide information that may be used by industry, academia, and government in hiring, education and training, and policymaking.

Workforce Issues

Findings in this phase related to educational and workforce issues indicate that the industry has ample room for workers to enhance their employability by improving their geospatial educational level, especially with GIS applications that incorporate remote sensing. Further, the educational community is not providing graduates with sufficient training in several skills, including geospatial applications tools and verbal and writing skills. The lack of sufficient verbal and written communication skills is a problem faced by other industries as well and corresponds with indications of a broad failing throughout all levels of the U.S. educational community.

Industry retention of trained employees is a major problem as well. Phases I-III found that many firms and agencies had a relatively high turnover of newer employees (less than five years). Responses to the Phase IV survey indicated that lack of advancement and adequate compensation are the two primary reasons for job dissatisfaction. In the growing, competitive fields of high technology requiring skilled, educated employees, the remote sensing industry may not be providing sufficient compensation and advancement opportunities compared to other high technology opportunities to retain the needed workforce.

Further, the generally smaller size of remote sensing firms compared to other high technology fields may limit opportunities for advancement and the highest compensation. These results may also reflect the competition for trained civilian geospatial and remote sensing employees by the non-civilian contractor firms in the military and security arenas, which are not well sampled in Phase IV.

Technology Issues

The largest part of the survey dealt with technology issues. Past phases of the industry forecast had revealed that demand for the highest levels of resolution was clearly not met by data suppliers; users desired higher resolution ground sample distances (6 inches to 5 m) to meet their needs. The broader availability of digital data of 1 m or better resolution (both satellite and aerial) has helped to meet that need as indicated by the Phase IV responses to the questionnaires, which point to higher satisfaction with available data. Satellite data providers have added substantially to their archives and aerial data providers have increased their capability to capture a wide variety of high resolution digital data.

Industry demand for high geospatial and vertical accuracy data continues, and Phase IV of the forecast highlights that data suppliers have closed the previous gap between elevation data supply and demand. High resolution digital elevation models are increasingly available from lidar, INSAR, or stereo imagery.

Film-based image acquisition shows a steeper demand decline than in the past. For digital imaging sensors, only demand for hyperspectral sensing data lags behind industry supply. Price, rather than the availability of data from new sensor technologies, seems to have become the differentiating factor in the demand for data from non-hyperspectral sensors.

While the mix of air and space based data collection appears to have equalized, this Phase IV survey reveals the use of a wide diversity of data acquisition technologies, including ground-based, unpiloted air vehicles (UAVs), and video cameras. This result clearly

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indicates potential for additional future information product differentiation to service the needs of the ultimate information customers.

The currency of data availability is one of the more dynamic measures in the industry. While the need for highly current data coverage overshadowed considerations immediately following the attacks of September 11, the need for data acquired and delivered quickly appears to have declined in the industry overall

The relative demand for area coverage is nearly flat across most scales. No clear trend is seen within the data other than perhaps an increase above 500 square miles.

The requirements for seasonality of data collection have evolved over the years. Many of the national mapping programs require leaf-off data collection to insure optimal imaging for the purposes of mapping. The relatively short period possible for this type of data collection has required firms to partner in order to complete the task in a timely way to meet the seasonality needs. Previous survey results showed that our industry consists mostly of many small to medium sized firms, but this survey indicates a degree of consolidation of small firms. If industry consolidation were to continue unchecked, seasonal data acquisition capability could be at risk

The Use of Moderate Resolution Data

For Phase IV, the survey included a new set of questions related specifically to the need for and use of moderate resolution satellite data, such as those from Landsats 5 and 7. About 70 percent of the total respondents use moderate resolution data in their work. For them, medium resolution data serve as primary data sources or as a well-known foundation for higher resolution data sets. For some 65 percent of respondents, medium resolution data are critical to their work.

Most Landsat data users seek Landsat 7 data when available, though many will also substitute Landsat 5 data when they are not. For example, when the Line-Scan Corrector problem experienced by Landsat 7 impedes their ability to employ those data, they most frequently turn to data from Landsat 5, though some turn to non-U.S. data supplies.

Most respondents who employ medium resolution data used federal and regional funds to purchase them.

Federal Government Policy

Through the commercial satellite remote sensing licensing function housed in NOAA NESDIS and other agencies, the federal government has assumed the responsibility promoting the use of remotely sensed data. Most phase IV survey respondents indicated that current government policy is sufficient for promoting sales of remotely sensed data from commercial satellites, but feel that it could do more to help support sales of aerial remote sensing.

Phase III forecast results indicated dissatisfaction with federal government controls on overseas data sharing and sales, Phase IV results indicate that that government-imposed data licensing and/or sharing restrictions have a negative effect on about 45 percent of respondents. A very small percent consider government controls to have a positive effect.

Introduction

In embarking on the Fourth Phase of the 10-year industry forecast, of the remote sensing and geospatial industry, ASPRS was seeking to extend the results of the first three phases in order to determine whether or not the trends noted in the first phases were continuing. The Phase IV survey also extended the previous results to use of, and demand for, medium resolution satellite data. We hope that the results of this survey will inform and stimulate discussion about the industry. Given the limited nature of the survey, the results cannot be used to make explicit predictions, but will indicate trends of interest.

In particular, ASPRS carried out the Phase IV survey in order to obtain current statistical information and future expectations from a representative sample of the remote sensing/geospatial community regarding;

- Use of and needs for specific requirements in geospatial information
- Use of moderate resolution imagery
- Workforce hiring needs and requirements
- The role of U.S. government policy in the geospatial industry.

These objectives formed the basis of a questionnaire that extended information gained from similar topics and questions in Phase I- III, and questions designed to elicit new information regarding the use of and needs for moderate resolution imagery information.

Description of Sample and Internet Survey

ASPRS has approximately 6000 members, with nearly equal representation from the government, private sector and academia. ASPRS made the survey available to active ASPRS members from August, 2005 through October, 2005. Members were notified by email three times throughout this period with a request to complete the on-line survey. Three hundred eighty-six (386) members responded to the Internet survey, which amounts to slightly over 6% of the target sample population.

Type of Respondent's Organization

Of the sample of 386, 323 respondents (84%) identified themselves as end users of remote sensing data/information. Two hundred and twenty-two (222) specified that their primary job was managing productivity in their organization, with the authority to purchase data/information.

Most respondents to the survey manage relatively small organizations. Fifty-five (55) percent of the respondents manage 5 persons or fewer in their organization. On the other extreme, 11 % of the respondents manage more than 20 persons. This response is in line with the more extensive sampling done in Phases I-III, which showed that the majority of remote sensing organizations are relatively small.

Of the respondents, 170 (44%) work in the governmental sector, 112 (29%) in the commercial sector and 104 (27%) for academia. This provides a representative basis for the analysis, approximately

[1]Charles Mondello, George Hepner, and Ray A. Williamson, "10-Year Industry Forecast: Phases I-III -- Study Documentation," Photogrammetric Engineering and Remote Sensing, Vol. 70, No. 1, January 2004, pp. 7-58

Size of Respondent Organization

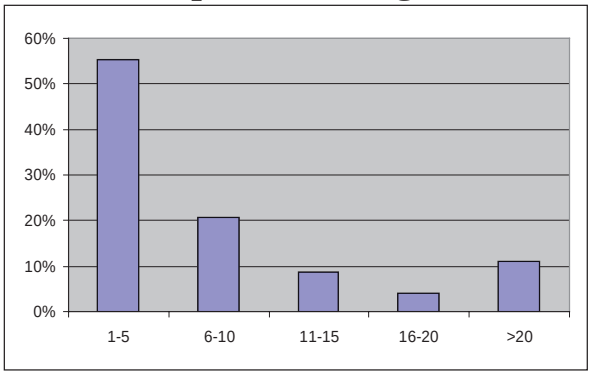

Figure 1. Number of employees in organization.

Primary Employment Area

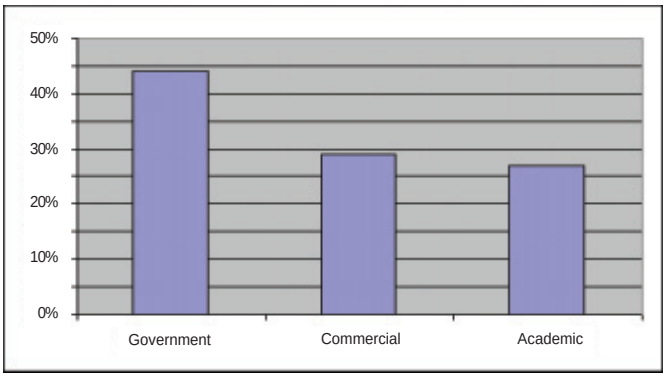

Figure 2. Primary Employment

equaling the sector diversity of the target sample population. More important, the results of the survey also represent the three primary components of the greater remote sensing community.

Limitations on Interpretation

This report summarizes responses to the questionnaire and thus presents general trends occurring in the industry, not specific statistical information with confidence sufficient for prediction. Generally, the sample size for this survey has approximately a (+/-) 4.8 confidence interval at 95% confidence level. The sufficiency of the sample size issue is confounded by the inability to control properly for assumptions of sampling theory (random, unbiased samples) that would allow rigorous statistical procedures. The Internet delivery of the survey does not allow rigorous sampling protocols as it depended on voluntary response of the sample population. Unlike Phases I-III, Phase IV relies solely on the Internet survey for data. Also, this survey primarily represents the trends and views of respondents from the civilian sector of the geospatial-remote sensing industry. Interpretations should be viewed with the survey limitations in mind. For example, the lack of respondents who have been in their job position for less than a year may reflect either a lack of hiring in the civilian sector in the past several years or the respondents' inability to answer many of the survey questions because of their short tenure on the job. Although there was no means to randomize sampling within the three employment sector stratifications, the results provide a useful stratification according to government, private and academic sectors.

Education and Workforce Issues

The survey asked respondents about their level of education (Figure 3). Approximately 40% of the respondents had completed a master's degree with 27% having an undergraduate degree and 30% a Ph.D. degree. This tends to be in line with the known educational levels of the overall ASPRS membership and the sample's segmentation between private sector, government and academia.

The Major Disciplines of Respondents' Work

The majority of respondents (123 or 32%) to this question listed geography as their primary discipline (Figure 4). This was followed by "other" at 15% (57), which included numerous other disciplines from atmospheric science to urban planning. This result

Level of Education

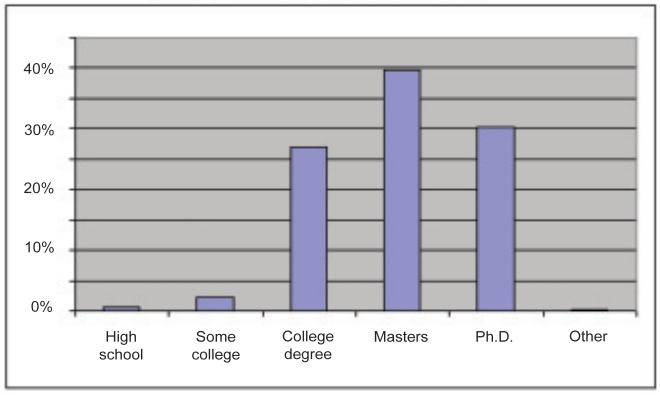

Figure 3. Respondent Level of Education

Skill Sets of the Respondents

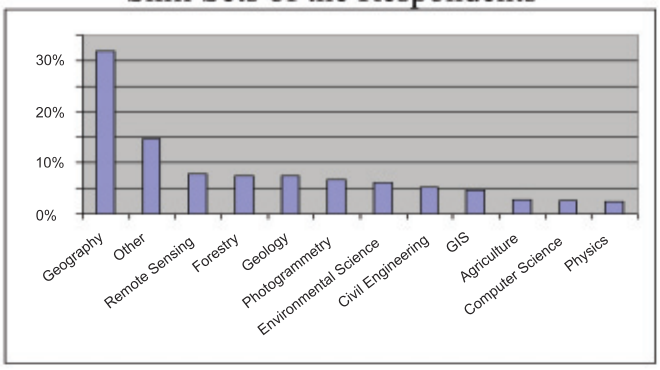

Figure 4. Respondent Major Discipline

is consistent with the results in previous phases of the Forecast, where comprehensive academic programs in remote sensing and geospatial information are centered in geography departments, but employees in government and private sector achieve degrees in numerous other disciplines, as well. Table 1 lists the other disciplines cited by respondents.

Answers to a question about the level of education most desired by organizations for their remote sensing workforce revealed that students and the educational community are not meeting the industry need for masters and PhD level graduates, and for graduates with technical training and geospatial certificates (Figure 5).

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The most cited needs for new hires were application GIS tools, verbal and communication skills, applications science and cartography/visualization. These results (similar to Phase I-III) reveal that the most needed skills areas involve the development of applications, especially in the GIS realm, rather than more basic areas of a particular sensor technology or related skill set. Interestingly, verbal and communication skills are the second most needed skill surpassing all of the other technical areas associated with remote sensing. This provides valuable insight into the apparent inability of current employees to speak and write effectively. It indicates the need for a broader education that focuses on analytic and communications skills as well as technical training. In contrast, the most difficult technical areas in which to hire were spread more evenly within the responses. Expertise in spatial statistics/analysis was cited as the most difficult to hire, followed by applications GIS, followed by expertise in photogrammetry.

Figure 6 shows the discrepancy between the current needs and the difficulty in hiring for these needed areas. Interestingly, while verbal and written communication was seen as a great need, the respondents felt that it was an area in which it was less difficult to hire. This seems to indicate that the hiring practices of firms and agencies are more focused on finding new hires with technical geospatial skills than those with communications skills.

Table 1. Other Disciplines Beyond Geography Cited by Respondents

Discipline
• Biology
• Anthropology
• Environmental Policy and Mgmt
• Workforce Education
• Ecology
• Other Engineering
• Astronomy
• Fish / Wildlife Biology
• Surveying
• Urban Planning
• Atmospheric Science
• Landscape Architecture
• Music, Arts, Humanities
• Business Administration
• Imaging Science
• Ecology
• Agronomy/Soils

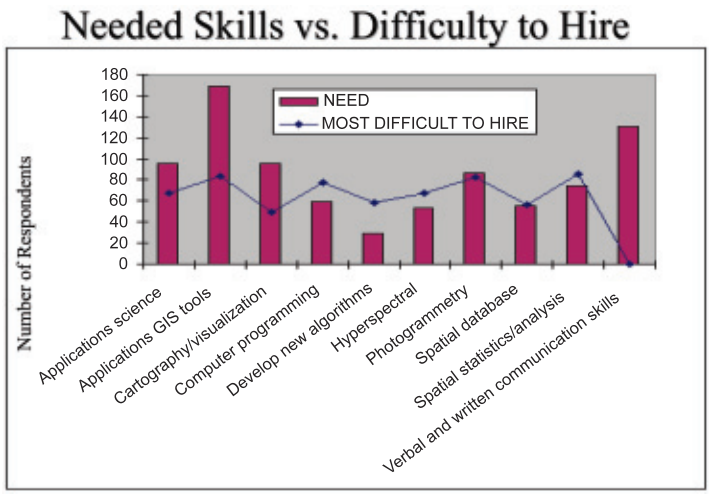

Figure 6. Skills Needed vs. Difficulty to Hire

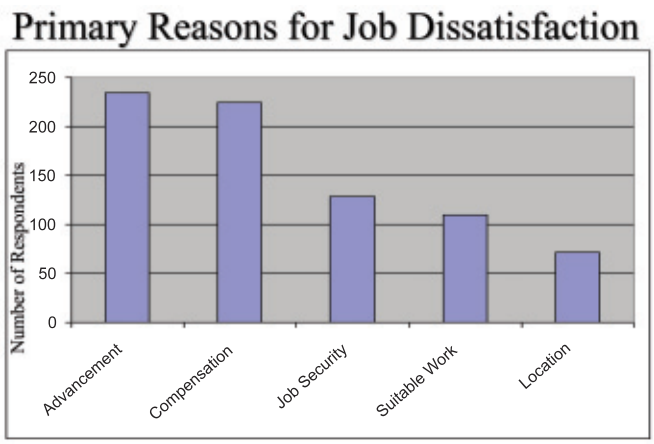

Figure 7. Job Satisfaction

Previous phases of the forecast indicated that many technical staff in agencies and firms leave the remote sensing field within 5 years after initial employment. This phase of the study asked for possible reasons for this finding. Apparently, the lack of opportunity for advancement in position and/or compensation causes many to leave the field. Less cited causes include lack of job security and lack of suitable work. These latter issues apparently have a lower impact on an employee's interest in remaining with a firm or agency (Figure 7).

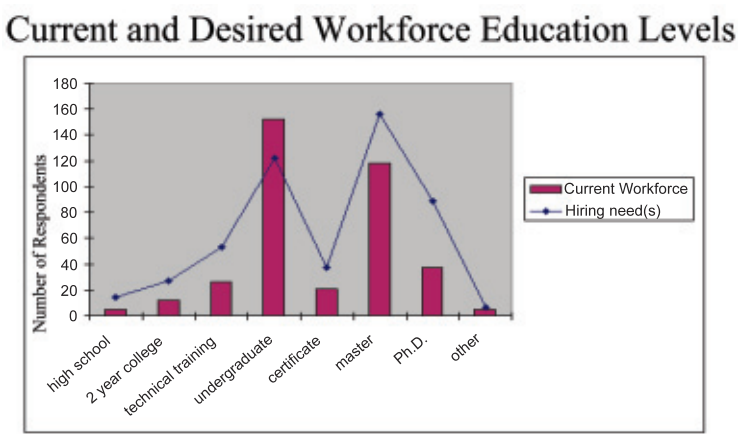

Figure 5. Workforce Education levels

Years of Experience in Remote Sensing

Most respondents to the questionnaire had at least four years of experience with remote sensing (Figure 8). However the largest number had greater longevity in the field, with 11 or more years of experience. Note the dip in number of respondents between 4-7 years experience and 11 and more years. This result agrees well with the results of Phase II, in which questionnaires revealed that "the bulk of the employees in the industry have either less than 4 years or greater than 11 years experience within the industry." However, the current phase of the study attracted a much higher percentage of respondents with more than 11 years ago than in the previous four phases in which about one-third of the workforce has remained in the field longer than 11years.

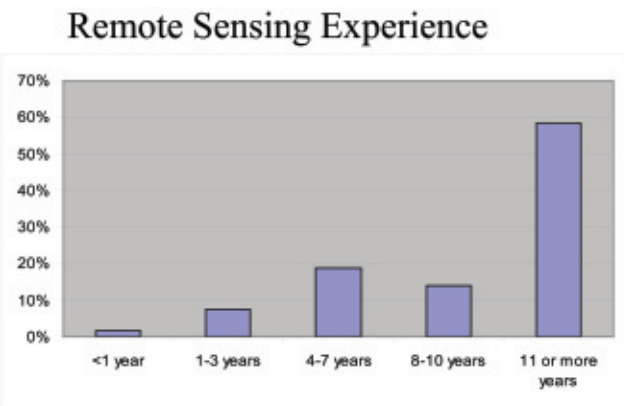

Figure. 8. Years of Experience

Education and Workforce - Summary and Conclusion

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Industry retention of trained employees is a major problem as well. Phases I-III found that many firms and agencies had a relatively high turnover of newer employees (less than five years). Responses to the Phase IV survey indicated that advancement and compensation are the two primary reasons for job dissatisfaction.

In the growing, competitive fields of high technology requiring skilled, educated employees, the remote sensing industry may not be providing sufficient compensation and advancement opportunities compared to other high technology opportunities to retain the needed workforce.

Further, the generally smaller size of firms may limit opportunities for advancement and the highest compensation. Also, these results might reflect the competition for trained civilian geospatial and remote sensing employees by the non-civilian contractor firms in the military and security arenas, which are not well sampled in Phase IV.

Technology Application Areas

Phase IV of the forecast provides an assessment of the market areas in which firms conduct business. The levels of interest in application areas are similar to those found in the previous phases. The telecommunications, real estate, insurance, business and entertainment/media remain the least served segments. These areas represent an opportunity for enterprising software developers that are able to develop user-friendly, cost-effective applications. The large software and search engine firms now vying for market share have initiated the introduction of raster remote sensing products to the general consumer and this development may finally affect market improvement within these segments.

Major markets noted below are those historically served by the remote sensing community (Figure 9). Through their analytical and business models they have driven many of the industry's new

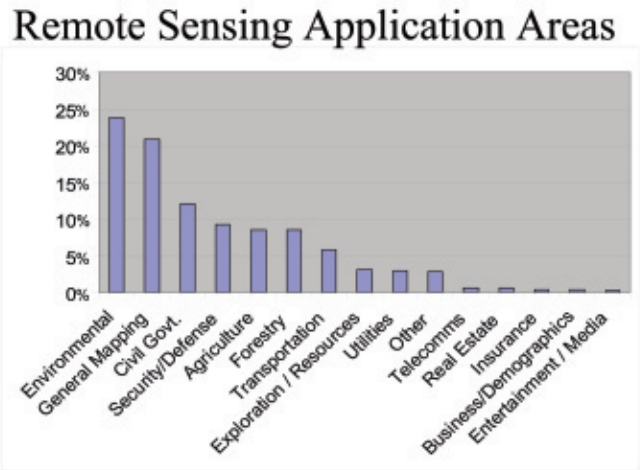

Figure 9. Remote Sensing Application Areas

data set features and technologies. Environmental, Agriculture, Forestry, Exploration and resources clearly benefit from digital IR, multispectral, and hyperspectral imaging. General mapping, civil government, security, transportation and utilities drive the needs in panchromatic and color imaging, as well as, direct georegistration and DEM limited performance systems and data.

Phase IV of the study added open-ended questions to allow the capture of new areas of interest. These included:

- Public Health
- Law
- Flood studies
- Food security
- Search and rescue
- History
- Cultural heritage

While there are a very limited number of responses citing these categories, they illustrate the diversity of the remote sensing industry and its potential long-term impact on society.

Spending Trends

In most purchasing categories, Phase IV respondents expect the level of total purchases to decline in future years. Further, they expressed increasing uncertainty about estimated future purchases with time. The answers to these questions are somewhat surprising, given the estimates of the Phases I-III, in which respondents estimated between 9% and 14% industry growth. These results may indicate that one can expect a leveling of growth in this industry. On the other hand, this result may reflect shifts in market segmentation; for instance, since it appears that those spending the most expect further increases, if the current business consolidation climate continues, growth may primarily occur in the larger, consolidated organizations and the total growth of the of the industry may continue as previously forecast. Because this result was not expected, we do not have sufficient supplemental information to draw a clear conclusion.

Figure 10 indicates considerable uncertainty by the purchaser; between 17% and 18% of respondents did not know how much was spent on the data they used in 2003 & 2005. In addition, the reduced spending trend at mid levels noted here may reflect uncertainty about the future state of the economy, or it may mirror

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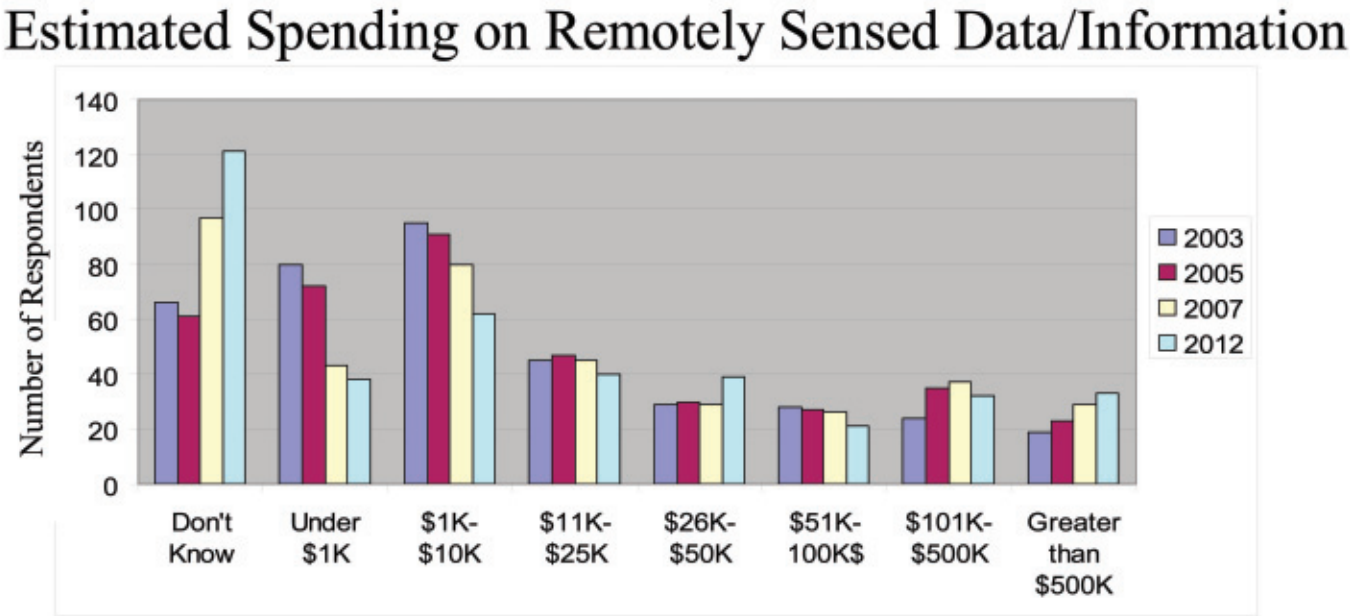

Figure 10. Spending on Remotely Sensed Data and Information

the gradual pricing reductions observed on many core industry products and services. For instance, advances in technology have driven orthophoto and Lidar pricing to become more competitive. This in turn may be reflected in the overall downward spending, but not reflect a reduction in volume of data purchased. These results also suggest that value-added companies may need to compete harder and develop new information products to maintain profitability. Overall, we believe that a clear determination of future remote sensing market strength will require additional assessment.

The sources of funding for the industry have a major effect on future industry growth, both in terms of movement into new segments as well as the possibility potential future spending cuts by the federal government. The government still provides the majority share of data to the industry (Figure 11). It is clearly a benefit for the overall health of the industry that the other prominent funding sources command a significant market position, which suggests increased economic diversity in the industry.

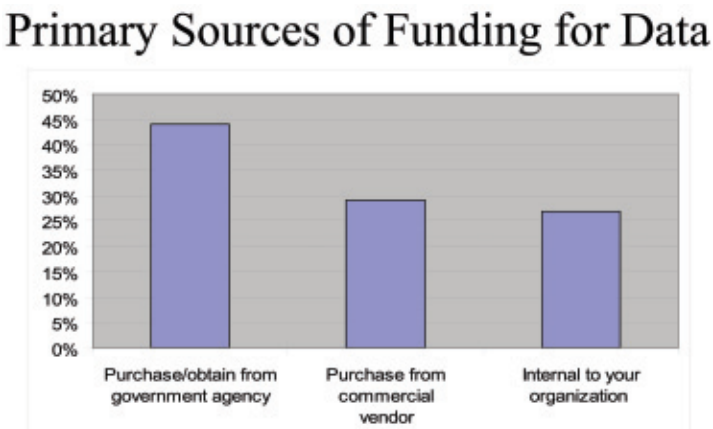

Figure 11. Primary Funding Sources for Data

Data Characteristics

The responses to the question about the importance of certain data characteristics reveal several interesting points (Figure 12). First, this survey turned up a higher level of importance placed upon radiometric quality than in past forecast results. In part this increase is related to this survey's spotlight on mid resolution data systems. These have been historically broad area coverage multispectral devices and have served the scientific, environmental community for many years. Such systems mandate a stable radiometric data set in order to make temporal comparisons. Additionally, since September 11, 2001 this metric has gained greater importance in the forecast results. By contrast, currentness of data has declined in relative importance. It appears that either some of the need has been fulfilled or it has subsided in criticality or simply awareness. Other metrics have retained similar scale weighting on the respondents' level of need. The additional questions and responses highlighted here further expand upon details around these metrics.

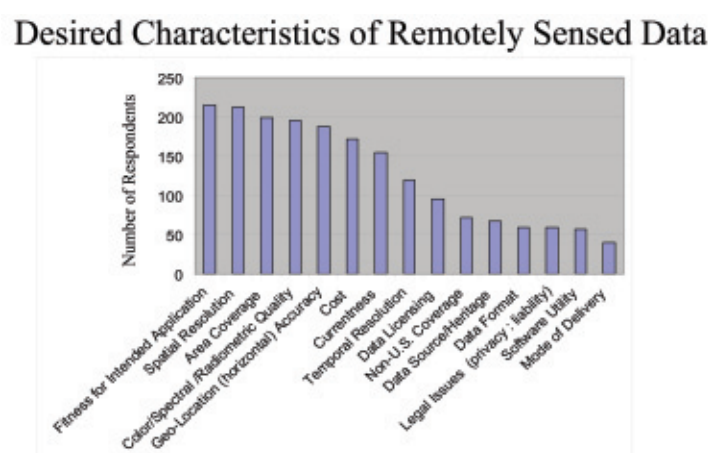

Figure 12. Data Characteristics

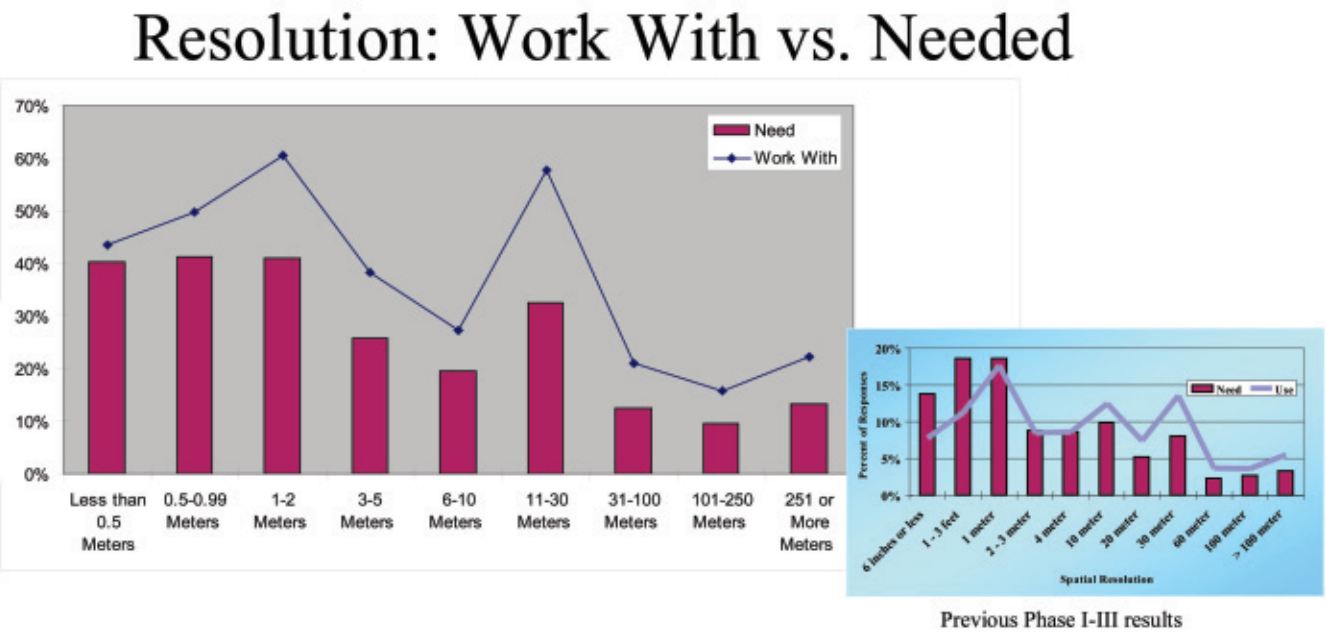

Figure 13. Resolution

Data Characteristics: Spatial Resolution

The question about spatial resolution "needs" versus the resolution of the data "worked with" reflects an interesting transition from previous surveys. Past surveys revealed that demand for the highest levels of resolution was clearly not met; data users wanted higher resolution data. Phase IV (Figure 13) indicates that more users are happy with the resolution of the data they use than in the past. The rise of digital aerial sensors, as well as the continued successful operation of high-resolution satellite systems and increasing market penetration of high-resolution data has met many of the remote sensing community's needs. Digital aerial acquisition has become a reality, with multiple vendors now offering commercial data acquisition using digital color, pan and infrared sensors. One meter resolution satellites are providing global data access through multiple commercial sources. Provision of better than 1-meter data is now the area of greatest potential growth. These trends are confirmed in the industry as prices for high-resolution orthophotography become very competitive. This shows that the customer base for high resolution data has expanded beyond the early adopters and has become more mainstream. The data indicate that there may be greater overcapacity at 1m & 10-15m resolution. Here again industry pricing of a few dollars per square mile reflects on scale of demand.

Data Characteristics: Geospatial & Vertical Accuracy

The industry overall requires high geospatial and vertical accuracy data as an end product and as source data for additional content generation (Figure 14-15). With the growth in automated aerotriangulation, Lidar, and direct geo-registration, much of this demand is well served, especially with new aerial digital imaging sensors. In this operational environment, technologies at one level drive improvements in other levels. The new imaging sensors with superior resolution and dynamic range require timely and current positional data to complete their data georegistration processing. Ground sample distances (GSD) of 6" and better offer users the ability to focus on smaller and smaller targets, each requiring better positional data for production. While differences in target populations and ranges exist compared to past surveys, we see considerable similarities in the overall shape of the trend.

With the above basis in demand for superior geo-positional accuracy, vertical accuracy is required to provide complementary quality. Vertically accurate source data are now required in many imaging systems that are now classified as DEM-limited in performance. The greatest error source in pixel placement for these systems is that associated with the source elevation data. Phase IV of the forecast shows that technology has closed the previous gap in elevation data supply versus demand. While the best levels of performance still show unmet demand, the overall match in "use" versus "need" indicates far less shortfall than in previous surveys. Overall, the industry is establishing a balance of supply and demand.

Data Characteristics: Image Types

The industry continues its utilization of technologies comparable to those of previous studies. Film based image acquisition has shown a steady decline since the inception of the forecast, and Phase IV demonstrates a steeper decline than in the past (Figure 16). This trend appears to be tracking the film versus digital transition of the consumer and professional photographic markets. For the first time, the study demonstrates a possible excess capacity in digital image capture as well. In the domain of imaging sensors, only hyperspectral data appear to lag industry demand. Elevation technologies present a far better equivalence to demand than seen in past market assessments. As previously noted, these trends in digital capture and elevation data sets are confirmed with noticeable industry data price reductions. Price, rather than new capabilities, seems to have become the differentiating factor in many cases.

Data Characteristics: Currency, Levels of Coverage, and Temporal Coverage

While resolution, accuracy and sensor type define the technologies employed, the metrics of currency, area size, and temporality define the service aspects of remote sensing Figure 17-19).

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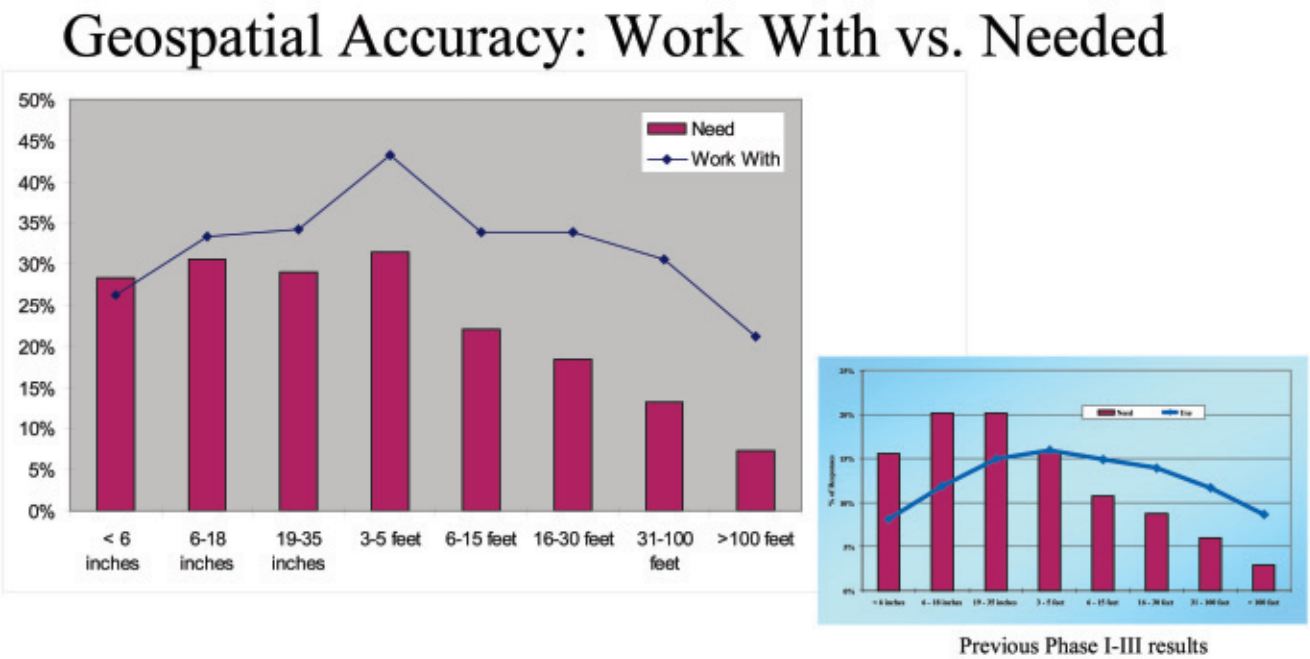

Figure 14. Geospatial Accuracy

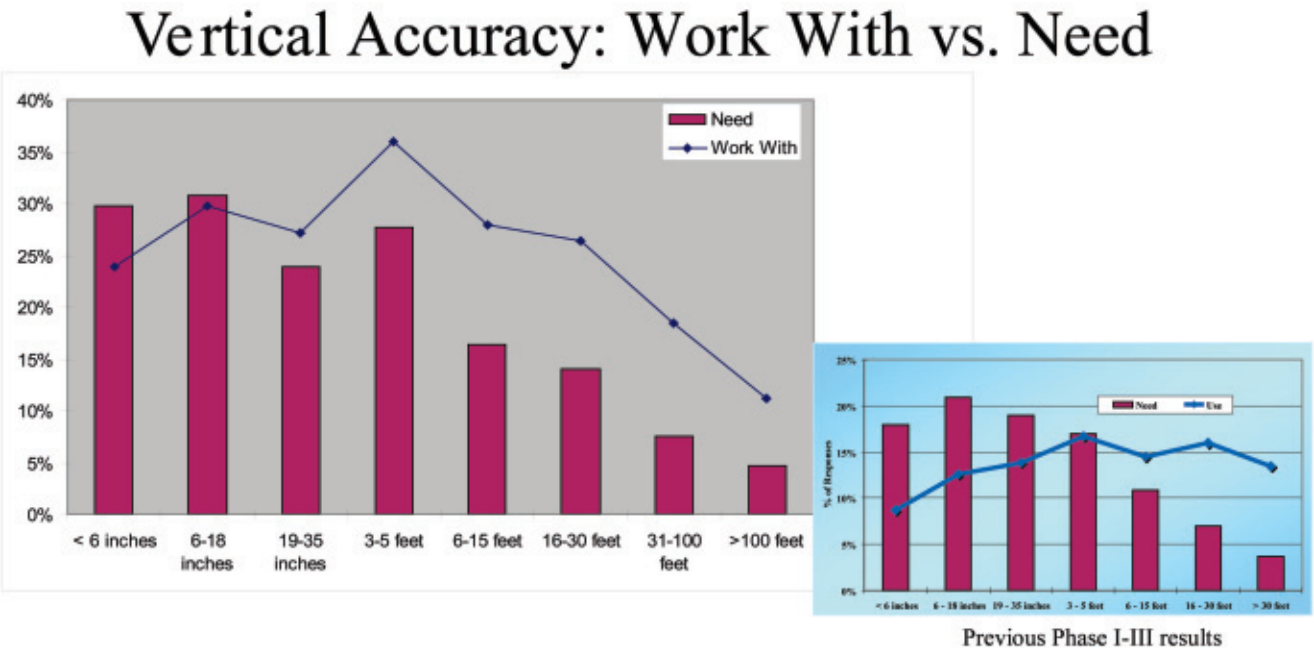

Figure 15. Vertical Accuracy

The currency of data is one of the more dynamic measures in the industry. The demand for "current" data is influenced heavily by global events. After the September 11, 2001 attack a strong increase was noted in demand for real time and near real time data Users understood the value of near real time data in the assessment of disaster, triage, and rapid response. Users and providers have developed systems to transmit and process data in the field on-site directly to emergency responders themselves. While this need overshadowed others post-September 11, this trend appears to be subsiding for the industry overall. A need does exist for real time data delivery and one-day turn around. In Phase IV it accounts for one-third of the industry responses. It is also important to note the decline in data demand as they age. Commercial vendors have multiple price points for new, versus archival, data. As data age more than over two years their utility significantly decreases for many applications and the price generally falls. This forecast provides additional focus on the use of medium resolution data. Prior to the Phase IV survey, it was expected that older data would show additional benefit for change detection. However, even for this segment the demand is low with the gap increasing with data currency.

Global events clearly drive the demand for the capture of data sets. Spikes from previous Phase I-III surveys have been smoothed out in this current forecast. The above inset graph shows survey results captured soon after September 11. It is apparent that as time

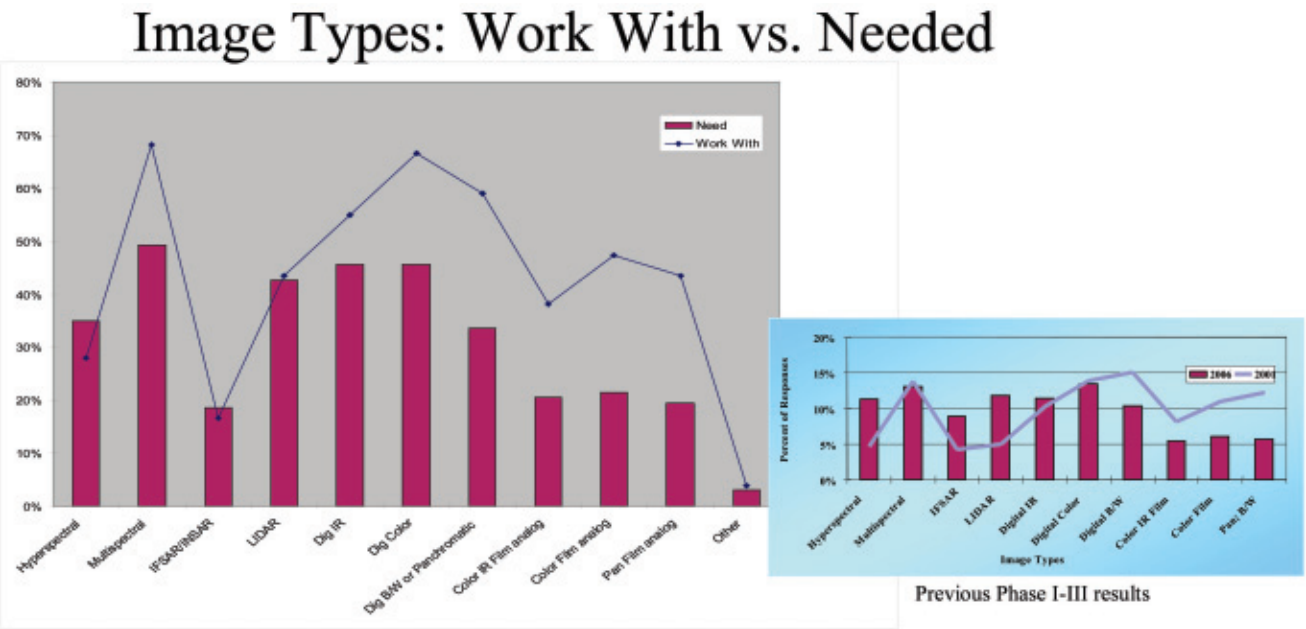

Figure 16. Image/Data Types

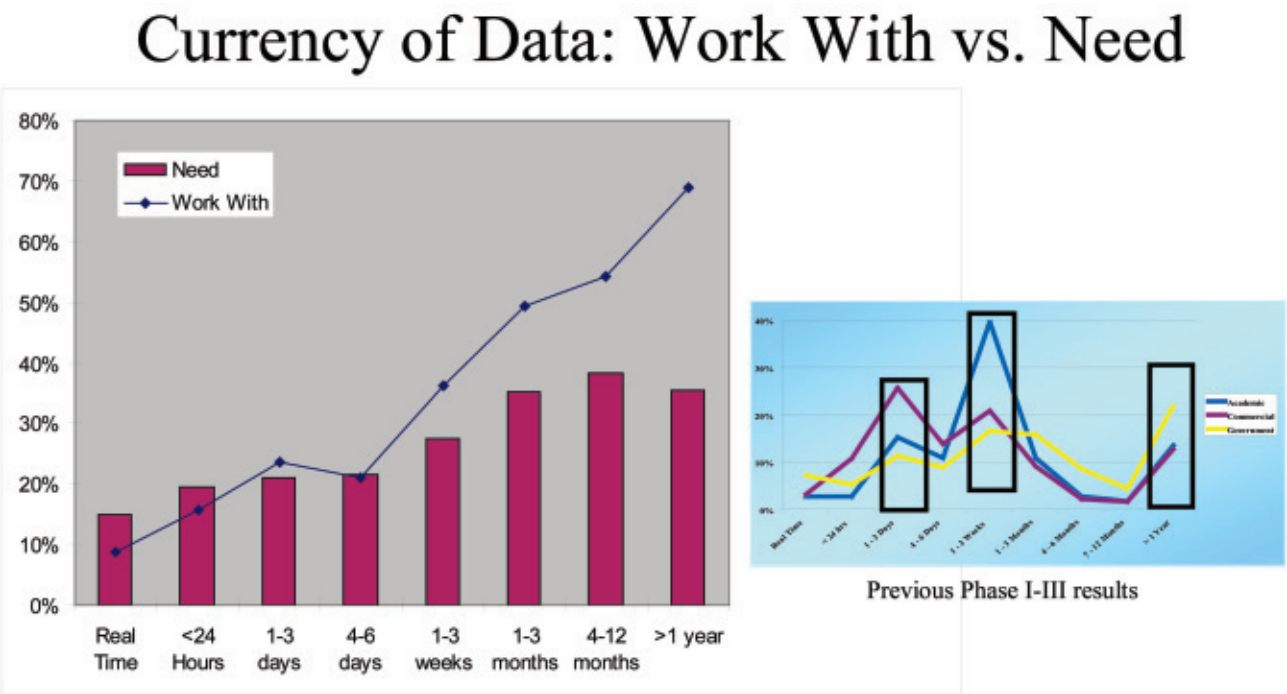

Figure 17. Data Currency

passes the perceived need for near real time data has decreased. Differences in population and ranges exist with past surveys, this may account for the differences in the longer term "Work With" and "Need" components in the 1-12 month windows.

Area coverage is nearly flat across most sizes (Figure 18). No clear trend is seen within the data other than perhaps the spike above 500 square miles. This is expected because of the uniform population mix. The spike on the right is doubtless based on this forecast's medium resolution data respondents. Medium resolution space based sensors commonly capture broad area coverage. The broad area coverage spike further highlights the demand for more regional coverage. U.S. counties generally cover these size areas. The graph further shows an overall reduction in data volume in comparison with current and future use. This trend replicates the possible leveling of imaging capacity in the industry.

After September 11, 2001 experts felt that increased frequency in imaging would become critical. The data indicate a break point in desired revisit times of one month or greater. Clearly the proposed market demand for real time data and those acquired with less than a 24-hour delay has not appeared. Reasonable price, capture and delivery windows appear to be commonplace, and in highest demand. This assessment is also based on the ability to process such vast amounts of data in a timely fashion. To easily

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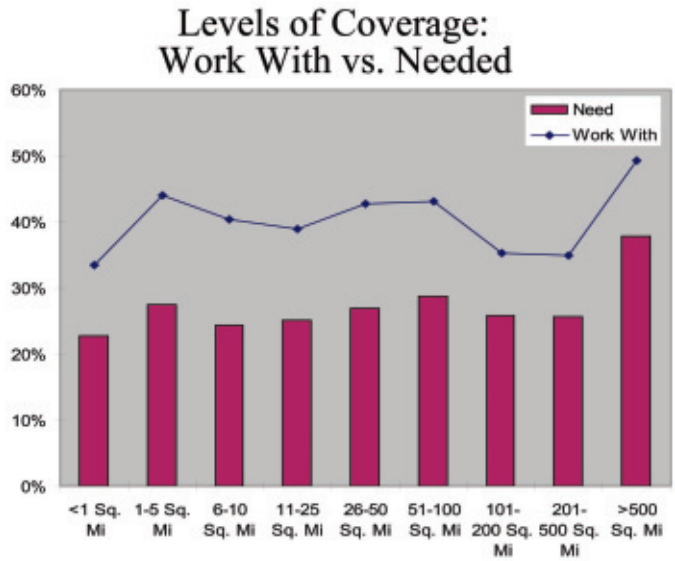

Figure 18. Area Coverage

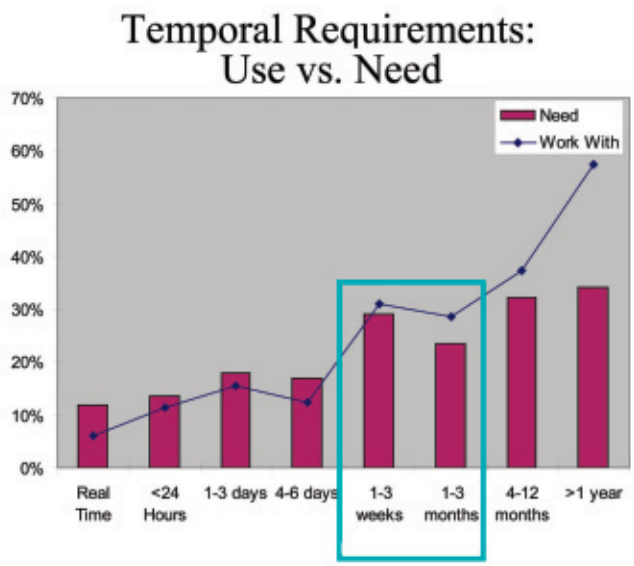

Figure 19. Temporal Requirements

Other Platforms and Uses

- Ground lidar
- Field surveys
- Aerial photographs
- Seismic/gpr
- IFSAR, Airborne Hyperspectral
- Source restricted
- Field Spectra
- Ground Based
- Ground geodetic surveys
- in situ
- Sonar
- Field Spectrometer
- Lidar
- Hydro acoustics/telemetry
- Spectral radiometer, NEXRAD
- Ground Measurements
- Boom mounted or handheld
- Lidar
- Ship
- Scanning
- and gps
- Field
- Lidar
- RC Aircraft (UAV)
- Close Range and/ or Van based
- Ground truth correction
- Remote Tags, Buoys, & ROVs
- Tripod mounted lidar
- Vehicle based sensors
- Spacecraft around other planet
- DEMs
- Tram or Helicopter
- Terrestrial cameras - sensors
- MAPS
- Terrestrial vehicle
- Marine based sensors
- Ground Sensors

exploit data collected daily, users need assistance in data interrogation. Market opportunities in this area are very diverse covering site target detection, assessment, insurance, emergency response, environmental and agricultural remediation. While change detection and assessment algorithms exist, they are highly dependent on the occurrence of similar imaging conditions. Automated analysis historically has mandated similar look angles, lighting, and considerable knowledge of the atmosphere. As the software scans an image it looks for radiometric similarities between data sets. Shadows in one frame but not in another can confuse an algorithm. Hyperspectral data are of benefit in this area because hyperspectral imagery and software can classify targets via band-to-band differentiation. Despite these advanatages, the data volumes from so-called hyperspectral cubes will further compound the data volume challenges for processing.

The requirements for seasonality of data collection have evolved over the years (Figure 20). Many of the national mapping programs require leaf-off data collection to insure optimal imaging for mapping. However, real property and agricultural generally mapping require leaf-on collection. Imaging timed for accurate crop and forest fire remediation can test the limits of many systems, both airborne and spaceborne. The non-uniform nature of these data collections has, over the decades, impelled the industry to size itself to fulfill these varied image capture scenarios. Corporate partnering has evolved in the aerial community to ensure that sufficient imaging assets (sensors and aircraft) are available to meet the seasonality needs. Previous survey results showed that our industry is fragmented into many small to medium sized firms. If industry consolidation were to continue unchecked, this seasonal data acquisition capability could be at risk

High-resolution satellites have changed the balance between aerial and space-based collection (Figure 21). The proportional use of satellite data has steadily increased compared to the aerial segment since the inception of the 10-year forecast. This study phase clearly shows additional gain in market share for satellite sources.

Of interest in this study phase is the "other" platform option in which open-ended responses were sought. The variety of sensor and platform combinations identified by the respondents is an obvious arena for future study. These include Lidar, Unmanned Air Vehicles, Seismic sensors, Ground penetrating radar, Tripod mounted Lidar, Terrestrial cameras, and Marine based sensors. The mix below highlights the diversity of the industry and ideally its capacity for continued growth.

Phase IV respondents clearly prefer data that are application ready or certified to an industry standard. In most cases, this improves their work throughput (Figure 22-23). However, a significant percentage of users prefer unprocessed data, which makes it possible for them to apply their own particular algorithms when processing data. This differentiation in the

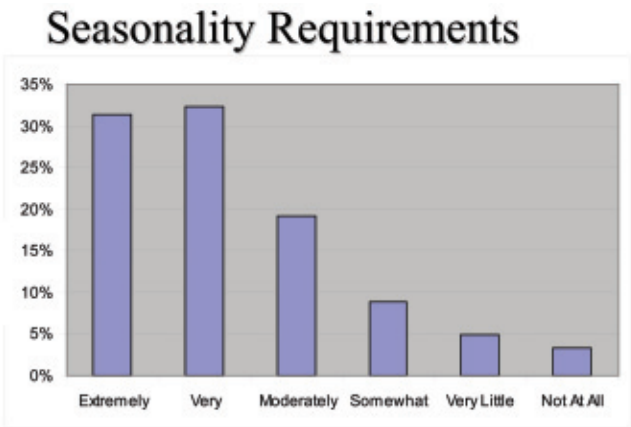

Figure 20. Seasonality Requirements

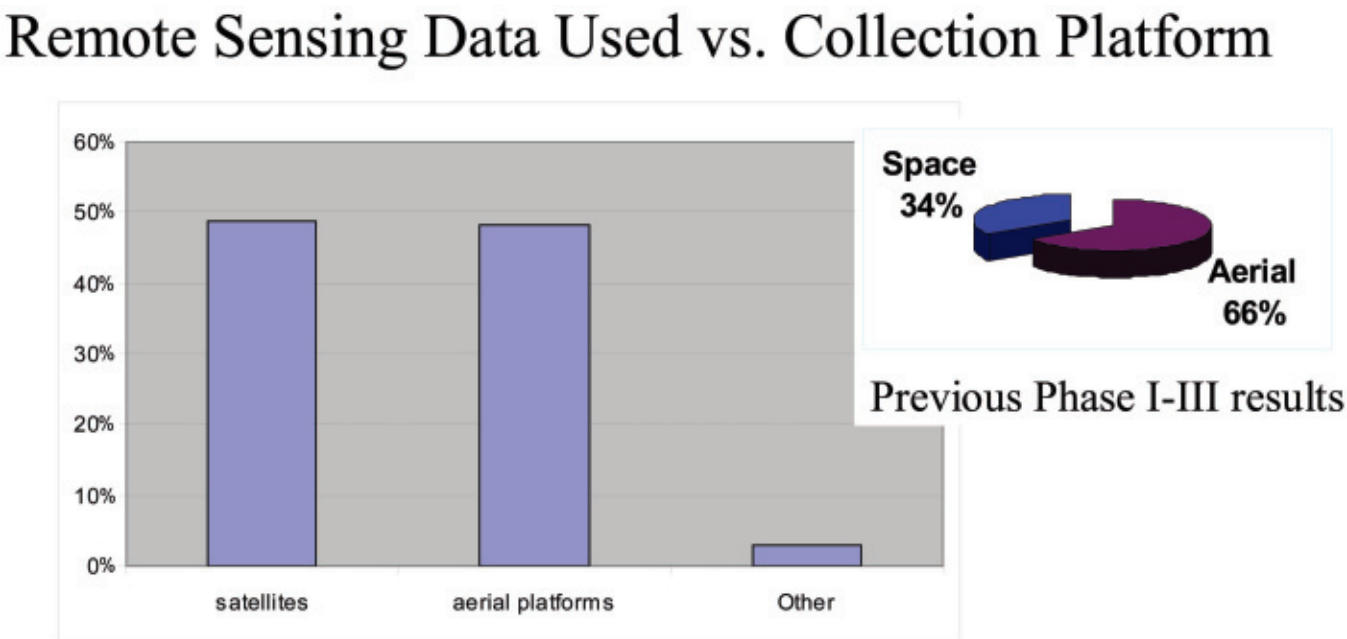

Figure 21. Data Collection Platform

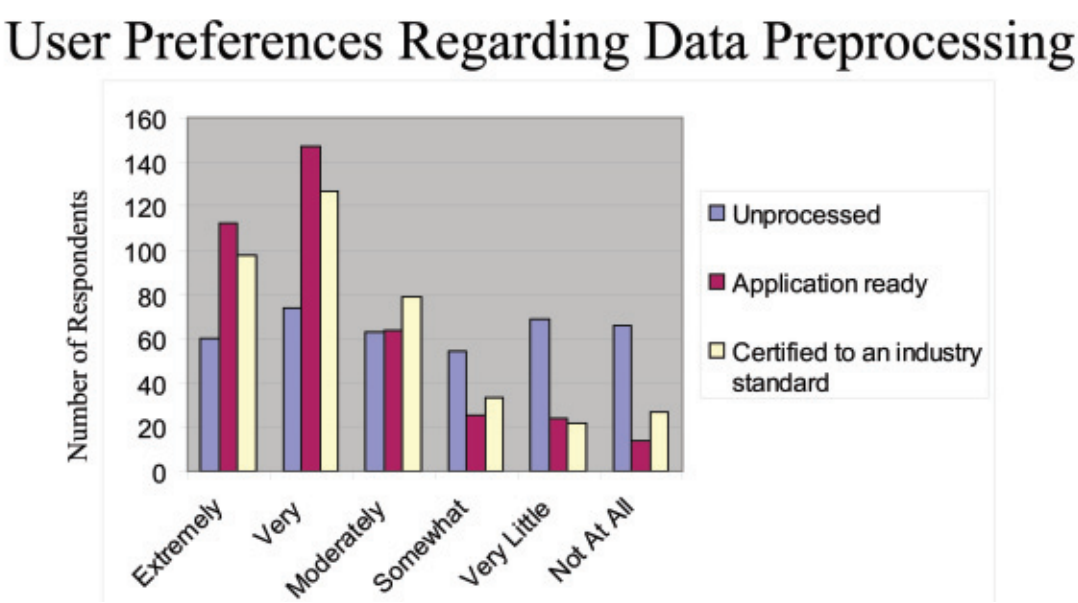

Figure 22. Data Pre-Processing

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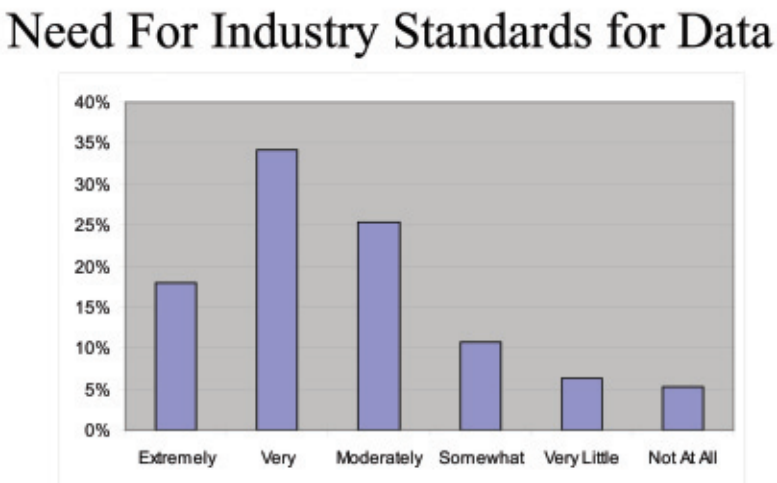

Figure 23. Data Standards

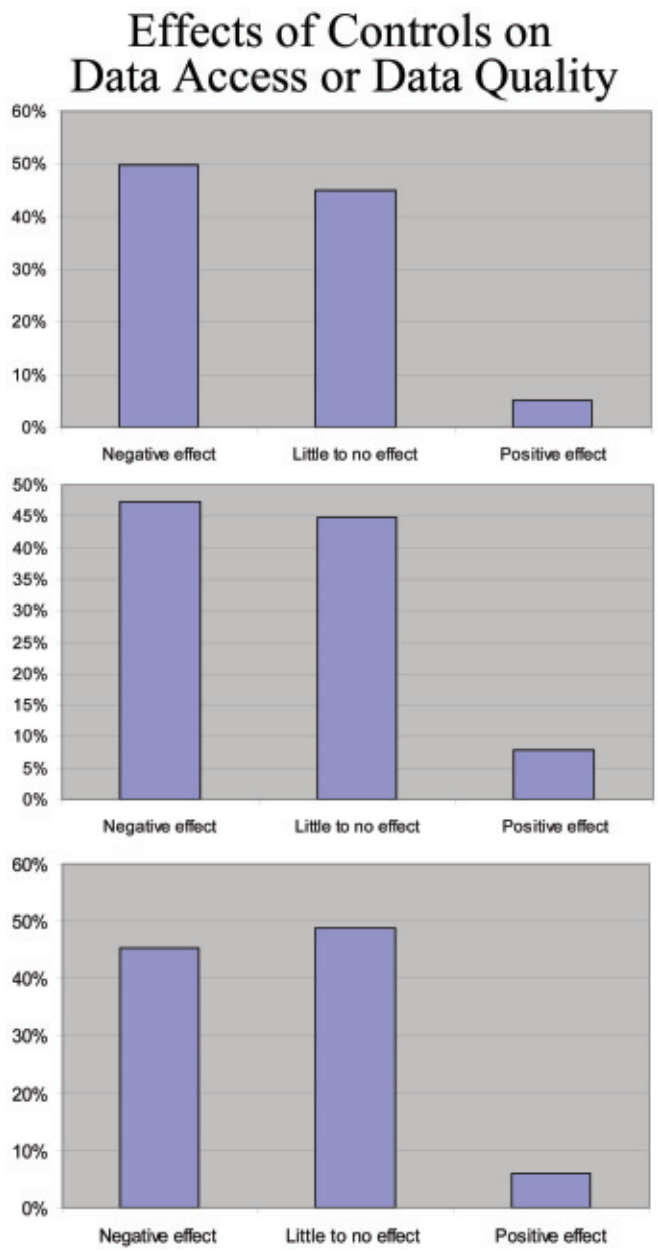

Figure 24. Licensing and Data Access Impacts

market indicates the need for both data providers and value added services will continue.

Data standards are extremely important in maintaining quality assurance and quality control on information derived from remotely sensed data. Hence, it is not surprising that most respondents felt that industry standards for data should be established. In legal cases, data heritage and "chain of custody" handling are of key importance in establishing the validity of analysis.

Questions regarding licensing or sharing restrictions were first added to the Phase III survey when companies and some data users raised concerns about government-imposed restrictions on certain data sales and distribution (Figure 24). As in Phase III, Phase IV results demonstrate that government-imposed data licensing and/or sharing restrictions have a negative effect on about half of the respondents, while restrictions on access to, or quality of, data have slightly less negative effect. Interestingly, about six percent of respondents cite a positive effect from such restrictions.

Restrictions on data ownership and/or copyright negatively affect about 47 percent of respondents. These restrictions are generally imposed by the companies that license data for use in order to protect their intellectual property. In many cases, such limitations are being eased in creative licensing arrangements that allow groups of users, such as state or county agencies, to use the data without restriction.

These results indicate that government-imposed restrictions continue to affect the marketplace negatively, hampering market growth. Over time, because they affect a significant portion of the marketplace, such controls may undercut U.S. leadership in the remote sensing marketplace, a position that is being affected by the proliferation of commercial and government-supplied satellite remote sensing systems around the world.

Use of Moderate Resolution Data

Phase IV asked a series of questions about the need for, and use of, moderate resolution data. The responses demonstrate that moderate resolution data remain in relatively high demand, even with the increasing interest in high-resolution satellite and aerial data. About 70 percent of the total respondents use moderate resolution data in their work IFigure 25).

In part, this continued interest stems from the fact that many projects use Landsat and other moderate resolution data as base data, even when also employing high-resolution satellite and aerial data. In fact, some 65 percent of respondents cited moderate resolution data as critical to their work.

Source of Funds for Moderate Resolution Data

Most respondents who indicated they needed moderate resolution data used federal funds to purchase the

imagery. Funds from regional sources are the next most important funding source, followed closely by academic funding (Figure 26).

Use of Landsat 7 Data

About 70 percent of respondents employ Landsat 7 data in their work compared to some 30 percent who do not, which corresponds closely to the overall use of moderate resolution data. Data customers who require the characteristics of the ETM sensor will primarily use data from Landsat 7, though many may make use of Landsat 5 data when appropriate Landsat 7 data are not available.

In June, 2003 the Landsat 7 satellite suffered a failure in its Line Scan Corrector (LSC) that caused the imagery to be less useable than before the failure. (See http://landsat.usgs.gov/project_facts/project_news/June_2003.php for more information on the issue.) NASA and the U.S.G.S. National Center for Earth Resources Observation and Science (EROS), in Sioux Falls, South Dakota were able to produce useable scenes by substituting data from other scenes acquired just before or just after each scene to fill in the affected parts of the image.

Nevertheless, since the LSC failure, many users have used alternative data sources for some critical applications. Most used Landsat 5 data, but others used a variety of other data sources, including foreign-owned and controlled systems.

Technology Application Areas—Summary and Conclusions

For Phase IV, the survey included a new set of questions related specifically to need for and use of moderate resolution satellite data such as those from Landsats 5 and 7. About 70 percent of the total respondents use moderate resolution data in their work. For them, medium resolution data serve as primary data sources or as a well-known foundation for higher resolution data sets. For some 65 percent of respondents, medium resolution data are critical to their work.

Most Landsat data users seek Landsat 7 data when available, though many will also substitute Landsat 5 data when they are not. For example, when the Line-Scan Corrector problem experienced by Landsat 7 impedes their ability to employ those data, they most frequently turn to data from Landsat 5, though some turn to non-U.S. data supplies (Figure 27).

Most respondents who employ medium resolution data used federal and regional funds to purchase them.

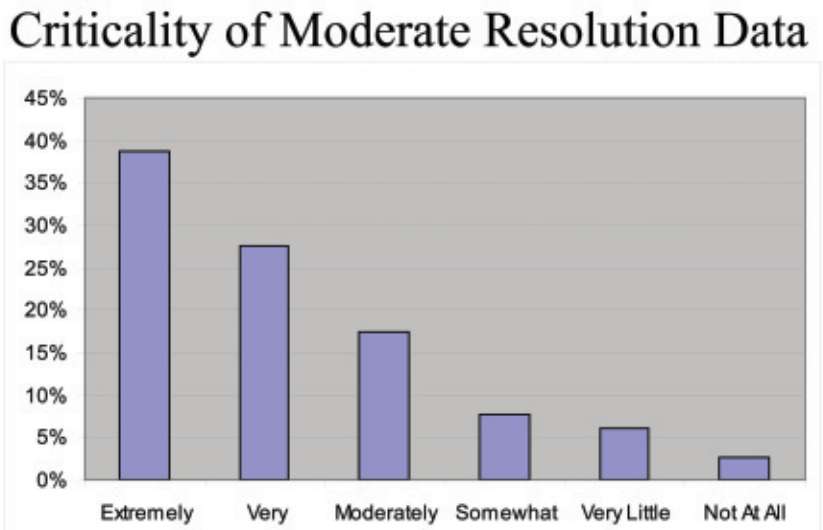

Figure 25. Moderate Resolution Criticality

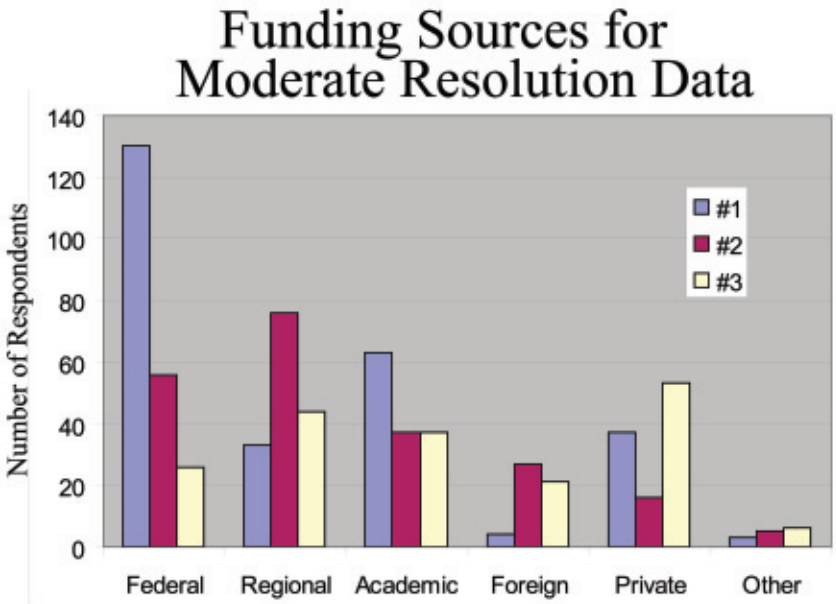

Figure 26. Moderate Resolution Data Funding Sources

Federal Government Policy

The federal government has the responsibility, through the commercial licensing office of NOAA NESDIS and other agencies, to promote the use of remotely sensed data (figures 28-29). Most phase IV survey respondents feel that government policy is sufficient for promoting sales of remotely sensed data from commercial satellites, with fewer (30 percent in each category—government, commercial, and academic) considering that it is insufficient. This suggests that the policy might need some adjustment to make it more supportive of this segment of the industry but that it is not currently broken. By contrast, when asked about the aerial remote sensing industry, most respondents felt that the government could do more to enhance sales in this segment.

U.S. controls on overseas technology transfers do not seem to hinder most respondents from carrying out their business, but of the number that expressed an opinion on the issue, some felt that government controls were a hindrance. Clearly such controls affect respondents within firms more than government or academic respondents.

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Federal Government Policy — Summary & Conclusions

Through the commercial licensing office of NOAA NESDIS and other agencies, the federal government has assumed the responsibility promoting the use of remotely sensed data. Most phase IV survey respondents indicated that current government policy is sufficient for promoting sales of remotely sensed data from commercial satellites, but feel that it could do more to help support sales of aerial remote sensing.

When asked about U.S. controls on overseas technology transfers, most respondents indicated that such controls do not hinder them from pursuing their business. For some few, these controls were a hindrance to their overseas sales.

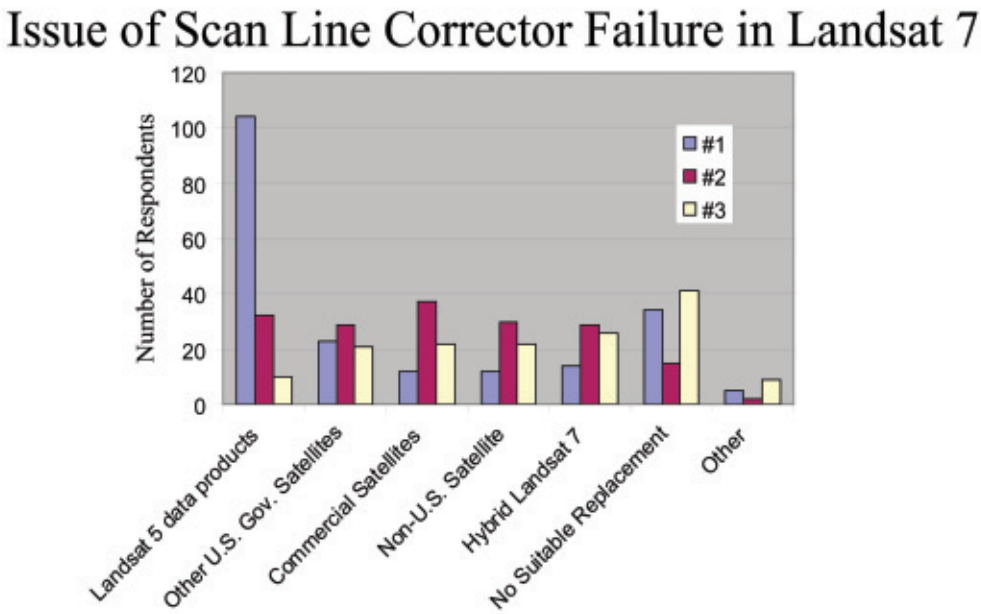

Figure 27. Landsat 7 Scan Line Failure Alternatives

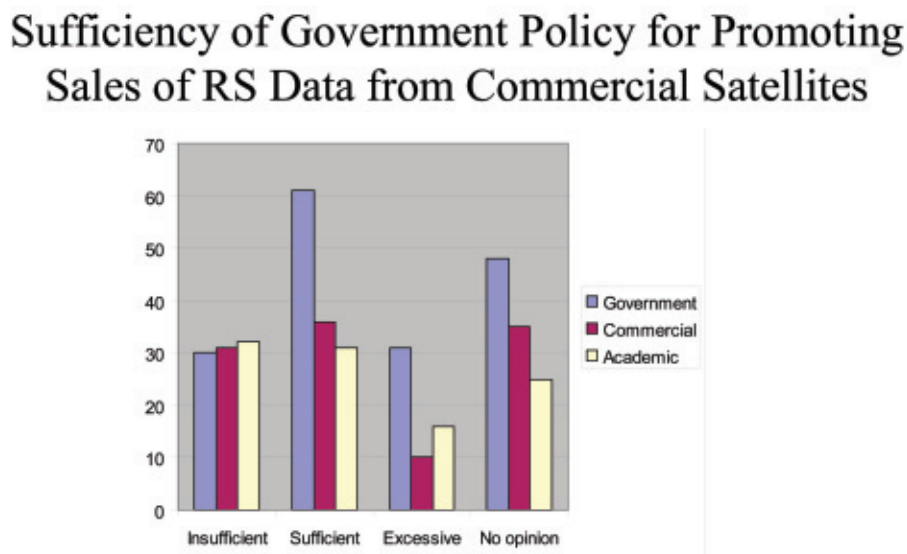

Figure 28. Government Policy Toward Commercial Satellite Data sales

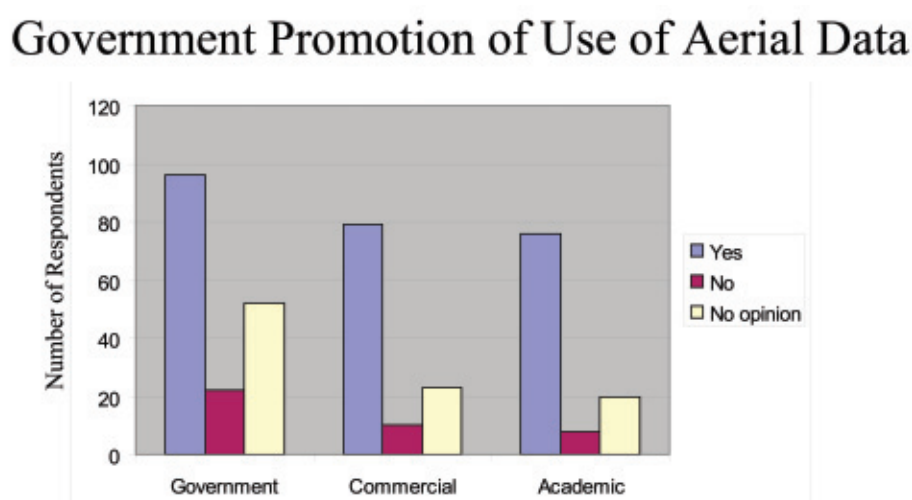

Figure 29. Government Policy Toward Commercial Aerial Data sales