STATE OF THE INDUSTRY REPORT

What Does the Future Hold for Remote Sensing?

As the volume of remote sensing data continues to proliferate globally, there's a critical need for improved data interoperability across a wide range of applications, as well as a legislative climate that supports such efforts.

To better gauge the sweeping advances under way in the Earth imaging industry, we challenged *Earth Imaging Journal*'s Editorial Advisory Board members to look ahead 5 years and offer their insights on the following three areas:

Technological Innovations • Applications Development • Legislation

TECHNOLOGICAL INNOVATIONS

JOHN COPPLE

CEO, Sanborn

The remote sensing industry continues to change rapidly. In the next 5 years there will be a significant amount of change as Earth is remotely sensed more than anyone would have ever thought. Not only is there going to be more satellites than ever before at a multitude of resolutions, but also the number of digital aircraft sensors continues to increase, along with thermal sensors, video cameras, light detection and ranging (LiDAR) systems, hyperspectral systems and others. The number of data points or pixels representing information about a point on Earth will be greater than ever before and will continue to increase. The resolution of the data continues to improve, as customers want higher quality products. The infrastructure to handle such increased data volume—processing, storage and network solutions—will make significant improvements during the next 5 years as products like large-scale, solid-state storage continues to become more affordable and new technologies come to market.

JOHN DELAY

Director, Architectures and Strategy, Harris Broadcast Communications, Government Solutions

Industrywide there's a rapid increase in signal and motion imagery sensors, which are creating an increased demand for multisensor intelligence systems that can manage, correlate and fuse sensor data sources regardless of type or physical location.

Multisensor intelligence consists of live and prerecorded signals in two basic forms: static media, such as images or photographs, and time-based media, such as signal intelligence, audio, video or human intelligence. Correlating sensor data typically requires extracting temporal, geospatial and essence metadata, which provide the basis for sensor correlation. New classes of imagery, Internet protocol (IP) cameras, persistent surveillance and LiDAR sensors are increasing the sheer volume of data collected annually. Correlating and fusing multiple sensor data for intelligence or business applications will provide valuable insight for businesses, as well as mission-critical insight for battle space commanders, homeland first responders and strategic decision makers. When combined, video, persistent imagery and signal intelligence sensors can generate yet untapped intelligence information. I predict that several technologies will make it possible to implement global multisensor networks:

PREDICTION 1: Cloud-based, multisensor intelligence networks will emerge. High-performance cloud computing products and services will become a key enabler to global multisensor intelligence networks. The following enabling technologies will drive the evolution of such cloud-based networks:

- Network transport, with lower latencies and higher traffic volumes (100gbps), will be required to support multisensor intelligence networks.
- Cloud-based storage and data access will bring 1,000x improvements in input/output data access, using global file systems that limit the need to move or replicate data.
- Object/cloud databases will have the ability to manage trillions of data transactions.
- Cloud-based encryption and security will allow secure multidomain data and user access.

PREDICTION 2: Video analytics and data mining algorithms will automate sensor correlation, fusion and visualization in multisensor networks. The use of video analytics for categorizing and interpreting images by recognizing objects in a timely manner is crucial in an imagery-centric sensor network, especially in applications related to surveillance and monitoring. Equally critical is data mining signal intelligence and correlating unstructured datasets to detect patterns of interest. The challenge remains that most analytics are developed for a specific application, making it difficult to run multiple algorithms simultaneously. The role of academia and national research organizations will be critical to making advances in this technological space. The following enabling tech-

nologies will advance the state of video analytics and data mining:

- Advances in CPU and image co-processers will enable real-time video analytics and data mining.
- The emergence of open analytics frame works will enable hosting many algorithms that can run on demand or in parallel.
- Analytics-driven search engines will emerge.

PREDICTION 3: As the volume of sensor data increases, the importance of sensor aggregation will lead to adherence to open standards for sensors and services. Over time one would expect the value of sensors to increase as the industry makes advances in sensor interoperability, implements analytics to automate processes and develops enterprise management systems and user interfaces that make it easier to extract intelligence information. Standards advances in the following areas will continue during the next five years to improve interoperability:

- Open Geospatial Consortium-compliant sensors and enterprise service-oriented architecture messaging will fuel sensor data correlation and fusion.
- The importance of Motion Imagery Standards Board standards will increase due to the increased complexity of motion imagery sensors.
- Standards will emerge that define ontologies that can be extracted by analytics processes.

Chief Technical Officer, MDA Geospatial Services

WILLIAM JEFFERIES

Predicting the future is always a risky proposition. Is it true that the longevity of any forecaster of the future is roughly equivalent to the number of years into the future he is forecasting? Hmmm …. retirement in 5 years may not be so bad.

The past few years have seen significant evolution of the Earth observation business. First, there has been a great increase in the number of missions, resulting in a massive increase in the amount of remotely sensed data available. Second, the complexity of those missions has increased substantially, with great strides in terms of improved resolution, increased sensitivity, and more frequencies and channels of information being available for the user. Third, systems have become increasingly flexible and agile, and in some cases more compact and streamlined, greatly enhancing a mission's ability to respond to operational demands. The result is that the user now is offered an unprecedented supply of increasingly sophisticated data sets from multiple sources.

To some extent, this has created a problem for the average customer. The array of data sources requires him or her to be conversant with more technical performance than ever before, in a time when budgets and resources necessary to master those data sources are under increasing pressure. Because of this, suppliers throughout the Earth observation industry all state the same thing: The key to success is to provide services of some kind in place of simple image data. Although not exactly a revelation, this realization is driving the industry to create more mature products to attract new customers and to retain existing ones. It's essential to understand the user domain and deliver solutions that fit their mode of operating.

In the next 5 years, I'm sure the development of sensor and satellite capabilities will continue to increase. Although it's tempting to speculate on those technical capabilities, the real challenge will be to take advantage of the wide array of data types and sources that will be available. The shear volume of imagery available for analysis is already immense and is overwhelming to some users. Add to this the technical complexity of such imagery, and the challenge to create and deliver the best information solutions becomes substantial. If we're to create and deliver advanced information solutions as opposed to simply image data, the best solutions will be those that integrate multiple data sources quickly and efficiently to exploit the wide array of available data. The biggest technical innovations will be those that manage this in highly efficient ways.

President, Global Marketing Insights

SHAWANA JOHNSON

The coming of age of the geospatial industry is now. The industry's ability to collect, distribute and access geospatial data continues to improve in terms of speed and precision of collection, timeliness of delivery, and affordability to the end user. However, there are several disruptive technology changes that are impacting the geospatial industry and will continue to do so for the next few years.

SENSOR PROLIFERATION. Myriad aerial, spaceborne and unmanned aerial vehicle (UAV) sensors are becoming available, offering more data to process and analyze as well as potentially more free data. In the next decade, more than 100 sensors will be launched as part of joint and individual programs by governments around the world. Every major space agency plans to make such data available for free to the public. All the data will be provided in Level 1B format, which still requires value-added analysis and processing to be usable. UAV research and development continues, which may lead to equipping airplanes that can fly in low Earth orbit, thereby avoiding air traffic restrictions and detection. Commercial UAV applications are prohibited in the United States due to Federal Aviation Administration regulations, but the UAV market is growing in Europe.

CLOUD COMPUTING. High-performance cloud computing products and services open the geospatial industry to a global market at reduced costs and allow for large volumes of data to be stored, accessed and manipulated without being ingested into users' systems. The challenge for remote sensing data and software companies is to change their business models from licenses and seats to data and services offered in an on-demand environment. Cyber security must be addressed, and those who decide to enter the cloud to save money and time must be convinced the cloud is secure. The companies developing cloud computing are proven entities, such as Google and Amazon, as well as their developer communities, and already have proved themselves capable of supporting a global audience and working with governments as technology partners.

SOCIAL NETWORKS. Global access to geospatial industry data and applications allows problems to be addressed and solved in a fraction of the time as traditional methods. The challenge is to discern what is true and accurate. Users also run the risk of their locations being known because of sophisticated geotagging capabilities.

Director, Center for Advanced Spatial Technologies, University of Arkansas

FRED LIMP

Developments in sensor systems such as multispectral LiDAR will provide exciting new data sets. Reductions in the price and sizes of sensors will make them more

STATE OF THE INDUSTRY REPORT

widely available. These sensors, coupled with unmanned aerial vehicles and other vehicle platforms, as well as simple hand-held versions, will make high-resolution data sets cheaper and more accessible. Increasingly the data stream will move from 2-D (map centric) to 3-D (object, feature-centric). Resolution—spatially, radiometrically, temporally and dimensionally—will continue to increase, creating processing and content extraction opportunities and challenges.

Founder and Chief Technical Officer, DigitalGlobe

WALTER SCOTT

There are several technologies converging that are going to have a profound impact on the remote sensing industry within the next five years. Advances in geospatial computing, accuracy improvements and greater spectral richness will drive innovation during the next 5 years, with highly automated feature extraction being the end result.

Vice President, North American Sales, GeoEye

BILL WILT

During the next 5 years, our customers will be looking for faster delivery of imagery products and other derivative data. We'll need to reduce the time between satellite tasking and delivering usable products into the hands of end users. Our production flow will require more automation, and our delivery mechanisms must continue to improve.

We'll develop much of this innovation to support our 10-year EnhancedView contract with the National Geospatial-Intelligence Agency (NGA). We seek technologies and operating techniques to prioritize, produce, analyze and distribute the data from our satellites more effectively and efficiently. In the next 5 years, technological innovation in our industry will be driven by the requirements stated by NGA Director Letitia A. Long at the GEOINT 2010 Symposium: one of the NGA's goals is "... putting the power of geointelligence directly in the hands of end users through online, on-demand access."

GeoEye is also working on developing our new satellite, GeoEye-2, scheduled to be operational in 2013. In sum, technology innovations in the coming 5 years should assure an even more robust remote sensing industry and far better service to our customers.

APPLICATIONS DEVELOPMENT

JOHN COPPLE

Applications development will lag hardware development in most cases. With billions of points now available from mobile LiDAR, the applications to handle it are few. While new processing applications like automated digital elevation models are arriving on the market, more improvement is needed in automated applications such as points to polygons, point to objects, etc., that enable the data to be used in more applications. The applications of the remote sensing data continue to improve with integrated datasets providing more information than ever before as customers find more and more ways to use the data as a substitute for other information sources. Change detection also will increase demand, as customers can't search through the volumes of data. Automated change detection will become a necessity. Customers will demand new applications such as integrated 3-D GIS and CAD functionality.

JOHN DELAY

With the potential of multisensor networks, search access and visualization technologies will become critical to extract information efficiently regardless of the user's device or network type. As cloud-based technologies become common, new approaches to user interfaces will be simplified because processer-intense functions will remain in the cloud and won't be performed on a remote user appliance. Early approaches to cloud-based experiences that don't require the content or processing to be local are coming from companies in the gaming industry like On Live. Multisensor intelligence applications will drive a shift from your typical client and application server environment to a services-based environment. I've got three related predictions:

PREDICTION 1: Immersive and collaborative user experiences will leverage abstracted programming languages, making it easy to customize software.

PREDICTION 2: Standards-based protocols such as PC-over-IP will be adopted on a global scale, allowing stateless desktop operating environments.

PREDICTION 3: App-based development environments will extend themselves to all forms of devices, PC, phones, set-top boxes, etc.

WILLIAM JEFFERIES

I believe there are two broad application areas that will become increasingly important in the next few years, partly because of their importance to the world community and partly because Earth observation uniquely meets their information requirements.

Maritime security management or maritime domain awareness is a multifaceted application area that includes the detection of illegal or noncompliant vessels, illegal ship discharge, pollution events and security threats. The logistics of providing surveillance using conventional observation techniques are daunting to the point that the vast majority of the world's oceans aren't well monitored. Advanced Earth observation services have been proven to increase the size and frequency of the area that can be monitored and the speed with which information can be obtained and disseminated. I have intentionally lumped together several aspects of maritime surveillance because often the same acquisition programs allow us to address multiple user requirements. Our experience in using spaceborne synthetic aperture radar (SAR) in conjunction

with other systems has demonstrated improved detection capability and reduced operating costs compared with many conventional solutions. As a result, we can provide more economical maritime domain awareness over larger areas. In the long term, this supports increased deterrence, which ultimately results in reducing the number of incidents and offenders.

Biomass monitoring is also a broad category, encompassing agricultural monitoring, land cover mapping and biomass change. At MDA, we're particularly excited about the polarimetric monitoring capabilities that RADARSAT-2 provides, giving us the opportunity to directly measure shape and structure of vegetation over broad areas at guaranteed time intervals. Used in conjunction with satellites such as the RapidEye constellation, we have data sources and techniques that allow us to go beyond simple detection of what is present to provide accurate data about the quality and quantity of biomass that is present. Whether the demand is driven from concerns about food security, alternative energy sources or the role of vegetation in climatology, I believe there are now both sources of data and emerging techniques that give us the capability to routinely monitor the world's biomass on a routine and regular basis.

SHAWANA JOHNSON

Application development is running at its highest level ever in the geospatial industry. With access to large amounts of free data from government space agencies—and more coming—developers are focusing on global climate change applications such as carbon sequestration and management, water resource monitoring and management, and global food security, among others. Additional impacts are:

INCREASED FREE DATA AVAILABILITY. With space agencies delivering more free data, the ability to leverage the Web will continue to require greater data and systems integration services. This could lead to fewer government-funded aerial imagery programs and a greater focus on space agency data and data interoperability.

AUTOMATED COLLECTION AND EXTRACTION. There's an increasing need for fused 3-D and 4-D data products, along with automated extraction tools that pull information from data. The ability to pull different data products from raw imagery or other sensor inputs will become a focus area for many users, who will have the ability to tune data inputs for their own purposes. Data providers will concentrate on creating more diverse data products.

The demand for such specialized data is already high, but the ability to deliver real-time information to create sophisticated programs that monitor and react to data inputs autonomously and adaptively will provide a platform for growth. The "app for that" mentality could easily evolve into a "data for that" ability, with software developers orchestrating different data feeds to create custom solutions.

The huge volumes of data available will require skilled technicians to verify, aggregate and analyze this information for rich insights. Web connectivity will feed these specialists. Organizations and governments might simply subscribe to regular data scrubbing and synthesis services.

PUBLIC DATA COLLECTION. Some open source and publicly provided data are replacing more traditional sources. For example, OpenStreetMap (*www.openstreetmap.org*), a free, editable world map, already has more geographic coverage than commercial aerial providers and is deemed "good enough" for a plethora of geospatial applications.

Mobile platforms are becoming increasingly important for data collection. These devices have greater location precision than ever before and, when coupled with location-aware applications, users can find anything, anywhere, anytime—not to mention anyone. The number of mobile platforms is quickly dwarfing other computing platforms, and innovations are occurring at a rapid pace. In-house computing systems will become less important, as wireless connectivity to large systems—held in a cloud or wherever they may be—will suffice. When volunteer input is combined with well-managed open geospatial software tools, the ability to gain access to new markets is limitless.

FRED LIMP

It seems clear that developments in the interface between photogrammetry, remote sensing and computer vision will lead to new automated tools for feature/content/information extraction from the new data streams and make the process more effective. Applications derived from sources such as Department of Defense-driven research in real-time 3-D battlefield awareness will move to a wider audience. This will have the effect of moving much of traditional remote sensing and GIS analyses into the cloud as services, with many applications residing in cloud-based "black boxes" that return value-added information rather than data.

As an educator, I'm particularly aware that we need to ensure our universities and colleges keep pace with this changing environment. At one level we need to prepare educated consumers—individuals who will be in business, government, etc., and will need to be able to intelligently select from the wide range of information services that will be available to them. At the next level we need to continue to grow the "artisans" who master the existing commercial software and tools and can be called upon to create information products meeting specific needs. Beyond that we need another category of individuals whose education merges traditional computer science skills with remote sensing, photogrammetry and other geospatial disciplines to create the cloud services. Finally, we need those individuals who are extraordinarily well prepared in mathematical, computational and physical sciences, and therefore have the skills to develop the next-generation sensors, systems and applications.

WALTER SCOTT

In the coming years we'll see applications built from the ground up to take advantage of the recent advances in spectral richness. DigitalGlobe's WorldView-2 satel-

STATE OF THE INDUSTRY REPORT

lite launched in late 2009 with eight spectral bands, and I suspect that will become the standard. We recently invited GIS professionals around the world to sample our new eight-band imagery, and the interest in the technology was overwhelming.

BILL WILT

We expect to see more applications that help analyze the copious data produced by remote sensing sensors. One of the stated goals of the National Geospatial-Intelligence Agency (NGA) is to "... create new value by broadening and deepening analytic

expertise of places informed not only by Earth's physical features and imagery intelligence, but also by human geography to better anticipate when something may happen and why." We simply don't have enough imagery analysts to fulfill this goal. We must design more analytical applications to provide automated change detection, feature recognition and related analysis. Specifically, we believe predictive analytics will become a major driver in our industry. This is exactly why GeoEye acquired GeoEye Analytics, formerly SPADAC, in early December 2010. GeoEye Analytics addresses NGA's goal by providing solutions that enable customers to analyze where activities or events may occur. We recognize the need for these analytical applications and plan continued enhancements during the coming years.

LEGISLATION

JOHN COPPLE

Legislation for the remote sensing community has come a long way. Although openness was accepted in the United States long ago, internationally most countries are still grappling with the amount of openness that's now available. Crowd sourcing and other low-cost methods of gathering reasonably accurate data will continue to increase. Internationally the policy of limiting data collection will continue to be the number one rule; however, countries will slowly "open up" as they realize the number and type of sensors will overwhelm the ability to "police" them. Countries, including the United States, will continue to struggle with a National Spatial Data Infrastructure and should let private industry move forward with it or it never will be accomplished. Web-based companies already have gathered many of the layers people and businesses need and want.

JOHN DELAY

An increased focus on regulatory and rights issues associated with sensors and multisensor intelligence networks is happening. In multisensor enterprises networks, intelligence information that otherwise doesn't exist from a single sensor can be derived from aggregating data gathered from one or more signals, imagery, video or human sources, potentially creating a regulatory challenge. These concerns are driving policy makers to pay attention to video surveillance, where privacy and data rights are becoming hot topics. Regulation will not only affect the sensors themselves but the aggregated data from the sensors, which will result in regulatory issues to be resolved: Regulations will evolve in the following areas:

- The Federal Aviation Administration will address domestic regulations that affect government and commercial rights to fly devices such as unmanned aerial vehicles, which will stimulate the market.
- Regulatory issues will need to address data ownership and privacy concerns—especially in the fixed-camera security segment—as a result of multisensor data extraction.

WILLIAM JEFFERIES

The demand for legislation is increasing, and we see various countries developing and implementing a variety of plans to manage the distribution of Earth observation data. In Canada, the Remote Sensing Act has governed our operations for a couple of years. As expected, there were some early teething problems, and I think it's fair to say that not many people were happy. Within the past year, it has gone much more smoothly as both enforcers and those enforced became more familiar and comfortable with what restrictions are in place and what procedures are necessary.

While the processes applicable to us in Canada have improved, there's still wide variation in legislation globally. In our case, we have restrictions on the distribution of high-resolution RADARSAT-2 data, and yet I can find higher resolution optical data freely available on the Web. We're seeing some progress on this front, but it's a long process.

In summary, I suspect legislation will be an increasing fact of life for several years to come. It's incumbent on the data providers and the Earth observation community to participate actively in the development of any legislation.

SHAWANA JOHNSON

Legislative impacts continue to shape the geospatial industry:

- The Levin-McCain Act deals with organizational conflicts of interest. The act has caused divestitures and business model changes in the U.S. defense contractor sector, especially in the geospatial industry as seen with the Northrop Grumman divestiture of TASC and the Lockheed Martin divestiture of EIG (now known as The SI Organization).
- International Traffic in Arms Regulations (ITAR) has resolutions in play that affect the U.S. launch industry and the remote sensing industry.
- Environmental legislation focused on global climate change and the carbon cap and trade programs globally continues to open the potential for geospatial applications. Once the United States enters this area with

official legislation, an even bigger impact will be seen as geospatial providers build products to support the U.S. carbon cap and trade market

• Changes to national security treaties and legislative cutbacks on defense budgets and earmarks always impacts the geospatial industry because it's so closely tied to government budgets.

Sometimes legislative changes cause the U.S. government to embrace commercial geospatial products and services and sometimes it chooses to develop additional geospatial capabilities itself. Both responses always end up supporting the geospatial industry in the long run because government supported and developed geospatial technology eventually ends up in the hands of commercial geospatial products and service developers.

FRED LIMP

It's becoming increasingly difficult to predict the federal legislative process for the next month—not to mention the next 5 years—so perhaps it's best to consider what may happen at the state and local levels. One of the long-term trends in the Earth imaging community has been the shift from national mapping and national assets to state and local ones. As data resolution has increased, data have become more rapidly accessible, richer and more valuable in local and state activities. State and local governments are increasingly spending funds for data acquisition—especially where there's good state coordination. Such is the case in Arkansas, where the state's Arkansas Geographic Information Office has done a superb job of coordinating data acquisition activities. The fiscal problems of the recession may put a short-term crimp in such activities, but that will only mean a greater demand as recovery happens sometime within the 5 years. As these data become more ubiquitous and higher resolution, complex challenges may arise regarding privacy and data acquisition that may lead to legislative action. Legislation often results from specific outrageous events, so we all need to be vigilant that we don't provide fodder to the process.

BILL WILT

Overall, GeoEye has benefited from a supportive legislative environment. National policy and law have helped sustain the growth and world leadership position of our industry. We now have the means necessary to greatly improve collection capacity and infrastructure to continually improve service to our entire customer base.

However, GeoEye would like to see consideration given to the policy that restricts our ability to sell imagery better than 0.5-meter resolution to any customer other than the U.S. government. We believe U.S. commercial companies need to maintain the technological edge to keep our global leadership position. We're making design decisions today regarding the capabilities of satellites that will be on orbit through 2024. Before we commit to expensive enhancements that would yield higher quality imagery, we need to know what the policy environment will allow us to take to marketplace.