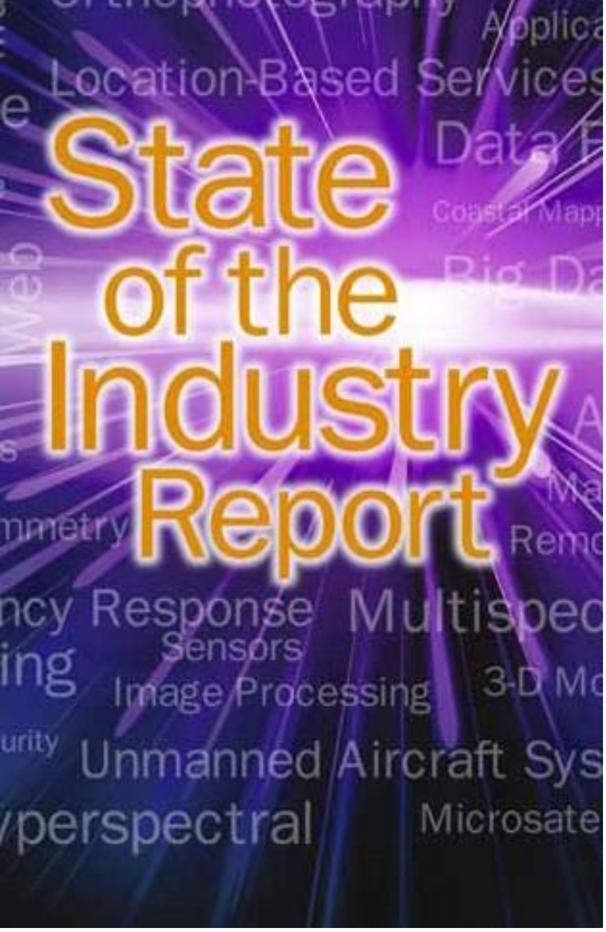

TECHNOLOGY
Tracking the Trends
Remote Sensing

Technology never stands still, as illustrated by the many advances that have burst onto the scene in the remote sensing industry during the last few years. From increasingly sophisticated Earth-observing systems to Web-enabled devices embedded with location technology, such advances have vaulted Earth imaging to the forefront of business and application development. *Earth Imaging Journal*'s staff solicited the professional views of our Editorial Advisory Board members on today's cutting-edge technology trends for our annual State of the Industry Report.

What are the most important geospatial technology advances of the last three years?

COTHREN: Implementing standards, standards and more standards, including:

• Browser (HTML5) and data (GeoJSON, etc.) standards, which make powerful Web-based mapping clients independent of plug-ins and thus more appealing and useful to a much larger audience.

Jack Cothren
Director, Center for Advanced Spatial Technologies, University of Arkansas

• Broad acceptance and implementation of mapping service standards, though they're not necessarily new.

• Official (E57) and de facto (LAZ) standards for airborne and terrestrial light detection and ranging (LiDAR) data.

DELAY: Never in the geospatial industry's history have new technologies advanced the industry at the pace of today's changes. Three big changes will continue to accelerate the use of geospatial information:

John Delay
CSO/Architect MI, Harris Government Communications Solutions

1. The implementation of Open Geospatial Consortium (OGC)-compliant Web services will provide network access to more geospatial information. OGC Web Service technologies have matured in recent years, rapidly increasing the amount of data accessible to address spatial information needs over global networks, including the accessibility of geospatial data by mobile devices.

2. The proliferation of location-based services and devices will continue to provide geospatial and temporal data and services to all types of mobile users. Such information, although useful for real-time navigation and location-based information, also provides new ways to predict existing and future trends. Location-based services allow users to correlate temporal and spatial information, thereby advancing the potential of activity-based intelligence tradecraft.

3. 3-D imagery is reshaping the geospatial marketplace due to the rapid adoption of LiDAR technologies, which are evolving for airborne, ground and fixed platforms. LiDAR is fueling the production of new higher-accuracy 3-D products as data collection, processing and production costs continue to fall.

JOHNSON: Geospatial technology has become more accessible due to its online usage for mapping, directions, etc., all of which contribute to a growing audience. The top three recent advances are high-performance

Shawana Johnson
President, Global Marketing Insights

HEATS UP Shaping the Industry

computing in the cloud, crowdsourcing and a continued move toward open-source software.

Cloud computing helps many geospatial users avoid the expense of hardware that can only hold small amounts of imagery and focus more on their ability to manage and process imagery. Being able to manipulate and process imagery in a high-performance computing environment allows a user to access data from any location whenever necessary. For small to mid-size businesses, the cloud is cost efficient and secure—at least as secure as possible given current commercial encryption technologies.

Crowdsourcing is a way to obtain services, ideas or content through an online community of people. The National Map Corps' crowdsourcing project already has submitted more than 25,000 structure or man-made feature updates to improve U.S. maps. Through this effort, civilian volunteers are making significant contributions to the U.S. Geological Survey's ability to provide accurate mapping information to the public. Such projects help the government and the private sector improve results even if budgetary reductions inhibit formal updates.

Open-source software helps users customize products for free and is changing the landscape for geospatial software providers who incorporate these tools into their proprietary offerings. Being able to receive information on a hand-held device quickly, easily and on location is the "new normal" and an increasingly large part of the geospatial workflow. Users want to add their own input to an application, and open-source software makes this process easier.

Kumar Navulur

Director of Next-Generation Products in Labs, DigitalGlobe

NAVULUR: Several important geospatial advances come to mind:

- The Global Positioning System (GPS) has become ubiquitous with the explosion of mobile devices.
- The map makers and location-based service companies that employ GPS-enabled maps have brought geospatial technology to the masses.
- Crowdsourcing has become mainstream by government/nonprofit organizations as well as commercial companies.
- The building information modeling industry has taken off with the advent of terrestrial LiDAR data.
- The remote sensing industry has reached a critical mass in terms of global collection capacity, processing and delivery.
- The United Nations Global Geospatial Information Management initiative is tackling global standards for geospatial data.

Brian R. Raber
Vice President, Geospatial Solutions, Merrick & Company

RABER: There's always going to be the latest cutting-edge data collection and processing hardware/software that will acquire data faster, possess more spectral bands, post-process in near real time, offer more spatial precision, have a higher point or pixel density, etc. However, an advancement that holds great promise is the ability to integrate point clouds into mainstream GIS, asset management and related applications. Many of the major remote sensing and GIS software companies, as well as specialized firms outside our profession, are working feverishly on this important market opportunity. The key will be to display sensor information/characteristics using native point cloud formats as well as have the ability to analyze such data and fuse them with additional ancillary data for unique applications. This is a critical component that will extend the value chain of normal data products.

As software packages interface more effectively with all types of point clouds, our profession could transform from a "points-and-pixels" provider to one that meets users' unique requirements with more robust spatial and application-specific intelligence. Many traditional remote sensing companies are making this transition, and other companies related to our profession are adding value to the point cloud.

Mladen Stojic
President, Hexagon Geospatial Division

STOJIC: The biggest transformational trend is the rise of nontraditional sensors, including unmanned aircraft systems (UASs) and mobile devices. For example, the synthesis of social media has created a new source of geospatial information in which there's a dialog about virtually every event happening around the globe.

Another tremendous change is the rapid rise of mobile offerings that reside in a thin-client setting. Now users can access smart apps that tap into data and analytics to support specific workflows. This movement is being reinforced by state and local governments, defense and intelligence agencies, utilities and larger commercial enterprises that embrace it.

Dummying down GPS to a map and an app has allowed anyone with a smartphone to effectively navigate in places he/she never has been before. What are some other ideas for enabling geospatial functionality for the masses that currently aren't available?

COTHREN: Indoor mapping and localization. The technology is here. What we don't have yet are accepted standards and base maps to fully implement and deploy such technologies. Many proprietary standards are being tested. For example, retailers are testing deployments in individual stores.

In 1997, Frances Cairncross wrote *The Death of Distance*, which discusses the idea that activities like purchasing goods in the Internet age wouldn't rely on location. But human experience is all about place. If anything, our mobile devices have allowed us to interact with the outside world in new and unexpected ways. For better or worse, most of us spend more time indoors than outdoors, and the coming indoor localization technologies will have an even greater impact in the way we interact with each other.

DELAY: The smartphone revolution is exciting, but GPS- service enablement goes well beyond smartphones. GPS chips are going into many different devices. In the intelli- gence community, this includes video sensors, laptop com- puters, blue-force tracking devices, guns, you name it—all of which can be geolocated. The exciting thing is this trend goes beyond navigation; it's part of a more comprehensive geoawareness because of location-based services.

GPS-service enablement brings about a shift toward real-time, intelligence-enabled applications. The potential of intelligent Web services delivered to a mobile device that can pop up the most recent intelligence reports before you enter a village or building are limited only by an application developer's creativity. The closest example to such an application is Urban Spoon, a popular restaurant application that provides a real-time geoaware view of all the available restaurants within a 360-degree view.

Another example is the work completed by the 3-D Computer Vision group at the University of North Carolina at Chapel Hill under the direction of Jan-Michael Frahm. His team invented algorithms that automatically create 3-D models of landmarks and geographical locations, using ordinary 2-D pictures available through online photo-sharing sites like Flickr. Such algorithms could have a profound effect on understanding infrastructures within areas of denied access for intelligence organizations.

With the global proliferation of smartphones, we'll see many things fall in place such as Web-enabled services, secure mobile devices and applications that provide near real-time intelligence information to our warfighters, police officers and firemen, just to name a few.

JOHNSON: Adding GPS functionality to phones or tablets has created an easily accessible way to connect with others around you through applications or geotagged photography and information. Users of these GPS-enabled applications can take advantage of multiple data sources through one product in real time, such as through Esri's ArcGIS Online mapping platform. The sky is the limit in terms of geospatial functionality for those who are already geospatially aware. For the masses, GPS-enabled devices are being upgraded continuously, which means their precision will keep getting better and they'll become increasingly easy to access. Besides smartphones and cars, GPS functionality is in wrist watches, bracelets and eyeglasses. Maybe the next GPS capability will be implanted in humans for tracking and/or protection.

NAVULUR: Since the dawn of civilization, humans have traveled from place to place. GPS-enabled maps have transformed this need in a unique way and have been adopted by billions of people. Additional areas where geospatial technology can have a huge impact include education and agriculture.

RABER: Smartphone apps already take measurements and input information from the field to the office. How- ever, soon these inexpensive solutions could populate an enterprise GIS and provide more real-time situational awareness as an event unfolds.

Several technologies now exist to create measurements and 3-D images that more precisely represent the interior and exterior of buildings and associated infrastructure. Such advances may not replace the need for traditional static LiDAR sensors or metric digital cameras, but these mapping apps can be an effective tool for some situations, especially when they're combined with crowdsourced attribute data. For example, Intergraph's Mobile Alert smartphone app collects and disseminates incident information from nontechnical citizens directly from field to office in real time as an event occurs.

There's a lot of debate about the authoritative nature of such data, but ultimately GIS software will have to accommodate the volume of data coming from such "sensors." Moreover, data standards, identity protection and best-use practices will have to be developed to validate and categorize such geospatial data to benefit society.

STOJIC: Geospatially enabled smartphones are poised to take off in new and unique ways in 2014. By taking a page from the philosophy that humans are sensors, many smart- phone users play an active role in enhancing the quality of government services—for example, Intergraph's Mobile Alert app. We'll also see more use of real-time, streaming video for emergency services through mobile apps. In addition, other industry verticals will leverage this kind of mobile data for enhanced decision making.

How will the coming commercially operated UASs change how we image the planet?

COTHREN: When the United States finally moves beyond the somewhat ad-hoc and site-specific approval process for deploying UASs—on which the Federal Aviation Administration (FAA) is making slow but sure progress—we'll see a move to a two-tiered data market: professional/legal users, who need certified accuracy, and media/game/popular users, who care about visual quality but not necessarily certified accuracy. There are many examples in which the cost of airborne data prohibits their use. Precision agriculture is a good example. In many small markets, farms don't operate at a scale that allows for economic use of airborne imagery. However, UAS technology offers a way for smaller operations to visually inspect their crops to identify stressed areas.

DELAY: Widespread UAS use will make remote sensing capabilities available to a broader commercial market segment, decrease costs and offload the Department of Defense's heavy burden to invest in UAS technology advances. Additionally, a UAS fleet could collect a large amount of data and provide a more persistent view of activities to aid many organizations and better serve communities. The migration of UASs to commercial industries also will fuel economic growth across the aerospace community.

JOHNSON: UAS technology and streaming video systems are regulated by the U.S. government and primarily used within the military. However, studies show UAS benefits go beyond military use to improve communities, strengthen public services and achieve many additional benefits for a variety of commercial and government organizations. For example, many potential users are interested in commercially operated UASs for search and rescue, weather forecasting, law enforcement, border patrol, precision farming and mail delivery. This is a natural progression from strict government usage to commercial usage and will change how we image our world and use the data.

FAA's interest in advancing the commercial drone industry precedes 2012, but civil performance standards are strict. Currently the European Union (EU) is spending more money on UAS and streaming video market research than the United States. Many EU companies are gaining practical application experience, with few restrictions, due to an influx of research fundng.

NAVULUR: UASs are a great addition to existing remote sensing platforms—both satellite and aerial. Whereas satellites can bring global capacity in restricted collection timeframes and aerial platforms are more stable to perform mapping appli- cations, UASs are ideal for monitoring applications, especially small areas. Such technology can be used for many tasks, in- cluding traffic monitoring, precision agriculture, pipeline mon- itoring, etc. I see UASs becoming an integral part of geospatial technology and providing economically viable, widespread monitoring capabilities for a variety of applications.

RABER: Despite the fact it is illegal to commercially fly UASs in the United States, this part of the remote sensing profession is about to explode. Currently, a shift from de- fense uses to common information collection requirements is redefining how we image the planet for small project imagery, video and surface model applications. There are also countless examples of non-remote sensing "compa- nies" disregarding FAA no-fly rules and gaining valuable market exposure and experience. Commercial UAS ap- plications will proliferate once FAA creates functional UAS safety standards, operating parameters and operator (pilot) certifications.

With increased pressure from public, private, academic and government interests, the need to create a safe airspace solution has greatly intensified. Besides efforts from FAA, universities and private-sector companies, there are several professional associations actively addressing many critical issues from an educational, advocacy, best practices and application point of view. Two of the more connected organizations are the Association for Unmanned Vehicle Systems International (AUVSI) and the Management Association for Private Photogrammetric Surveyors (MAPPS), whose members have great interest in being able to quickly, yet thoroughly, define UAS parameters to safely enter the national airspace so they can begin providing remote sensing services. For more information, check out AUVSI's recent report, *The Economic Impact of Unmanned Aircraft Systems Integration in the United States* at *www.auvsi.org/econreport.*

Finally, derived data from UAS sensors will require a fresh look at standards, quality-control procedures and deliverable products. Because data products derived from a sensor payload on a UAS will gain acceptance quicker than anyone can imagine, there will be added pressure to qualify and quantify criteria that are considered the norm when using traditional photogrammetry approaches.

Stojic: The rise of commercially operated unmanned aircraft will allow virtually any organization to be spatially aware and leverage geospatial imagery in new and unique ways. From domestic search-and-rescue missions to crop management, the uses are nearly limitless and provide an additional sensor for seeing the world. For example, full-motion video, typically used by military drones, can be implemented by utilities for tracking and visualizing their assets in ways that augment LiDAR and other types of imagery. UAS imagery will be just another color in the imagery palette to enhance any organization's decision-making process.

On a scale of 1-10, how are we doing at managing the expanding volume of Earth observation data from a growing number of sensors? How can we do better?

COTHREN: I'd give us a 5, but we're improving quick- ly. The cost of storing and archiving digital data always will be a concern. A larger immediate concern is discover- ing and disseminating appropriate data within a useful timeframe. This is where I think effective Web portals and data and metadata standards are beginning to take hold and mature. Efforts to make data available and usable are under way throughout government and industry.

One prominent example in the science community is the National Science Foundation's Earth Cube. OGC is playing a major role in this effort, which is addressing data standards that make it easy to share and integrate disparate data types and implementing portals that ease data discovery and use. In addition, the Earth Cube community is trying to align its work with other networks, such as the intergovernmental Group on Earth Observations.

DELAY: The intelligence, defense and civil communities are changing how they define Earth observation, which now encompasses an ever-increasing variety of location-aware mobile, ground, airborne and satellite sensors that can produce massive volumes of information. This continues to increase the volume of Earth observation data, which drives the need for standards, compression, storage and other infrastructure changes.

Overall the defense and intelligence community struggles to keep up with commercial best practices and continues to be challenged by the rapid increase in data volume and a lack of data interoperability. However, progress is being made with advances in OGC Web services, which are being widely adopted across the defense and intelligence community. This puts the community at a 6 on a scale of 10, with a further acceleration in adoption as the Intelligence Community-Information Technology Enterprise (IC-ITE) architecture is implemented to dramatically improve geospatial data access across secure and unsecure networks.

Another challenge is keeping up with the variety of new Earth observation data received and making such data available for analysts. This effort begins with good foundational data models as well as implementing tagging methodologies to make data easily discoverable. Progress in commercial and government segments (4 out 0f 10) is being made to implement unified data models that can bridge the gap between today's structured and tomorrow's unstructured data models. However, unifying data tagging for each data type varies widely, depending on the data type. Overall the challenges that face our community in dealing with today's rapid influx of new and exciting Earth observation data are trivial compared with the potential impact of the intelligence information that can be garnered from such data.

JOHNSON: On a scale of 1-10, the grade will vary de- pending on who you ask and their understanding of Earth observation data. Someone who works for a government agency such as NASA or the U.S. Geological Survey may select 8 as the most appropriate grade based on how they manage today's expanding volume of Earth observation data from a growing number of sensors.

However, what would a geospatial practitioner say? Geospatial experts know the grade varies depending on who you are, and the only thing that counts is whether you can access data quickly, easily and accurately to solve your client's problem. These experts are well aware of the growing volume of data and the lack of interoperability between systems and software, so perhaps the grade would be 2. Conversely, for a new user who runs a local pizza shop and can use online Web maps to find clients for mailings and obtain easy travel directions while looking at a satellite or aerial image, maybe the grade would be 10.

A global, interoperable, cloud-architected system that provides users with unfettered, easy access to Earth observation data anytime and anywhere is key to sensor management and access. Earth observation data must be provided in a way that allows users to incorporate other datasets to make their own applications and solve their specific problems. For those who are successful, the grade may be a 10—until the next development.

NAVULUR: If we're talking about individual geospatial data sources, I'd give us a grade between 5-8. As for the geospatial industry making all the datasets work with each other effectively, the grade plummets to about a –3.

As the famous U.S. military saying goes, "We are swimming in sensors and drowning in data." We have multiple geospatial technologies that can collect data at macro, meso and micro scales. What's missing is a unified framework on how various datasets can be combined for actionable intelligence. We need to come together as an industry to integrate geospatial technology into the fabric of a common person's daily life. OGC is doing its part with establishing interoperability standards, but we need to create common datasets for solving real-world problems.

RABER: From the viewpoint of managing true 3-D point cloud data and fully integrating such data into the busi- ness process , I'd give our profession a 4. This rating takes into account that the "geospatial big data" issue goes well beyond managing data, as it also includes storing, sharing (disseminating), visualizing, fusing, analyzing and extract- ing valuable information from such a rich dataset. All of the well-known GIS software companies have methods to reformat LiDAR data for viewing purposes; however, leveraging the richness of point cloud data within a GIS, CAD or specialized end-user application is virtually nonexistent.

As the demand for a true solution to this problem grows, the capability to instantly visualize, disseminate and stream such datasets is commercially available. Such software solutions don't rely on hardware, traditional GIS software or point decimation. Instead, the so-called "big data" problem is on the verge of being solved by industry innovators such as Autodesk and Bentley as well as newcomers from the video game industry. One such innovator, Euclideon, has developed unlimited detail (UD) technology in a software product called Geoverse. This solution instantly visualizes 100 percent of a point cloud and its associated attributes, plus it "fuses" various types of imagery to create a virtual 3-D model. The following Web link directs you to a YouTube video that explains the Euclideon approach to handling large amounts of point clouds: *http://www.youtube.com/watch?v=Irf-HJ4fBls.*

As Geoverse and other software products continue to evolve, true 3-D applications can take advantage of the sensor technologies that create point clouds. In addition to solving the visualization and dissemination problem, current development efforts are focused on integrating efficiently compressed point clouds into applications that help geospatial users analyze problems as they actually appear in the real world in real time.

STOJIC: Thanks to advances in remote sensing, most large organizations have to deal with massive and increasing volumes of data. In theory, this should present more opportunities to view and analyze geospatial data for enhanced decision making. However, most organizations—whether a utility or a government agency—deal with data overload on a mind-numbing scale.

The problem is that files aren't managed in ways that make it possible for users to find, or even have confidence in, the currency and accuracy of the data they contain. At the same time, organizations need to manage the exponential growth in storage requirements, user demand and performance expectations. Fortunately, compression formats, such as ECW, are available to meet this expanded need and manage large volumes of geospatial imagery. If I was to grade our efforts, I'd say we're at a 7 and rising. EIJ