The State and Future of GEOINT

2017

USGIF
United States Geospatial Intelligence Foundation

The United States Geospatial Intelligence Foundation (USGIF) was founded in 2004 as a 501(c)(3) non-lobbying, nonprofit educational foundation dedicated to promoting the geospatial intelligence tradecraft and developing a stronger GEOINT Community with government, industry, academia, professional organizations, and individuals who develop and apply geospatial intelligence to address national security challenges.

USGIF executes its mission through its various programs, events, and Strategic Pillars:

Build the Community

USGIF builds the community by engaging defense, intelligence, and homeland security professionals, industry, academia, non-governmental organizations, international partners, and individuals to discuss the importance and power of geospatial intelligence.

Advance the Tradecraft

GEOINT is only as good as the tradecraft driving it. We are dedicated to working with our industry, university, and government partners to push the envelope on tradecraft.

Accelerate Innovation

Innovation is at the heart of GEOINT. We work hard to provide our members the opportunity to share innovations, speed up technology adoption, and accelerate innovation.

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Some years we can see trends coming a mile away. Other years, they are not so obvious. Considering where our Community is in the evolution of GEOINT as a profession, both patterns are currently true. Some trends are quite obvious: the need for greater and more collaborative government engagement with industry; employers looking for easier ways to differentiate potential employees; technological advances that are changing our profession and our daily lives.

But some trends are not as obvious. The underlying higher education structure is changing in support of competency based education. Forms of communication are constantly changing—for many teens texting is passé, as is Facebook. Current instant communication kings Twitter and Snapchat will, within a relatively short timeframe, give way to other, perhaps not yet invented forms of communication. Voice to text is now accepted and ubiquitous. Schools no longer teach cursive writing and students often “type” their assignments via smartphone and print wirelessly, eschewing computers altogether. Yet NPR recently ran a story about the use of typewriters as the preferred method of writing stories in parts of the developing world, primarily because of a combination of inconsistent electricity delivery and lack of internet connectivity. Ours is a world full of contrast, with a widening electronic communications divide, both within countries and among nations.

The rise of the machines is now front and center. Analysts from all organizations want answers, not data. Data providers have rebranded as data analytics providers. Platform-as-a-Service, Analytics-as-a-Service, and Drones-as-a-Service are all real offerings. For the GEOINT analyst, deep learning—the advancement of machine learning—is no longer on the horizon. It is here. Teams of analysts routinely combine their knowledge and skills to solve tough problems. Today, data science and deep learning tools in a virtual team setting augment these collaborations. The future analytic state will continue to see these teams form and dissolve quickly, perhaps in days or even hours.

Small sats and unmanned systems have been unleashed as a result of changes to commercial satellite launch, airspace regulation, and technological innovation. Although the future appears bright for these collection platforms, many of us openly question how to turn the promise of small sat or UAS imaging into profitable operations. It all starts with competent analysts who can understand, sift through, triage, and choose from myriad inputs—who can collaborate with data scientists and algorithm developers and add the context computers cannot. Analysts remain at the heart of the GEOINT enterprise. Even as the Community looks to automate analyses, we seek the next level of understanding—a deeper look into what the data tell us. Deep learning helps point us in the direction of additional needed research and lets us demonstrate the value of both computational efficiency as well as the power of the human brain.

This year, we changed the name of the State of GEOINT Report to "The State and Future of GEOINT," which more accurately reflects the content received from our authors and provides the global GEOINT Community with a continuing forum for future casting. In a world full of challenges and opportunities we all know that every event occurs in some place at some time. Predicting the "W5H" (who, what, where, when, why, and how) of the future is not easy or simple. Rather, it is difficult and complex. Furthermore, educating and training analysts who are able to make those predictions is more important than ever as the impact of mistakes, false positives, and false negatives is heightened.

We would like to thank all authors and others who contributed behind the scenes to make this publication a reality. If you would like to be involved in future publications, be on the look out for announcements from USGIF in late summer/early fall. We hope you enjoy The State and Future of GEOINT 2017 report, and that like its predecessors, the document fosters thought and discussion throughout the broad GEOINT Community.

Darryl G. Murdock, Ph.D.
Vice President of Professional Development

USGIF

Taming the Tedious, Overcoming the Challenging, and Simply Improving Our Daily Lives: A View of Deep Learning

By Peter Hanson; Todd M. Bacastow; Cordula A. Robinson, Ph.D.; Barry Tilton; Robert Albritton; David Foster; and Daniel Bonnel

Since the Industrial Revolution, technological advancements have continuously changed the relationship between human and machine. Automating processes, saving time, and increasing efficiency have transformed tedious daily tasks and profoundly improved the way humans live. With major advances in computing and access to an explosion of data, the next major change is the evolution of deep learning (DL), a subset of machine learning (ML). Advancements in algorithm development techniques and the availability of affordable hardware, primarily graphics processing units (GPUs), have enabled DL to continue to improve, scale, and become increasingly useful for a variety of disciplines and communities beyond a select few scientists. Expediting the consumption, processing, and synthesizing of once inconceivable volumes and variety of data, DL offers analysts objective insight to the world and allows them to provide more complete and informed analysis in a fraction of the time. DL, like most technology, expands capabilities once thought out of reach.

Machines Complement Human Analysis

Starting with basic tasks, humans have grown to rely on the vast capabilities of machines. Gone is the era of visiting a bank to get money from a human teller, we now take for granted that ATMs are available anytime, anywhere. Although ATMs are very different from DL, human acceptance of the machine's ability to augment human tasks had to begin somewhere. Fast-forward a few decades, and we find ourselves in a time of smarter machines that can take on more tasks, even those tasks that are cognitive in nature.

Sophisticated machines have now moved us into an era in which the capabilities to process and sort huge quantities of information, recall thousands of details, and, most importantly, to assess links, patterns, and identify alternatives in data analysis have significantly surpassed what humans can do alone. This new era of DL provides an opportunity to augment and complement analysts' ability to make better decisions.

DL affords researchers, analysts, scientists, and even consumers many advantages:

An objective analyst: While human analysts have always strived for objectivity in their analyses, providing an unbiased viewpoint continues to challenge even the best analysts. Humans can see alternatives or find and consider information that may refute their hypothesis. But personal biases often lie in the background of our consciousness, thereby clouding our ability to see everything objectively. Sometimes human emotions that are difficult to overcome have a role in our analyses; we become enamored with our own theories and look for information to support our thinking and throw out information that may contradict it. DL algorithms are designed to enhance human objectivity by automating the discovery and categorization of data, dispassionately bringing forth emerging correlations, new information, and weighted alternatives for consideration. Analysts make the final determination—but the power of an objective analytic partner offers richer results, a more balanced viewpoint, and a more rigorous justification for our own analysis.

Pattern recognition: Training machines to recognize patterns opens entirely new opportunities to not only "offload" tedious tasks but to significantly enhance the ability to find new connections and insight from data that would have taken considerable effort on the part of the human. While traditional methods required a human to hardcode algorithms, thereby recognizing only what a human already knows to look for, DL adapts and refines its algorithms to recognize patterns in data and enable automated identification of anomalies, emerging trends, shifts in data, and connections in data not previously understood. This ability accelerates analytic efforts in medical research, anticipatory intelligence, automatic target recognition and image processing, financial markets, and many others. Pattern recognition does not replace the human's interaction with the data but provides them with valuable new insights potentially more quickly than before.

Alternatives in the data: The machine's ability to rapidly assess huge amounts of data can assist the sorting process. In today's information environment, analysts are pummeled with huge volumes of data. One myth regarding data is that it is all new and unique. Rather, analysts find themselves sifting through information that is duplicative, contradictory, erroneous, or only tangentially related to the topic of interest. This filtering process is burdensome to the human brain and hinders the ability to discern new and unique information. The unnoticed, truly new information is often the key to anticipating new and emerging trends and events. Analysts often find, when forensically reviewing data after an event, a missing piece of information that would have given them advanced insight. The answer is not always hidden in the data, but more often than not, what appears to be erroneous information is in fact critical. Using DL algorithms and the advantage of the machine's data review capability, data can be rapidly sorted, filtered, and narrowed down to the key points. Those same algorithms can also identify potentially related data points that the human had not recognized or considered. The ability to quickly process and assess data to find new and unique patterns or anomalies, weigh and rank the alternatives, and calculate relationship probability makes DL immensely valuable to the analyst.

Operating in the background: Machines can operate as "silent" aids to humans and can be finely tuned to operate "in the background." Once the machine has been trained to understand the questions under review, the gaps in knowledge, and the data being sought, it can run automatically and bring forth the information required when needed. In some scenarios, one can see this partnership as more than just an aid but instead as a proactive process to cue humans to new information, warn of events, and point to emerging trends as necessary.

Continuing this move into a more cognitive realm in which machines do some thinking for us provides innumerable opportunities for advanced analysis and problem-solving. This move should be welcome, however, humans remain skeptical of this new world on many levels. Part of their discomfort relates to the technology and its level of maturity. Another part is something more fundamental—some feel threatened by these new capabilities and remain concerned that this evolution is about replacing the human. As referenced before, the ATM has enabled bank customers to have ready access to money on their own terms and schedules, freed up bank employees to deal with more difficult customer questions, and saved banks money by not employing as many tellers. But advances in DL go well beyond the ATM example. Deeper analytics that provide decision advantage, smarter solutions, and lifesaving answers are within our grasp and already in practice.

Current Uses of Deep Learning

Medical

Keeping up with the massive flow of research data on breast cancer is a challenge for scientists. In the 2016 Camelyon Grand Challenge, a team from Harvard Medical School's Beth Israel Deaconess Medical Center used DL to identify metastatic breast cancer. The competition aims to determine how algorithms can help pathologists better identify cancer in lymph node images. The results validated the Harvard team's hypothesis: Human analysis combined with DL achieved a 99.5 percent success rate, thus proving a pathologist's individual performance can be improved when paired with artificial intelligence (AI) systems, signaling an important advance in the practice of identifying and treating cancer.

Automated Crop Management

Blue River Technology developed a DL solution called LettuceBot, which analyzes crops via tractor, photographing 5,000 young plants a minute and using algorithms and machine vision to identify each sprout as lettuce or a weed. LettuceBot helps farmers combat converging trends: the increasing resistance of weeds to herbicides and the decline of available chemical treatments. LettuceBot technology can help farmers reduce chemical use by 90 percent. LettuceBot is already used in fields that provide 10 percent of the lettuce supply in the United States.

Geographic Object-Based Image Analysis (GEOBIA)

DL has enabled Geographic Object-Based Image Analysis (GEOBIA) to be a powerful tool in efforts to detect and confirm conflict-mining activities in the Democratic Republic of the Congo (DRC). While standard change detection of remotely sensed data can identify potential mining sites, confirmation of the activities, characteristics, and likely purpose of those mining sites are difficult to ascertain without additional contextual knowledge. Development of geographic object-based models and analysis that provide this further contextual knowledge is labor intensive without the assistance of automated iterative image classification and the partition of imagery into image objects. DL enables GEOBIA approaches to scale for larger geographic study areas, more complex object-based modeling, and more accurate and sophisticated intelligence. In the DRC, DL resulted in targeted military action and focused humanitarian aid designed to combat illegal mining activity and reduce associated violence.

Automated Radio Frequency Spectrum Management

Scientists, engineers, and analysts are applying DL to acoustic wave propagation modeling, sonar analysis, and various segments of the radio frequency (RF) spectrum. Imagine a battlespace in which troops didn't have to worry about spectrum management. An automated system would assign RF frequency, mitigate interference, and deny enemy intrusion into U.S. communications networks. DL can help declutter an increasingly crowded battlespace spectrum by learning radio and spectrum usage patterns of friendly forces, enemy forces, and local citizens. DL models can learn these patterns and make decisions on asset allocation much quicker than humans. As wireless technologies become more common in the battlespace, spectrum collaboration and frequency de-confliction will become impossible for humans to manage. DL models and other artificially intelligent systems will be required to augment human spectrum managers.

Crowdsourcing and Deep Learning

Data sets for training and testing remain a key input needed for DL since, like humans, this form of AI learns from examples and reinforcement. The training sets are the benchmarks to which the algorithms refer and learn. This training data can be generated by human input and curation, and crowdsourcing is one technique used to generate large amounts of training data.

In the past few years, crowdsourcing has become a reliable means to rapidly generate geospatial data when groups of people are organized around a common goal, such as response efforts during or following natural disasters. Online mapping platforms such as OpenStreetMap and Tomnod provide users with simple tools to identify and map features from overhead imagery. Such map data helps aid workers more quickly and completely assess damage and render assistance where it is most needed. Crowdsourced geospatial data sets can also serve as inputs to train DL models by providing examples of map layers such as buildings and roads that can be automatically extracted. Using DL to automate feature identification and extraction will improve the speed, scale, and frequency that such geospatial data can be generated, which, in turn, fuels downstream analytics.

Crowdsourcing can also be part of an iterative process to improve model performance. If the accuracy of such models is below a certain threshold, additional examples of crowdsourced data can be fed back into the algorithm to improve results via a process of active learning. As a DL algorithm trains on more data, the accuracy typically increases. This is similarly apparent with an increase in the number of passes through data. Predictions can be categorized as true negatives, false negatives, true positives, and false positives of truth, where the degree of false negatives demands the requirement for further refinement.

Beyond serving as a means to produce training data, DL can in turn improve crowdsourcing performance. Such algorithms can work behind the scenes to identify key contributors in the crowd, identify patterns in data or analyses, or focus the crowd on analytic tasks that require human input to improve the performance of the algorithm by focused tuning. The ability to use DL techniques to improve crowdsourcing is one of the ways to overcome quality control issues inherent to engaging large crowds of contributors with varying backgrounds and levels of experience.

Crowdsourcing serves as an important means to both enable DL with training data and improve the performance algorithms. ImageNet, one of the largest corpuses of labeled training data for computer vision, used Amazon's Mechanical Turk to label millions of photos. Within the geospatial domain, similar crowds are used to tag objects in satellite imagery to generate training data. Though manual crowdsourcing has proven effective for data generation over relatively small geographic areas for short periods of time, automating the extraction of features will help geospatial data sets to be more complete and current. More importantly, automating the creation of foundational map features and straightforward analytic tasks will allow humans to contribute specialized knowledge and to focus on more complex analysis.

Unstructured Data

The randomness (or complete lack) of critical metadata is one of the biggest hurdles for GEOINT to move beyond exploiting large-format images from scheduled and controlled collectors to exploiting images from smartphone cameras and other mobile equipment. Similarly, many reports, stories, articles, and other text-based communications contain information from which location and time could be derived, but in which the information is not explicit. Both of these circumstances are opportunities for the employment of unstructured data exploitation techniques. Smart search algorithms designed to discover location and timing information from data should be developed and employed to provide context data for the nearly universal public data stream. This data can also be correlated with information from formal collectors such as commercial satellites for even greater utility.

Convolutional neural networks and other DL models greatly outperform traditional computer vision techniques at tasks such as image recognition, object detection, and feature extraction. Image analysis is a sweet spot for modern DL approaches. However, DL can be applied to many data formats other than ubiquitous image raster data types. Analysts can significantly speed up analytic workflow by applying DL models to radar, interferometric synthetic aperture radar, synthetic aperture radar, and other active signals-based data sources.

Conclusion

In an era of smarter machines that have eased the burden of tedious daily tasks, humans are faced with the need to accept systems with cognitive capabilities now being developed. We can resist the introduction of DL into our everyday lives and continue to drown in masses of data, or we can embrace the opportunity to reach new levels of data analysis, solve previously insurmountable problems, and enrich our daily lives with the assistance of DL algorithms.

Geodata Analytics-as-a-Service

By Ben Conklin; Barry Tilton; Kevin Hyers; and Cordula A. Robinson, Ph.D.

Anyone with access to data wants to exploit and understand it. They want to draw conclusions and make decisions, predict outcomes, and identify patterns and trends based upon data. As more location-based data is collected, tools that make it easy to analyze geodata need to be provided to the entire analytic community. Currently, geospatial analysis tools are only provided to GIS users in the form of desktop software. To unlock the full potential of geospatial data, the GEOINT Community needs to provide Geodata Analytics-as-a-Service (GaaS). GaaS offers a web-based platform where any analyst can have access to powerful geospatial analytic tools to support their analytic workflow.

The application of geodata analytics allows analysts to gain a better understanding of their environment, access timely answers to their questions, and apply operational knowledge to the information. Providing GaaS will give analysts better access to tools and information while simultaneously offloading simple GEOINT analytic problems from the analyst's desk, offering them more time to explore complex problems and define new methodologies.

GaaS is much more complicated than providing data as a service. Geodata services have well defined and broadly adopted standards. Geodata analytics does not have the same maturity of open standards. Additionally, analysis is fundamentally a loosely defined discipline with many potential pitfalls if exposed in the wrong way to inexperienced users. GaaS needs to provide a unique set of capabilities across a continuum of problems, from the simple to the complex.

From Simple Visualization to Solving the Impossible Puzzle: The Analytic Continuum

In thinking about analysis-as-a-service, it is useful to consider analytic methods from their simplest to most complex forms. Each level of complexity can have a defined solution and an appropriate audience for use. The simplest of analytics can be leveraged by the widest variety of users, while a small group of highly trained individuals can properly use sophisticated tools. These lines aren't hard and fast, but many types of analytic services can be categorized using this method.

Simple visualization is the first level of analytics, and it is part of the delivery of GaaS. In simple visualization, analytic tools are applied on top of the data, and filter and aggregate information to help a user gain knowledge. In GEOINT, there are three key aspects to the visualization of data: time, space, and relationships. Data services expose these three variables in the data and use tools to query and visualize information based on these factors. Simple visualization adds in situational understanding and helps to make GEOINT data digestible.

The next level of GaaS is self-service analytics. These algorithms are developed using predefined models and applied to the data with user-defined input. The user can select operational parameters, such as location, equipment characteristics, or limiting condition, and execute the tool. The user views the results as a new data set. A typical example of this kind of analytics is visibility analysis, in which a user defines an observer location and other characteristics, then receives information showing the visible and non-visible areas on a map. Traditionally, this type of analysis is built directly into software applications; now GEOINT platforms are allowing this same analysis to be shared as standard web services and accessible to a wide variety of clients.

Expert analytics is needed to solve more complex problems. Predefined algorithms cannot be used to answer every analyst's question, but users can combine tools in new ways to process data and create robust information products. This type of workflow requires a trained analyst who can apply analytic rigor to problems and can also select the right tool for the job. In this case, the analytic service needs to be richer. Rather than only exposing single interface tools, analysts need access to an analytic workbench from which they can combine analytic tools and algorithms in new and useful ways. In addition to sharing their analytic results, they can share their analytic methodology as models for other experts to use. GaaS facilitates this kind of sharing and helps analysts connect with one another through the creation and curation of analytic tool libraries.

The final level of GaaS strives to solve the enigma problem, where there are too many unknowns to leverage expert models and existing algorithms—thus stretching the limits of analytic services. With an enigma problem, the analytic workbench becomes more of a lab environment. Raw tools and data are made available for experimentation and hypothesis testing. First level principles are applied to develop new methods. Exploitation of raw data occurs, and analytics will deterimine if new data needs to be collected or if new software capabilities need to be developed. The outputs of this advanced process are new analytic models. Once the models are validated and time-tested, they are made available to experts or published as new self-service analytic tools. GaaS provides the publication environment for these newly developed tools, and can also provide a way for analysts to request this advanced support.

Technology Advancements Enabling Analytics-as-a-Service

Technology advancement enables new ways for analytic services to deliver value to the GEOINT Community. New kinds of GEOINT data are being collected all the time. New sensors are creating integrated GEOINT data, and open-source and crowdsourced data are creating enormous volumes of information. Spatiotemporal big data systems yield the ability to store and access this data for exploratory analytics. These systems leverage new cloud infrastructure to provide access to everyone in an organization and across the Intelligence Community.

For the simplest form of analytics, new visualization techniques are beginning to take hold. Business intelligence and data science techniques are being applied to GEOINT data to create new statistical views. Linking these tools to the traditional, map-based view of GEOINT further extends this simple form of analytics. Advanced user interfaces allow exploration of more dimensions in the data. 3D technology in browsers makes data visualization richer. Maps, charts, and timeline tools are integrated in simple applications for rich data exploration. In the future, immersive technology such as virtual reality, audio, and haptic feedback could add even more dimensions to analysis.

GEOINT analytic platforms are being implemented and rest on the foundation of big data and cloud computing, adding critical services to the enterprise. They provide environments for combining GEOINT data in predefined visualizations. They allow for the simple sharing of data and analytic tools in easy to configure apps. They create an environment for analysts to share tradecraft and to publish new analytic services. These open platforms provide application programming interfaces (APIs) for embedded developers in an organization to create new analytic tools and applications. As these platforms evolve, they will connect to deep learning and artificial intelligence environments for more in-depth, real-time analysis of data.

Implications of Analytics-as-a-Service

GaaS enables technology that will extend the reach of GEOINT services to the entire analytic workforce. Analysts will be able to draw conclusions and make decisions, predict outcomes, and identify patterns and trends based upon data and the application of analytics. This will increase the demand for geospatial data and tools. The growth of GEOINT to new audiences will require new ways of doing business. Trained GEOINT analysts will need to be placed at different levels to support the demand for advanced methods. Training methods must evolve to train GEOINT consumers in new analytic tools. Policies need to be developed to ensure authoritative models are leveraged and prevent the use of incorrect methods.

Analytic services also require the development of new standards. The nature of analytic tools makes them difficult to standardize, but a fundamental architecture needs to be enforced to ensure logical separation of data, analytic process, and user interfaces. These must interoperate as part of the intelligence enterprise. In addition, analytic tool-sharing standards need to be developed. New metadata definitions will be required to capture the analytic qualities of the service. Metadata definitions need to address standards of quality and reliability, represent uncertainty in the data and model, and describe their fitness for purpose. Competing tools can be categorized and, when necessary, standards enforced.

As the workforce becomes more literate in GaaS, they will require additional training. The so-called “geo-native” is familiar with consumer mapping and understands how to interact with maps and perform simple analytic functions such as navigating to a location. The efficient use of GEOINT analytics goes beyond consumer mapping technologies and requires additional broad level training for a non-geo workforce to leverage the tools correctly.

Professional analysts will also require additional training; rather than simply performing analytics, some analysts will need to be trained as “tool makers.” These tool makers will support the rest of the analytic workforce by developing new tools to exploit new data sources or to assist in answering new questions. They will need to understand basic principles to develop useful and reusable tools. Analysts should be rewarded for sharing their tradecraft knowledge. The tool developers will connect directly to the end users of their tools so they can refine and improve processes over time.

GaaS is the next logical step for providing GEOINT services, moving beyond simple sharing and visualization of data. NGA’s GEOINT Services already provides the foundation technology to enable GaaS and simply needs to formalize the capability to share and develop analytic tools and tradecraft. NGA has hosted application challenges that have proven it is possible to deliver GaaS. The next step is to formalize a program to address the standards and training needs to extend this capability to the entire workforce. GEOINT services can connect to the work performed at other agencies to capture GEOINT tradecraft. This would help to create a rich set of initial capability.

Gaas will be a force multiplier for the GEOINT workforce. The reach of geospatial analysts will extend as new users pick up GEOINT tools. Analysts will also have more time for complex problems as they offload routine requests to simple apps. They will be able to collaborate and share their tools and techniques with like-minded professionals. New data can be collected and structured to support emerging analytic processes.

Data Science Teams: GEOINT Analysis of the Future

By Rafael de Ameller and Michael Hauck

Who would have thought an augmented reality game would reach 75 million users within a month of its release, and the average user would spend 43 minutes a day in that artificial reality? In July 2016, Pokémon GO rose to the No. 1 spot in both the Apple and Android App Stores in record-breaking time. It is a harbinger of the future, and a prime example of the concept of immersive GEOINT discussed in the 2016 State of GEOINT Report.

Pokémon GO, however, is just part of the story. The big news is the continued exponential increase in data—much of which includes location information such as where the data was created, where it is stored, where it is used, or its relationship to other location-based data. The volumes of data are mind-boggling, and so is the increase in its rate of production. The new reality is the creation of far more available data than there are human eyes to observe. The days of a team of experts analyzing the latest image from a one-of-a-kind source are over for all but the most denied areas.

In this new reality, the GEOINT Community will need teams of diverse experts because the work being performed is increasingly complex, thanks in part to the proliferation of multimodal collection systems that require some level of expertise for each collection component. Moreover, customer expectations have now been influenced by the likes of Pokémon GO.

What Customers Want

Imagine public safety stakeholders being able to know before a hurricane makes landfall which areas have an increased risk of additional flooding and fallen trees due to soil saturation, and would thus be susceptible to outages or road closures. Emergency managers could proactively deploy personnel. For example, data science teams could exploit NASA's Soil Moisture Active-Passive Earth observation mission for this purpose.

There are hurdles, however, to practical use of Earth observation data in areas such as emergency management. Much Earth science research data is shared across departments, agencies, and the public, yet the data sets are often not accessible to decision-makers. One reason is a lack of expertise in accessing the data in a relevant and timely fashion. Data science teams would need both remote sensing and emergency management expertise.

Cloud-based, Software-as-a-Service data visualization solutions combined with open data standards provide a way forward to facilitate the kind of necessary collaboration. They allow consumers, industry, governments, and non-profit organizations around the world to integrate GEOINT into their data visualization tools and operations.

Currently, most organizations store and manage data in their own manner, with little or no valuable metadata or expertise to exploit the information outside of their own systems. Cloud technology providers such as Amazon Web Services allow organizations to benefit from massive economies of scale on shared infrastructure, facilitating data accessibility while reducing costs.

For example, the National Weather Service handles massive amounts of data and data products. However, the agency is moving away from a product-based operating model to one in which interpretation and relevant information is provided through Impact-based Decision Support Services (IDSS). Success depends on the relationships with the weather service's core partners, such as the emergency management and water resources management communities. Those users need more actionable weather, water, and climate information from the agency. So, the agency is placing staff closer to where IDSS workloads are located, deepening the relationship between the agency and stakeholders. Essentially, it is building ad hoc data science teams.

Advances in Imagery Compel a Team Approach

One of the factors that compel a team approach is the explosion of geospatial data. This has come as a result of advances in technologies developed primarily outside the geospatial industry. New materials, higher capacity batteries, miniaturization of electronic components, more powerful processors, increased bandwidth, the proliferation of wireless-connected smartphones, open-source software, the global use of social media, and cloud platforms all contribute. In the geospatial industry, these technologies have underpinned the development of low-cost sensors that can be deployed on commercial unmanned aerial systems (UAS), terrestrial mobile mappers, and small satellites. Today, even small companies can command a specialized imaging satellite that only the wealthiest nation states could afford just a decade or two ago.

Newly available commercial sensors facilitate new commercial imagery products and services. For example, short-wave infrared (SWIR) can see fire through smoke. Synthetic aperture radar allows collection of topographic data through cloud cover. Multi-band LiDAR facilitates seamless bathymetric and topographic mapping in transition zones. High-definition video cameras allow a continuous, real-time look at the Earth from space. New multi-band visible and infrared imagers can completely cover half of the Earth every few hours.

New sensors deployed on new platforms increase the availability of data from various points of view, ranging from space-based observation to ground-based, from kilometer to millimeter resolution, from whole-Earth images to tightly defined areas of interest. Inexpensive commercial UAS can now carry sophisticated LiDAR sensors to create close-range, high-precision maps. Airplanes carrying high-resolution thermal sensors can see cracks in dams and pipes. Robotic tunneling vehicles can map underground spaces. Geospatially-registered, full-motion video is commercially available from vehicles in space, on the air, and on the ground. As technology advances, an unprecedented array of commercial sensors can now be placed on a similarly unprecedented array of platforms to collect imagery never before possible.

What this means is it's getting harder for a single specialist to have all of the necessary expertise. It also means organizations are driven to employ generalists because they cannot find—or cannot afford—all of the specialists needed to cover each source technology or data type. While the proliferation of sensors and data creates new opportunities for analysis, it also makes analysis more difficult if done the "old-fashioned" way. A new way is needed that leverages multidisciplinary teams.

Beyond Imagery: Geospatial Big Data

In addition to imagery, consider the wide variety of other location-based data being generated every day by human and machine activity. Reflect on the activities and interactions of people revealed in social media. Factor in the location information intrinsic to telecommunications traffic—particularly mobile. Add the measurements and actions of infrastructure elements managed with Supervisory Control and Data Acquisition systems. Couple that with the engineering information contained within infrastructure asset inventories. Add geo-tagged banking and point-of-sale transactions. Finally, at a high level, integrate the economic and social information contained within census data.

The spatial, spectral, and temporal resolution of commercially available imagery and other location-based data continues to progress with no end in sight. As the volume of data has increased, so has the complexity of the data, which means the potential number of cross-correlations increases exponentially. Certainly, the scale of data in question is well beyond terabytes and petabytes. Although the term "big data" is without a consensus definition, geospatial data as described above certainly qualifies, given the volume, velocity, and variety of data in flux. This situation presents a compelling need for a new analytic framework appropriate for the age of "geospatial big data."

Geospatial Data Science

There is currently no consensus meaning for "data science," although the term is routinely applied in the analysis of also loosely defined "big data." Arising from the field of statistics in the 1960s, data science has recently come to capture various interdisciplinary approaches to computer-based analysis. To analyze big data, the data scientist needs to consider the nature of the data; is it structured or unstructured, streaming or stored, real-time or historic, qualitative or quantitative, measured or simulated, real or virtual? Other fields related to data science include data mining, machine learning, knowledge discovery, and predictive analytics.

Given the volume of data, much of the analysis must be automated, so data science has at its heart algorithms to extract knowledge from data. More than simple coding ability is needed to write a useful algorithm. The analysis is likely to require whole libraries of algorithms—which is one reason open-source software and data are so appealing to many data scientists, who also tend to appreciate the massive storage and computation power of cloud platforms. Visualization is where today's data science seems to fall short. The visualizations look great in the movies, but in real life are incredibly difficult to generate for general problems for which visualizations have not already been designed.

While visualization certainly includes traditional, two-dimensional maps and charts, some emerging technologies for visualizing data have gained commercial traction. Sophisticated analytic solutions include Palantir, Recorded Future, and Spotfire, but there are simple, consumer-facing visualizations as well. Examples include mobile games such as Pokémon GO, storytelling applications such as Story Maps, and navigation units such as Garmin or apps such as Waze.
The exciting new frontier is immersive visualization, for which the technology is driven largely by computer games and industrial design and simulation. Anyone who has donned 3D glasses to watch a Pixar animated film has experienced storytelling within a virtual world. If the virtual world is a replica of the real world, then virtual walk-throughs are possible for places one could not otherwise visit. Alternatively, as one walks through the physical world with augmented reality technology, one virtually "sees" the pipes behind the walls of a building or labels for

objects that have been geo-located. For training and simulation, what one sees can be altered so that, for example, an electrician could see a live wire as red-hot. Thanks to consumer and high-end industrial markets, these data visualization technologies are rapidly becoming commercial off-the-shelf products.

What Makes a Data Scientist?

Like any good analyst, a good data scientist asks the right questions then looks for answers hidden within the data. Therefore, a data scientist should understand the problem domain, be it politics, military science, engineering, economics, etc. The extra dimension of data science is the volume and complexity of data for analysis, so a data scientist should also understand computing and be comfortable with complexity. He or she must be able to perform formatted and free-format data input/output, organize storage of the data, and be able to write or use tools to analyze the data. Writing algorithms to explore the data can be very challenging, because one has to figure out how to turn a question into code. This is detective work, in which discovery leads to discovery, yet not all hypotheses test positive. A good data scientist must be able to dig through the details, while at the same time maintaining a high-level perspective. Once answers are obtained, the data scientist must be able to effectively share the insights with others. He or she must be able to clearly state the question(s), articulate the answers, and explain how the insights were obtained, all of which is best done through visualization. But, possessing the personality and skills to successfully perform all of the aforementioned is a tall order for one person.

The Case for Data Science Teams

Since few people possess all data science knowledge, skills, and abilities, teams will be required to fully exploit all data science has to offer. What comprises a good team would depend on the problem at hand, but the most important player on the team would be someone who knows how to ask the right questions—likely a domain expert, hopefully with good communication skills and a curiosity that is not easily satisfied. Geographers, historians, political scientists, military scientists, engineers, geologists, etc., would likely fit this profile. In addition to domain specialists, useful expertise on a data science team includes statistics, signals processing, database architecture, visualization, and modeling and simulation. Ingesting, organizing, and processing data each require specialized expertise as well. Where can one find such people? Academic departments in the areas of mathematics, physics, computer science, electrical engineering, operations research, philosophy, architecture, economics, marketing, and linguistics, to name a few. An effective data science team must be able to wrestle with data in its full complexity. That is the new reality.

Perhaps this is the future of GEOINT analysis. Data science teams will interact with stakeholders to find answers to their hardest problems. This will empower individuals to make better decisions when interacting with GEOINT data. The products created by data science teams will be designed to be easy to digest and share among decision-makers, subject matter experts, and all who could benefit from the information. Regardless of their location or the device they use, the data will be accessible anywhere and anytime. Well-rounded data science teams and ubiquitous data will help all stakeholders unlock the full value of geospatial big data and the GEOINT it makes possible.

Solving the “Big Hot Data Mess”

By Anthony Calamito; Christopher Tucker, Ph.D.; and Abe Usher

You can’t talk about GEOINT these days without acknowledging the explosion in new big data sources or the accumulation of traditional data sources into large, hard-to-manage data repositories splintered across multiple networks. Big data is also being fragmented by security half-measures and otherwise made generally inaccessible to all of the newfangled big data solutions with which everyone is so enamored. In short, you can’t talk about GEOINT these days without talking about the “big hot data mess” the GEOINT Community currently faces. In this article, we will raise more questions than provide answers, as the answers to date have proven elusive.

Senior leaders, enterprise architects, technology vendors, and software experts are promising to make GEOINT data analysis faster, better, and cheaper, and to provide amazing insights never before possible. They promise to let us collaborate in new and interesting ways using GEOINT data. And they promise to magically have this data flow to the very edge of every network on which the mission is conducted—until, that is, they see the current state of our data.

These new technologies assume all entities, including the National Geospatial-Intelligence Agency (NGA), have actually acquired/licensed the right data and have meaningful access to this wide array of data. These technologies also assume the data hasn’t been squirreled away into countless different physical storage environments on multiple networks with no concern for how many redundant copies of the data have been and continue to be generated. This is compounded by the fact that the full metadata needed to help solve analytic problems is not always available.

The global GEOINT Community—intelligence professionals, warfighters, humanitarians, first responders, municipalities, and businesses—yearns for the wonders of ubiquitous, secure, and time-dominant access, big data analytics, machine learning, and everything else they hear about in the latest Silicon Valley tech press. So, how can the GEOINT Community reach this technical nirvana that has become our new base expectation? How can we understand the big hot data mess and take concrete steps to transform our basic GEOINT infrastructure to comport with modern technological expectations?

The Kitchen Metaphor for Data Challenges

To understand the GEOINT Community's data challenges, we must have a clear understanding of how impact and value are produced. The value creation process of deriving intelligence from data is much like the operations of a well-run kitchen. Chefs (subject matter experts) use utensils to process and combine raw ingredients using repeatable recipes to produce nutritious, delicious food. Similarly, analysts use technology tools with specific methodology to process and combine raw GEOINT data to produce relevant intelligence products. In the GEOINT Community, we have great "chefs" with excellent "recipes," but we don't have a good handle on our "ingredients" (data).

Not everyone knows where to find the ingredients they need to do their job. Some ingredients are stored in the wrong place—like storing ketchup in a freezer where it is rendered useless, or burying spices in the backyard where they will never be discovered by other chefs.

Think of a talented chef who repeatedly makes peanut butter and jelly sandwiches because those are the only ingredients she can find or has access to. As a result of our "ingredient challenges," we are extremely limited in the advanced "utensils" (tools) we can bring to bear.

Know the Data

Why doesn't every GEOINT desktop have access to every piece of relevant spatiotemporal data that exists, whether government-generated, commercial, or open source? Does the GEOINT Community have a grasp of the massive proliferation of data that is occurring? Does it at least have an exhaustive accounting of what exists, even if it doesn't have the actual data? Does the community know who is the primary source of the data and not the middleman? What are the business and legal terms (the data licenses) under which it could gain access to each?

Do governments or businesses have a contract vehicle that allows for immediate, time-dominant data access? How do government and commercial entities share and exchange data? How can citizens provide free services back to the government? How can citizens and corporations pay for government collected or collated data so the government can continue to provide data to them in a form that allows easy consumption and provides for commercial entities to profit from government provided data? How can the government leverage citizen scientists to collect, correct, and update unclassified data sets open to the public? What are the privacy implications of unclassified data being made publically available?

Has the massive proliferation of such sources of data outstripped the GEOINT enterprise's ability to maintain such an ongoing assessment? It's unclear. However, the confusion spawned by this proliferation and our haphazard grasp of it contributes to the big hot data mess.

Does NGA have access to the newest, hottest, best source of data? Of course it does. Somewhere. But whom do I ask for it, and how can I discover this data?

Buy the Data

NGA's proposed Commercial Initiative to Buy Operationally Responsive GEOINT (CIBORG) vehicle for acquiring data may solve the problem of U.S. government access to this proliferation of data. It is too soon to tell, but perhaps CIBORG will provide transparency with regard to the terms under which NGA and National System for Geospatial Intelligence (NSG) partners can rapidly acquire every kind of spatiotemporal data under the sun. Perhaps it will become clear what it means to have each data source available to the U.S. national security community, international partners, humanitarian partners, and indeed the whole of government and even private citizen use. Will this be the moment when NGA proactively, vigorously, and exhaustively builds a dynamic acquisition vehicle that provides the kind of transparency needed to clean up this big hot data mess? Actions, not rhetoric, will tell the tale over time.

Crowdsourcing the Data

With the popularity of citizen science and the desire for more transparency within government, how can organizations like NGA better leverage crowdsourcing as a means to create and collect data? Initiatives like OpenStreetMap have proven the value of leveraging a community of users from around the globe for creating data sets in areas that have been underserved, are too dangerous to visit, or have not been a focus of data creation.

So, what changes to policy are needed to ensure valuable crowdsourced data sets like OpenStreetMap and others are considered valid, timely data sources like those created by NGA? Will NGA open its unclassified data sets and enable citizen scientists to verify and edit them as needed? With a growing number of autonomous data sensors and an increasingly capable citizen science initiative, how will NGA adapt and leverage crowdsourced data sets as much as possible?

Migrate the (Legacy) Data

Assuming NGA understood all the data sources and mastered their acquisition, we then have the huge burden of the legacy/heritage environments that splinter the management of this data across many networks, file systems, databases, and APIs. This burden makes the timely, efficient, and effective use of big data questionable at best. Plenty of baroque technological strategies have been pursued in the past two decades to wicker these legacy/heritage environments together so seamless data access could be achieved. However, it is the cloud—and, for the GEOINT Community, the Intelligence Community Information Technology Enterprise (IC ITE) cloud—that finally offers the promise, but not yet the reality, of migrating data into an environment that will allow the community to take advantage of modern technologies and strategies. IC ITE offers hope that at least parts of the big hot data mess may soon end. But the path ahead remains challenging.

Cloud Manage the Data

The authors recommend a four-step process to begin to address complex data challenges:

1. **Mission needs inventory:** Create specific user stories that define the most common activities that support common GEOINT mission threads.
2. **Data inventory:** Inventory government, commercial, and public GEOINT data sources.
3. **"Unlock" analytics:** Decouple data from analytics by storing GEOINT content in IC ITE cloud-based open storage systems (e.g., Hadoop, HBase, Accumulo, Elasticsearch) that provide multiple ways of accessing content such as ArcMap, QGIS, full-text search, Google Earth, etc.
4. **Simplify data discovery:** Put significant effort into communicating to analysts, software engineers, data scientists, and leaders how to access data for each GEOINT mission thread.

Once the transition to the IC ITE cloud occurs, the U.S. government GEOINT Community will be able to consistently apply new and evolving big data and machine learning techniques—on every data source, at global scale, and at whatever arbitrarily dense temporal rate available. Because the IC ITE cloud will exist at every level of classification, powerful technologies will allow for data to be stored at the level of its classification, with seamless cross-domain access for people and processes on every higher network.

Open Geospatial Consortium (OGC) web services and other kinds of micro-services will be enabled on this data and deployed on the elastic cloud within powerful containerization strategies that provide unprecedented flexibility and scalability.

Suddenly, the data will be easily exposed for cataloging and a wide range of indexing schemes that will revolutionize discovery and access. This will also enable a real discussion about new ways individuals, teams, and communities with a vast array of processes can collaboratively interact with each other among the data. The age of the big hot data mess will be over. But, what will it allow us to do?

Leap Forward in Advanced Analytics

The face of GEOINT will be radically transformed by decoupling data analytics from data storage by moving relevant data into an elastic cloud with simple standards for data structure and access. The GEOINT Community will be able to fully exploit the global wealth of data generated about the planet every second of every day, to provide our nation time-dominant decision advantage in the realm of international affairs.

An endless variety of analytic algorithms will be run in real time, concurrently, and service many different mission sets. Machine learning will enable the augmentation of human analytic capabilities, sifting through the endless deluge of data, finding the known, and queuing up the unknown for analysts to solve. And geospatial narratives will be fed and constantly updated by these processes, collaboratively curated by the modern analytic workforce. The volume of continuously dispatched data will be enormous. The fidelity of data derived from it will be unparalleled, and its update cycle will be significantly faster than today. This will be the era in which GEOINT accelerates intelligence insight to action as never before imagined.

Collaboration and Commercialization in the GEOINT Business

By Rafael de Ameller, Robert J. Farnsworth, David Gauthier, Lisa Spuria, and Steven Truitt

The geospatial industry is at an inflection point similar to the microelectronics sector in the '70s and '80s. What was once a capital-intensive and single-purpose industry dominated by government influence and a few large entities is becoming publicly available and multipurpose with myriad smaller contributors. This trend has wide-ranging effects, many of which are discussed in this State of GEOINT Report, although none is more important for the future of the geospatial industry than how the definition of products and services will drive collaboration and competition.

Collaboration emerges when there is sufficient diversity that partnership is economically efficient. Collaboration often coexists with competition, as an environment with many connections between organizations creates opportunities for invention and competition. The connected growth of collaboration and competition incentivizes incumbencies and customers to focus on core values, and is both the motive and governing factor for innovation and the range of potential value the geospatial community can collectively deliver.

This article covers two main trends in collaboration and commercialization, and draws conclusions between them. The first trend is the shift from a government-centric to a commercial-centric environment. The second trend is about the fundamental nature of geospatial products and services—how commoditization, specialization, and niches evolve from the structure of the industry. We close with a discussion of what the intersection of these topics teaches us about areas in which the geospatial community would do well to cooperate versus areas in which ruthless competition is for the better.

Passing the Baton: From Government to Commercial

Many commonplace technological advances began with federal investments and requirements. These investments did not have immediately obvious commercial applications or any plan for transitioning them to civilian life, but they proved worthwhile on a national scale. The military especially has a strong historic influence on technology, with many high-tech programs initially shrouded in secrecy or grown out of necessity to solve social challenges. However, as observed repeatedly, numerous technological advances have found their way into commercial products, advanced society, and sparked entirely new industries.

Many of the phenomenal technological changes of the last few decades stemmed from major research and development investments by federal government agencies and departments. Indeed, in her book, *The Entrepreneurial State*, Mariana Mazzucato wrote, "Truly radical innovation needs patient, long-term, committed finance. This type of finance is hard to find in the short-termist private sector. So it's no surprise that modern capitalism has seen the increased role of the state in providing patient capital and directly investing in innovation development."[1]

Programs such as NASA's mission to the moon and the Defense Advanced Research Project Agency's (DARPA) development of ARPANET resulted in profound changes to global life—today we are launching commercial imaging satellites, planning for civilian travel to Mars, and the world is connected globally via the internet. Other investments, which perhaps do not receive the same level of notoriety, have had many of the same results:[2]

- U.S. Air Force/RAND/DARPA investment in artificial intelligence has driven advances in machine learning.
- DoD/NIST/DARPA focus on GPS for military uses now enables location analytics for smartphones, automobiles, fitness trackers, etc.
- National Laboratories investment in supercomputing for nuclear programs drove major advances in computing power and applications.
- U.S. Air Force investment in red LED lights has been a catalyst for the replacement of fluorescent and incandescent lights.
- Seismic imaging developed for nuclear testing by the National Labs/DOE has had major implications for oil and gas exploration.

GEOINT, too, is following this trend to move technology from the government sector to the private sector as cost efficiency and commercial applications are identified. Specifically, emerging trends are: to move away from a government-only analytic workforce and products to commercially developed analytic products; to focus on the development of automation tools to meet the oncoming persistent imagery environment; and to create analysis-as-a-service through

1. Mariana Mazzucato, *The Entrepreneurial State*. New York: Anthem Press, 2013.
2. Examples from research included in: Patricia Panchak, *Major Technology Advances that Began with Federal Research Funding and Support* [*IndustryWeek* , February 6, 2014], slideshow.

which consumers will primarily purchase information derived from imagery and other sources and not purchase the raw data sources.

In-depth analysis from GEOINT sources and specific products such as maps has traditionally been produced and consumed by governments and large organizations. These specialized products were developed to assist decision-makers related to policy, military operations, civil engineering, land use, disaster response, and other problem sets. In recent years, with the arrival of commercial imagery, the commercial market has developed a range of analytic products, some industries faster than others. A specialized tradecraft, in-depth analysis of imagery has been applied to a number of new problem areas and resulted in the training of analysts in its use.

These shifts in the GEOINT enterprise, as a result of long-term investment by the federal government, represent the current revolution underway and epitomize the full life cycle of new technologies making the shift to commercially enabled capabilities.

Government's Shift to Consumer

As industrial capabilities and academic knowledge of geospatial technology and analytics continues to grow, it is inevitable that innovation and advancements in commercial technology will outpace government-run research and development. This trend has appeared in many technology sectors over time, including the modern-day transistorized computer and cloud solutions. Whereas computer hardware manufacturing is capital intensive and took years to extend its reach beyond government-funded development, the deployment of technology services seemingly happened overnight.

As with technology, the role of government will change as new GEOINT services become available and commercial markets drive innovation. As automation achieves trusted status and commercial markets witness the opportunities offered by frequent coverage, the government sector will reach developmental maturity. GEOINT Analysis-as-a-Service (GaaS), available to all consumers across industries and government, will come to the forefront. As this occurs, government agencies will no longer need a large analytic workforce to perform traditional imagery analysis and can either downsize or shift those analysts to more difficult or complex tasks. Commercial analytics companies will be able to provide automated and detailed analysis, and industries looking for new insights will be able to subscribe to these sophisticated GEOINT analytic services.

At a minimum, the U.S. government will need to understand the relative value of many new service providers and ensure it does not purchase the same core services many times over. Like today's GPS, a universal geospatial service may launch thousands of useful lightweight applications for the public. Yet this raises concerns for public safety and consumer protection. Should the government also publish its knowledge of the market and recommended services to ensure private citizens get a fair service for the cost? Growing pressure for regulation will develop as the industry gains momentum and questions such as these arise. Topics will possibly include the governance of international standards, a means of accrediting service providers, and the monitoring of market forces.

The industry must recognize the strategic significance of geospatial information between nation-states—therefore, the government's need to maintain a healthy commercial base—and balance this pressure with the economic pressures to outsource. For example, the medical community routinely outsources radiological expertise to doctors who are experts in exploiting medical imaging sensor data.[3] It remains to be seen whether the United States will do the same with services for outsourcing analysis of crop health, urban parking optimization, or perhaps even military intelligence.

The Commercial Innovation Explosion

Insights companies gain by adopting geospatial intelligence capabilities have led to improvements in performance and productivity as well as a reduction in costs. GEOINT is required more and more by industries and professionals to remain competitive. Implementation of a geospatial capability has to date been defined by four major categories: collection, storage, processing, and visualization.

Commercial companies small and large, governments, and nonprofit organizations around the world are taking advantage of geospatial tools. Without investing in infrastructure or staff, software solutions increasingly allow companies with limited budgets to leverage geospatial data. Empowering individuals to make better decisions while interacting with mapping apps and services has brought geospatial technologies to all market verticals and promoted geospatial innovation. This growth in the available market has spurred fierce competition among providers of similar services and strong collaboration among those that provide different services, all in order to meet the rising demand for an integrated whole.

From geo-tagged, crowdsourced data collected from smartphones to organizations installing networks of sensors and geo-tracking their entire workforce, hardware and software firms are continuously innovating to bring solutions to an expanding market that requires collection solutions. These continuously growing streams of data require storage to properly accumulate

3. James Brice, "Globalization Comes to Radiology." *Diagnostic Imaging* (2003). http://web.mit.edu/outsourcing/class1/DI-radiology-1.htm.

all of the information. Cloud technology providers allow organizations to benefit from massive economies of scale on shared infrastructure, enabling data accessibility and increasing efficiency while reducing the cost of scalable storage.

In addition to continuously improving open-source and commercial desktop software for processing, geospatial software firms partnering with cloud computing providers now offer Software-as-a-Service (SaaS) web-based GIS solutions. This ability to offer specific services is a direct effect of collaboration. The relatively low barriers to entry for both consumers and producers have led to strong competition and a growth of options. As a result, many industries lifting the burden of dealing with in-house desktop or server GIS software have finally brought geospatial solutions into their enterprise business intelligence. Visualization is how insights from geospatial data become operational and useful for decision-making. Open standards, APIs, data access, and software bring GIS tools previously only available to specialists to the entire workforce, and visualization service providers can now form viable businesses around niche needs due to lower costs.

The Nature of the Beast: Geospatial Products and Services

The products and services available in the GEOINT environment are the other side of the equation when we want to understand how everybody collaborates and competes. Just as there are trends in the government and commercial sectors, there are trends within each product and service category. This section describes critical characteristics and commonalities of available products and services as broken down into the rough categories of remote sensing, extracted information, and detailed analysis. Competition within and collaboration across sectors and these product and service categories will be the defining influence of GEOINT for the foreseeable future.

Remote Sensing

Remote sensing, especially from high altitudes or space, is a very technically difficult problem limited in complexity by the physical characteristics of the world. This means that over time incremental refinements make common what was once extremely expensive. This is playing out today with the widespread implementation of overhead imagery satellites—a capability almost exclusively reserved for large governments not more than a decade ago. Over time, diminishing costs will mean these capabilities continue to become more impressive and common.

As these capabilities grow, the requirement to automate and streamline processes becomes ever more important. Initial space-based imagers provided reels of film unique to that platform and for the specific analysts that viewed them, often taking weeks or months to get the first insight. Today, one can look on a variety of web-based maps and see orthomosaics or 3D renderings seamlessly stitched from multiple sources—all done autonomously and in near real time. This occurred as a result of standardization to a few commonly accepted formats of imagery so that, within reason, any analyst can use products from any sensor.

This standardization, the ability to depend on repeatable resources, has led to the growth of downstream businesses and wide adoption of the basic mapping and navigating capabilities geospatial information has enabled. As these trends persist, direct competition will continue to drive optimizations and turn once specialized capabilities into commodities—so long as the community's collective agreement to collaborate using common formats remains. It is imperative for both open competition among collectors and the continuation of collaboration among consumers that the collected source data (imagery or otherwise) continues to fit standard formats and converge to well-accepted representations.

Extracted Geospatial Information

The discovery of new insights about the world and patterns of activity using advanced geospatial data analytics requires the benefits of scale and interoperability across multiple data sets. Achieving the required level of scale demands widespread extraction of geospatial information across all sources and phenomenologies. One can think of this as akin to "atom smashing" in particle physics, which is used to reveal the existence of hidden particles and sub-particles that make up the structure of the universe. Similarly, geospatial experts can use humans and machine learning algorithms to "smash" little bits of vector geospatial information out of every image, video, data cube, or piece of free text. This might reveal a new bridge, a change detection result, a vehicle tracklet, or the room number in a building at a certain postal address. Achieving the necessary interoperability demands all sources adhere to appropriate standards and also that the resulting information be geospatially tagged to allow for automated discovery as metadata can describe its own structure to the entity seeking to use it.

The greatest challenge for utility in such a data rich environment will be lineage and pedigree of the extracted content. How is a pattern recognition algorithm to know the accuracy and precision of the source that generated a change detection result? What is the probability of a false positive? With regulated standardization, it could be expected that a piece of vector data self-report both the spatiotemporal accuracy and precision of the original sensor content from which it was extracted, as well as the receiver operating characteristic (ROC) curves, accuracy, and precision carried for the algorithm(s) used to create it. This context is needed to understand how to correctly interpret one sub-particle of information in a universe of data. However, without standards, data could cause harm to GEOINT analysis through misunderstanding or be unusable and therefore of no value. This presents a challenge for the GEOINT Community to solve: We need to acknowledge and account for the richness of information both in and behind our insights. However, there is not yet a well-accepted way to capture and convey this. As a result, a large market of geospatial products and services are being made available with undetermined value due to a lack of standards.

There are several ways this environment can evolve: the emergence of a regulator; self-organization through independent standards organizations such as the Open Geospatial Consortium; walled gardens controlled by one or few large companies; or a continuation of the current uncertainty. The most direct path is for the government or another watchdog organization to provide market knowledge and consumer advice—they could endeavor to inspect, investigate, and accredit third-party products and services and even publish their value determinations. Regardless of the path and implementation, the use of standards for developing rigor when publishing lineage information for data, products, and services could have a widespread positive effect. Vendors in this environment would compete by provisioning higher quality services of known value with independent proof-of-value to differentiate their superior offerings from the noise of unvalued and lower-quality content. This would be a welcome result of competition and collaboration. Alternatively, a market could develop whereby purveyors of extracted content and analytics develop exclusive business relationships with specific remote sensing vendors, allowing them to compete based upon exclusivity versus product quality. In this case, a customer may suffer the right to choose services from many vendors with equally unverifiable lineage and unknown value to the services they provide. This is the most likely (and undesirable) effect of the walled garden scenario.

In-Depth Analysis

The pinnacle of value created by geospatial content is in-depth analysis that can lead to strategic business or policy decisions. This type of analysis requires professionals who understand the factual content, the underlying measurements, the limitations of both, and the context within which their customer lives. By combining all of these, along with a background on the subject, a skilled geospatial analyst can make remarkable conclusions about a wide variety of topics.

One attribute of detailed analysis is that analysis created for one purpose or organization will rarely resemble that of another. For example, a military analyst may identify the patterns of an adversary and use that to predict future behaviors, while a very similar process may lead a business intelligence analyst to identify popular times for competing stores. The end products will look and mean different things to inform different needs, even as the processes used may be similar.

Additionally, analysis often incorporates proprietary information to the organization that sponsors it. The very questions being asked of GEOINT can be quite sensitive. This may be innocuous for some, but it serves as a strong disincentive to share in-depth analysis for others. Even for those who are willing or eager to share their in-depth analysis, the value it provides can be opaque to others not in similar positions. Yet this is not always true; for example, deep analysis of the distribution of food in a disaster area can be of common concern, while a detailed understanding of the food preferences as a result—less so. This variance, and the time involved in making use of or even understanding deep analysis places large barriers to entry on mass production.

Conclusion

Actionable insight is found when the products and services available can be combined in a useful way to answer (or pose) questions. There are several major conclusions that can be drawn.

First, there is a large opportunity in the near term to make information extracted from already available data broadly accessible. The one commoditized product in the GEOINT world is that of remotely sensed data. With nearly all types of sensors, there is a reasonably interchangeable common product expected as an output. This common basis can be used to build the next level of products and services, and in the process to explore and standardize the range of extracted information. Furthermore, the shift from a government-dominated remote sensing constellation to a commercially owned and operated one will only accelerate this opportunity. The more commonality there is at the information level, the faster the demand growth will become as additional businesses depend on these streams of information.

Second, analysis and the generation of actionable knowledge will continue to be specialized and custom-built until there is more growth and agreement on standard practices at lower levels. Even if the extraction of factual information rapidly becomes a commodity, the application of those facts to a particular business or mission will remain unique for the foreseeable future as a result of the many ways it can be applied. What will change, and presents an opportunity for analysis organizations, is the potential for automation and detail that can be applied to an analysis problem. This ability to customize answers to the problem at hand will remain a key differentiator for custom product generation in the next few years, while the increasing availability and reliability of data and information will reduce the costs of doing business.

A strong influence on the expected specialization of analysis is the increase in data sources, particularly the seeming inevitability of persistent imagery coverage. This growth will give rise to new applications of imagery and provide new insights to many industries—resulting in even more capability that will require the development of standard approaches. Currently, a heavy focus of the persistent imagery industry remains on new collectors—getting them built and launched. Lagging behind are efforts to address the analysis of the data collected by these sensors. As the collection platforms mature, the industry will take a more aggressive approach to image analytics by developing more sophisticated automation tools to maximize the full potential of these new sensors. Automation will be one of the biggest changes to the GEOINT enterprise in decades. The realization of scalable, automated feature extraction and automated change detection will transform imagery analysis by taking the tedium out of mundane tasks currently performed with a high number of man-hours. This shift to a greater reliance on automation will free analysts to focus on more complex analytic problems, growing this portion of the industry.

Finally, most organizations that consume geospatial information will move away from the ability to produce content as a necessary business function and instead move toward the consumption and application of independently provided services. This is a natural consequence of specialization that began with niche knowledge and grew into large industries, and has been proven in many industries all over the world. In the initial microelectronics analogy, the move away from integrated design-fab firms toward licensed and outsourced design, manufacturing, assembly, and marketing was instrumental in dropping the costs of electronic products and opening huge markets. Therefore, most organizations that rely on geospatial understanding will shift to a consumption model with a dedicated industry to provide the final products and constituent components they need to make better decisions.

The Fluid Employee: Adaptability in the 21st Century

By Steven Fleming, Brad Janocha, and Luis Machado

We live in a world of data connections; there is no moment in our lives not affected by the interconnections and translation of data across screens and time zones. As our personal lives adapt to the 21st century, our professional lives seem to lag behind. There has been a push to improve the technological capacity of the workforce by making better tools and providing in-depth training for professionals to use them more capably. The consequence of supremely well-trained individuals specialized in one skill set is the creation of silos that hinder communication and delay potential action steps. While there is an argument that validates the need for experts, the 21st century connected world requires something additional in the workforce. There is a vital need for a cross-cultural and cross-disciplinary adaptable professional, capable of transitioning knowledge from one field to another.

Today's problems are a function of yesterday's solutions; where once specialization was heralded as the race to achieve mastery, it is today frowned upon in an increasingly complex and interconnected world. Having mastery of one skill set or being specialized in one area is no longer critical in information technology. Tomorrow's professionals need to be more than a specialized employee—they need to be specialized learners. Further, integration and collaboration with other disciplines (e.g., data science, analysis, visualization, etc.) is necessary to address complex problems.

As an increasingly complicated and intermingled world breeds more complex problems, the integration of specializations (recognizing the value of linking experts with novices) is necessary. Iterative specialization for those in the GEOINT workforce is strongly recommended. Having teachers become students is often difficult in the professional environment, but the potential rewards are immense. Encouraging individuals to embark on iterative specialization would likely enhance the lines of communication within organizations as more knowledge becomes translatable between individuals fluent in various specializations.

Long-term planning today for the problems of tomorrow will provide a workforce that is capable of exactly the kind of transformational, cross-disciplinary approach needed in the Intelligence Community. In doing so, the goal is to anticipate the problems of the future by equipping the organizations facing them with individuals who are competent, professional, and capable of rapid adaptation. Their strengths will lie in their ability to communicate effectively with each other as well as to decision-makers and data providers, to react to questions, and to respond with innovative thinking. However, in planning for the future, the community cannot overlook the present. We still need formal structures to address present-day issues.

Cultivating Talent: Creating Bridges Between Worlds

Every need organizations have, whether academic, private, or governmental, can be filled by some combination of the resources, material, and skills held by another organization. This idea is an expansion of the idioms that “Two heads are better than one” or “No one is as smart as everyone,” which should be the basis for how the GEOINT Community should adapt to present challenges. The message is not to devalue what is currently in place, but to continue to build internally and intra-systemically, bridging the areas where boundaries restrict opportunities.

Incorporating theoreticians, educators, researchers, and students into the professional GEOINT workforce allows sharing of cross-platform and cross-disciplinary perspectives. What seems impossible to one group is seen as theoretically possible for another, and there are clear advantages to sharing ideas in both structured and unstructured scenarios. There are standard tools for taking advantage of these exchanges. Internship clearinghouses, sabbaticals, and visiting fellowships allow for the crossing of academic talent into the professional workspace. And the reverse should also be pursued to carry the talents of professional operators into the world of academia and bring to life concepts and theories. A version of this is being put into practice at the National Geospatial-Intelligence Agency (NGA) with the launch of its eNGAge program, which is designed to support the exchange of personnel between industry and academia.

An expansion of that idea is the development of team structures pulled together from academic, government, and professional organizations. Comprised of subject matter experts and novices, these teams concentrate diverse skill sets and backgrounds to address pressing key intelligence questions (KIQs). These teams could be formed as small and independent think tank equivalents, with one general supervisor within the team reporting on progress and successes to a centralized forum with oversight capabilities. A small number of teams could be arranged per broad subject area, in a fashion similar to NGA’s GEOINT Pathfinder project.

The idea of creating teams incorporating talent from various areas is not new to the industry. Matrixed organizations have been used in a similar fashion for years, combining vertical and horizontal integration to expand decision-making and idea-generating capacity. In a matrixed organization, the horizontal integration relates to different personnel being assigned to one solution team without losing their primary employment tasks. One general manager whose authority extends horizontally across departments/groups manages their contributions to the solutions. Vertical integration refers to the primary employment tasks within a standard organizational hierarchy, where authority flows downward through a department/group. Without losing the advantages of matrixed organizations, the team structure is an expansion of the same idea.

Teams would engage in collaborative efforts across fields (academic, private, governmental) rather than departments. Teams would be developed to mine talents of diverse skill sets—not just of distinct specialties, but also specifically by the inclusion of novices and specialists within the same team. Individuals would continue their employment in their chosen area and collaborate with their group as time allowed, with one member of the team undertaking a rotating position of authority centralizing and reporting on their progress. The expansion of the team idea is based loosely on the concept of a “fire team” in the Army, tasked to address a situation in a small but adaptable unit while forming part of a larger oversight structure. The team gains a measure of independence to operate into the unknown, seeking answers, while the valued intelligence is reported back.

The obvious advantage to the team structure, beyond the potential for innovative solutions, is the creation of bridges across information sectors, organizations, and departments where teams could be created. A second advantage of the team structure is the potential to create an index of all individuals available. If members reported assessments of each other, especially if team members rotated through to teams, said index would provide an internal perspective of all individuals involved. That resource would allow for quick reformulation of groups by the oversight organization, teams built around specific KIQs when short-term responses were needed. Managed by an oversight agency or organization, teams could be adaptable, responsive, and innovative in the disruptive formation.

NGA is an obvious organizational choice to develop this team structure and expand upon programs it currently operates. An initial step toward this idea would be to expand the GEOINT Solutions Marketplace (GSM) and encourage teams to self-identify and cooperatively develop ideas by working outside the silo of their particular organization. Instead of being an environment in which standalone organizations can pitch solutions and innovative ideas, GSM has the potential to create disruptive teams of diverse backgrounds that could cooperatively outthink any one organization. Solving present challenges will mean leveraging current talent into the most effective positions, while innovatively ushering in the next generation of workers.

Cultivating Habits: Education for the Professional World

The future of the GEOINT workforce lies beyond the education, training, and professional experience of the current workforce. It lies in the establishment and fostering of long-term relationships that allow the cultivation of new talents for current and future organizations. These relationships need to build on the current work being done by USGIF, NGA, and others that bridge gaps among government, academic, and private sectors. Development of a workforce of cross-disciplinary employees through a focused educational program must become a priority. This educational development process can start with the introduction of GEOINT at the K-12 level.

Beyond the potential for the next generation of professionals to begin their geospatial education in grade school, the idea of GEOINT constructed as a supplement directly integrated in education curriculum dovetails into Next Generation Science Standards (NGSS) goals of creating an aware citizenry. GEOINT is a critical tool in that effort, beginning with the premise of geo-locality—building awareness of the space one inhabits and what one's surroundings are.

K-12 education has slowly begun to incorporate technologies typically found under the GEOINT umbrella, such as remote sensing, landscape analysis, and geographic analysis. The curricular objectives included under NGSS provide a platform to stretch even further. NGSS were published in April 2013 and are a newly formulated standard to teach science curriculum in K-12 education. Currently adopted in 17 states and the District of Columbia, NGSS were created from the National Research Council's (NRC) "Framework for K-12 Science Education," published in 2011. As a part of the National Academy of Sciences, NRC pulled together nationally and internationally known scientists, engineers, and researchers to develop the framework, which is being adapted by states to redesign science learning to prepare students for college and careers. NGSS objectives focus on creating system-wide thinking and modeling lessons intended to facilitate K-12 learning and critical thinking skills.

NGSS has the potential to create a generation of thinkers who will become the adaptable professionals the GEOINT workforce needs. This holistic and hands-on approach to science and engineering is grounded in three guiding dimensions: Science and Engineering Practices, Crosscutting Concepts, and Disciplinary Core Ideas. Through the Science and Engineering Practices (SEPs), students cultivate work ethic and skills, becoming critical thinkers and problem-solvers who use scientific reasoning to ask and answer KIQs. Evidence-based education will be essential in climate change arguments and in addressing the social phenomena leading to global security problems. SEPs guide students through understanding social phenomena, while also framing the Crosscutting Concepts (CCs) that transcend scientific disciplines. CCs help develop an analytical prowess, enabling students to recognize the patterns, cause and effect relationships, and other broad but essential conceptual knowledge intrinsic to all fields of science. An understanding of these principles enhances the Disciplinary Core Ideas (DCIs) that guide a student's academic career. DCIs maintain NGSS's vertical alignment, allowing students to build an understanding of disciplinary ideas (e.g., human impact on Earth systems, climate change, etc.) throughout their K-12 education.

When enriching NGSS-aligned curriculum with GEOINT technologies, program designers should use the Five E's of Science to shape their lessons: Engagement, Exploration, Explanation, Elaboration, and Evaluation classically outline science lessons, and, when combined with NGSS and GEOINT, the classes become more meaningful. SEPs guide students in the Exploration phase through which GEOINT technologies such as GPS, GIS, or remote sensing could be used to investigate DCIs, CCs, and KIQs. GEOINT technology could be used to explore scientific phenomena and data on the K-12 level. Students experiencing NGSS curriculum implementing this technology would graduate from high school as adaptable, versatile analysts who have already engaged with GEOINT tools.

There are academic institutions currently developing and implementing templates that introduce students to GIS, programing, fundamentals of coding, and 3D modeling. These are NGSS-suitable and provide introductory lessons to the very technologies used by analysts in major defense and intelligence organizations. There is potential for private and government organizations to similarly join or engage in cooperative efforts to develop a GEOINT curriculum built directly into educational activities to foster aware and engaged students.

Universities in Maryland are currently developing STEM (science, technology, engineering, and math) programs for K-12 level students that teach critical thinking through GEOINT applications including GIS and 3D modeling. Those efforts are an early step in the direction of potential cross-cultural and cross-disciplinary learning. Many areas of study, from history, math, social studies, and physics should incorporate the early stages of GEOINT material to provide the solid foundation to cultivate more technically competent professionals-to-be. GEOINT is itself an application of STEM; this understanding and the NGSS framework create an opportunity the GEOINT Community must take advantage of. Collaborating with educational partners is often a matter of expressing an interest in doing so. Educators rarely have a surplus of useful support, and our industry needs to invest in the next generation talent.

There is a place in education for GEOINT, and there is a place in the GEOINT Community for professionals from the field of education. As the private sector and the government sector continue to foster connections and develop strategies maximizing the advantages of funding to opportunities, the potential for educational partnership should not be lost. Through USGIF and NGA, there are systems that connect and combine the three orbiting spheres. As a community, we should actively seek engagement outside of our "bubble" and take advantage of available resources to communicate our needs and abilities.

NGA has a renewed commitment for transparency in unclassified data, which is fundamentally changing the way the public understands the value of GEOINT. The community at large should commit to develop partnerships and engage with others. We have the potential to build the teams to engage the KIQs of the present and the opportunity to integrate the ideas that will train the workforce of tomorrow into NGSS standards. All branches of the GEOINT Community need to grow the partnerships that will make those efforts successful.

Core GEOINT Skills and Competencies for Nextgen Analysts

By Todd Massengill; John Gaughan; Joel Harrison; and Colleen McCue, Ph.D.

The previous 15 years have included rapid changes in the amount and nature of traditional GEOINT data, including commercial airborne and satellite imagery available at resolutions and refresh rates never before imagined. At the same time, the increase in non-imagery locational data available has far exceeded the amount of available imagery, effectively evolving the definition used by global GEOINT practitioners to include sources, methods, and enabling technology not considered when GEOINT was a nascent professional discipline.

While this increased access to geospatial content and capabilities represents new opportunity for the GEOINT profession, the identification and maintenance of core GEOINT skills and competencies will be necessary to ensure the continuous improvement and perpetuation of essential GEOINT knowledge and tradecraft. In addition to the identification of core GEOINT skills and the establishment of associated training requirements, external education and "marketing" would support the development of the "informed GEOINT consumer" who would be able to differentiate between professional GEOINT services and many of the self-serve capabilities now available. The consumer referenced is both the global population of those that consume geospatial information products and decision-makers using GEOINT products to make those decisions. Finally, better understanding of the millennial and subsequent generations will better position the professional global GEOINT Community to leverage unique knowledge, skills, and abilities of practitioners, while also anticipating and effectively mitigating gaps in core skills or experience.

As we witness this expanding definition and associated "democratization" of GEOINT, the professional GEOINT Community should consider the following:

Inward: *Identify core GEOINT skills and competencies and establish training requirements to protect the professional GEOINT legacy and ensure the perpetuation of core GEOINT knowledge and essential tradecraft.*

The rapid proliferation of spatially-oriented data and high-performance computing has created tremendous opportunities for the GEOINT professional. Spatially-oriented data that were not even considered a few years ago are now widely available to the professional GEOINT Community, as well as to the broader public—frequently in real time or near-real time and with spatial, spectral, and temporal resolutions that far exceed those only imagined in the early days of remote sensing.

The development and broad deployment of high-performance computing and visually compelling display environments has made location-based analysis relatively simple and intuitive. Traditional barriers to entry, including access to geospatial content and tools, have been removed while interest in multi-INT analysis has risen, making these capabilities increasingly available to the GEOINT professional, all-source analyst, and layperson alike. We must ensure traditional GEOINT education emphasizing core imagery and terrain-based GEOINT principles and related tradecraft is not being replaced in favor of training focused largely on "buttonology"—creating geospatial technicians versus professionals in many domains. Nonetheless, the democratization of GEOINT data, products, and services prompts the larger community of users to question whether GEOINT will remain a separate professional discipline, or if it has evolved to just another intelligence sub-discipline available to the all intelligence analysts.

As the GEOINT Community moves to embrace new, improved, and promising sources, methods, and technologies, it must ensure critical geospatial thinking is not replaced by attractive "easy button" solutions. Efforts to support this requirement are already underway, including the incorporation of analytic methodology and techniques, as well as ensuring geography theories and models are central to GEOINT analyst education. Moreover, training emphasizing analysis as a process that lets the problem guide the solution enables the intellectual agility necessary to seamlessly incorporate new sources, methods, and technologies as they become available. Further supporting this educational model, the National Geospatial-Intelligence Agency (NGA) has articulated a clear requirement for an "integrated analytic environment" that is embodied in "a unified GEOINT platform that aligns disparate tools, algorithms, and capabilities into an interoperable, data-centric exploitation and analytical system of systems." Finally, effective instantiation of these requirements will be validated through the development and rigorous use of assessment tools and methods that measure problem-solving skills and "knowledge" rather than "how-to" skills and technical proficiency.

Outward: *Develop an external education or "marketing" strategy designed to highlight the difference between professional GEOINT services and other readily-available, self-service capabilities to educate the broader community and create "informed GEOINT consumers."*

The increased availability of self-service capabilities has expanded access to geospatial content. Most adults now have direct experience with the use of these capabilities for route planning, shopping, real estate, and many other tasks. In addition, emergency management increasingly leverages the unique nature of the geospatial environment for the visualization of complex information in an intuitive, actionable manner that also provides context. While these represent great benefits associated with our increased ability to provision content in a geospatial environment, they also may have created a false sense of competence among end users. The onus is on the professional GEOINT Community to identify and promulgate core GEOINT skills and tradecraft and ensure perpetuation of the profession. Additional education and even "marketing" may be necessary to ensure end users understand the value proposition of professional GEOINT services and related products. Specifically, the community should consider education and marketing that address not only the unique differentiators associated with professional GEOINT services, but also the "art of the possible." In some situations, this education may occur during the requirements phase when the analyst is discussing options with the intended end user including alternative approaches or future analysis, while other occasions may support the use of educational narrative in the methods and results sections that guide interpretation of the results to include caveats. This becomes particularly important as the goal of effective visualization frequently is to present the results in an easily consumed, intuitive manner that addresses the "I'll know it when I see it" requirement. This often creates the misperception that geospatial analysis is similarly simple, easy to execute, and based on intuition rather than well-founded geographic theory and tested geospatial science.

The democratization of GEOINT has been associated with the broad proliferation of geospatial content and related capabilities. As with many things, however, just because you can do something does not necessarily mean you can do it well, or even that you should. For example, the ability to measure the Euclidean distance between two points, or to perform simple route planning in many of the online geospatial capabilities currently available is markedly different from a true route mobility calculation or least cost path analysis. Similarly, the use of location-based decision support capabilities, including tools that can infer location and make spatially "informed" suggestions, makes GEOINT seem almost "automagic." Without understanding sources, methods, and associated constraints on the interpretation and use of these capabilities, errors in interpretation can result in faulty decision-making. For example, analysis of local crime data taken out of context may reveal compelling "hot spots" that correlate perfectly with the police headquarters or local precinct offices as these frequently are the locations from which citizen complaints are filed and other police work is completed. Similarly, other police-initiated activities to include narcotics and vice enforcement often are staged at locations that support operational requirements to include officer safety. Because these locations are associated with specific neighborhoods, it is easy to support the inflated and faulty assumptions used regarding local crime patterns. In another trends example, the analysis of mortality data can create the faulty impression that hospitals are inherently unsafe places given the number of death certificates filed at those locations. While the consequences associated with faulty inference in a search for a good barber or locating a new retail outlet may be significant to the lay end user, they are markedly different than the consequences associated with faulty interpretation of GEOINT in other settings. Therefore, if the goal of intelligence is to provide information and related insight to decision-makers so they can make informed judgments regarding policy and the management of risk, then uninformed or overconfident use of these capabilities will have serious consequences, which may include faulty interpretation of the results and misallocation of resources, or even loss of life in some domains.

Many professional GEOINT analysts understand the importance of educating the end user, including guidance regarding the appropriate source and/or method for the task, as well as education regarding the interpretation and use of GEOINT analytic products. Sometimes this guidance might be as simple as suggesting specific visualization techniques to highlight relevant findings. In other situations, this guidance can set the conditions for informed interpretation and use of the results in support of allocation and optimization of scare resources, particularly where time is of the essence or lives hang in the balance. Extension of this current practice to include differentiation between professional GEOINT services and related products, as well as the value-added benefits associated with the use of advanced GEOINT analytic techniques versus the many self-service capabilities, will enable end users to make informed choices.

Millennials: *To prepare the next generation of GEOINT professionals, the unique knowledge, skills, abilities, and experiences of the millennial and subsequent generations should be understood and leveraged in support of GEOINT professional excellence.*

It is increasingly likely that future generations will enter the community with some level of experience with spatially-oriented data, including mapping. This experience may increase their curiosity regarding the "art of the possible" as it relates the use of location-based content and the associated importance of geospatial context in understanding their environment, and even whet their appetite for more precise and powerful sources, methods, and technology as a GEOINT professional.

Conversely, casual experience with location-based content and related technology may impart a false sense of security or competence in geospatial analysis. Will future generations be willing to devote the time and effort to learn core imagery and GEOINT tradecraft when "easy button" solutions are readily available and easy to use, even if they lack the precision, accuracy, and reliability of professional GEOINT capabilities? Will "good enough" be sufficient, particularly as all-source analysts increasingly view spatially-oriented content as just another "INT" available for consumption in the multi-INT environment? Moreover, mastery of specific GEOINT sources and methods frequently requires many years of experience and ongoing professional development and training. The increasing trend in younger professionals of advancing their careers by frequently changing roles and positions may cause a disruptive churn in a profession that historically required commitment to training and extensive experience to approach mastery. Will the experience and expertise necessary to sustain professional GEOINT churn with them?

Basic education and common life experiences increasingly diverge from the traditional skill set required for many GEOINT roles. For example, even something as simple as touch typing or keyboarding skills can no longer be assumed given the extensive use of handheld devices, and young people increasingly not only embrace but rely on voice-activated capabilities, which significantly limit the requirement for manual data entry. The irony is that until the U.S. Intelligence GEOINT Community catches up, new hires may require additional training to ensure they are able to create content accurately and reliably. Meanwhile, non-intelligence GEOINT analysts that can use their mobile devices are able to run rings around data entry and are not constrained by limited input methods. Alternatively, we may take a cue from these young professionals and explore other methods for data entry, particularly those less vulnerable to keystroke errors. This seeming limitation may actually offer an opportunity for the Intelligence Community to embrace voice-translation capabilities, which have been adopted by many other professional domains such as medicine with similar requirements for accuracy and reliability in transcription.

Similarly, young professionals accustomed to broad, unfettered access to content may feel constrained by limitations associated with working inside secure environments or authorities that limit their access to specific content. As community leaders have noted, young professionals may also wonder why they are required to leave their "smart" devices outside analytic spaces. These requirements and constraints, in association with the amount of geospatial work increasingly available outside the Intelligence GEOINT Community, may present an impediment to recruitment as young talent could opt for geospatial analyst roles in the commercial and other unclassified sectors. As the global community generally recognizes the importance of open-source content and the limitations associated with working in a cloistered information environment, the proliferation of commercial imagery and unclassified non-imagery location data uniquely positions the non-intelligence GEOINT Community as leaders in the move to embrace commercial and other open, unclassified sources, methods, and technology. Therefore, this "challenge" may represent a unique opportunity as GEOINT emerges as the "right place, right time" for young professionals eager to embrace open-source content and innovative technology. Ultimately, perpetuation of GEOINT as a profession will require a workforce ready, willing, and able to forego "easy button" solutions and acquire the knowledge, skills, abilities, and experience necessary to successfully develop and sustain geospatial critical thinking skills and related core imagery and terrain-based tradecraft. Consideration of these factors and how they can be addressed will be important to ensure the community can not only recruit, but effectively retain new talent.

Discussion: *The increased access to and use of spatially-oriented data has supported better understanding of and appreciation for geospatial analysis, because location does matter. GEOINT offers unique opportunities for young professionals eager to shape the future of the field.*

Seeing school children actively engage in crowdsourced imagery analysis efforts in support of archaeological searches and conservation programs is exciting and promises to increase their interest in geospatial intelligence. Minimally, this exposure serves to elevate the geospatial literacy of the population. Ideally, early exposure to or engagement with geospatially-enabled content and related capabilities will prompt some to pursue GEOINT as a profession. Similarly, ready access to location-based information has increased the public's ability to identify and access resources, locate places of interest, and even disseminate important public safety and emergency response information in an easy-to-interpret format because location with context provides insight. Moreover, the ability to execute computationally intensive geospatial analysis in real time or near-real time can provide end users with timely analysis and a genuine decision advantage.

But the proliferation of capabilities has the potential to yield the unintended consequence of confidence grounded in a shaky foundation of self-service tools that may visualize and manipulate spatially-oriented data but are thin on analytic rigor. This is particularly true with tools stripped of expert options that enable a skilled GEOINT professional to effectively validate and refine the results in support of accurate and reliable geospatial products. Almost simultaneously, training programs that emphasize technical proficiency with specific sources, methods, or technology over critical geospatial thinking have slowly eroded the importance of traditional GEOINT education. These programs favor “buttonology” over core imagery and terrain-based GEOINT principles and related tradecraft, and the creation of geospatial “technicians” in many domains creates cause for concern regarding the longevity of GEOINT as a profession.

Conclusion

As responsible stewards of the profession, the professional global GEOINT Community can effectively respond to and leverage these changes in support of ongoing professional excellence by ensuring the identification and propagation of foundation level geospatial concepts and principles, critical geospatial thinking, and core imagery and GEOINT tradecraft through capacity development and training that are tool agnostic, incorporate geographic theory and models, and can be evaluated. At the same time, the community owes it to end users to educate them on the differences between readily available self-service capabilities and professional GEOINT services, including key differentiators and the “art of the possible.” Experience also suggests the “informed consumer” becomes a better partner, particularly when this education becomes an integral part of the entire analytic relationship from the requirements stage through messaging and narrative guiding proper interpretation and use of the results. Finally, recognizing the unique knowledge, skills, abilities, and experiences millennials and subsequent generations offer will enable the field to evolve and grow by leveraging their unique perspective, knowledge of ubiquitous technology, and sense of connectedness, empowering them to help shape the future of the profession. Doing so will enable the community to effectively incorporate new sources, methods, and technologies, while protecting core skills and tradecraft to ensure professional GEOINT tradecraft services remain available now and into the future.

Activity-Based Intelligence: Understanding Patterns-of-Life

By Patrick Biltgen, Ph.D.; Todd S. Bacastow, Ph.D.; Thom Kaye; and Jeffrey M. Young

Activity-based intelligence (ABI) is an analysis methodology that rapidly integrates data from multiple sources to discover relevant patterns, determine and identify change, and characterize those patterns to drive collection and create decision advantage. Unlike the traditional intelligence cycle, which decomposes multidisciplinary collection requirements from a description of the target signature or behavior, ABI practitioners have advanced the concept of large-scale data filtering of events, entities, and transactions to develop understanding through spatial and temporal correlation across multiple data sets.

Since the Babylonians created the first geospatial intelligence (GEOINT) products around the 5th century B.C., time and geography were essentially decoupled. Cartography represented the world at a snapshot in time. When the first photoreconnaissance satellites were lofted in the 1960s, the focus was largely on locating large, fixed military installations and mapping Soviet territory. Periodic sampling on the order of days or weeks was sufficient for arms control treaty monitoring of hostile foreign nations. Events such as the Soviet Invasion of Czechoslovakia, the Great Scud Hunt of Operation Desert Storm, and the search for terrorists post-9/11 drove demand for sources and methods of GEOINT collection and analysis that could capture dynamic activities. The focus shifted from describing large-scale activity to fine-grained “patterns-of-life” of individual entities.

A pattern-of-life is “the specific set of behaviors and movements associated with a particular entity over a given period of time.”[1] The focus on the individual is the fundamental uniqueness of the ABI method and drives the need for a new set of techniques and approaches to intelligence analysis. Technological advancements of the

1. Patrick Biltgen and Stephen Ryan, *Activity-Based Intelligence: Principles and Applications*. Boston: Artech House, 2016.

past two decades—a revolution in information technology and the dawn of "big data"—enhance our ability to collect and process large volumes of data. Tradecraft advancements including both mind-set shifts and new analysis methods allow analysts to make sense of this flood of data to understand individual behaviors and activities in the context of the environment. By resolving entities and understanding patterns-of-life, analysts can build models of potential outcomes and anticipate what may happen.

Technological Advancements

Inferring an outcome from a small number of observations is a dangerous proposition, especially when the dynamic and often unpredictable actions of humans are concerned. ABI promotes a deductive approach to analytic reasoning. Deduction reduces the space of potential outcomes by eliminating the impossible, but because much more data is required, technological advancements that improve the resolution and ubiquity across the spatial, temporal, and spectral dimension are needed.

Advancements in spatial resolution and ubiquity are the most intuitive for GEOINT professionals. Since the early days of GEOINT, we have seen increasingly crisp and colorful imagery over increasingly large swaths of the Earth. Start-ups such as Planet promise to image our Earth daily, providing unprecedented insight into human activities at global scale. Transportation start-up Uber partnered with DigitalGlobe to use high-resolution imagery to identify new lanes and traffic patterns, pinpoint the optimal pickup and drop-off locations, and ultimately improve the passenger experience. Thousand-dollar commercial drones beam ultra-high-definition video to smartphone-based controllers. ABI benefits from improvements in the spatial dimension because individual activity patterns can be discerned from the background. This improves the accuracy of pattern-of-life analysis because analysts don't have to infer what is happening inside or in between each pixel.

The most stunning transformation of GEOINT in the past 15 years involves the temporal dimension. Simply put, video killed the photography star. Multiple dash-mounted cameras captured an exploding meteor in Chelyabinsk, Russia, in 2013. A U.S. Coast Guard camera caught US Airways Flight 1549's miraculous landing on the Hudson River. Footage from body-worn, traffic, and security cameras pepper 24-hour newsfeeds. Today, there are more than 100 Air Force Predator and Reaper drones aloft, sending high-resolution video to ground sites around the world. New wide-area persistent surveillance systems such as the Air Force's Gorgon Stare pod-mounted sensor package are used to track people and vehicles in city-sized areas. Google's Terra Bella (formerly Skybox Imaging) stunned the world in 2013 when it released the world's first high-definition video from space. Human motion is one of the most powerful activity indicators and is central to the development of an entity's pattern-of-life. As affordable and persistent high-resolution sensors proliferate worldwide, mapping patterns-of-life becomes feasible because analysts also do not have to infer what is happening between scheduled, separated collection opportunities. For the first time, analysts can map complete motion transactions at massive scale.

Improvements in spectral diversity—the proliferation of sensors that capture increasingly broad samples across the electromagnetic spectrum including combinations of non-traditional phenomenologies—represent the most transformative and revolutionary advancement shaping the GEOINT Community today and into the future. Orchestrated "multi-intelligence" collection was a rare and expensive prospect when sensors were limited, but as the GEOINT marketplace "darkens the skies" with more and different kinds of sensors, simultaneous collection on a single entity will become commonplace. Development of a pattern-of-life using a single sensor type is extremely difficult because the sensitivity of collection cannot be improved without also increasing the false alarm rate. The integration of multi-sensor, co-collected data allows the strengths of one data source to compensate for the weaknesses of another, enabling analysts to paint the complete picture of an entity's pattern-of-life. This approach also makes it much more difficult for an adversary to practice denial and deception because he may be observed in many different ways that are difficult to mask simultaneously. Finally, let's not forget the ultimate "new" multi-INT sensor: our mobile devices that drip digital data as we move simultaneously through geospace and cyberspace. The ability to collect and integrate these information sources with relevant geospatial context provides the basis for developing accurate and robust patterns-of-life.

Tradecraft Advancements

The three technological advancements—in spatial, temporal, and spectral resolution—enhance ABI collection and provide a mechanism to capture a complete pattern-of-life, but making sense of all this data in time to do something about it represents a fundamentally new challenge for analysts. Three axioms enable the mind-set shift necessary to develop, understand, and formalize patterns-of-life.

The first axiom may be called "Clapper's Law." In 2004, then-director of the National Imagery and Mapping Agency (NIMA) James R. Clapper said, "Everything and everybody has to be somewhere." This simple and powerful principle is the basis of the ABI pillar of "Georeference to Discover." Spatially indexing all data allows discovery of activities. Everything happens somewhere. Nothing can be in two places at once. Nothing can be nowhere. Because of these existential constraints, analysts can implement the powerful techniques of hypothesis testing and deductive reasoning: By eliminating all the places where the entity is not, the one remaining place is where the entity must be. Repeated application of this process across time produces a bona fide pattern-of-life unique to a single entity.

A second axiom, the concept of time-geography developed by Swedish geographer Torsten Hägerstrand, formalizes the concept of a pattern-of-life by describing a path taken through space-time: "Life paths become captured within a net of constraints, some of which are imposed by physiological and physical necessities, and some imposed by private and common decisions." Hägerstrand describes capability constraints "which limit the activities of the individual because of his biological construction and/or the tools he can command," such as the hours of sleep required per night or the maximum velocity of a vehicle. Coupling constraints define "where, when, and for how long the individual has to join other individuals, tools, and materials in order to produce, consume, and transact." This includes the interaction of the entity with objects such as cars, office buildings, and smartphones. Authority constraints describe the degree to which access to certain regions or resources such as a locked vault, a crowded communications channel, or a particular seat at a movie theater are controlled at a given time. An authority constraint might even be a social or religious preference such as vegetarianism or a defined prayer hour. This constraint-based approach formalizes the mathematical relationships that define an entity's pattern-of-life. When linked with Clapper's Law, Hägerstrand's method helps analysts deductively narrow the possibility space by eliminating large chunks of infeasible "somewhere."

The third axiom, widely known by geographers, is called Tobler's First Law of Geography: "Everything is related to everything else, but near things are more related than distant things." Tobler's Law is the basis for spatial autocorrelation. Because nearer things are more likely to be significant, it further focuses reasoning efforts and the deductive process on the spatial and temporal conditions that are most likely to be true. When combined with the first and second principles, Tobler's Law completes the mind-set framework necessary to implement ABI. Analysts know everything must be somewhere, they know how to constrain the possibility space, and they know how to prioritize geospatial information based on proximity.

Putting It All Together

USGIF board member Jeff Jonas noted that to catch clever criminals, "one must either collect observations the adversary doesn't know you have or be able to perform compute over your observations in a manner the adversary cannot fathom." Increases in spatial, temporal, and spectral diversity ensure almost everything about our lives may be captured by one or more sensors and stored indefinitely. The mind-set shifts driven by ABI provide the basis for a framework to reason through these large volumes of data, understanding how humans move across and interact with the Earth. Formulating patterns-of-life and separating the signal from the noise requires human analytical thought, but also new tools and approaches that make it easier for analysts to filter data, quantify patterns, and test hypotheses.

Standard statistical methods, regression techniques, and models are almost always based on the assumption that the variables are independent. But people are not lifeless particles governed by Brownian motion or Kepler's laws; we are complex entities whose activities are constrained and influenced by geography and other societal, relational, biographic, historic, and preferential constraints as outlined in the three axioms. For these reasons, human activities are not entirely random processes. Seemingly unrelated activities and behaviors cast as a spatiotemporal narrative expose the previously undiscoverable threads of motivation, purpose, and implication. Integrating and studying historical data that describes the activities of an entity across time and space improves an analyst's understanding of that individual's pattern-of-life. Adding the set of constraints and likely outcomes produces a model of what the analyst thinks will happen and a series of hypotheses that can be tested with real-world observations.

Modeling techniques provide promise, but these cannot be large-scale, aggregated, population-level models, kinematic models of object motion, or statistical demographic-based models of behavior, because they fail to capture the nuances of the individual based on his or her behaviors, activities, beliefs, and motivations. The GEOINT discipline increasingly includes statistical methods, but analysts must be trained in mathematical techniques to avoid detecting and reporting on spurious correlations. Automation might save time spent on routine tasks like searching for and reformatting data, but as former National Geospatial-Intelligence Agency (NGA) analyst Stephen Ryan notes, the "dumpster diving" gives analysts an intimacy and familiarity with data that improves their ability to analyze it.

There is no magic "ABI tool" that features a "find bad guy" button. ABI provides a series of techniques, a change in mind-set, and a methodological framework for data analysis that is becoming increasingly important in our increasingly complex world.

Conclusion

Bloomberg forecasts that by 2030 the world will host 40 megacities—cities with at least 10 million people—with increasing population densities. These megacities will be filled with self-driving cars, automated restaurants, tracking cameras, and always-on streaming connectivity to the world. Dozens of digital transactions (beginning with your toothbrush's daily report and ending with your pillow's temperature optimization) will be required to operate your gadgets, your job, and your body. Almost every object in the world will have an Internet Protocol (IP) address and be connected to everything else. And every one of these objects and transactions will create another record in your lifestream and define your insuppressible pattern-of-life.

In his book *Connectography*, author and futurist Parag Khanna describes an evolution of the world from physical and political geography to a functional geography that describes how humans use and interact with the world. As mobility, telecommunications, energy, finance, and the supply chain are increasingly integrated and as people freely move through geospace and cyberspace, methods for ABI and the principles outlined above will become increasingly important in understanding the world.

With all the focus on spinning globes, dancing dots, and shiny satellites, it's easy to lose sight of the fact that intelligence is about avoiding strategic surprise. NGA Director Robert Cardillo, in his 2014 "Director's Intent" document, challenged his workforce to view GEOINT through "the lens of consequence." Consequence is about anticipating what may happen, why, and what the GEOINT Community can do about it. ABI techniques, tools, and tradecraft are critical to understanding patterns-of-life. Integrating the activities of humans upon the ubiquitous foundation of our physical, cultural, and functional geography and continuously updating our knowledge of these interacting forces represents the next fundamental shift in the state of GEOINT.

From Layers to Objects: Evolving the GEOINT Analytic Tradecraft

By Todd S. Bacastow, Ph.D; Dennis Bellafiore, Ph.D.; Susan Coster; Stephen Handwerk; Lisa Spuria; and Gregory Thomas, Ph.D.

This article addresses the tradecraft implications of moving from layer-based geospatial intelligence (GEOINT) to object-based GEOINT.[1] The terms "layer-based GEOINT" and "object-based GEOINT" are used to capture a way of thinking (i.e., a paradigm, including tradecraft, analytic methods, and technologies). The focus is how analysts routinely think about solving a problem. In such paradigm thinking,[2] actions are taken according to the dominant perspective, which may not be reflected wholly in the documented tradecraft. As a result, the needed changes in tradecraft, training, and thinking may be a struggle for the GEOINT Community.

The community is evolving toward the object-based GEOINT paradigm because of the emerging array of object technology, data, and information. Significantly, object-based GEOINT is not any particular tool or a technology, but is enabled by developments such as activity-based intelligence (ABI) and object-based production (OBP). OBP is the technology and production capability that creates a conceptual "object" for people, places, and things. The object becomes the single point of convergence for all information and intelligence produced. Objects also become the launching point to discover information and develop intelligence.

Objects and object-based analysis are not new. What is different is the imperative to move the GEOINT tradecraft beyond the prevailing layer-based thinking. Object-based analysis enables analysts to more accurately model the real world in the way humans naturally interact with it. There are many benefits of object-based GEOINT, but the tradecraft must adapt.

Intelligence analysts have observed objects for more than a century. For any given object, the who, what, when, where, and why have been collected, analyzed, recorded, and reported. An object received a unique identifier, and attributes were assigned to the object. As automation was introduced into the workplace, the data were captured in layers, or spreadsheets, where each row was a discrete object, and the columns identified the attributes of the objects. These are known as relational databases. An inherent shortcoming of this approach is the difficulty to see how different objects might be related to one another as well as how time might affect these relationships. In the relational database realm, analysts must use cognitive abilities to study object relationships over time—a difficult and time-consuming undertaking. Further, only a limited set of objects and data can be comprehended. In the mid-'80s, programmers developed algorithms for graph-structured objects and CAD applications, and the term object-oriented database was created.[3]

1. We specifically do not use the abbreviation OBG to avoid confusion with established programs such as object-based production (OBP).
2. J.K. Swindler, review of *Simplicity: A Meta-Metaphysics* by Craig Dilworth. *The Review of Metaphysics*, 68, no. 3 (2015), 649.
3. T. Atwood, "An Object-Oriented DBMS for Design Support Applications." *Proceedings of the IEEE COMPINT 85* (September 1985), 299-307; N. Derrett, W. Kent, and P. Lyngbaek, "Some Aspects of Operations in an Object-Oriented Database." *Database Engineering*, 8, no. 4 (December 1985), IEEE Computer Society; D. Maier, A. Otis, and A. Purdy, "Object-Oriented Database Development at Servio Logic." *Database Engineering*, 18, no.4 (December 1985).

Layer-Based Analysis

Geospatial education and analytic thinking are heavily influenced by an early method of environmental planning in which Earth data were graphically displayed on Mylar sheets assembled in various combinations to determine areas of environmental constraint.[4] Educators often cite Ian McHarg's 1969 book, *Design with Nature*, as having influenced the basic overlay concepts that later developed into geographic information systems (GIS). GEOINT's use of layers is rooted with environmental planning's use of transparent acetate map overlays as implemented in the Intelligence Preparation of the Battlefield (IPB) process.[5] GIS allowed direct automation of the IPB process, through which layers are stored electronically rather than on Mylar sheets, and different layers are combined and computers calculate constraint areas.

A layer-based focus is still dominant in geography education in general and GEOINT in particular. The layer-based analysis examines the differences between the maps or layers. Location is the primary construct for analysis when using layers of data. Layers, whether Mylar or electronic, offer an orderly but fixed-in-time means to think about the Earth and the relationship among features. Critically, layer-based GEOINT analysis begins with heavily pre-filtered observations and proceeds to a conclusion in light of the generalized evidence.

Object-Based Analysis

Introducing object-based analysis brings actor, time, location, and action together as the analytic framework. In object-based GEOINT, the analyst's methodology changes from looking at differences between layers to examining changes of many small things in space and time. Understanding these changes exposes forms, patterns, functions, and diffusion—it is a discovery paradigm. Technologic advancements beyond organizing data into layers allow analysts to handle the smaller elements that make up a layer. These elements are objects. Objects have been likened to creating electronic "baseball cards" for individual items.[6] These objects include attributes such as location, time, extent, etc. The objects can be related, indexed, searched, and updated with respect to location and time or to another set of objects. The analyst can then construct a narrative, such as a hypothesis, to better understand activities and events. Seemingly isolated activities can be cast as a narrative exposing interwoven threads. Objective-based GEOINT is deductive reasoning in which the analyst begins with the assertion and proceeds to a specific conclusion. The object framework is in n-dimensional space rather than the two-dimensional space of geospatial layers.

Struggling to Change

Technological changes create anxieties for analysts and managers. Such is the case with changing from a layer-based analytic framework to one that is object-based. There are two key problem areas that contribute to the anxiety: tool mismatch and data complexity that increases cognitive loading.

First, technologies and tools are never perfectly aligned with the work they are intended to support. The tools can try to be a "one size fits all" solution, but the competent professional ultimately tailors either the tool or its outputs/inputs to compensate for any mismatch in tool interface to data availability, formats, or desired work. This is the case for existing tools in the analyst's toolbox—they don't interface well with object-oriented data structures and work. These tools were originally created to support traditional, layer-based GIS methodologies and tradecraft. The work implicit in these tools revolved around layer manipulation techniques and structures that had evolved through necessity from limited computer memory and processing power resources. A lot of the problem-solving "heavy lifting" was done by professional reasoning and the tools supported the creation of a standardized output product format. Instead, the tools need to evolve and provide logical support during the actual problem analysis.

Analysis was provided on a backdrop of a fused map, image, and occasionally other data layers as annotations or text. The tools provided a context enabler for the analyst to tell the intelligence narrative; they didn't usually provide decision process maps or technical subject matter expert experience that informed an analyst's decision-making process. The "heavy lifting" of logical, multidimensional problem-solving that took place in an analyst's head was actually object-based thinking techniques not yet supported by existing data storage structures and tools. Technology continues to limit this type of analysis; however, new 3D and immersive screen displays may pave the way for real change. To update traditional analysis to object-based analysis will require technologies and tools be developed that include the inputs of new object data structures and provide additional problem-solving frameworks that can support analysis algorithms and ground truth models to compare and contrast against.

Second, object-based analysis derives its power from the creation of a different type of data manipulation. Historically, one of the main contributing reasons for the data layer-based approach has been limited computing power available for desktop manipulation of data. Data were often

4. Ian McHarg, *Design with Nature*. New York: Doubleday, 1969.

5. R. Glinton, J. Giampapa, S. Owens, K. Sycara, C. Grindle, and M. Lewis, (2004). "Integrating Context for Information Fusion: Automating Intelligence Preparation of the Battlefield." *Proceedings of the 5th Conference on Human Performance, Situation Awareness, and Automation Technology*, iAA, 224.

6. Biltgen, P., and Ryan, S. (2016) Activity-Based Intelligence: Principles and Applications, Boston, MA, Artech House, p. 154.

filtered early in the workflow via accepted GIS data combination techniques and tradecraft to simplify the problem space. The data analyst worked to minimize excess data, merging multiple hypotheses down to minimal complexity levels so an analyst could then identify a narrative, working hypothesis, or model that was logically supported by the remaining data. This was necessary as the human brain has limitations on working memory and maximum cognitive load.[7] Data were "lost" during this filtering process in the sense that there was no longer a need to revisit it for new insights once a plausible narrative was determined. The data layers were difficult to change once they were established and to manipulate once created. They were, in essence, "static" data forms.

One can compare the pre-filtered approach of GIS layers to the incremental-build approach of object-based GEOINT workflows. As the workflow unfolds, the pre-filtered approach deals with less and less unfiltered data, and the incremental-build approach creates alternative models of the space-time activities and can accommodate more and more data.

The comparison between the pre-filtered and incremental-build approach can be summarized as follows:

1. The starting points are different:

a. The pre-filtered approach interprets the information selected as an accurate record of reality and defines this as data.

b. The incremental-build approach captures all data inputs and the algorithms used to capture the information and store all of this as data.

2. The filtering of data is different:

a. The pre-filtered approach uses relational database pre-defined categories and layers.

b. The incremental-build approach uses the first objects to filter and define the space-time activities, but all data is kept as the data set grows.

3. The author's methods are different:

a. The pre-filtered approach employs expected mental models and arrives at a best fit.

b. The incremental-build approach uses multiple hypotheses and performs iterative analysis techniques to create more hypotheses and better and better fits.

4. The intent of the interpretation is different:

a. The pre-filtered approach follows a narrative structure that aggregates the interpretation, shapes understanding, and best conveys the intent.

b. The incremental-build approach dynamically creates the interpretation of the intent as data is added and the complexity of objects grow.

5. The map design is different:

a. The pre-filtered approach is limited by the foundational layer and the tools used for presentation and visualization.

b. The incremental-build approach interprets more complex objects as data are added and utilizes the presentation and visualization that are best for the analyst and potentially the decision-maker.

6. The analysis provides a different perspective:

a. The pre-filtered approach produces a static report that balances the biases and interpretation of the analyst and relies on the decision-maker's understanding. This operates much like a fixed-focus lens—parts of the report are in focus while other parts are blurred.

b. The incremental-build approach tells a story over time utilizing the network of dynamic objects thus able to provide ongoing analysis as more data are added to the model. This operates much like a variable-focus lens—all parts of the report are in focus.

In contrast, the object-based model seeks to retain all data and iteratively restudy it to forge new connections between evolving objects. A GEOINT object can be defined as a digital data construct that holds intelligence data points that are relatable by a shared geographic location on Earth or in space. These data points, associated by a shared geographic location, do not need to be in the same data formats nor at the same points in a timeline. An object is allowed to "evolve" over time as new data are added and the analyst discovers the object has relationships with other objects. These object relationships are stored as digital tags in the database. As the object relationships are discovered and expand over time, networks of objects are created.

The ultimate power of an object is the data within the object are digitally tagged as "related" to each other and can therefore be manipulated at a more detailed level by advancing computer technologies. Data no longer needs to be pre-filtered and reduced to layer states for exploitation as a result of low computational power. Objects can exist either as unconnected containers of location-based information or as part of a larger data network of objects and relationships created either with or without filtering and selection criteria. This available computer-enabled option to filter or select criteria-based data first is dependent on the type of problem the analyst is trying to solve—at times there are known selection criteria (e.g.,, tanks usually stay on land); other times (especially with respect to big data analysis), the intent is to search for previously unknown and new patterns

7. W. Huang, P. Eades, and S. Hong, "Measuring Effectiveness of Graph Visualizations: A Cognitive Load Perspective." *Information Visualization*, 8(3), 139-152.

(e.g., financial trends, statistical traffic information via Google, or unconstrained growth in a market).

Both unconnected objects and object network types of information can promote tipping and queuing, a starting point for pattern or trend recognition (layers usually don't carry the change over time component) or prediction modeling. The exploitation options therefore are enhanced in the object paradigm. The computational power available today allows the data to be stored indefinitely and re-evaluated against different scenarios of interest—even scenarios that occur over extended periods of time (known as activity-based intelligence or ABI). Algorithms that will be developed in object-based GEOINT analysis will take this tagged data and search for known pattern matches. They will study object relationships that have been built in the database and compare with ground-truthed intelligence information.

Multiple intelligence hypotheses will be carried within computer memory simultaneously as they are investigated with no limitations caused by human cognitive constraints. As new data are added to the database, some scenarios will be proven false and others will be supported and become part of a static snapshot in the intelligence report. The ability to save and manipulate data in this fashion will enable analysts to more efficiently investigate multiple narratives, to share objects with other analysts, to build known pattern libraries over time to compare against, to examine intelligence patterns and activities over larger time periods, and to revisit earlier reports and re-analyze intelligence situations. This object-oriented data structure allows data to grow and change over time, and the motivating power for change is data knowledge builds on itself and can be shared with the entire analysis community via the digital cloud framework currently under construction.

Creating Change in Tradecraft, Training, and Thinking

In addition to understanding the object construct's motivating power for change, it is also significant to appreciate how technology has driven work structures, workflows, and tradecraft. Technology has a significant and often unappreciated influence on the workforce's belief of how work should be done. These beliefs can linger long after the introduction of new technology or work structures. This is the case with respect to the concept of "layers" in a GIS, the key technology and approach for today's GEOINT practitioner.

The tradecraft and learning implications of object-based analysis are far-reaching. Object-based analysis is an integrating methodology that promotes "making sense" of relations among different components of human behavior. The expert analyst creates models, which help to make the connection. Models are frameworks to help understand the nature of the problem, derive potential solutions, and anticipate constraints. Technology aids in the evaluation of the models. Object-based analysis aids the sense-making process by filling the gap *between* the conceptual and the logical levels. This approach involves observing, recording, and acting upon the world at small levels of detail. Models are built of objects and logically put together. Analysts assemble the world as they see it in space and time. Layer-based analysis is focused on planned-problem-solving. Planned-problem-solving relies on well-understood conceptual models and predefined logical map layers. "Predefined" poses challenges when applied to messy, real-world problems for which the conceptual and logical models cannot be completely predefined.

The implications for GEOINT training and education are significant. Cognitive research has identified "dimensions of difficulty" that require increased expertise.[8] The dimensions are situations requiring increased mental effort on the part of learners. A few of the key dimensions in object-based GEOINT are:

- Static map layers versus dynamic objects that are not organically organized as a map
- Discrete data represented as a static map versus continuously changing discrete objects
- Discrete organized data themes that are fixed at a time versus interactive data elements that can be constantly organized
- Homogeneous layers of an area of interest versus heterogeneous objects that comprise an area of interest

The "dimensions of difficulty" mirror the differences between analyzing layers of data versus objects. Object-based GEOINT analysis will require the analyst to meet the challenge of reasoning from objects, seeking and finding cues of actions within and across individual objects and time. Technology enablers will be developed that will aid the analyst, but this will take time and money and doesn't replace the fundamental shift in problem-solving culture that will be necessary to solve the more complex, multi-scenario problems facing the Intelligence Community.

There are many differences between layer-based and object-based GEOINT analysis. The following list of attributes demonstrates the differences:

1. Base Data Organizational Structure

a. Layer-based is grounded in relational database management systems (RDBMS) based on the relational model invented by Edgar F. Codd at IBM in 1970.

b. Object-based is grounded in object-oriented database management systems (OODBMS) that support the modeling and creating of data

8. R.R. Hoffman et al. (2010) Accelerated Proficiency and Facilitated Retention: Recommendations Based on An Integration of Research and Findings from a Working Meeting, Air Force Materiel Command, Report AFRL-RH-AZ-TR-2011-0001 p. 40.

as objects created by Michael Stonebraker and Lawrence A. Row—later defined by Malcolm Atkinson in 1985. All conceptual entities are modeled as objects.

2. Supporting Technology

a. Layer-based GEOINT technologies include electronic light tables, GIS software such as ArcGIS, and a number of specialty tools.

b. Object-based GEOINT technologies include OODBMS, big data technologies (search and match algorithms), technologies that data search, tag, and manipulate subsections of data that meet specific criteria (time window, location buffer on ground, etc.). Tags, once applied, are saved back into the object structures for future use.

3. Flexibility

a. Layer-based GEOINT placed in a standard layer format can be "stacked" in a viewer. It is usually a time static data view unless the layer is continuously updated and recreated.

b. Object-based GEOINT databases allow dynamic new object data updates and either snapshots in time or additional ongoing pattern matching, sorting, and new relationships building and saving data sifting via background algorithms that could run autonomously. Models can be formulated (object networks) and used as basis for hypotheses—"What if?" scenarios. As data is added, it will attempt to be "related" to existing models and objects, and if it doesn't match anywhere, it's not "thrown away" but saved for later comparisons.

4. Data Complexity

a. Layer-based GEOINT layers are usually "like-spec'd" types of data categorized together.

b. Object-based GEOINT objects are multi-INT, multi-spec data structures tied relationally via location on the ground. If two objects are "time coincident" at the same place on the ground, they are "suspect" for a relationship. Due to the multiple types of data that can be related, these objects contain lots of complex data types, however, the base object concept retains its relational simplicity. Standards for objects are being created at this time.

5. Time Orientation

a. Layer-based GEOINT layers usually contain data that is within certain windows of time to keep them relevant to each other for a report.

b. Object-based GEOINT objects are intended to grow over time and gain more and more data and relationships. Technology enablers allow analysts to take a "time slice" across the data objects in a geographic area or to follow objects across time (ABI) to tell a story or narrative. It's up to the reporter to pick the "view" of the data to present.

6. Data Tagging/Indexing

a. Layer-based GEOINT standard spec'd data contains metadata fields that can be searched by tools, and most imagery can be thumbnail represented in JPEG format.

b. Object-based GEOINT object data structures can grow and expand for any new types of spec'd data "related" by space/time to the existing object data. The key to the object is the word "relationship." Is the data linked in some way? It doesn't have to be spec'd the same in its raw input format—the key is to retain the fact that they are related, the detailed analysis within the data can happen later.

7. Extensibility for New Sensors

a. Layer-based GEOINT requires either tool updates to handle the new spec or new tools that know how to manipulate and display the data format when developing new layers for new sensors.

b. Object-based GEOINT tagging means any new sensor type can be related within an object structure. Calibrating the data for internal object comparison and fusion is still a tool-based task that requires some tool specialization, but, in the framework of the cloud and services, new algorithms may "plug and play" for situations such as these.

8. Hard Problems

a. Layer-based GEOINT layers have limits on how well they could present relationships in the data. Many hard problems had to be solved in the analyst's headspace and a textual dialogue presented in the report. These reports were difficult to relate to any earlier or later reports (tagging not very effective), so the continuity of time was usually hard to maintain.

b. Object-based GEOINT data is tagged and organized within a computer database structure so it can constantly (as need) be re-sifted digitally and new patterns or trends sought after—aka models matched. This presents huge benefits to the analysts as they don't lose previous history or information, they continue to add to the data in the relational model, and they can tag related data forward and backward in time. Taking different "views" of the data can present new insights that would not have been realized in the past.

9. Analyst Thinking Style

a. Layer-based GEOINT layers usually mean sifting "down" through the data. "Like go with like" types before the analyst can find a narrative that "fits" what is left. This leaves open room for biases when it comes to constructing narratives.

b. Object-based GEOINT objects retain "all" the data attached to them. They create relational links that can be manipulated across space and time and added to as new data appears. This can be a more complex 3D or 4D type of thinking than layers as the analyst has to remain cognizant of carrying multiple threads or hypotheses at once until some or all are ruled out—either due to newly discovered relationships that don't fit the models or new data that disproves a hypothesis. New hypotheses can always be created if the original ones don't work, as analysts keep the original data relationships intact in the database and can iteratively revisit the data with new thinking paradigms and models.

Conclusions

There is an imperative to move the GEOINT tradecraft beyond layer-based thinking. Layers of data will continue to exist, but an evolutionary change to object-based analysis is unavoidable. Object-based GEOINT provides richness not possible in the layer-based paradigm and enables the analyst to more accurately model the real world. No longer constrained by layers, analysts will more readily handle the complexities of today's problems.

The conceptual move from layers, the larger volumes of intelligence data, and the new analytic options will challenge the analyst. Anticipating this change is important. The geospatial analyst needs education and training to move to the object paradigm. The academic community must prepare GIS and GEOINT students to examine changes in objects in space and time. Students must learn how to identify forms, patterns, functions, and the diffusion of effects. Most importantly, the GEOINT Community needs to prepare analysts to cope with the increased complexity.

The Shifting Landscape: The Relationship between GEOINT and Human Geography

By Gwyneth Sutherlin, Ph.D.; William Chadsey; and Shannon C. Pankow

In the GEOINT Community, we must not only strive to see our environment, but to sense it. In the past, this has meant developing new technologies such as radar to enhance imagery and support the monitoring of physical objects and features in order to halt large armies or plan maneuvers. Today, threat comes in a different form—from non-state actors that operate online and off, waves of migration, climate changes that drive conflict, and webs of cross-border trafficking that span continents. Human geography (HG) constructs have provided analysts with the technology and capability to sense this type of threat, beginning with the use of location to understand, anticipate, and more deeply analyze the patterns of behavior among people who live in a given area.

HG as a Foundational Analytic Approach

HG is not only a discipline; it is an approach to analysis. It provides analysts with an understanding of the physical geography and the networks among people who live in a particular region. By relating groups of people and their attributes to location, HG is no longer a layer, but can be considered foundational GEOINT. Primary attributes that describe the sociocultural context of the people in each location are ethnicity, religion, language, and social relationships. Social relationships form the fabric of a society and can vary between and within cultures to include tribal allegiances, criminal networks, or oligarchic structures. It is the relationship between locations, people, and these attributes that generate many of the most complex human patterns, such as identity, motivation, bias, allegiance, dialect, and radius of influence for prominent individuals. Our origin is a significant part of who we are. Our beliefs and behaviors are influenced by the history and events of that location. Perhaps it is the place we strive to protect, the site of an attack that prompts retaliation, or the origin of our family name that gives us standing in the community. Groups and locations have a connection, and GEOINT can capture it through HG.

Understanding who is in the location where you are operating is as vital as knowing the location itself. For this reason, more and more GEOINT Community members—from law enforcement to media to humanitarian non-governmental organizations (NGOs)—are benefiting from HG methods, content, and technologies. Small satellites and unmanned aerial vehicles (UAVs) make it possible for humanitarian crisis responders and small organizations to link imagery with field data about human networks. Graph databases and cloud-based content make integrating relationships easy and fast. There is no longer a reason to separate data into layers. Relationships are the new model currency of GEOINT and HG represents the best manifestation of this currency. Using HG as a foundation to relate events from social media to radio towers, or roads to disease prevalence, makes physical data relevant to how human populations live, spend money, move, and react. HG provides analysts with an understanding of the relationship between the physical geography and the networks among people who live there so they can begin to sense relevant activities. A model that can leverage the full scope of HG will be able to meet the complex challenges the community faces with the State of GEOINT in 2017.

Human Geography and Gray Zone Conflict

Gray Zone activities exemplify the type of challenge for which HG is needed because they are inherently ambiguous and conducted through means that are difficult to detect. Gray Zone activities are defined as non-combat activities which have some level of aggression, occur between states or between states and non-states such as ISIL, and have a high level of ambiguity in terms of what policy or legal framework the activities fall under and how those activities are perceived and interpreted. Often performed alongside direct conflict,[1] Russian activities during the Cold War epitomized the Gray Zone challenge. Currently, Russia, China, Iran, and Saudi Arabia are pursuing agendas that bear similar marks. The HG GEOINT approach helps detect patterns to determine the effects of propaganda by connecting locations and actors. Using HG content situates ambiguous events or actors of unknown allegiance within a sociocultural network with attributes such as ethnicity, religion, language, and extended social relationships. The HG content serves as a foundation to begin exploring complex and uncertain Gray Zone activities that have evolved from or threaten to escalate to the overt conflict environment. The HG GEOINT approach provides analysts with a way to "map" Gray Zone activities and provide support in any counter measures.

HG and Violent Extremism

One of the most pernicious Gray Zone activities is the spread of propaganda, ideology, and even recruitment. Violent extremist organizations (VEOs) have been highly successful at exploiting social media to recruit across a variety of cultures and even orchestrate terrorist acts. The White House Executive Order (EO) "Developing an Integrated Global Engagement Center to Support Government-wide Counterterrorism Communications Activities Directed Abroad" created a strategic counterterrorism narrative to diminish the influence of VEOs abroad.[2] This EO further instructed how the messaging will involve partnership building to communicate a positive and resonant narrative. To achieve this goal means determining the VEO's audience and influencers, locations, and intragroup content, as well as how to identify local partners connected to those audiences that can successfully counter message. GEOINT that leverages HG relationships can help link the online communication network to the offline geography of the members of that network so analysts can support the development of counter messaging. Understanding the content and the individuals in the networks comes from the context of location, which is why an HG GEOINT approach will be successful in supporting the counterterrorism messaging efforts.

A strong counter to violent extremism is development. Diminishing the "push" factors of poverty, poor governance, low levels of education, and poor access to health services increases security. To address these challenges requires the integration of sociocultural data with physical feature data. For example, using HG, development agencies and nonprofits can determine if the physical location of a planned school or food program will unfairly benefit a particular group because of the location. Similarly, for development projects in post-conflict regions, such as those planned for Iraq, HG is invaluable when determining which groups have a claim to which locations. This is vital to understand and prepare for resettlement of displaced persons and refugees as well as for vetting partnerships and hiring staff. Preference or bias to a group in one location could affect operations in a location far away due to social relationships. Cohesive planning will involve foundational GEOINT—HG.

HG Crosses Borders

It is the cross-border nature of many threats that makes GEOINT essential and foundational. For example, by adapting the historic Saharan trade routes between the Levant and West Africa, ISIL has connected terror cells such as the Tuareg in Northern Mali with ISIL in Syria to procure weapons, supplies, and income sources. There is an increase in drug traffic from West Africa into European markets, the proceeds of which are alleged to support ISIL activities. Illicit trafficking networks frequently take advantage of porous borders and instability of conflict environments to hide, and they offer a convenient network for VEOs to exploit. An HG approach can assist in understanding the locations and relationships among these overlapping networks to support their disruption. HG captures the global relationships among these groups and allows us to sense threats that are based in relationships and not otherwise visible to map. This approach allows analysts to contribute points of financial and resource disruption within ISIL's network in order to help dismantle the terrorist organization.

1. Philip Kapusta, "The Gray Zone." *Special Warfare* 28, no. 4 (2015): 18-25. http://www.soc.mil/swcs/SWmag/archive/SW2804/October%202015%20Special%20Warfare.pdf.
2. Barack Obama, (2016). *Executive Order 13721: Developing an Integrated Global Engagement Center to Support Government-wide Counterterrorism Communications Activities Directed Abroad and Revoking Executive Order 13584* 81, no. 2 (March 17, 2016): 146850. United States: Office of the Federal Register. https://www.hsdl.org/?abstract&did=791347.

Population flows across the geography, whether groups are fleeing conflict or seeking resources, thus the community is better prepared to meet the challenge by linking the groups to their geography. Such is the case for pandemic risk preparedness. The sources, onset, and spread of pandemics depend critically on sociocultural mores, psychosocial response, and messaging effectiveness. Recent examples, such as the Ebola outbreak in West Africa, demonstrated that big data analytics cannot help in regions that do not produce data. "Unsafe burial practices were responsible for about half of new Ebola cases in some areas. We had to understand these traditions before we could persuade people to change them," said Anthony Banbury, former United Nations (UN) Assistant Secretary General for Field Support.[3] Banbury persuaded the UN to hire their first anthropologist because he surmised that sociocultural knowledge of the location would provide more operational guidance than big data models. With early adoption of HG as foundational GEOINT for disaster preparedness, including pandemics, these sociocultural models would already have been in place to guide, filter, and alert critical issues such as this.

Tracking climate change and its effects on population movement provides data that can be used to combat cross-border trafficking of people for forced labor and the sex trade. We see these effects in countries such as Vietnam, where a multi-year drought and accompanying salinization of water sources and croplands has led to entire communities being forced to abandon their homes and fields. Able-bodied workers are enticed by fraudulent offers of work that entrap them in forced labor or slavery. The elderly, infirm, and young are left to fend for themselves, making them easy targets for human trafficking, especially young girls and boys.[4] By utilizing data related to population movement due to climate issues, HG analysis can be used to pinpoint areas most vulnerable to human trafficking to support law enforcement and anti-trafficking law and policy development.

Many GEOINT Communities Relate Through HG

The populations of dense urban environments called megacities most acutely feel climate crises. Using only satellite imagery, sensors, and technologies to monitor physical features like electrical grids and roads has proven difficult to analyze potential risks associated with these locations such as pandemics and terrorist networks that can easily blend into a non-traditional battlefield. GEOINT that approaches megacities as a web of relationships between infrastructure and the populations that occupy it provides richer operational information to understand subcultures, population pockets, and micro-networks to help analysts map and prepare for the unique risk set megacities present.

Another labyrinthine problem where a HG GEOINT approach is appropriate is wildlife trafficking. Countering this illicit trade has seen an increasing commitment and driven partnership across government, NGO, academic, and private organizations—thanks, in part, to the Obama Administration's Presidential Task Force on the issue. The patterns of wildlife trafficking are similar to terrorist or criminal networks that smuggle illicit weapons, oil, drugs, or even humans. Routes take advantage of insecure or unstable regions, particularly those with porous borders.[5] Imagery alone cannot see these routes. For example, in China, the rise of rhino horn purchases is linked to the production of replicas of ancient carved cups held by emperors to signify wealth, which has taken on significance in China's growing economy. The relationship between groups of people, the sociocultural driver of the illicit trade, and the locations can be combined in GEOINT with HG to coordinate law enforcement efforts, inform policy about where "road blocks" would be effective in the illicit network, and to disrupt the drivers of the trade.

Conclusion

Some might ask, is this approach really GEOINT and is it truly foundational? This skepticism comes from those who believe GEOINT should stay true to its roots and focus on imagery and terrain. However, the nature of the problems the GEOINT Community is challenged to support has changed. Each time the environment or situation demanded new methods and technologies, the community responded by providing a measure and means to sense that environment in order to prepare, plan, respond, and be resilient. In 2017, the GEOINT Community must continue to evolve by shifting HG into use as a foundational and wholly integrated approach rather than a peripheral layer. Using HG practices to integrate and relate GEOINT and other sources gives analysts the context and baselines necessary to understand different places and cultures, behaviors and motivations, and sense what cannot be seen—the constantly shifting sociocultural landscape.

3. Anthony Banbury,. "I love the UN, but It Is Failing." *The New York Times*, online (March 20, 2016). http://www.nytimes.com/2016/03/20/opinion/sunday/i-love-the-un-but-it-is-failing.html?_r=0
4. TUOI TRE NEWS. "Drought Forces Vietnam's Mekong Delta Residents to Leave Home, Family for Work. " *TUOI TRE NEWS*, online (May 6, 2016). http://tuoitrenews.vn/34652/drought-forces-vietnams-mekong-delta-residents-to-leave-home-family-in-search-of-work. (See also vnmission, "2016 Trafficking in Persons Report." *U.S. Embassy and Consulate*, online (July 1, 2016). https://vn.usembassy.gov/2016-trafficking-persons-report-vietnam/.
5. Jihan Seniora and Cédric Poitevin, *Managing Land Borders and the Trafficking of Small Arms and Light Weapons*. Brussels, Belgium: Groupe de recherche et d'information sur la paix et la sécurité (GRIP), 2010. http://www.poa-iss.org/KIT/2010-GRIP-Report-EN.pdf.

The Rise of the GEOINT of Things

By Stuart Blundell, Gabe Chang, David Foster, and Michael Hauck

The Internet of Things

The Internet of Things is one of the 10 elements comprising the GEOINT Revolution as described in the 2016 State of GEOINT Report. Arguably, it has been with us for about a decade now, but is still in its infancy. Even less mature, but just as inevitable, is the GEOINT of Things (GoT) being born out of the Internet of Things (IoT).

What is the GEOINT of Things? Imagine you have a trillion agents running around the planet doing your bidding. The Internet of Things is the current world of billions (and soon, trillions) of interconnected things that sense, think, act, and communicate. These things exist physically somewhere, so they have a location in “geospace.” IoT is inherently geospatial, so this is a huge opportunity for GEOINT practitioners to expand the domain of their tradecraft, especially when we consider what some of these “things” are. They can be as discreet as a tire pressure monitor on a car, or as ubiquitous as a security camera at a retail outlet. They can be as sophisticated as a drone making a 3D map in real time, or as dumb as a sensor in a basement detecting moisture. How powerful is this paradigm? Consider the supervisory control and data acquisition (SCADA) systems of 30 years ago, compared with those of today that are networked globally with access to elastic computing, crowdsourced data, artificial intelligence algorithms, and banking systems. Geospatially accurate, location-based data are poised to become the transactional currency of GEOINT.

However, GoT is not yet the overarching paradigm it is destined to become as GEOINT shifts from an age of paper maps and a handful of billion-dollar satellites to a new age of geospatial big data. In 10 years, the nature of GEOINT will be drastically different, and GoT will be a major element of that shift. Recent market reports on geo-location intelligence estimate that by 2020, 20 to 30 billion devices—not counting computers, smartphones, and other mobile devices—would be connected to the internet and generating location data.

Transforming the Ubiquitous IoT into the GoT

Smartphones are the most obvious element of IoT. There are now more than a billion of them all over the planet, even in the least-developed countries. Smartphones are on most of the time, and they move through space and time as people eat, sleep, work, shop, and play. These devices are connected to a global telecommunications network that interoperates across time zones, languages, political systems, financial environments, and social contexts. The devices tend to have sensors to detect shock, light, temperature, barometric pressure, battery status, radio frequency (RF) signals, and, of course, location. Cameras on these phones are getting more sophisticated with each new release—more and more phones are capable of conveying 3D depth perception using stereoscopic camera technology. Smartphones run applications that enable them to access and control other smartphones (e.g., family trackers and enterprise management software), wearable electronic devices (e.g., fitness trackers), lighting and thermostats (e.g., smart home switches and products such as Nest), and even unmanned systems and satellites (e.g., apps such as Parrot’s FreeFlight and Orbit Logic’s SpyMeSat).

Transportation systems are another great example of the way in which IoT has become part of modern life. By its nature, transportation is about movement, so an instrumented transportation system knows when things are where and whether they are moving or otherwise changing. Transportation “things” are now widely interconnected under the rubric of intelligent transportation systems. The things include vehicles, traffic control signals, navigation systems, tollbooths, parking meters, and even cargo. For example, vehicle telemetry systems such as GM’s OnStar know when a vehicle has been in an accident, prompting an automatic call for emergency services. Transponders report legal weight, safety ratings, and credentials as trucks continue down the highway while legally bypassing weigh stations. Other transponders automatically debit an owner’s account as vehicles drive through tollbooths. In many cities, parking meters are now connected to the internet and able to take payments by credit card. Even traffic signals are networked, some now with cameras designed to report red light violations, and others that can be centrally controlled to adjust for real-time traffic conditions. Most shipping containers are now tracked with RFID devices or scanner codes. And, most obviously, on-board navigation systems are connected to the internet—in many cases with two-way communication, so the system can learn from the experience of each navigator in real time. It’s not just cars and trucks, either. Airplanes, ships, busses, and trains are increasingly connected.

IoT as an Economic Force

One common misconception is that IoT is new. As sensors become ubiquitous, the actual cost to produce each unit declines. Marry decreasing per unit cost with improved communications bandwidth needed to support the volume of data analysis and transactions, and the value to governments and businesses at all levels continues to grow. Back-end processing is increasingly powerful and cost-effective.

More than nine billion devices are connected to the internet, including computers, smartphones, tablets, and more, and this number is expected to rise dramatically within the next decade. These devices make measurements continuously, thereby creating a history of measurements that can be analyzed in space and time to detect motion or other change.

In the weather domain alone, The Weather Company, now owned by IBM, ingests more than 100 terabytes of third-party spatiotemporal data daily from more than 800 different data sources, including satellites, personal weather stations, smartphone pressure sensors, and more. As one of the largest IoT platforms in the world, forecasts are produced for 2.2 billion locations every 15 minutes.

People who work in aviation, energy, insurance, media, and government rely on weather information for data, technology platforms, and services to help improve decision-making and respond to weather's impact on business.

Instrumented, Interconnected, and Intelligent

There are many challenges to unlocking the value in IoT. Building the framework to support IoT infrastructure can be quite complex. In ensuring a robust infrastructure, one must support a world that is increasingly instrumented, interconnected, and intelligent. To address these IoT challenges, one must consider:

- **The range or variety of devices:** How to quickly connect a broad range of new and legacy devices.
- **Awareness at scale:** How to capture big data from devices at scale without stressing networks.
- **Real-time analytics:** How to analyze in-flight data to predict, detect, optimize, and anticipate.
- **Easy orchestration:** How to rapidly wire devices together and create logic without programming.
- **Enabling Access:** How to expose and monetize information and services while maintaining privacy and security.
- **Geolocation:** What level of accuracy and precision is needed; and, fundamentally, how to fix a location, especially inside structures, underground, or beneath water.

Is IoT-Derived Intelligence Really GEOINT?

Is IoT really GEOINT? Not traditional GEOINT perhaps, but if not GEOINT, than what kind of INT? Each thing exists in physical space at a particular time and may be permanent or ephemeral, static, or in motion. To the extent that each of these things collects and shares time- and location-stamped data about its environment or activity, IoT provides an unprecedented rich source of geospatial information. The volume of data is mind-boggling, and the data is constantly changing in response to natural and artificial activity. Imagine the possibilities for discerning patterns of activities and relationships among actors. Imagine the power to visualize connections between things and people as they change over time, and for simulating future possibilities.

This is not a future world. It is the world of today that we are just beginning to appreciate in a new way. So why don't we notice it? Like the integrated circuit chip, IoT is embedded in our infrastructure and so tightly integrated with our daily lives that we take it for granted. And that is exactly why GoT can be such a powerful paradigm for making sense of all-source intelligence. Moreover, the physical nature of GoT makes intelligence information all the more actionable. Each thing exists in time and space, so each sensor measures uniquely from a particular location at a particular time. Time- and location-stamped data in motion forms a basis for historical analysis, state description, and predictive analytics, which can then be used to take action.

Trial Definition for GoT

What is the GEOINT of Things? Certainly, it is a new concept awaiting a definition, so here is a proposed definition:
GoT is the intersection of rapidly evolving, interdependent, and widely available knowledge environments and technologies accounting for integrating, leveraging, and describing location, time, and relationships between humans, objects, activities, and their physical and terrestrial surroundings enabled by the networked age. In this paradigm:

- GoT impacts everyone connected to the IoT and even those who are not. Its varied effects (good or bad) also extend to the 4.2 billion without internet access due to decisions made and actions taken by governments, industry, non-government organizations, and private actors.
- Everyone is a sensor, to what degree depends on their level of connectedness, activity, and, exposure.
- Everything has the potential to be a sensor.
- Everything is somewhere, nothing is nowhere.
- Every measurement is made at a particular location and time.
- Because it is part of everyday life, location's extraordinary value may easily be taken for granted, overlooked, or underappreciated, but nonetheless is relevant to daily individual and organizational activities.
- The IoT is dynamic—things are constantly in motion, and the data constantly changes with time.

Enablers of GoT

Another interesting feature of GoT is it inherently benefits from crowdsourcing of both data and analytics. Because things either make measurements, commit actions, or both, the greater the number of things and the more different kinds of things that participate in the data stream, the better. As the world becomes more connected, the data that record human and machine activity becomes increasingly diverse and powerful. Such large volumes of data can complicate the analysis, but commercial services that exploit particular aspects of the data use cloud platforms and crowdsourced analytics to make correlations for specific applications such as location-based advertising, shipping logistics, supply chain optimization, and even commodities trading.

To fully exploit GoT will require massive compute power and telecommunications pipes because the number of interconnected things is already in the billions and headed toward the trillions. Each of these things may be capable of making multiple measurements and taking multiple actions per minute. Many of these things will be moving, so historic locations, patterns of motion, and physical proximity of things will need to be stored and analyzed, leading to predictive models of future locations and interactions. It is easy to see how quickly the volume and velocity of data will grow over time. Imagine the current challenge of maintaining signals intelligence (SIGINT) capability, and then multiply the volume of data by trillions. Today's SIGINT challenges will seem small compared with tomorrow's GoT challenges.

Artificial Intelligence Meets GoT

Accompanying the revolution in location-based intelligence from IoT is a growing use and acceptance of artificial intelligence (AI) both in the fields of machine learning and computer vision. In a recent *New York Times* article by Quentin Hardy, major commercial software companies such as GE, Oracle, *salesforce.com*, and many others are investing in AI to unlock the hidden value of their data using technologies such as machine and deep learning. The traditional GEOINT applications of AI have largely focused on geospatial data production problems. With the advent of relatively inexpensive cloud computing resources, more AI applications are being developed to detect unusual patterns in data that more often than not have a location component. In an era of big data that includes mountains of Earth observation imagery, the shifting focus in the GEOINT Community is on the detection and visualization of patterns in geospatial data rather than extracting features such as the exact rooflines of a house. It's great to have the building footprints, but the real money and intelligence is in the detection and anticipation of patterns and behaviors.

To meet these GoT-induced challenges, global GEOINT practitioners must adapt. The production of geospatial products (e.g., imagery composited from sensors that are part of the IoT) will be automated by necessity because no human will be able to keep up with the volume and velocity of data. Preliminary analyses will similarly be automated by necessity. Therefore, the workforce will need: the expertise to capture and organize the torrents of data from a wide range of time and location-enabled sensors; the domain expertise to recognize the difference between information and mere data; and the skills to visualize and form information products in a compelling way that enable decision-makers to quickly see what is important amidst a data sea of complexity, detail, and unimaginable quantities. The evolution of IoT into true GoT is already underway. It is up to the GEOINT Community to build into its existing business practices and academic curricula the methodologies and opportunities for current GEOINT analysts to work with and experiment with IoT data.

Small Satellites: The Future is Brighter Than Ever

By Mary E. (Becky) Cudzilo; Christopher DeMay; Jolyon D. Thurgood, Ph.D.; and Darrel L. Williams, Ph.D.

From the University of Surrey's launch of technology demonstrator UoSAT-1 in 1981 to the 2016 launch of BlackSky's 1-meter optical imager Pathfinder-1, small satellites have changed the face of overhead geospatial data collection. Each year, small satellites become even smaller, more sophisticated, more capable, and less expensive. It is predicted that small satellites (under the currently accepted definition, systems weighing more than 12 kilograms and under 500 kilograms) will soon replace or at the very least augment larger, more exquisite satellites[1] as the industry offers less expensive alternatives that can be deployed and improved at a much faster pace.

In the past, small satellites were considered university research projects—cube sats that students built to have fun and learn about satellites. Cube sats are miniaturized satellites constructed using multiples of 10 x 10 x11.35 centimeter cubic units called a "U" and are typically less than 1.33 kilogram mass per unit. That perception of small satellites has proven to be both stale and shortsighted. While cube sats are in the news as the flavor of the year,[2] fully capable small satellites are becoming highly adept at making money. A recent U.S. government example of this is the National Geospatial-Intelligence Agency (NGA) awarding $20 million to Planet to utilize imagery from the company's 6-kilogram cube sats.[3] Outside of the government domain, small satellites are moving forward commercially; for example, Sierra Nevada Corporation building the next-generation ORBCOMM fleet of 18 or more 130-kilogram small satellites.[4] According to *SpaceNews*,[5] venture capitalists invested $1.8 billion in space companies in 2015—more than twice the amount received in the preceding 15 years combined. Whether small satellites are launched for Earth observation, science, or for other commercial data acquisition, there is both money and mission to be found, as *Fortune* confirms.[6]

Many ask are small satellites capable enough to replace or augment large satellites? The miniaturization of technology and an entrepreneurial environment ripe for new opportunities have advanced small satellite technology into the competitive marketplace. Consider that satellites the size of IKONOS, at 817 kilograms, launched just 16 years ago, are now being replaced with 83 kilogram systems such as Terra Bella's SkySat small satellites, which offer the same agility, accuracy, and resolution. Fully redundant, very capable systems are being built and can even be purchased online through the NASA Rapid Spacecraft Development Office (RSDO)[7] or directly from spacecraft providers. Each bus can be defined and specified uniquely from a basic standard model to include full redundancy.[8]

Small satellites fulfill roles hidden in plain sight that many people are unaware of. Galileo, the global navigation satellite system (GNSS) that is currently underway by the European Union (EU) and launched by the European Space Agency weighs in at 675 kilograms for each of the 14 satellites already launched and replaces existing Global Positioning System (GPS) access to the 1,415-kilogram GLONASS system with the same redundant architecture and commercial capabilities. In addition, MDA's RadarSat-2, at 2,200 kilograms, is used in conjunction with ExactEarth-1's automatic identification system (AIS) to provide maritime domain awareness to the U.S. Coast Guard and Department of Homeland Security.[9] While ExactEarth-1 is a small satellite at 100 kilograms, the capabilities of both satellites will be encompassed in a single next-generation synthetic aperture radar (SAR) system. In March 2017, Surrey Satellite Technology will launch NovaSAR, which has small, 3-meter by 1-meter SAR and AIS payloads combined,[10] providing commercial small satellite maritime domain awareness capability in a small

1. Paul Voosen, "NOAA Issues First Contracts for Private Weather Satellites." *Science*, September 16, 2016, http://www.sciencemag.org/news/2016/09/noaa-issues-first-contracts-private-weather-satellites; see more at http://spacenews.com/41836amos-conference-us-air-force-planning-three-satellite-replacement-for/ and http://www.coloradospacenews.com/surrey-satellite-us-wins-nasa-contract-for-landsat-instrument-study/.
2. Elizabeth Howell, "CubeSats: Tiny Payloads, Huge Benefits for Space Research." *SPACE.com*, October 6, 2016, http://www.space.com/34324-cubesats.html.
3. "NGA Introductory Contract with Planet to Utilize Small Satellite Imagery." *NGA.mil*, October 24, 2016, https://www.nga.mil/MediaRoom/PressReleases/Pages/NGA-introductory-contract-with-Planet-to-utilize-small-satellite-imagery.aspx.
4. Turner Brinton, "Sierra Nevada Ramps Up Small Satellite Assembly Line." *SpaceNews*, April 24, 2009, http://spacenews.com/sierra-nevada-ramps-small-satellite-assembly-line/.
5. Debra Werner, "Sure, NewSpace Is a Big Deal." *SpaceNews*, April 11, 2016, https://www.spacenewsmag.com/feature/sure-newspace-is-a-big-deal/.
6. Clay Dillow, "Here's Why Small Satellites Are So Big Right Now." *Fortune*, August 4, 2015, http://fortune.com/2015/08/04/small-satellites-newspace/.
7. Rapid Development Spacecraft Office, NASA, "Spacecraft Catalog," May 16, 2016, https://rsdo.gsfc.nasa.gov/catalog.html.
8. Committee on Earth Sciences Space Study Board, *The Role of Small Satellites in NASA and NOAA Earth Observation Programs*, Chapter 4. Washington, D.C.: The National Academies Press, 2000, https://www.nap.edu/read/9819/chapter/6.
9. U.S. Department of Homeland Security, United States Coast Guard, "AIS Class A Ship Static and Voyage Related Data (Message 5),", http://www.navcen.uscg.gov/?pageName=AISMessagesAStatic.
10. Surrey Satellite Technology, "NovaSAR-S—The Small Satellite Approach to Synthetic Aperture Radar," https://www.sstl.co.uk/Downloads/Brochures/115184-SSTL-NovaSAR-Brochure-high-res-no-trims.

fully redundant package of 400 kilograms. Even NASA's Jet Propulsion Laboratory are utilizing small satellites to investigate long-term climate change.[11]

According to research by Surrey Satellite Technology US, 20 to 30 50-kilogram to 500-kilogram satellites are launched per year, thereby rapidly overtaking launches of 500-kilogram or larger satellites annually. This number is restricted to slightly larger systems and does not include the sizable number of cube sats Planet is launching. Some of the numbers are based on the trend toward small satellite constellations—starting with the five-satellite RapidEye constellation in 2008—which has now exploded into the aspirations of a broad and diverse generation of new companies such as Aquila, BlackSky, GeoOptics, HawkEye 360, Hera Systems, Iceye, OneWeb, Planet, Satellogic, and Spire.

Technological advances have enabled small satellites to compete in the large satellite world as many facets of satellite technology have become smaller.

- New solar panel cell technology combined with honeycombed aluminum or carbon fiber enables small satellite panels to be lighter, smaller, and less expensive.
- Lithium-ion battery technology has drastically improved in the last 10 years to provide more consistent power in a smaller, lighter package.
- Star tracker technology now enables single-, dual-, and triple-headed configurations to provide precise attitude accuracy in a two-kilogram package.
- A new micro-cooling unit developed by Lockheed Martin is opening up the small satellite market for thermal and infrared imaging.
- Honeywell International has micro-electromechanical sensors—high-performance inertial packages that used to require 33 cubic inches of space but now fit into two cubic inches.[12]
- TiNi Aerospace provides smaller franibolts and release mechanisms that enable smaller mass with the same reliability.
- Blue Canyon Technologies,[13] Surrey Satellite Technology,[14] and Millennium Space Systems[15] all offer highly capable reaction wheels for small satellites.
- Small motors are now available to reduce mechanism sizes.[16]

Plans were recently announced at the 2016 Small Satellite Conference in Logan, Utah, for the manufacture of many different types of small propulsion systems based on electrospray, micro-RF ion, ammonia-fueled micro-resistojet, green monopropellant, and micro-pulsed plasma thrusters. This rapid miniaturization and advancement in hardware required for a capable satellite allows for a smaller, cheaper package to be built with similar payload capabilities as larger, traditional satellites.

Given modern budget constraints, leveraging lower-cost small satellite constellations will allow organizations to provide enough funding and thereby improve revisit times and mitigate the effects of random failures or gaps in coverage. The NASA Sustainable Land Imaging (SLI) Office is targeting a small satellite constellation for the Landsat-10 era to take advantage of increased capabilities, coverage, and revisit times. In 2014, the SLI Office had six companies investigate whether a Landsat-8 compliant optical and thermal imager, including calibration mechanisms, could be built to fit on a small satellite.[17] Multiple fully compliant, fully redundant designs/prototypes were developed for one-fifth the cost of the current Landsat system and presented at the Joint Agency Commercial Imagery Evaluation conference.[18] In 2016, the NASA Earth Science Technology Office awarded six more projects to develop technologies for smaller Landsat-compatible instruments, one even seeking "spectrometer on a chip" technology.[19] NASA is looking to the future, where they can build many smaller versions of the single large satellite to satisfy user requests for more revisits and more coverage.

This evolution of technology that is allowing small satellites to complement and replace earlier generations of space assets comes at a time of accelerated change in related areas such as big data analytics. Even without the explosion of small satellite systems deployed in the form of constellations, data overload is the new reality for users. The amount of data that small satellite constellations are generating is causing small satellite companies to build their overall architecture with vertical integration in mind, ensuring their offerings are more about answering questions than providing pixels. The traditional roles of Earth observation such as satellite operators and the associated "value-added" community are disappearing. DigitalGlobe, HawkEye 360, and smaller companies such as Hera Systems not only offer raw data to customers but also solutions such as apps to extract

11. NASA Jet Propulsion Laboratory, "NASA Small Satellites Will Take a Fresh Look at Earth," November 7, 2016, http://www.jpl.nasa.gov/news/news.php?feature=6671.
12. Honeywell, "Satellite Guidance and Attitude Control,"https://aerospace.honeywell.com/en/products/navigation-and-sensors/satellite-guidance-and-attitude-control.
13. Blue Canyon Technologies, "Reaction Wheels–High Performance Attitude Control," http://bluecanyontech.com/portfolio-posts/reaction-wheels/.
14. Surrey Satellite Technology, "Attitude and Orbit Control Systems,"http://www.sst-us.com/shop/satellite-subsystems/aocs.
15. Millennium Space Systems, "Reaction Wheel–RWA1000," http://www.millennium-space.com/brochures/RWA1000Brochure.pdf.
16. Physik Instrumente (PI) GmbH & Co. KG, "PiezoWalk® Piezo Motors—Nanometer Precision with a High Feed Force," https://www.physikinstrumente.com/en/technology/piezoelectric-drives/piezowalk-piezo-motors/.
17. NASA Goddard, "About NASA Sustainable Land Imaging," https://sustainablelandimaging.gsfc.nasa.gov/.
18. USGS, "JACIE Program and Presentations," https://calval.cr.usgs.gov/archive/jacie-2015/3446-2/.
19. NASA Earth Science Technology Office, "17 Projects Awarded Funding Under the Instrument Incubator Program (IIP)," https://esto.nasa.gov/files/solicitations/IIP_16/ROSES2016_IIP_A42_awards.html.

meaning from the data and merge it with other information to deliver a new level of analytics.[20] Small satellites may become the key element in proving the power of this new space infrastructure.

The next step for small satellite companies to fully compete with or augment large satellite operators will be to improve complex, onboard processing capabilities to allow decision-making and automated tasking without a ground system in the middle. Since small satellites traditionally have less power, mass, and space than large satellites, increased onboard processing capability will be key to pushing small satellites forward. Digital technologies continue to improve at a rate of approximately twice the performance every 18 months in a combination of speed, processing power, or density, therefore, increased computing power on small satellites is becoming a reality. Hera Systems' designs already incorporate onboard analytics to provide near real-time solutions and alerts,[21] as a complement to the more conventional downlink for ground processing. In addition, onboard computers with enhanced capabilities to support satellite processing are being developed by a number of companies.[22] Applications are being developed for these onboard computers that will allow small satellites to redirect their tasking based on real-time knowledge of what is needed, without a human in the loop. The new threat of cyber attacks in space will require not only large satellites to be protected but also small satellites.[23] Increased processing capabilities will be key to supporting onboard cybersecurity in a small satellite package.

Government and commercial small satellite solutions have begun to converge into compact, sophisticated packages that provide what the end user desires in real time and on demand within the required budgets and timelines. The technology improvements for smaller subsystems and capabilities are allowing small satellites to become the new workhorse throughout the space industry. With low-cost, agile, robust solutions now available in small satellites, the timeline for improving all customer capabilities is now measured in years, not decades.

20. Carrie Shaw, "Satellite Companies Moving Markets." *Quandl.com*, July 6, 2016, https://blog.quandl.com/alternative-data-satellite-companies.
21. Doug Messier, "NASA, Hera Systems Enter into Remote Sensing Space Act Agreement," http://www.parabolicarc.com/2016/08/05/nasa-hera-systems-enter-remote-sensing-space-act-agreement/.
22. Ran Ginosar, "Survey of Processors for Space," http://www.ramon-chips.com/papers/SurveySpaceProcessors-DASIA2012-paper.pdf.
23. The Aerospace Corporation, "The Cyberspace Operational Environment," http://www.aerospace.org/research/mission-assurance/cyber-security/.

Unmanned Aerial Systems: A Maturing GEOINT Tool

By Andrew Shepherd; Shawn Kalis, Ph.D.; and Ronald Storm

The past few years have seen dramatic advances in the capabilities and applications of all types of unmanned systems, progress which has been paralleled by equally impressive reductions in cost, complexity of operations, and regulatory barriers. Perhaps the most notable changes in the United States have been in the realm of unmanned aerial or unmanned aircraft systems (UAS).

For the past decade, UAS have been considered large platforms requiring large investments to capture quality imaging. Due to the recent investment and advancements in technology by companies such as DJI, which in 2015 was valued at $10 billion,[1] remote-controlled aircraft previously considered toys have become professional products with truly autonomous flight capabilities, 4K imagers, image stabilization and collision avoidance systems, 30-minute flight times, integrated mission-planning capabilities, and even computer vision capable systems, such as Follow Me, which will use visual recognition to track individuals.[2,3] This new generation of UAS, which is often referred to as "Prosumer Grade," has changed the price point to collect recent, rapid, and relevant imagery for applications where imagery collections were cost-prohibitive.[4]

DroneApps, which recently developed a case study on imagery costs, said: "One area where the price comparison is relatively simple is unit price. The total cost of the launch and operation of the Landsat 8 imaging satellite was estimated by NASA to be in the region

1. Ben Popper, "Drone Maker DJI Nabs $75 Million in Funding at a $10 Billion Valuation." The Verge, May 6, 2015, http://www.theverge.com/2015/5/6/8554429/dji-75-million-funding-investment-accel-10-billion-valuation.
2. DJI Phantom 4, https://www.dji.com/phantom-4.
3. FOLLOW ME - GPS and Visual Tracking, http://blog.parrot.com/2016/10/31/follow-now-drone-can-follow-adventures/.
4. Patrick C. Miller, "Consumer Drone Sales Expected to Skyrocket in Coming Decade." UAS Magazine, January 21, 2016, http://www.uasmagazine.com/articles/1403/consumer-drone-sales-expected-to-skyrocket-in-coming-decade.

of $855 million. A Cessna 172 airplane, a model regularly used for aerial imaging, costs roughly $300,000. A professional automated mapping drone like senseFly's eBee RTK costs about $25,000, while DJI's Phantom 3 UAS, which hovers on the border of the consumer and professional markets, is around $1,000."[5] When imagery costs drop orders of magnitude, it is valuable to explore the advancement in the new generation of Prosumer UAS.

Before exploring the current state, future, and implications of UAS in GEOINT, it is helpful to establish a standard definition from which to build a common understanding.

UAS are also known by other names, including remotely piloted aircraft (RPA), unmanned aircraft (UA), unmanned aerial vehicles (UAV), and perhaps most commonly—and sometimes controversially—drones. For the purposes of this article, we will use the UAS nomenclature because it best describes the technology as a multifaceted system, many of the diverse onboard sensor systems directly apply to GEOINT, and it is the term used by the Federal Aviation Administration (FAA) when referring to unmanned systems operating in the National Airspace System (NAS). As the UAS is a system of systems, it may be divided into the following six major elements: 1) the aircraft itself, a broad variety of which have been developed to serve an ever-expanding application space; 2) the payload, which are tools carried to meet specific objectives driven by the UAS mission requirements, often taking the form of a sensor—a key component for GEOINT applications—with the sensor type being determined by the collection requirements; 3) the command and control suite used to guide the UAS to and from the mission areas; 4) the communication data links that carry the command and control and sensor information to and from the platform; 5) the launch and recovery components; and 6) the most important component, the human in the loop. It is important to recognize the true system of systems nature of UAS, particularly those that have utility for GEOINT applications, always keeping the requirements and objectives in the forefront when considering the value of UAS for any application.

Small UAS: What Has Changed?

The intelligence and defense communities have benefited from the integration of UAS capabilities for several decades. However, many of the advantages were realized in overseas operations, within restricted airspace, and through waivers that allowed operation in the U.S. An impetus for the sea change from solely government or research and development activities to general commercialization has been the rapid development and integration of commercial technologies in the small UAS and sensor systems, at affordable prices, that now meet market needs in a broad range of use cases. The cost of entry has decreased from hundreds of thousands to just a few thousand dollars for a GEOINT-capable, professional UAS solution. Sensor technologies that were once only carried on board a large UAS, like the U.S. Air Force Predator or Global Hawk, are now mounted on lightweight UAS used by police departments, power companies, agricultural firms, videography businesses, college researchers, etc. The accessibility of such systems is due to the significant reduction in aircraft and sensor size, weight, and power (SWAP) requirements brought about by micro-computers, integrated circuitry, the developments in solid state memory, and wafer-level optics and packaging technologies, just to name a few. In addition to the familiar cellphone electro-optical (EO) still and motion video cameras that were first mounted on small commercial UAVs, there now exist miniaturized multispectral and infrared (IR) technologies that have become readily available for use on small commercial platforms. Additionally, 12-ounce phased-array radar systems and Light Detection and Ranging (LiDAR) systems that weigh as little as three pounds are starting to make their way into the commercial market.[6] The resulting market pressure has played a significant role in encouraging additional corporate investment, expanding UAS education and training programs, and driving a race toward the establishment of commercially competitive advantages that leverage UAS capabilities—all activities that increase the demand for small UAS to fly in the NAS.

In August 2016, the United States took a significant step toward the full integration of UAS into the NAS with the FAA issuance of regulations governing their common use for non-recreational purposes. This was a seminal event marking one of the most significant changes to Federal Aviation Regulations in decades. Title 14 of the Code of Federal Regulations, Part 107, "Small Unmanned Aircraft Systems," is the rule that now enables the commercial use of small UAS without the need for regulatory exemption or waiver.

Part 107 has established clear guidance related to operating limitations, remote pilot certification, maintenance and inspection, and other key aspects of UAS use. For example, the rule states that aircraft must weigh less than 55 pounds and be operated at speeds less than 100 miles per hour. Small unmanned aircraft cannot be flown at altitudes more than 400 feet above ground level or from a structure, at nighttime, or from a moving aircraft or vehicle unless it is over a sparsely populated area. Visual-line-of-sight to the aircraft and visibility of three miles from the control station must be maintained at all times, and flights over people not directly participating in

5. "Price Wars: Counting the Cost of Drones, Planes and Satellites." https://droneapps.co/price-wars-the-cost-of-drones-planes-and-satellites/.
6. IRIS RADAR SENSOR, Integrated Robotics, http://integrated-robotics.com/our-technology-solutions/uav-radar-research/.

the UAV's operation are not permitted. For many small UAS operations that support civil and commercial GEOINT activities, the latitude provided in the new regulations is sufficient. However, exemptions may still be sought through a waiver process by which the FAA may grant permission for flights not otherwise allowed, including those at faster speeds, higher altitudes, beyond-line-of-sight, or after dark. Law enforcement and firefighting activities, post-disaster recovery and relief operations, and private sector manufacturers and technology developers conducting research and development, crew training, market surveys, and flight demonstration activities are a few examples where waivers may be requested.

Part 107 also established a remote pilot-in-command role and an associated remote pilot certificate. The FAA requires the remote pilot to pass a practical knowledge test at a designated testing center and be vetted by the Transportation Security Administration. Traditional manned aircraft pilots who are certified and current are simply required to complete an online training course provided by the FAA to receive their new certificate. Ultimately, the remote pilot is responsible for the safety of operations and compliance with all applicable regulations. Of course, to achieve and maintain safe operations, additional training on specific UAS, safety risk management, and concepts of operations may be required beyond the minimum certification requirements set forth by the FAA. An example of additional requirements is training qualifications for pilots who fly over forest fires, per regulations from the Bureau of Land Management.[7] Likewise, other organizations are preparing for future anticipated regulations to certify small UAS pilots who fly for commercial fire departments, security companies, and disaster relief organizations.[8]

In addition to the regulations, it is important to consider the legal and ethical factors that may influence the use of UAS for a potential application, particularly those with GEOINT remote sensing requirements. The U.S. Supreme Court has held that an individual generally does not have a Fourth Amendment right with respect to aerial surveillance, but some state courts have arrived at different conclusions in specific cases related to privacy expectations associated with aerial sensing. However, the advancement of technology can cause changes to the reasonable legal expectation of privacy and what the public deems acceptable. As public acceptance of UAS operations becomes more commonplace—for example receiving packages and food deliveries via UAS—awareness of local, state, federal, and even international laws and how they may influence a proposed UAS implementation will be necessary to ensure compliance and reduction of legal liability. Knowledge of such laws will become more important as UAS package delivery systems become routine, increasing the probability of dropped packages or other accidents, and private security and law enforcement missions become normal, requiring oversight to protect civil liberties.

Case law has been developed related to the ownership of airspace collection of aerial sensed data and expectations of privacy,[9,10] but in most cases these are still directly related to traditional manned collection platforms. However, in recent years, privacy advocates have increased efforts to enact laws regulating the use of UAS by law enforcement, insisting states require warrants before the government may use a UAS, and the manned collection examples provide precedent that can be leveraged for UAS cases. The National Telecommunications and Information Administration (NTIA) convened a series of efforts to increase privacy protection. On February 15, 2015, President Obama issued a presidential memorandum instructing NTIA to "convene such a process to develop and communicate best practices for privacy, accountability, and transparency issues regarding commercial and private UAS use in the National Airspace System."[11]

The significant increase in civil and commercial applications of UAS will inevitably continue to result in legal actions, providing a clearer understanding, via the courts, of the similarities and differences from currently established precedent on airborne surveillance activities and privacy. In addition to privacy considerations, operators should also be aware of how trespass, negligence, nuisance, insurance exposure, and other forms of liability may be recognized and diminished. As with manned aircraft activity, identification and understanding of the risks is vital to ensure appropriate mitigations are implemented (e.g., What happens if a UAS surveying property crashes into a house, or into a commercial power line?). This will require companies and other organizations to establish internal and external risk mitigation policies, procedures, practices, and oversight of commercial UAS operations mirroring those of commercial and private traditional aircraft operations.

Leveraging Government and Exemption-Driven Experiences

Prior to the publication of the Part

7. Bureau of Land Management Fire and Aviation UAS program, https://www.blm.gov/nifc/st/en/prog/fire/Aviation/uas.html.
8. RITA UAS/UAV Unmanned Aircraft Operator Training Program, http://www.rescueinternational.org/.
9. United States v. Causby, 328 U.S. 256 (1946) was a United States Supreme Court case related to ownership of airspace above private property.
10. California v. Ciraolo, 476 U.S. 207 (1986), was a case decided by the United States Supreme Court, in which it ruled that warrantless aerial observation of a person's backyard did not violate the Fourth Amendment to the United States Constitution.
11. National Telecommunications and Information Administration Best Practices for UAS Privacy, Transparency, and Accountability, https://www.ntia.doc.gov/files/ntia/publications/voluntary_best_practices_for_uas_privacy_transparency_and_accountability.pdf.

107 regulations, the FAA allowed UAS operations for non-recreational purposes through Certificates of Authorization, issued directly to public entities, or via the Section 333 Exemption process, for those wishing to engage in commercial activities. Much was learned from this period that both informed the development of the current small UAS regulations and helped to leverage and guide the commercialization of the UAS industry going forward.

Research organizations, including the National Science Foundation (NSF) Center of Unmanned Aircraft Systems and its constituent academic research universities, employed the waiver processes to advance development of technologies useful to the center's government and industry partners. In many cases, these projects have focused on GEOINT-related applications and directly contributed to the development of industry capabilities. Additionally, the Alliance for System Safety of UAS through Research Excellence (ASSURE) serves as the FAA Center of Excellence for UAS research, and was formed to provide research capabilities to enable the rapid, safe, and efficient integration of UAS into the NAS while advancing commercialization. The ASSURE team is actively engaged in analyses and research that will not only benefit small UAS operations, but will also directly advance future implementations of larger and more capable UAS. Additionally, the FAA established six UAS test sites in December 2013 that have enabled stakeholders to collaboratively pursue research and development activities that would otherwise not be permitted.

These are only a few of the many public, private, and collaborative ongoing efforts advancing the state of UAS-related technologies and addressing operational requirements and applications. Much has also been learned from decades of successful UAS use supporting government applications overseas, including intelligence, surveillance, and reconnaissance. Those interested in pursuing the integration of UAS capabilities for civil and commercial activities, including civil GEOINT applications, should explore what has already been accomplished through these government and civilian activities. Organizations such as ASSURE, the Association for Unmanned Vehicle Systems International (AUVSI), the Department of Defense (DoD), Sinclair College's National UAS Training and Certification Center, the Unmanned Aerial Vehicle Systems Association, and USGIF may be contacted via their websites to help address specific UAS goals.

Current State and Future Trends in Civil UAS Technology

As with any technology, UAS should be viewed as a tool that may be used as a standalone capability or integrated with other resources to accomplish goals. Data may be collected from ground assets, UAS, traditional manned aircraft, high-altitude assets, nano or micro satellites, and traditional satellite remote sensing resources. The appropriate application of UAS as an additional tool has the potential to both complement existing collection assets and to provide data types and quality that were otherwise not available or too cost prohibitive in the past.

Prior to any UAS implementation, data and information requirements, as well as specific mission applications, should be considered. Attention should be given to what available assets can accomplish the work, whether any information requirement gaps exist, the cost-effectiveness of a single or combined UAS solution, and how data may be processed and fused to create actionable information. A few examples of current civil or commercial UAS applications in the GEOINT domain include agriculture management, where spectral data is collected to address irrigation, soil variation, and pest and fungal issues; search and rescue, as demonstrated in the finding of a missing child in Harvey County, Kansas, last October; post-natural or man-made disaster relief assessment, such as those used in Ecuador by GlobalMedic in April 2016 to examine buildings and provide aerial mapping of earthquake affected areas;[12] environmental monitoring; natural resource surveys; traffic monitoring; and pattern of life analysis.

In each case, a determination of the requirements must be made and appropriate sensor types selected. As previously mentioned, sensor types are becoming more common in small UAS applications, and not only include still frame and video EO and IR systems, but also multi- and hyperspectral, acoustic, and chemical/biological sniffers. Some aircraft can also carry LiDAR and Synthetic Aperture Radar (SAR) sensors, but due to the additional SWAP requirements for these systems, coupled with system costs, there has been limited deployment of most active sensing systems on commercial UAS. However, an increase in active sensors is expected as more companies continue to develop smaller, lightweight, and less expensive technologies.

The UAS types with which sensors are paired generally fall into the broad categories of fixed-wing, vertical takeoff and landing, or some form of transitional aircraft. The performance of even what could be considered hobbyist or consumer grade small UAS have dramatically increased in the past several years in nearly every sense, including flight duration, effective operational range, integrated sensor options, onboard memory, communication and data link bandwidth and range, and ease of maintenance, training, and use.

12. *GlobalMedic Ecuador Earthquake Response.* GlobalMedic David McAntony Gibson Foundation, May 15, 2016, http://globalmedic.ca/programs/view/globalmedic-ecuador-earthquake-response-2016.

The development of civil and commercial UAS solutions to date has largely focused on single UAS operations, often operating independently from other ground or airborne assets. However, as technology continues to advance and regulations become more permissive, opportunities to integrate UAS with surface, other air, and even space-based assets will expand and become more easily achievable. One application that has already achieved some success is the integration of UAS with ground-based assets to support missions including search and rescue. One notable example is the integration of UAS with standard ground assets by Project Lifesaver International to assist in the search and rescue of individuals with cognitive disorders.[13] Although many aspects of UAS technology are already fairly capable, operators in any application space should ensure they adhere to all current regulations, including limiting a single operator to a single UAS.

UAS Training and Education

Often, some form of online, in-person, or blended training is necessary to ensure safety of operations and a complete understanding of system concepts of operations that would not be included in the FAA-required minimum training. Unlike manned aircraft that require system specific training and check rides, the FAA has made no such requirement for small UAS pilots. However, in addition to the regulatory necessity of obtaining the Remote Pilot Certificate, some UAS original equipment manufacturers have established their own system training standards that may be required or suggested when a client acquires one of their aircraft. This has most often been the case for UAS specifically designed for professional applications, often with GEOINT focuses such as mapping and infrastructure inspection, rather than basic, consumer grade, commercial-off-the-shelf systems.

Another capability transitioning from government to civil training spaces is the implementation of live, virtual, and constructive (LVC) technologies. As defined by the DoD modeling and simulation community, LVC simulations use real people who are involved with or operating real systems (live), real people operating simulated systems such as flight simulators (virtual), or simulated people operating simulated systems (constructive). The use of LVC as a pedagogical approach means more complex training scenarios can be accomplished cost-effectively with multiple sites participating remotely. As a recent example of how LVC can be used to support civil UAS training, in August 2016, Sinclair College's National UAS Training and Certification Center collaborated with industry partner Simlat to design and execute a groundbreaking civil LVC exercise. The exercise linked the center's mobile ground control station, live flight of a Sinclair UAS, and ground-based participants at the National Center for Medical Readiness in real-time with participants in Sinclair's UAS Simulation Lab on the Dayton, Ohio, campus and Simlat's headquarters in Israel. This capability demonstration highlighted advanced UAS applied research and training capabilities centered around a search and rescue scenario, including live participants, interactive virtual simulated capabilities, and constructive entities, showcasing the global reach now possible through strategic partnerships.

As the commercial UAS industry continues to rapidly mature, training and education options will have to meet new requirements as well. Remote and blended online and in-person learning can save time and establish baseline understanding, reducing the extent of expensive in-person sessions. Competency-based education (CBE) is also emerging as a way for those with prior experience or aptitude in a topic to advance quickly through curriculum while exhibiting mastery of required goals and objectives. Again, Sinclair College's National UAS Training and Certification Center is leading explorations of this approach through a NSF grant awarded to create a CBE short-term technical certificate in aerial sensing data analytics. In addition to the program's outreach to underserved populations, there is also a veteran's recruitment component. The UAS industry, and advanced technology fields in general, must recognize the value of integrated network learning tools such as LVC, accelerated CBE programs, and flexible academic and career pathways to enable the effective and timely training of a workforce for jobs that didn't even exist in the civil space a short time ago.

What's Next?

The current FAA guidance under Part 107, combined with the cost reductions created by UAV and sensor miniaturization, and the availability of reliable UAS makes today the time for those in non-DoD, GEOINT-related domains to explore how the integration of UAS as an additional tool can support their goals and objectives. The role of UAS has expanded beyond intelligence and defense activities and now includes a broadening range of civil and commercial applications made possible through significant advances in technology, reduction in the cost of operations and data collection, regulatory guidance, and improved training and education networks.

Data collected by UAS have already been adopted in commercial GEOINT operations with the volume, quality, and overall percentage of data contributed only expected to increase in the coming years. A good example of UAS technology application is the agricultural company Monsanto, which in 2016 invested in

13. Alex Davies, "Lockheed's New Drone Will Help Rescuers Find Missing People." *Wired*, April 28, 2015, https://www.wired.com/2015/04/lockheeds-new-drone-will-help-rescuers-find-missing-people/.

Ag Image Analytics company Resson, in order to advance digital agriculture and data science using information collected by UAS and ground sensor systems. Monsanto's goal is to use these technologies to give farmers information about the state of their fields and crops, and help them maximize yields, assess soil conditions, and assist with detecting diseases and viruses.[14] General Electric (GE) is another company investing in UAS and cloud technologies. Last year, GE invested in software company Airware in order to use its cloud technology to analyze UAS data collected over power lines in the United States. and abroad to identify threats to the infrastructure.[15] As active sensors such as LiDAR and SAR become more viable, additional data will add to both the capability of UAS as an asset and to the amount of data collected. Therefore, consideration must also be given to how new data will be transmitted, stored, processed, and fused with other sources to achieve the greatest potential benefit.

Stakeholders should expand collaborative efforts, seek to leverage past and ongoing work, and continue to integrate UAS capabilities into existing applications by interacting with organizations such as USGIF, AUVSI, ASSURE, and others. It's also vital to enhance existing and develop new capabilities for UAS by investing in UAS-related STEM (science, technology, education, and math) programs—sharing experiences as teachers and mentors, sponsoring students in UAS-focused programs, and directing resources to UAS education and research and development efforts. Attention should also be given to the regulatory process, with academic and commercial entities with UAS experience participating in discussions with the FAA and other legal entities to help determine how larger and more capable UAS will be leveraged once permitted through future regulatory integration. This is truly an exciting time for the GEOINT discipline as it stands ready to fully leverage the extraordinary capabilities of civil and commercial UAS operations.

14. Louisa Burwood-Taylor, "Why Monsanto Invested in Ag Image Analytics Company Resson. *AgFunder News*, June 24, 2016, https://agfundernews.com/why-monsanto-invested-in-ag-image-analytics-company-resson6053.html.
15. Jonathan Vanian, "GE is using drones to inspect the power grid." *Fortune*, October 23, 2015. http://fortune.com/2015/10/23/ge-drones-power-grid/.

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