



2018 STATE AND FUTURE OF GEOINT REPORT



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.



The State and Future of GEOINT 2018

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INTRODUCTION

Established in 2004 as a 501(c)(3) nonprofit, non-lobbying educational foundation, the United States Geospatial Intelligence Foundation (USGIF) provides leadership to the extended GEOINT Community via the three pillars that define the Foundation's strategic goals: Build the Community | Advance the Tradecraft | Accelerate Innovation.

USGIF pursues these goals via academic engagement, from the K-12 level through post-graduate studies, professional development training courses, focused topical workshops, networking events, member-driven committees and working groups, and our annual GEOINT Symposium—the largest GEOINT gathering in the world. The GEOINT Revolution surges on, and the Foundation's work is more important than ever as rapid technological advances outpace our collective ability to discern the potential applications, intended impacts, unintended consequences, and associated legal, ethical, and moral challenges.

USGIF's annual State and Future of GEOINT Report is one of our most popular publications. It is downloaded, shared, discussed, and referenced often, and stimulates a rich and sustained discussion regarding the myriad opportunities embedded in the expanding GEOINT discipline. Each year, through the lens of people, process, technology, and data, the report offers an intriguing set of observations.

While we continually adjust the process by which the report is created based on lessons learned, the core of the undertaking remains relatively unchanged: member volunteers, facilitated by USGIF staff, come together in brainstorming sessions to develop themes and article concepts. Heretofore solely done in person, this year we added a virtual component to that initial "germination" phase. Our member volunteers form writing teams to tackle the topics of interest, and then work through a process of peer feedback, which for the first time this year included an Editorial Review Board. We finish by copyediting and selecting which bits of content will be in the printed report and which will be offered solely online.

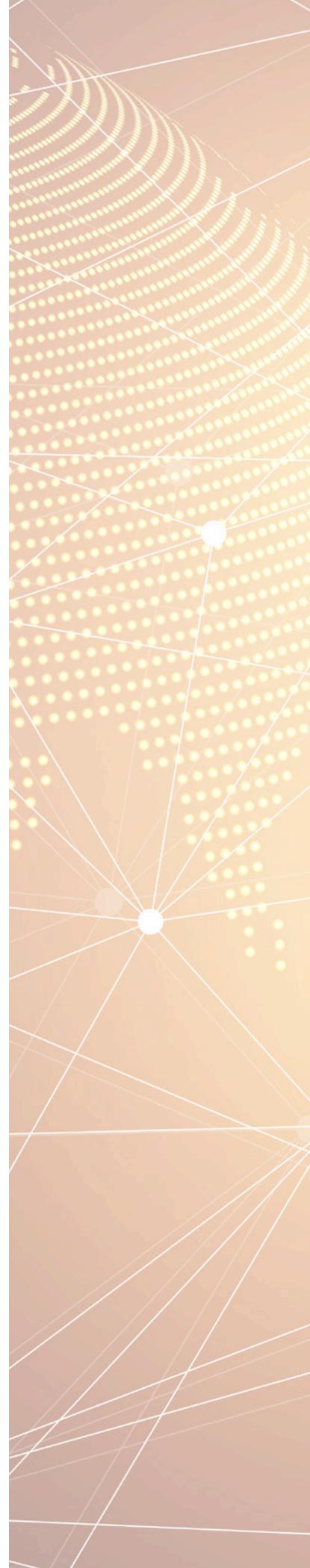
The State and Future of GEOINT Report is an exemplar of USGIF at its best: member volunteers working collaboratively with the staff, in teams that span academia, industry, and government—and, also for the first time this year, continents—to provide thought leadership for the GEOINT Community. It's our fervent desire that the 2018 edition, like the three before it, will generate thought and discussion, and contribute meaningfully to the future of our tradecraft and profession. I'd like to thank USGIF Strategic Partner Member Accenture, whose funding helped make this year's publication possible. I sincerely appreciate the efforts of all those involved with the production of this year's report. I pledge on behalf of our organizational members, individual members, board of directors, and staff that we will eagerly endeavor to remain thought leaders and the convening authority for the GEOINT Community in its broadest sense for many years to come.



Keith J. Masback
CEO, United States Geospatial Intelligence Foundation

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GEOINT at Platform Scale

By Chris Holmes, Planet; Christopher Tucker, USGIF Board of Directors; and Ben Tuttle, NGA

Today's networked platforms are able to achieve massive success by simply connecting producers and consumers. Uber doesn't own cars, but runs the world's largest transportation business. Facebook is the largest content company, but doesn't create content. Airbnb has more rooms available to its users than any hotel company, but doesn't even own any property.

In his book, "Platform Scale: How an Emerging Business Model Helps Startups Build Large Empires with Minimum Investment," Sangeet Paul Choudary describes how these companies have built two-sided markets that enable them to have an outsized impact on the world. He contrasts the traditional "pipe" model of production, within which internal labor and resources are organized around controlled processes, against the "platform" model, within which action is coordinated among a vast ecosystem of players. Pipe organizations focus on delivery to the consumer, optimizing every step in the process to create a single "product," using hierarchy and gatekeepers to ensure quality control. A platform allows for alignment of incentives of producers and consumers, vastly increasing the products created and then allowing quality control through curation and reputation management. In this model, people still play the major role in creating content and completing tasks, but the traditional roles between producer and consumer become blurred and self-reinforcing.¹

A Platform Approach for Geospatial Intelligence

So, where does the geospatial world fit into this "platform" framework? Geospatial intelligence, also known as GEOINT, means the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on Earth.² In most countries, there is either a

full government agency or at least large, dedicated groups who are the primary owners of the GEOINT process and results. Most of the results they create are still produced in a "pipe" model. The final product of most GEOINT work is a report that encapsulates all the insight into an easy-to-digest image with annotation. The whole production process is oriented toward the creation of these reports, with an impressive array of technology behind it, optimized to continually transform raw data into true insight. There is the sourcing, production, and operation of assets used to gather raw geospatial signal, and the prioritization and timely delivery of those assets. Then, there are the systems to store raw data and make it available to users, and the teams of analysts and the myriad tools they use to process raw data and extract intelligence. This whole pipe of intelligence production has evolved to provide reliable GEOINT, with a growing array of incredible inputs.

These new inputs, however, start to show the limits of the pipe model, as new sources of raw geospatial information are no longer just coming from inside the GEOINT Community, but from all over the world. The rate of new sources popping up puts stress on the traditional model of incorporating new data sources. Establishing authoritative trust in an open input such as OpenStreetMap is difficult since anyone in the world can edit the map. And the pure volume of information from new systems like constellations of small satellites also strains the pipe production method. Combining these prolific data volumes with potential sources of intelligence, like geo-tagged photos on social media and raw telemetry information from cell phones, as well as the process of coordinating resources to continually find the best raw geospatial information and turn it into valuable GEOINT, becomes overwhelming for analysts working in traditional ways.

The key to breaking away from a traditional pipe model in favor of adopting platform thinking is to stop trying to organize

resources and labor around controlled processes and instead organize ecosystem resources and labor through a centralized platform that facilitates interactions among all users. This means letting go of the binary between those who create GEOINT products and those who consume them. Every operator in the field, policy analyst, and decision-maker has the potential to add value to the GEOINT production process as they interact with GEOINT data and products—sharing, providing feedback, combining with other sources, or augmenting with their individual context and insight.

Transforming GEOINT Organizations from Pipes to Platforms

The GEOINT organizations of the world are well positioned to shift their orientation from the pipe production of polished reports to providing much larger value to the greater community of users and collaborators by becoming the platform for all GEOINT interaction. Reimagining our primary GEOINT organizations as platforms means framing them as connectors rather than producers. Geospatial information naturally has many different uses to many people, so producing finished end products has a potential side effect of narrowing that use. In a traditional pipe model, the process and results become shaped toward the sources consuming it and the questions they care about, limiting the realized value of costly assets.

Becoming the central node providing a platform that embraces and enhances the avalanche of information will be critical to ensure a competitive and tactical advantage in a world where myriad GEOINT sources and reports are available openly. The platform will facilitate analysts being able to access and exploit data ahead of our competitors, and enable operators and end users to contribute unique insights instead of being passive consumers. The rest of this article explores in-depth what an organization's

1. Sangeet Paul Choudary. *Platform Scale: How an Emerging Business Model Helps Startups Build Large Empires with Minimum Investment*. Platform Thinking Labs; 2015.

2. 10 U.S.C. § 467 - U.S. Code - Unannotated Title 10. Armed Forces § 467. Definitions. <http://codes.findlaw.com/us/title-10-armed-forces/10-usc-sect-467.html>.

shift from pipe production toward a platform would actually look like.

Rethinking GEOINT Repositories

A GEOINT platform must allow all users in the community to discover, use, contribute, synthesize, amend, and share GEOINT data, products, and services. This platform should connect consumers of GEOINT data products and services to other consumers, consumers to producers, producers to other producers, and everyone to the larger ecosystem of raw data, services, and computational processes (e.g., artificial intelligence, machine learning, etc.). The platform envisioned provides the filtering and curation functionality by leveraging the interactions of all users instead of trying to first coordinate and then certify everything that goes through the pipe.

Trust is created through reputation and curation. Airbnb creates enough trust for people to let strangers into their homes because reputation is well established by linking to social media profiles and conducting additional verification of driver's licenses to confirm identity, and then having both sides rate each interaction. Trust is also created through the continuous automated validation, verification, and overall "scrubbing" of the data, searching for inconsistencies that may have been inserted by humans or machines. Credit card companies do this on a continuous, real-time basis in order to combat the massive onslaught of fraudsters and transnational organized crime groups seeking to syphon funds. Trust is also generated by automated deep learning processes that have been broadly trained by expert users who create data and suggest answers in a transparent, auditable, and retrainable fashion. This is perhaps the least mature, though most promising, future opportunity for generating trust. In such a future GEOINT platform, all three of these kinds of trust mechanisms (e.g., reputation/curation, automated validation/verification/scrubbing, expert trained deep learning) should be harnessed together in a self-reinforcing manner.

Most repositories of the raw data that contributes to GEOINT products attempt to establish trust and authority before

data comes into the repository, governed by individuals deeply researching each source. The platform approach embraces as much input data as possible and shifts trust and authority to a fluid process established by users and producers on the platform, creating governance through metrics of usage and reputation. These repositories are the places on which we should focus platform thinking. Instead of treating each repository as just the "source" of data, repositories should become the key coordination mechanism. People searching for data that is not in the repository should trigger a signal to gather the missing information. And the usage metrics of information stored in the repository should similarly drive actions. Users of the platform, like operators in the field, should be able to pull raw information and easily produce their own GEOINT data and insights, then and contribute those back to the same repository used by analysts. A rethinking of repositories should include how they can coordinate action to create both the raw information and refined GEOINT products that users and other producers desire.

Core Value Units

How would we design a platform that was built to create better GEOINT products? In "Platform Scale," Choudary points to one of the best ways to design a platform is to start with the "Core Value Unit," and then figure out the key interactions to increase the production of that unit. For YouTube, videos are the core value unit, for Uber, it's ride services, for Facebook, it's posts/shares, and so on.

For GEOINT, we posit the core value unit is not simply a polished intelligence report, but any piece of raw imagery, processed imagery, geospatial data, information, or insight—including that finished report. For the purposes of this article, we'll refer to this as the "Core Value Unit of GEOINT (CVU-GEOINT)." It includes any annotation that a user makes, any comment on an image or an object in an image, any object or trend identified by a human or algorithm, and any source data from inside the community or the larger outside world. It is important to represent every piece of information in the platform, even those that come from outside with questionable provenance. Trusted actors

with reputations on the platform will be able to "certify" the CVU-GEOINT within the platform. Or they may decide it is not trustable, but will still use it in its appropriate context along with other trusted sources. Many CVU-GEOINTs may be remixes or reprocessing of other CVUs, but the key is to track all actions and data on the platform so a user may follow a new CVU-GEOINT back to its primary sources.

Maximizing Core Value Units of GEOINT

It is essential that as much raw data as possible be available within the platform, both trusted and untrusted. The platform must be designed to handle the tsunami of information, enabling immediate filtering after content is posted to the platform, not before. Sources should be marked as trusted or untrusted, but it should be up to users to decide if they want to pull some "untrusted" information, and then, for example, certify as trusted the resulting CVU-GEOINT because they cross-referenced four other untrusted sources and two trusted sources that didn't have the full picture. Open data sources such as OpenStreetMap, imagery from consumer drones, cell phone photos, and more should be available on the platform. The platform would not necessarily replicate all the data, but it would reference it and enable exploitation. These open data sources should be available to the full community of users, as the more people that use the platform, the more signal the platform gets on the utility and usefulness of its information, and, subsequently, more experts can easily analyze the data and certify it as trusted or untrusted.

It should be simple to create additional information and insight on the platform, where the new annotation, comment, or traced vector on top of some raw data becomes itself a CVU-GEOINT that another user can similarly leverage. An essential ingredient to enable this is to increase the "channels" of the platform, enabling users and developers in diverse environments to easily consume information and also contribute back. This includes standards-based application programming interfaces (APIs) that applications can be built upon and simple web graphical user interface (GUI) tools

that are accessible to anyone, not just experts. It would also be important to prioritize integration with the workflows and tool sets that are currently the most popular among analysts. The “contribution back” would include users actively making new processed data, quick annotations, and insights. But passive contribution is equally important—every user contributes as they use the data, since the use of data is a signal of it being useful, and including it as a source in a trusted report is also an indication of trust. The platform must work with all the security protocols in place, so signal of use in secure systems doesn’t leak out to everyone, but the security constraints do not mean the core interactions should be designed differently.

Filtering Data for Meaning

Putting all the raw information on the platform does risk overwhelming users, which is why there must be complementary investment in filters. Platforms such as YouTube, Facebook, and Instagram work because users get information filtered and prioritized in a sensible way. Users don’t have to conduct extensive searches to find relevant content—they access the platform and get a filtered view of a reasonable set of information. And then they can perform their own searches to find more information. A similar GEOINT platform needs to provide each user with the information relevant to them and be able to determine that relevance with minimal user input. It can start with the most used data in the user’s organization or team, or the most recent in areas of interest, but then should learn based on what a user interacts with and uses. Recommendation engines that perform deep mining of usage and profile data will help enhance the experience so that all the different users of the platform—operators in the field, mission planning specialists, expert analysts, decision-makers, and more—will have different views that are relevant to them. Users should not have to know what to search for, they should just receive recommendations based on their identity, team, and usage patterns as they find value in the platform.

The other key to great filtering is tracking the provenance of every piece of CVU-GEOINT in the platform so any derived

information or insight also contains links to the information that came from it. Any end product should link back to every bit of source information that went into it, and any user should be able to quickly survey all data pedigrees. Provenance tracking could employ new blockchain technologies, but decentralized tracking is likely not needed initially when all information is at least represented on a centralized platform.

Building readily available source information into the platform will enable more granular degrees of trust; the most trusted GEOINT should come from the certified data sources, with multiple trusted individuals blessing it in their usage. And having the lineage visible will also make usage metrics much more meaningful—only a handful of analysts may access raw data, but if their work is widely used, then the source asset should rise to the top of most filters because the information extracted from it is of great value. If this mechanism is designed properly, the exquisite data would naturally rise to the surface, above the vast sea of data that still remains accessible to anyone on the platform.

It is important to note that such a platform strategy would also pay dividends when it is the divergent minority opinion or insight that holds the truth, or happens to anticipate important events. The same trust mechanisms that rigorously account for lineage will help the heretical analyst make his or her case when competing for the attention of analytical, operational, and policy-making leadership.

The Role of Analysts in a Platform World

To bootstrap the filtration system, the most important thing is to leverage the expert analysts who are already part of the system. This platform would not be a replacement for analysts; on the contrary, the platform only works if the analysts are expert users and the key producers of CVU-GEOINT. Any attempt to transform from the pipe model of production to a platform must start with analysts as the first focus, enabling their workflows to exist fully within a platform. Once their output seamlessly becomes part of the platform, then any user could easily

“subscribe” to an analyst or a team of analysts focused on an area. The existing consumers of polished GEOINT products would no longer need to receive a finished report in their inbox that is geared exactly to their intelligence problem. Instead, they will be able to subscribe to filtered, trusted, polished CVU-GEOINT as it is, configuring notifications to alert them of new content and interacting with the system to prioritize the gathering and refinement of additional geospatial intelligence.

The consumption of GEOINT data, products, and services should be self-service, because all produced intelligence, along with the source information that went into it, can be found on the platform. Operators would not need to wait for the finished report; they could just pull the raw information from the platform and filter for available analyst GEOINT reports. Thus analysts shift to the position of the “curators” of information instead of having exclusive access to key information. But this would not diminish their role—analysts would still be the ones to endow data with trust. Trust would be a fluid property of the system, but could only be given by those with the expert analyst background. This shift should help analysts and operators be better equipped to handle the growing tsunami of data by letting each focus on the area they are expert in and allowing them to leverage a network of trusted analysts.

The other substantial benefit of a platform approach is to integrate new data products and services using machine learning and artificial intelligence-based models. These new models and algorithms have the promise to better handle the vast amounts of data being generated today, but also risk overwhelming the community with too much information. In the platform model, the algorithms would both consume and output CVU-GEOINT, tracking provenance and trust in the same environment as the analysts. Tracking all algorithmic output as CVU-GEOINT would enable analysts to properly filter the algorithms for high-quality inputs. And the analyst-produced CVU-GEOINT would in turn be input for other automated deep learning models. But deep learning results are only as good as their input, so the trusted production

and curation of expert analysts becomes even more important in the platform-enabled, artificial intelligence-enhanced world that is fast approaching. The resulting analytics would never replace an analyst as it wouldn't have full context or decision-making abilities, but the output could help analysts prioritize and point their attention in the right direction.

Recommendations for GEOINT Organizations

Reimagining GEOINT organizations as platforms means thinking of their roles as “trusted matchmakers” rather than producers. This does not mean such agencies should abdicate their responsibilities as a procurer of source data. But, as a platform, they should connect those with data and intelligence needs with those who produce data. And this matchmaking should be data-driven, with automated filters created from usage and needs. Indeed the matchmaking should extend all the way to prioritizing collections, but in a fully automated way driven by the data needs extracted from the system.

A GEOINT organization looking to embrace platform thinking should bring as much raw data as possible into the system, and then measure usage to prioritize future acquisitions. It should enable the connection of its users with the sources of information, facilitating that connection even when the utility to the users inside the agency is not clear.

- Be the platform for GEOINT, not the largest producer of GEOINT, and enable the interaction of diverse producers and consumers inside the agency with the larger intelligence and defense communities and with the world.
- Supply raw data to everyone. Finished products should let anyone get to the source.
- Govern by automated metrics and reputation management, bring all data into the platform, and enable governance as a property of the system rather than acting as the gatekeeper.
- Create curation and reputation systems that put analysts and operators at the center, generating the most valuable GEOINT delivered on a platform where all can create content. Enable filters to get the best information from top

analysts and data sources by remaking the role of the expert analyst as curators for the ecosystem rather than producers for an information factory.

The vast amounts of openly available geospatial data sources and the acceleration of the wider availability of advanced analytics threaten to overwhelm traditional GEOINT organizations that have fully optimized their “pipe” model of production. Indeed there is real risk of top agencies losing the traditional competitive advantage when so much new data can be mined with deep learning by anybody in the world. Only by embracing platform thinking will organizations be able to remain relevant and stay ahead of adversaries, and not end up like the taxi industry in the age of Uber. There is a huge opportunity to better serve the wider national security community by connecting the world of producers and consumers instead of focusing on polished reports for a small audience. The GEOINT organization as a platform would flexibly serve far more users at a wider variety of organizations, making geospatial insight a part of everyday life for everyone.

GEOINT on the March: A French Perspective

By Ret. Col. Frédéric Hernoust, former French Air Force engineer; Thierry G. Rousselin, Ph.D., consultant and TMCFTN CEO; David Perlberg, former GEOINT manager with the French MoD; Nicolas Saporiti, consultant and Geo212 CEO; Jean-Philippe Morisseau, consultant and former French SOF GEOINT/imagery analyst; and Ret. Gen. Jean-Daniel Testé, former French Space Commander and OTA CEO

The French Defense Situation

As a former colonial power involved in many conflicts, France has developed an important military geography culture and tradition.¹ The end of the Cold War followed by the Gulf War in 1990 underlined the strategic role of imagery intelligence and military geography. Both marked the development of Earth observation capabilities to provide self-assessment for French defense with satellite imagery, accurate maps, and standard data products to power army command and weapon systems. When the concept of geospatial intelligence (GEOINT) appeared 10 to 15 years ago, the appropriation in France came from small, independent actors who tried

to combine imagery intelligence with geographic data (secret services, special forces, or industry SMEs). And French manpower were actors (and sometimes a driving force) in the development of GEOINT at SatGen (the European Union Satellite Center), which played a pioneering role in Europe since 2009. But in recent years, the growing needs of French military forces to benefit relevant and actionable intelligence products pushed the Direction du Renseignement Militaire (DRM) to get new capabilities and empower GEOINT in France. Mainly (and also publicly) carried by DRM and Direction Générale de la Sécurité Extérieure (DGSE), the rise of GEOINT as a discipline in France was directly

influenced by the American approach and experiences. By creating a center dedicated to GEOINT in 2014, DRM showed its will to create a joint synergy inside the French Defense and initiated a transformation of French military intelligence and geography. Named Centre de Renseignement Géospatial Interarmées (CRGI), this center intends to rationalize the institutional means and develop tradecraft for multisource data fusion, the same way DGSE has operated since 2009.

Today, French GEOINT is shared between two main structures: military geography, which is coordinated by the Bureau Géographie, Hydrographie,

1. For more information on French Military Geography refer to: Paul David Régner. *Dictionnaire de Géographie Militaire*. CNRS Editions; February 2008.

Océanographie, Météorologie (BGHOM), and military intelligence, which is coordinated by DRM. Paradoxically and unlike the approach of many allies, the arrival of this new center didn't lead the French Defense establishment to merge these traditional structures. If this choice is officially supposed to preserve the autonomy of each service and provide better coordination throughout CRGI, it underlines divergences between geography and intelligence about GEOINT. Like the National Imagery and Mapping Agency—the U.S. predecessor to the National Geospatial-Intelligence Agency (NGA), DRM faces difficulties that can be explained by cultural differences between these two traditional domains and their different methods of supporting the armed forces.

Defense Industry

For the French defense industry, GEOINT transformation was not a straightforward process. For a few actors, the change was first only cosmetic, renaming former imagery intelligence (IMINT) or GEO departments under a newly branded GEOINT flag. But for industry leaders involved in the U.S. and international market (like Spot Image, today renamed Airbus DS), the transition appeared necessary to interact with NGA, but also with Google or other commercial giants. Since 2012, we see a move with the creation of new small or medium enterprises (SMEs) and start-ups trying to develop dedicated offers, or existing SMEs changing their business model. But, despite actions from the Defense Procurement Agency (through its labs¹), the level of coordination and cooperation among large defense contractors (Airbus, Thales, Safran, Dassault Aviation) and small newcomers remains to be improved. The size of the French market is too small and pushes French companies toward servicing the European market.

Education and Training

France was a pioneer in GEOINT education with the creation of the GEOINT course at Mines ParisTech, one

of the top French engineering schools, as early as 1999.² The GEOINT discipline has a strong military connotation in France, which did not help its academic development. Regarding education for future GEOINT analysts, France has a strong IMINT background (through CF3I since 1993) and until now relied on classical degrees in remote sensing, GIS, economic intelligence, data analytics, or geo-decision. Terrorist attacks in France in 2015 and 2016 had a large impact on public opinion and pushed universities to reconsider the importance of intelligence as a discipline. The first French master's degree in GEOINT started in September 2017, as a cooperation between Paris 1 University and the Intelligence Campus of the Ministry of Defense (MoD).

Research and Development

Even if GEOINT as a research topic has been seldom recognized until now in France, our country relies on its large Space and especially Earth Observation expertise (through the Spot, Helios, Pléiades, CSO/MUSIS legacy), and a strong research and development field in geographic information.

As GEOINT requires the management of huge amounts of data in various formats, contents, and big data solutions, it benefits, as elsewhere, from the incredible appeal driven by new economy professional and mass-market developments. In early 2017, the French government identified 180 start-ups and 70 academic laboratories involved in artificial intelligence (AI), and launched a national plan to develop this domain,³ which impacts military applications. AI seems to be a promising solution to face the challenge of GEOINT and smartly manage huge amounts of data. France has numerous assets in AI that have already attracted many corporate laboratories to the country (Facebook, Huawei, Sony, etc.). Thematic actors play an important role as well. For instance, the Institut National de l'Audiovisuel leads an impressive program to identify original information from copies and altered data, and set up

both academic researches and a big data platform that capitalizes and analyzes the whole information produced by French media during a year.⁴ Such platforms match with one of the main GEOINT challenges: Enhance the automatic research, collection, and analysis of huge raw information sources, separate original from copy, capitalize it, and make them easily accessible to analysts.

Looking at the diversity of research initiatives, one of the key challenges will be to organize connections between domains and to allow defense and GEOINT to benefit from those technological assets and more globally share the costs of the essential and expensive infrastructure, enhance the skills, and develop the required tools. The Intelligence Campus,⁵ the new intelligence innovation cluster started in 2016 by DRM, aims to provide a common ground for defense contractors, innovators, researchers, academics, and students willing to embrace intelligence careers. That kind of initiative should help create a synergy and raise awareness of start-ups with potential interest in the Intelligence Community.

International Cooperation

For France, international cooperation is advanced and fruitful in the main GEOINT elements of geography and intelligence.

For geography, it is first and foremost focused on co-production programs that allow the sharing of a heavy workload that no individual country, not even the U.S., could achieve alone. These co-productions have also been a driving force for standardization and normalization, with positive consequences for interoperability. But working on joint programs in the long run also has multiple positive impacts on geospatial operational exchanges.

Intelligence relies on two main mechanisms:

- Bilateral exchange in which each partner benefits from its counterpart's areas of

1. <http://www.defense.gouv.fr/english/dga/innovation2/dga-lab>. Accessed December 6, 2017.

2. The goal of this course, which has trained more than 500 students in 18 years, is not to prepare them for GEOINT careers but to provide GEOINT awareness for future decision-makers.

3. National French Plan: France IA. <https://franceisai.com/> and <http://www.enseignementsup-recherche.gouv.fr/cid112129/lancement-de-france-i.a.-strategie-nationale-en-intelligence-artificielle.html>. Accessed on December 6, 2017.

4. INA is the repository of all French radio and television audiovisual archives: <http://recherche.ina.fr> ("Interface de visualisation" project).

5. <http://www.intelligencecampus.com/>. Accessed December 6, 2017.

expertise. Africa is a good example for French strengths. Here, exchanges are on a give-and-take basis.

- Multinational intelligence exchanges under NATO, the EU umbrella, or through international coalitions gathered for military operations.

In both cases, national sovereignty supersedes international cooperation.

Allied cooperation in GEOINT is ongoing and will be bred from GEO and INT cooperation expertise and procedures. The French involvement, although new, allows the country to join a restricted club. SatCen⁶ played a decisive role in the process of sharing tools, methods, and training at the European level, and French cooperation with this center helps national progress.

But this positive view must be balanced, as we already see negative factors. First, for allies/partners, U.S. investment and seniority in the field creates fears they will not catch up on the technological side and will be forced to use U.S. turnkey solutions without being able to develop a national (or even European) industry. This feeling seems to be shared by European countries that developed a strong defense industrial policy to protect their national companies. Concerns cover new technologies such as big data, AI, data mining, robotics, and massive intelligence. Currently, required human and financial resources could seem out of reach for European budgets, if only to be able to exchange information. The same fears appear between major European partners (like France or the UK) and smaller European partners. GEOINT as a discipline, using all these new techniques, could lead to a new divide between countries, while one of its goals is to reinforce information sharing.

Civilian and Business Appropriation

Considering the GEOINT field in its largest definition (production of relevant information and geospatial analysis for decision-makers), most French companies are “dealing” with GEOINT. Insurance, (geo)marketing, logistics, finance, social networks, advertising, security, defense, etc., know the benefit

they can gain from the discipline. Consequently, many companies in France are seriously pursuing GEOINT, but most of the time without naming it such. And those businesses seldom interact with defense contractors, handling most of their needs with ICT companies or GIS software providers.

Civilian and business community investment in the GEOINT field is proportional to potential returns on investment. When a financial trader invests in geospatial insight superiority tools, it should be able to quantify precisely the benefits gained from this competitive edge.

French GEOINT, Main Challenges

Words, Their Translation, and (Lack of) Definition

Since the 16th century, intelligence has developed a double meaning in English: capacities of the mind; and information, information processing, and espionage. In French, there are two different words: “intelligence” for the capacities of the mind; and “renseignement” for information. Hence, the use of “geospatial intelligence” or “GEOINT” in French leads to multiple misunderstandings. Additionally, most early adopters in France were defense contractors eager to describe their former GEO and IMINT business under a fancier name. The translation issue, paired with the lack of formal education and definitions, led to use of the term GEOINT, without a clear and shared meaning. This has evolved since 2013, with the organization of seminars gathering military, academic, and business experts on GEOINT issues and the first French “Convention GEOINT” in June 2016 at Creil Air Base. But we still lack a French “GEOINT for Dummies” book allowing everybody to share the same definition.

Cultural Differences

GEOINT is about understanding the human landscape and activities. This understanding is influenced by French culture, education, history, and relationships with former French colonies.

The history of social sciences shows large differences between the French track and English or U.S. tracks. For decades in France, physical geography was the main preoccupation of surveyors and Army geographers while human geography was the preserve of universities with limited connection between universities and intelligence topics, contrary to England or the U.S.

Cultural differences are also linked with political and military history. Each colonial power had its own methods and interactions with local populations, which led to specific ways to understand, model, and describe the physical and human environment. This leads today to different views on those territories as well as different views of their GEOINT puzzles. These cultural differences should be viewed as an opportunity, with each partner bringing its specific knowledge and assets, as long as the common model does not erase those cultural gems.

Human Resources

The biggest challenge for French GEOINT may be to educate and maintain its workforce as much as recruiting new analysts and system experts. The national Intelligence Community needs to hire experts able to support the growth of agencies and to fulfill future requirements. The small size of DRM and DGSE in the field of GEOINT compared to an agency like NGA forces French Defense to explore different strategies and take direct benefit from operational experiences, improve information sharing between agencies, focus on areas of interest, and develop automation to improve data processing. The priority for intelligence agencies is also to recruit educated experts in new jobs such as big data engineers, database experts, or data scientists, which is challenging today because of great demand in these areas.

Despite its goal to increase its workforce in coming years, DRM faces a lack of academic training in GEOINT and other emerging areas. This situation may have heavy consequences on recruitment and may push the agency to find other solutions such as outsourcing. In today’s

6. https://www.satcen.europa.eu/what-we-do/geospatial_intelligence. Accessed December 6, 2017

context of growing big data, this may be a solution to face critical issues of the future.¹

Budget Constraints

In recent years, the budgetary pressure on the French Armed Forces has relaxed due to the evolving international situation. This led in 2008 to the “knowledge and anticipation function” among the five strategic functions of the White Paper on Defence and National Security.² According to the 2013 White Paper,³ “this function has particular importance since a capacity for autonomous assessment of situations is key to free, sovereign decision-making.” The recently published French Strategic Review⁴ confirms those priorities.

GEOINT capacity is at the core of this knowledge and anticipation function and therefore has been in some ways preserved. Development of intelligence-gathering capabilities, notably for space programs, is a priority for the next programming and budgeting period up to 2025, and is illustrated by the scheduled launch in 2018 of the first French CSO satellite, an optical component of the European MUSIS space imaging system.

However, traditional armament programs do not easily suit GEOINT, which requires more innovative and agile solutions, geared by military operational constraints and experience feedback through short evaluation cycles and evolution of French and allied joint operations doctrine.

This pragmatic approach is illustrated by the new Laboratoire d’Innovation Spatiale des Armées (LISA),⁵ co-chaired by the Joint Space Command and Procurement Agency. While not dedicated only to GEOINT, it will address most of the relevant GEOINT issues.

Making a Difference in Operational Support Improvement

Intelligence is essential for planning, command, and control of military operations, but is also the cornerstone of

crisis prevention. GEOINT should bring a better understanding of an operational environment and the ability to evaluate efficiently a situation’s potential at all decision levels.

The ambition of DRM/CRGI is to maintain a connection between tactical, operational, and strategic levels by deploying GEOINT expert teams on battlefields. It has two main advantages; it allows tactical units to easily access GEOINT products and helps GEOINT experts develop a better understanding of operational needs and conditions. But it is still difficult for units at operational and tactical levels to have access to good levels of intelligence, notably because neither their analysts nor their systems are adapted to the GEOINT approach.

Agencies need to improve their operational support means and develop new capabilities to provide deployed forces with an on-demand and near real-time access to relevant intelligence through an integrated geospatial environment.

Moreover, French GEOINT should shift priorities to include a more “bottom-up collaborative” approach to allow decision-makers with precise situational awareness and warfighters to share relevant information.⁶

French GEOINT, Our Recommendations

In France, if the community now shares the basic goals of GEOINT, the U.S. model cannot be transposed directly. To bring a useful contribution, France has to develop its own GEOINT, based on its culture and adapted to its resources and assets (scientific, technical, human, budgetary, organizational) to create innovative interactions with its defense partners and with a globalized industry.

Ambitions

If French GEOINT size and ambitions are not comparable to those of NGA, it faces

similar issues on the need to develop new solutions and processes, to increase human resources, and to keep pace with the huge amount of data to be processed.

As for geographic data production and services, partnerships and outsourcing can be applied to intelligence to monitor permanent infrastructures or large areas. This approach can bring flexibility to help armed forces to focus on hard problems and operational support.

Organizational Challenges

The relationship between institutions, industry, and academics does not allow France to directly transpose U.S. initiatives and practices. At best, industry researchers are driven with academic laboratory support. There are few industrial interactions and it limits the short-term emergence of this market. Another challenge is to merge different cultures, especially when they are not scientific or technological. However, GEOINT needs this crossing between various domains. Cultural change within companies is needed.

Normalization Challenges

If normalization has been one of the big successes of the past 30 years for the exchange of geospatial information, the cultural differences have a big impact for the normalization of information describing populations, religions, or activities. It will be an important challenge for all allies.

Conclusion

French GEOINT is in a transition phase and faces huge and exciting challenges. A necessary cooperation must be stimulated inside industry, between industry and academics, and in various fields mixing social and technical sciences. The main success criteria will be related to processing of huge data flows and dissemination to decision-makers and users with decisive support and relevant situational awareness, anytime, anywhere.

1. In another approach to promote the use of GEOINT, DGSE educates its analysts to use a virtual globe for basic GEOINT analysis. The secret service built up a “GEOINT back office” in support of all-source analysts in charge to produce complex work like geo-fencing or predictive analysis.

2. Livre blanc Défense et Sécurité Nationale. La Documentation Française, June 2008.

3. French White Paper Defense and National Security. La Documentation Française, July 2013.

4. Revue Stratégique de Défense et de Sécurité Nationale. La Documentation Française, October 2017.

5. Armed Forces Laboratory for Space Innovation.

6. As an example, the Auxilium project, which is used today by warfighters of the Sentinelle Operation (French military operation on the French territory after January 2015 terrorist attacks).

France must create a GEOINT Community to accelerate the development of the discipline inside and outside of defense. A multidisciplinary national organization dedicated to GEOINT is necessary to set goals and continuously develop the discipline, animate the community, and facilitate exchanges between agencies, private companies, and academics. French academics have also a role to

develop GEOINT culture and educate the future workforce. New courses must be adapted to train future GEOINT experts.

Initiatives such as the Intelligence Campus or LISA are a necessary first step, but need to include—as soon as possible—ancillary activities such as accurate education of human resources on new intelligence matters: GEOINT, of

course, but also automation of processes, open-source data mining, and more. And those initiatives must motivate schools and universities to join and invest in the domain. With strong coordination of these entities rather than creating a unique one, integration of GEOINT as a foundation of all intelligence disciplines would lead to higher efficiency and a new edge in French Intelligence.

Actionable Automation: Assessing the Mission-Relevance of Machine Learning for the GEOINT Community

By Todd M. Bacastow, Radiant Solutions; Abel Brown, Ph.D., NVIDIA; Gabe Chang, IBM; David Gauthier, NGA; and David Lindenbaum, CosmiQ Works

Machine learning (ML) has existed in various forms for many decades, but it is only in recent years, with the advent of new deep learning techniques and hardware with more robust compute power, that algorithms have achieved instances of “human-level” performance. The ImageNet Challenge,⁷ with its large visual database, has driven significant improvements in visual object recognition. In 2017, ImageNet yielded algorithms that achieved less than three percent error rates for identifying objects in everyday photos—a metric considered to be better than even expert human performance levels.⁸ However, this does not mean such algorithms will replace humans. Although the results are impressive, ImageNet consists of photos of everyday objects. In contrast with the geospatial domain, satellite imagery has added complexities of overhead perspective and limited labeled training. For these reasons, deep learning-based approaches offer tremendous potential to support geospatial analysts and decision-makers in leveraging the vast amounts of data generated by an ever-increasing number of sensors and data acquisition techniques.

Internet search, image recognition, human speech understanding, and social media applications of deep learning have had considerable success recently, though a clear integration road map for the defense and intelligence communities remains a challenge due to the complexity, scale, and

sensitivity of the diverse mission portfolio. This article seeks to characterize the state of ML for the geospatial intelligence (GEOINT) Community and explore current mission relevance. The promise of deep learning is the ability to harness the power of machine processing at speed and scale to assist humans in achieving better outcomes versus using traditional and possibly laborious manual approaches.

Opportunities and Challenges

ML offers promising assistive technologies for humans to harness automation, or semi-automation, of traditionally manual tasks where speed and scale are often needed to meet today’s challenges. This trend is playing out across many industries, from media to medicine, and, of course, defense and intelligence. A key enabler across all industries is the availability of massive amounts of data within the domain. These data—coupled with high-performance, relatively low-cost computing power and the ability to harness distributed workforces to create labeled training data through crowdsourcing—have created a perfect storm for the acceleration of ML applications. The use of ML is becoming a necessity given the vast data volumes from a proliferation of sensors, and growing mission requirements in our complex, interconnected world. When trained with the intelligence of humans, algorithms offer scale, speed, and,

increasingly, enhanced accuracy, which allow analysts to accomplish more and focus on tasks to which they add the most value.

Increasingly, analysts and data scientists need to manipulate the vast incoming data in more intuitive ways. Integration of analytic tools, ML techniques, natural language, or better user interfaces has yielded more efficient means to query and search data stores for insightful nuggets of information. As ML is inherently an iterative, albeit speedy, approach to arrive at the “right” answer, the opportunity exists through deep learning frameworks to test numerous hypotheses, reduce false positives, and achieve a more robust interpretation of the data.

Additionally, with the proliferation of new sensors and phenomenology comes an increased need to automate metadata tagging, integrate a variety of data formats, and curate raw information before being ingested and exploited. The fusion of a variety of datasets can yield alternative means of tipping the detection of obscure objects and corroborating results (data veracity).

One of the most significant challenges in achieving mission relevance with ML for GEOINT Community applications are the prerequisites, including the availability of large labeled training datasets and the fragility of algorithms that work

7. Andrej Karpathy. “What I Learned from Competing Against a ConvNet on ImageNet.” *Andrej Karpathy Blog*, September 2, 2014. <http://karpathy.github.io/2014/09/02/what-i-learned-from-competing-against-a-convnet-on-imagenet/>. Accessed December 10, 2017.

8. Aaron Tilley. “China’s Rise in the Global AI Race Emerges As It Takes over the Final ImageNet Competition,” *Forbes*, July 31, 2017. <https://www.forbes.com/sites/aarontilley/2017/07/31/china-ai-imagenet/#103e8ec1170a>. Accessed December 10, 2017.

well in research and development environments but may have limitations if operationalized. Training data are ideally generated from sources with: 1) access to the necessary compute resources; 2) a labor force with requisite ML knowledge; 3) an understanding of the operational timelines and performance requirements; and 4) large enough input datasets of significant value. These four building blocks are needed in order to train algorithms so they can be run in a timely manner (or in real time) to meet mission timelines. Once created, experts then must measure performance and validate the utility of algorithms in real-world situations.

The Current State of Machine Learning

The current state of geospatial uses of ML in the GEOINT Community is primarily focused on developing new algorithms and improving accuracy, often measured by precision and recall. Much of this research focuses on applying advancements in computer vision to the geospatial domain given the abundance of imagery from various sensors. Within the last two years, six such computer vision datasets and competitions were launched related to geospatial applications:

- IARPA's Multi-View Stereo 3D Mapping Challenge
- The SpaceNet Challenge¹ by CosmiQ Works, DigitalGlobe, and NVIDIA
- The Defence Science and Technology Lab's Semantic Segmentation Challenge
- IARPA's Functional Map of the World Challenge
- Planet's Forest Recognition Competition
- USSOCOM's Urban 3D Challenge

These open competitions developed their own training data and metrics to benchmark algorithm performance. This training data creation is significant. For example, the SpaceNet Round 2 building footprint dataset took approximately 24

days to produce roughly 300,000 building footprints over 424 square kilometers across four cities. In addition, the winning algorithm took a full week to train on one graphics processing unit (GPU)—a timeline that could be accelerated with more GPUs. Inference time, or the speed at which the trained neural network can operate against new data,² was approximately 1,800 square kilometers a day, though the amount of time and data it took to reach that algorithm speed reduces its application space.

If an algorithm is fragile—i.e., it requires retraining for every new situation—it will be difficult to use these algorithms to address emerging GEOINT problems. It is important to understand the training time and data requirements for an algorithm, in addition to performance metrics such as precision and recall to explore an algorithm's potential accuracy for future mission applications.

OpenStreetMap is mostly maintained through manual means in which contributors add to the map using heads-up digitizing from overhead imagery or by uploading GPS tracks for areas they see the need to update. To prioritize areas where urgent updates are needed, the Humanitarian OpenStreetMap Team's tasking manager lists buildings, roads, and land use as major features that are requested to be mapped. In addition, the two most common types of mapping requests are disaster response and missing maps. Current algorithms have the potential to aid in accelerating missing map tasks. The potential to apply algorithms to amplify and extrapolate the efforts of human contributors is significant.

However, in disaster response situations, timelines are important. A key question to tackle is: "How can you provide good enough solutions quickly enough to be useful for a real-world disaster response and recovery situation?" If it takes three weeks to produce the training data required to employ ML, the benefit to first responders will be limited since the timeline will be out of the response period

and significantly into the recovery period for most events.

In addition to short timeline problems that have base level mapping requirements, such as buildings and roads, there is now significant effort placed into mapping the population of the world. Every year, Oak Ridge National Laboratory produces the LandScan³ product, which provides global population distribution data at 1-km resolution. This product is created by fusing geospatial information with census data, and is used for a wide range of activities such as epidemic modeling or vaccination campaign planning. As ML algorithms produce solutions to underlying geospatial problems, they will improve the accuracy of these population maps. While population mapping does not have the short-term timeline a disaster response dictates, it does need to maintain currency. The scale of the effort provides significant challenges in both maintaining consistency in the data product and also maintaining an acceptable data refresh cycle to provide the yearly updates required. As operationally relevant algorithms emerge, understanding the scale and quality of the data is important.

ML approaches can assist with situations in which data labelers can be assisted to speed up a process as well as in situations when the dataset is so large that human-only analysis is not feasible. As the community continues to explore ML approaches to GEOINT problems, we must also continue to explore how to make these algorithms and models effective against the wide range of conditions that occur in real-world scenarios.

A Case Study: Machine Learning within NGA

Based upon a 2017 Major Issue Study conducted by the Office of the Director of National Intelligence (ODNI) Systems & Resource Analyses organization, the National Geospatial-Intelligence Agency (NGA) is working with its Department of Defense (DoD) and

1. Todd M. Bacastow. "The SpaceNet Challenge Round 2 Has Launched." *DigitalGlobe Blog*, April 11, 2017. <http://blog.digitalglobe.com/developers/the-spacenet-challenge-round-2-has-launched/>. Accessed December 10, 2017.

2. Michael Copeland. "What's the Difference Between Deep Learning Training and Inference?" *NVIDIA Blogs*, August 22, 2016. <https://blogs.nvidia.com/blog/2016/08/22/difference-deep-learning-training-inference-ai/>. Accessed December 10, 2017.

3. Oak Ridge National Laboratory. *LandScan*. <http://web.ornl.gov/sci/landscan/>. Accessed December 10, 2017.

Intelligence Community (IC) partners on a strategy and integration road map for implementing ML capabilities. Because of its historic mission and massive stake in automating imagery exploitation going forward, NGA is taking the lead on managing the research, development, and governance of computer vision (CV) capabilities for satellite and airborne imagery. “Computer vision is concerned with the automatic extraction, analysis, and understanding of useful information from a single image or a sequence of images. It involves the development of a theoretical and algorithmic basis to achieve automatic visual understanding.”⁴

In addition to coordinating which organizations will develop which capabilities, NGA recognizes the critical nature of producing standards across the areas of technical specifications, data interoperability, algorithm lineage, and validation criteria for CV solutions. It aims to support these standards with a governance model that encourages open innovation and transparency—something not often seen in government agencies.

As a first step, NGA recently announced the creation of an Office of Automation, Augmentation, and Artificial Intelligence (AAA) that will begin to formalize its implementation plan. The high-level strategy for adopting operational AI is built into the name of this new office: it is to automate routine tasks to give critical time back to employees while at the same time augmenting complex decision-making tasks with machine support. For the first time, cutting-edge AI technologies are delivering promising results in both of these directions for applications relevant to GEOINT production operations.

Examples of automating routine tasks for GEOINT operators using ML are data preparation, data conditioning, and image search (using CV) functions. Applying recent advances in deep learning to such tasks is expected to create a surge in human productivity. Orders of magnitude increases in productivity are necessary for NGA and its partners to possibly exploit the ever-growing tsunami of available

imagery. The ability to find and extract relevant information in a deluge of data makes ML critical to mission success. Examples of augmenting complex decision-making tasks are resource optimization, hypothesis testing, and pattern-discovery functions. Applying ML solutions to such tasks is expected to result in better decision support through the use of more source data and the ability to increase complexity by understanding multivariate interactions. In simple terms, machines can search across more datasets using more variables to discover correlations that humans cannot. Humans can put those findings into a larger mission context to understand if they are relevant. Automation and augmentation are initial steps in implementing a spectrum of AI solutions.

While NGA recognizes the inherent power of ML for increasing the productivity of its mission output(s) and the complexity of its decision-making, ML solutions also introduce a significant challenge to their own utility: perceived lack of trust and transparency. One of the first requirements for ML solutions within the GEOINT Community will be the ability to unmask their methods—something even Google has expressed difficulty doing with its DL networks.⁵ NGA requires a framework for operationally testing and evaluating ML solutions to provide a level of confidence through validation and verification that those solutions will work properly for their defense and intelligence customers. Any mission partner working on ML solutions today needs to consider this fundamental aspect of their utility.

Additionally, there are other factors that can be built into AI solutions to raise their credibility. For one, the design of the user interface can offer continuous feedback as to the inner workings of the system. The simplest representation of this today is an on-screen visual cue that identifies when the machine is processing a request with a status bar. With AI systems, the range of feedback to and communications with the user will be far more complicated and therefore require

an emphasis on elegant design. NGA ultimately desires AI solutions that offer a gentle user orientation with high degrees of trust building, two-way feedback, and transparent verifiability as to the solution’s mission effectiveness.

Finally, NGA has outlined a strategy to generate a labor force ready for AI capabilities—what it refers to as a “data-enabled workforce.” Through a combination of wide-scale training and education opportunities and a targeted recruiting strategy, NGA has identified its technical workforce goals and objectives in detail for the next five years. Harnessing these new capabilities is a challenge many government agencies and commercial entities will also face. To benefit from automation, an organization must help educate their workforce on the fundamentals of ML so this capability can be applied to manual tasks across various roles.

Conclusion

So, the question remains: “Is ML mission relevant today for the GEOINT Community?” The short answer is: “Yes, and its relevance is growing.” While challenges remain around creating labeled training data, training algorithms, and applying them in mission context with transparency to the user, significant progress has been made in the last year and ML is having mission impact as mission needs grow. Public prize challenges have contributed to making geospatial data more accessible for ML research, allowing algorithms to be developed that may have eventual mission uses.

This relevance will continue to grow each year as more data is available for training, the availability and power of compute increases, algorithms improve, and the number of missions supported by ML continues to expand. The barriers to harnessing the advantages of ML will continue to decrease, and more end-users will benefit from this technology to better perform their core job functions. ML will continue to create rich opportunities for GEOINT mission across many sectors.

4. “What Is Computer Vision?” The British Machine Vision Association and Society for Pattern Recognition. <http://www.bmva.org/visionoverview>. Accessed December 10, 2017.

5. Ariel Bleicher. “Demystifying the Black Box that is AI.” *Scientific American*, August 9, 2017. <https://www.scientificamerican.com/article/demystifying-the-black-box-that-is-ai/>. Accessed December 10, 2017.

The Future of GEOINT: Data Science Will Not Be Enough

By Christopher M. Parrett, U.S. Army, INSCOM; Andrew Crooks, Ph.D., George Mason University; and LTC Thomas Pike, U.S. Army, SSI

By the year 2020, many experts predict the global universe of accessible data to be on the order of 44 zettabytes—44 trillion gigabytes—with no signs of the exponential growth slowing.¹ As a result, data science has quickly been thrust to the forefront of the international job market, and people cannot seem to get enough of it.² Salaries for data scientists have increased significantly in the past few years, as the demand for a workforce fluent in scripting, machine learning (ML), and data analytics inundates jobsites spanning the globe.³ Websites such as *glassdoor.com* list the top three jobs of 2016 as data scientist, DevOps engineer, and data engineer. As a result, the market is responding with a slew of data science degree programs, with indicators that more students are opting for bachelor's and master's degrees over Ph.D.s, likely in an attempt to enter the competitive job market.⁴

Supporting this observation is the fact that salaries for data scientists started to level off as an influx of new data scientists entered the job market.^{5,6} Still, the demand for data scientists remains high,^{7,8} and the race to score employment in one of the century's "sexiest jobs" is arguably at its peak with little sign of slowing down.⁹

The United States Intelligence Community (IC) is just now starting to demand these skills in earnest as it strives to maintain its leading edge to support national policy-makers and military forces, as

well as to protect the nation's borders and interests abroad. While the delayed diffusion of private sector practice to the public sector is not new,^{10,11} the speed of the technology growth has exacerbated the time lag and placed the IC behind the power curve.¹² The rapid growth in sensor diversity and volume in the unmanned aerial systems (UAS) market alone,¹³ compounded with the resulting flood of derived products, structured observations, and increasing volumes of publicly available information is simply overwhelming analysts.^{14,15}

The data scientist's ability to navigate petabytes of raw and unstructured data, then clean, analyze, and visualize the data, has routinely proven their value to the decision cycles of their often non-technical leaders.¹⁶ It is no wonder then the demand signal to meet the IC's big data problem has created a buzz around data science, with many senior executives wanting more of "it."

However, there is little strategic assessment of what actual skills will be needed in the future or how these emerging technologies and data science tools should reshape the IC's organizational dynamics. But this is not solely the fault of senior executives. We feel there is a definition problem with data science; it is too general, too broad, and continually expanding. We also believe that while data science undoubtedly has a future in the National

Geospatial-Intelligence Agency's (NGA) vision to "Know the Earth, Show the Way, Understand the World," the community must go beyond statistically analyzing data collected on the world around us to truly gain an understanding of the people who inhabit the world.

Future policy-makers and military leaders will be faced with a complex environment that is increasingly urban and unstable,¹⁷ where the observed complexity of people's behavior over time is actually a reflection of the complexity of the system in which they are immersed.¹⁸ The information technology revolution we are witnessing with data science is allowing policy-makers and military leaders to see the complexity of the world they are trying to influence, but to grapple with this complexity will require new mental and organizational paradigms. Geospatial intelligence (GEOINT) is critical to the characterization and understanding of this complex world, providing the context and visualization necessary to support the decision-making process at all echelons.¹⁹ Perhaps for this reason, the most demanding area for advancement in computational tradecraft should be in the realm of GEOINT. The overwhelming volume, size, diversity, complexity, and speed at which geospatial data is generated requires significant improvements to the processes fielded by today's GEOINT practitioners.²⁰

Future GEOINT practitioners will also

1. William Koff and Paul Gustafson. DATA rEVOLUTION. Computer Sciences Corporation (CSC); 2016. <https://www.csc.com/lefreports>.
2. S. Miller and D. Hughes. *The Quant Crunch: How the Demand for Data Science Skills Is Disrupting the Market*. Industry White Paper. Burning Glass Technologies; 2017.
3. Brian Suda. Data Science Salary Survey. O'Reilly Media, Inc.; 2017.
4. Linda Burch. "The Burch Works Study: Salaries of Data Scientists." May 1, 2017. www.burchworks.com/study/Burch-Works-Study_DS-2017-final.pdf.
5. Ibid.
6. David Ramel. "Data Scientists Flooding Field, Salaries Leveling Off." *ADTMag.com*. September 11, 2015. <https://adtmag.com/articles/2016/05/02/data-science-salaries.aspx>.
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8. David Ramel. "Data Scientists Flooding Field, Salaries Leveling Off." *ADTMag.com*. September 11, 2015. <https://adtmag.com/articles/2016/05/02/data-science-salaries.aspx>.
9. T.H. Davenport and D.J. Patil. "Data Scientist: The Sexiest Job of the 21st Century." *Harvard Business Review*. 2012.
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11. Joe Pappalardo. "The Pentagon's Long, Slow Process of Getting New Tech Is About to Change." *Popular Mechanics*. November 30, 2016. <http://www.popularmechanics.com/military/research/a24081/what-the-pentagon-can-learn-from-app-developers/>.
12. Sandra Erwin. "Cold Dose of Reality on DoD Technology." *National Defense*. April 19, 2017. <http://www.nationaldefensemagazine.org/articles/2017/4/19/cold-dose-of-reality-on-dod-technology>.
13. Jeremiah Gertler. U.S. Unmanned Aerial Systems. Congressional Research Office. Washington D.C.: Government; 2012.
14. Thom Shanker and Matt Richtel. "In New Military, Data Overload Can Be Deadly." *New York Times*. January 16, 2011. <http://www.nytimes.com/2011/01/17/technology/17brain.html>.
15. Herbert Simon, *The Sciences of the Artificial*, (third edition). Cambridge, MA: The MIT Press; 1997.
16. University of Wisconsin. "What Do Data Scientists Do?" <https://datasciencedegree.wisconsin.edu/data-science/what-do-data-scientists-do/>. Accessed September 29, 2017.
17. The U.S. Army Operating Concept: Win in a Complex World. TRADOC Pamphlet. U.S. Army Training and Doctrine Command. 2014.
18. Herbert Simon, *The Sciences of the Artificial*, (third edition). Cambridge, MA: The MIT Press; 1997.
19. JP 2-03, Joint Pub 2-03: Geospatial Intelligence Support in Joint Operations. Joint Pub. Joint Chiefs of Staff. 2012.
20. NGA. "Statement for the Record before the House Armed Services Committee." May 19, 2017. <https://www.nga.mil/MediaRoom/SpeechesRemarks/Pages/Fiscal-Year-2018-Priorities-and-Posture-of-the-National-Security-Space-Enterprise-Robert-Cardillo.aspx>.

need to apply these data to support requirements for near real-time human interpretation and synthesis into intelligence in order to describe and visualize the operating environment and provide objective predictions of physical and human actions.²¹ The National System for Geospatial Intelligence (NSG) must transition away from a discipline doctrinally constrained by multiple single-source stovepipes and embrace a multidisciplinary, dynamic, and computational analytic approach dedicated to addressing complex geographic and social issues.²²

During USGIF's GEOINT 2017 Symposium, NGA signaled its intent to shift its workforce planning heavily toward data science, even suggesting it will no longer hire analysts without computer programming skills.²³ Even the director of NGA is taking a Python course.²⁴ Naturally, NSG members are following NGA's lead, initiating pilots to build out data science capabilities within their current structures.^{25,26,27}

In all the demand for data scientists, something is lost—the fact that data science will not be enough for the future of GEOINT.

Data Science Undefined

Today's NSG leaders are united in their recognition for the need to respond to the increasingly massive amounts of generated data—growing in veracity and volume—and want employees capable of searching, wrangling, and analyzing the massive amounts of data. These leaders seem to agree that data science is the profession appropriate to perform these duties, regardless of the fact that only a de facto definition for data science exists.²⁸ A recent U.S. Air Force (USAF) white paper on Intelligence,

Surveillance, and Reconnaissance (ISR) offers a definition in which data scientists “[extract] knowledge from datasets ... find, interpret, and merge rich data sources; ensure consistency of datasets; create visualizations to aid in understanding data; build mathematical models using the data; and present and communicate data insights/findings to a variety of audiences.”²⁹

Data science is not a new phenomenon. In fact, as early as 1977, John Tukey—the scientist who coined the term “bit”—was developing statistical methods for digital data. In a 2013 blog “rant,” one author posits data science is simply the “application of statistics to specific activities.”³⁰ Following that, “we name sciences according to what is being studied. ... If what is being studied is business activity ... then it is not ‘data science,’ it is business science.”³¹

This is an extremely important counterpoint to the USAF ISR white paper that concludes, “adding ‘data science’ to an intelligence analyst’s job description would both diminish the focus on his or her core competency (intelligence analysis) and also result in sub-optimal data science.”

We feel the danger in the current NSG narrative is the expected degree of data science integration and focus. Integrating new technologies to one’s career field is critical, and we see that intelligence analysis should not be any different. It is not that data science is a powerful breakthrough in and of itself, but rather it is the application of computational analytic tools to enhance domain knowledge that demonstrates exponential gains.

Exacerbating the definition problem is the tendency of leaders to excitingly convolve developing technologies into data science, most likely based on the

assertion that the technologies rely on big data and computers, and thus, are data science.³² Artificial intelligence—traditionally captured under the umbrella of “computer science”—is suddenly being lumped under “data science” as well, possibly because it requires massive training data.

This brings to light the emerging problem of senior leaders throughout NSG and industry blurring the lines of an already loose definition and searching for the rumored “unicorn:” a geospatial or imagery analyst that can map-reduce multiple near real-time data feeds from the cloud, develop a ML neural network and deploy them into the cloud, and improve computer vision to automatically extract targets—ultimately providing policy-makers with advanced visualizations of predictive assessments on socio-political activities. This turns the focus on data science into a cure-all black box instead of an integral tool that should be present in each career field.

While this may seem like semantics, it is an important point for the community to realize the implications of the narrative that data science can provide all the answers without knowledge of geospatial and social sciences.³³ The NSG must establish a common understanding of what data science can, and, perhaps more importantly, cannot do in order to develop concrete strategies to move forward.

Data science is focused on how to access, store, mine, structure, analyze, and visualize data. This requires deep expertise in computational statistics and plays an important part in getting pertinent data from the information technology and computer science sphere into the hands of the geospatial and social scientists focusing on their subject matter expertise. However, this

21. The U.S. Army Operating Concept: Win in a Complex World. TRADOC Pamphlet. US Army Training and Doctrine Command. 2014.

22. Christopher Parrett. “Army GEOINT Support to Megacity Environmental Framing.” *Military Intelligence Professional Journal*, 51-58, 2016.

23. Kristin Quinn, “A Global GEOINT Enterprise.” *Trajectory*, June 4, 2017. <http://trajectorymagazine.com/global-geoint-enterprise/>.

24. Robert Cardillo. “GEOINT 2017 Symposium (Remarks).” NGA.mil, June 5, 2017. <https://www.nga.mil/MediaRoom/SpeechesRemarks/Pages/GEOINT-2017-Symposium.aspx>.

25. Jenna Brady. “Army Lab Hosts First Data Science Meetup.” *ARL*. December 30, 2016. <https://www.arl.army.mil/www/?article=2933>.

26. B.M. Knopp, S. Beaghley, A. Frank, R. Orrie, and M Watson. *Defining the Roles, Responsibilities, and Functions for Data Science Within the Defense Intelligence Agency*. Government. RAND Inc.; 2016.

27. USAF. *Data Science and the USAF ISR Enterprise*. Government. 2016.

28. Gil Press, “12 Big Data Definitions.” *Forbes*. September 12, 2014. <https://www.forbes.com/sites/gilpress/2014/09/03/12-big-data-definitions-whats-yours/#3d2b8ec413ae>

29. USAF. *Data Science and the USAF ISR Enterprise*. Government. 2016.

30. R. Bloor. “A Data Science Rant.” *Inside Analysis*. August 12, 2013. <http://insideanalysis.com/2013/08/a-data-science-rant/>

31. Ibid.

32. Carlos Perez. “Deep Learning Is Transformative, Data Science Is Just Informative.” *IntuitionMachine.com*, January 3, 2016. <https://medium.com/intuitionmachine/data-science-is-informative-but-deep-learning-is-transformative-316e61871dd8>.

33. Chris Anderson. “The End of Theory: The Data Deluge Makes the Scientific Method Obsolete.” *Wired.com*. <https://www.wired.com/2008/06/pb-theory>. Accessed September 29, 2017.

deep expertise comes at a price, as few data scientists will be experts in critical geospatial principles and rather will likely focus more on their ability to write processing scripts.¹ For instance, while the application of pure data science has discovered new species through statistical signatures, it offers no information on “what they look like, how they live, or much of anything else about their morphology.”² Data scientists are also not software developers, which means they are unlikely to implement the algorithms and develop the tools to auto extract objects from imagery or deploy progressive neural networks.³ Moreover, as tools implement more successful ML algorithms, analysts will likely be expected to elevate to higher-level tasks. For these reasons, it is highly unlikely data science is the answer to the problems geospatial and social scientists are trying to solve, but rather serves as a tool to be leveraged when and where appropriate.

The reality of the deluge of spatial-temporally enabled data is that it is both a data science problem and a geospatial domain problem. A modern weapon system offers an analogy. Soldiers spend countless hours developing the expertise to effectively employ the weapon system, while still performing some basic maintenance and operations. In direct support of this system, however, mechanics and system specialists that are part of the team complete most of the major maintenance and modernization. Consequently, when the weapon system is operating subpar, discussions between the crews and maintainers are critical. Similarly, the ability to script and their understanding of statistical algorithms will improve GEOINT analysts’ effectiveness operating their tools in addressing more complex issues, but the primary concentration should be on their fundamental intelligence tradecraft and domain knowledge. It follows that

as the GEOINT analyst focuses on the challenges of synthesizing data on the complex geospatial and social environment into intelligence, computer and data scientists should focus less on basic data formatting and process simplification for GEOINT analysts, concentrating more on the challenges of researching, developing, processing, visualizing, and developing new data streams and tools that are critical to maintain the IC’s competitive edge.

The benefits of this symbiotic, multidisciplinary approach go beyond data science. GEOINT analysts who are versed in the foundations of computer and data science, and able to communicate with data and computer scientists, will be able to overcome the hurdle of data wrangling and advance toward geospatial computational social science. This position is in line with an earlier published RAND Corporation paper for the Defense Intelligence Agency, in which data science is termed “a team sport.”⁴

The Future GEOINT Analyst

Geospatial computational social science (CSS) is an emerging area of diverse study that explores geographic and social science through the application of computing power,⁵ which includes data science. With origins closely tied to that of advanced computing and GIS, the geospatial CSS field is in relative infancy when compared to the traditional schools of sociology, political science, anthropology, economics, and geography. It is important to note CSS does not replace these traditional social sciences, but rather advances them through applications of computational methods.^{6,7} By leveraging high-performance computing, advanced geostatistical analytics, and agent-based modeling, geospatial CSS empowers a multidisciplinary approach to the development of methodologies and algorithms to gather, analyze, and

explore complex geospatial and social phenomenon.

Geospatial CSS presents a nexus of geographical information science, social network analysis, and agent-based modeling. It will require a solid foundation in geographic principles and the ability to apply computational thinking to complex social problems.⁸ Already, there are programs being written that simulate a 1:1 ratio of humans to computer agents. Imagine a catastrophic scenario in a megacity such as New York, and being able to simulate what every human in the city may do in reaction to the event being layered over high-precision terrain, physical models of buildings, super and subterranean features, dynamic traffic patterns, and reactive infrastructures.⁹

Data science methodologies will undoubtedly play a key part in future multidisciplinary teams, helping to find the proverbial “needle in the stack of needles.” Geospatial CSS, however, is not only about making statistical inferences based on zettabytes of spatial-temporal observations; it is concerned with the exploration of the theories and processes that result from interactions caused by the observables. In a complex world, the aggregation of these interactions provides more unique pathways to understanding the reasoning behind the behavior of our adversaries than would a holistic analysis of the whole system. To further the needle in a stack of needles analogy, geospatial CSS aims to provide insight into as to why a needle would fall a particular way, and into a particular position in space and time, in that stack of hay. Geospatial CSS will be key in advancing GEOINT to “Understand the World.”¹⁰

Recommendations

The NSG should work closely with academia to shape future geospatial

1. Karsten Strauss. “Becoming a Data Scientist: The Skills That Can Make You the Most Money.” *Forbes*. September 11, 2017. <https://www.forbes.com/sites/karstenstrauss/2017/09/21/becoming-a-data-scientist-the-skills-that-can-make-you-the-most-money>.
2. Chris Anderson. “The End of Theory: The Data Deluge Makes the Scientific Method Obsolete.” *Wired.com*. <https://www.wired.com/2008/06/pb-theory>. Accessed September 29, 2017.
3. Rudina Sesi. “The Rise of AI Will Force Data Scientists to Evolve or Get Left Behind.” *Forbes*. January 31, 2017. <https://www.forbes.com/sites/valleyvoices/2017/01/31/the-rise-of-ai-will-force-a-new-breed-of-data-scientist>.
4. B.M. Knopp, S. Beaghley, A. Frank, R. Orrie, and M. Watson. Defining the Roles, Responsibilities, and Functions for Data Science Within the Defense Intelligence Agency. Government. RAND Inc.; 2016.
5. P.M. Torrrens. “Geography and Computational Social Science.” *GeoJournal*, 75(2):2010, 133-148.
6. Richard Medina and George Hepner. “Note on the State of Geography and Geospatial Intelligence.” NGA. January 1, 2017. <https://www.nga.mil/MediaRoom/News/Pages/StateofGeographyandGEOINT.aspx>.
7. C. Cioff-Revilla. *Introduction to Computational Social Science*. Springer International Publishing; 2017.
8. Ibid.
9. George Mason University. Characterizing the Reaction of the Population of a Megacity to a Nuclear WMD. September 29, 2017. <http://socialcomplexity.gmu.edu/dtra-project/>.
10. Robert Cardillo. “GEOINT 2017 Symposium (Remarks).” NGA.mil, June 5, 2017. <https://www.nga.mil/MediaRoom/SpeechesRemarks/Pages/GEOINT-2017-Symposium.aspx>.

computational social scientists who will be able to apply advanced computational methods, such as agent-based modeling, social network analysis, geographic information science, and deep learning algorithms toward analyzing and understanding physical and human geographic behaviors. Whereas high-performance computing and ML and visualization fall mostly within computer science and image science, geospatial CSS presents the nexus of geographical information science, social science, and data science. Future GEOINT analysts will require enhanced skills, applying computational power to explore and test hypotheses based on social and geographic theory to truly achieve the understanding of human interactions.

We recommend the NSG focus analytical modernization initiatives on forming multidisciplinary teams to attack key

intelligence questions using geospatial CSS now to refocus the narrative on future. We understand data science techniques are still widely needed now, but feel the NSG community must come together to decompose data science for the future, focusing on key skills that rely not only on data, but on advances in information technology (IT) architectures, computation, and the application of geospatial computation to the social sciences. This also will help to delineate and define tasks to establish government workforce structure and career development, especially in the Armed Services, where traditional career series such as Intelligence Specialist (0132), Physical Scientist (1301), or Operations Research Systems Analyst (1515) strictly define work roles.¹¹

History has repeatedly shown new technology does not change the

conduct of war alone, but it is how new technologies are integrated which creates advantage.¹² This work will also guide industry initiatives and shape academia for the future geospatial scientist, rather than risk investing in a skill set that may be superseded in the future. In other words, generalizing data science as a black box catchall will risk creating generalists. This would result in the NSG losing oversight of what truly matters, which are analysts utilizing pertinent spatial-temporal data to provide timely, accurate, and objective assessments to not only monitor and analyze observed activity, but also to provide understanding of the geographic and human processes. This understanding requires the application of advanced computational methods to support the intelligence needs of policy-makers and warfighters.

The Past, Present, and Future of Geospatial Data Use

By Dayna Behm, BAE Systems; Tony Bryan, Midwest Cyber Center; Joshua Lordemann, Leidos; and Steven R. Thomas, Ball Aerospace

Over the past quarter century, information in the form of digital data has become the foundation on which governments, industries, and organizations base many of their decisions. In our modern world, there exists a deluge of data that grows exponentially each day. Companies and institutions have come to the awareness that not only must they have access to the right data at the right time, but they must also have access to analysis of the raw data to make correct decisions. The proper collection, analysis, and usability of timely and relevant data can mean the difference between success and failure.

“As organizational decisions increasingly become more data driven, businesses need to assure decisions are made with the most accurate data. That explains why so many organizations have made data collection and analysis a strategic and organizational priority and recognize data as a mission-critical asset to manage.”

- Harvard Business Review¹³

Hence the constant search for new data sources, tools, solutions, and experts. Hence the persistent quest for new ways to use data, find relationships in data, and discover patterns in data. As we reflect on the uses of geospatial data, one of the most significant growth areas in the broader world of data is the area of data visualization. Whether rendering information in two or three dimensions, geospatial data is the key to visualizing data, which is why it has become one of the most sought after forms of data. Geospatial data was traditionally confined to use by the military, intelligence agencies, maritime or aeronautical organizations, etc. Today, the use of geospatial information has expanded into almost every market and institution around the globe, with the discovery that it can provide new levels of insight and information. Geospatial data has become an integral element in how companies and organizations conduct business throughout the world. As we look at how

geospatial data is being used in the past and present, it makes us question how the uses of this data will change in the future.

Geospatial Data in Retail

Unbeknownst to most consumers, data drives the world of retail. Google, Amazon, and Walmart have realized the value of geospatial data to achieve growth and digital transformation, and now others are following suit. To tailor products, services, and goods, it is important to know the socioeconomic information of your customers. Specifically, geospatial data can provide retailers data on income, housing/rent prices, surrounding business performance, population, and age. These details determine the brands and the products they carry. For example, a store like Macy's or JCPenney in an urban location will carry different brands than it would in a suburban or rural community.

Another way retail uses geospatial data

11. OPM.gov. OPM Classification and Qualifications. <https://www.opm.gov/policy-data-oversight/classification-qualifications/general-schedule-qualification-standards/1500/operations-research-series-1515/>. Accessed September 29, 2017.

12. Max Boot., *War Made New: Technology, Warfare, and the Course of History, 1500 to Today*. New York: Gotham; 2006.

13. Michael Schrage. "How the Big Data Explosion Has Changed Decision Making." *Harvard Business Review*. Harvard Business Publishing, August 2, 2016. Accessed online September 17, 2017.

is in combination with weather pattern predictions. In areas prone to hurricanes, tornadoes, or extreme winter weather, it is necessary to change items overstocked or on hand. In times of catastrophe, such as Hurricanes Harvey, Irma, and Maria, stores like Home Depot typically carry a surplus of generators. In the restaurant industry, Waffle House prepares to provide a limited menu during times of inclement weather. During predicted storms, especially in the South, Waffle House will order the necessary food to operate on a limited menu to provide their customers with breakfast in times of need. Also, weather pattern visualizations allow grocery stores to know when they should stock up on non-perishable items. Although storms are not predictable, the times and trends year after year are, and the ability to forecast at least a few weeks ahead can increase profits and better serve customers in times of need.

In a more traditional brick-and-mortar industry, such as banking or fast food, companies like Subway and Wells Fargo can select future optimal sites and assess the past performance of existing locations. Socioeconomic data as well as information like traffic patterns, foot traffic, and the number of residences in the area can be helpful when choosing a location. Geospatial data can also provide information on competitors in the area and forecast upcoming trends or construction projects that may affect business. For example, it's important to know if a major, long-term road construction project is planned that may impact traffic patterns and accessibility of the business location.

The use of geospatial data in retail is not a new development. People began using customer data for retail sales forecasting back in post-World War II, however, it wasn't until the 1990s when our technology improved enough to allow companies to perform "data mining" on their customers and retail stores. Since then, data mining has gone from raw statistics to incorporating other technologies such as artificial intelligence to help log and track activities in certain locations.¹

The creation of GIS software in particular provided companies with a multitude of information. Through the use of thematic map coloring, companies are able to visualize geographic patterns that may not otherwise be seen in the raw data. By entering the raw data into data tables and then instructing the GIS software to generate the data into a layer on the map (such as placing pins on the map to mark where a company's best customers lived), it creates a visual that allows retail companies to recognize certain patterns in the population. Different layers of maps can also be added or taken away to provide additional/less information with just a click of the mouse. For example, if a company was viewing a map that showed where the best customers lived but wanted to focus on the average annual income of the population living near the store, they could uncheck the layer showing where the best customers lived and select the average annual income layer instead. These abilities make GIS an invaluable asset for any retail business.²

Geospatial Data in Health Care

Health geography and the application of geospatial data and techniques continues to expand its influence and use to support more accurate and timely decision-making in the healthcare market. Research continues into the application of social geography and redefining health care from a model of treatment to a model of prevention and wellness.

Geospatial data is essential for both the study of epidemiology and the geography of health care. When we "know the earth," when we discover patterns and influencing factors, when we understand how a population is influenced by social and cultural norms, only then can we begin to understand the effects on humans and their health needs.

Many diseases are being researched today using geographic techniques. The location of water, IV drug users, environmental hazards, or the nomadic patterns of people can all provide clues and knowledge to determine where the greatest healthcare need could exist in

the future. One such example follows.

Geospatial research teams are using commercial data to develop simultaneous sky and ground truth for detecting and tracking nomadic pastoralists in rural areas of Africa. Using algorithms originally developed for defense intelligence, industry has prototyped solutions that can detect and geo-locate new dwellings in the Lake Chad region. Analysis helps develop patterns of life, including health-related information, based on data availability. This information can be provided to workers on the ground in order to provide efficient vaccine and medical care to nomadic populations.

Industry is also applying advanced algorithms to epidemiology to refine the scope and improve the cost-effectiveness of imagery tasking for more sensitive and specific results. For example, geospatial technology is being used to detect and geo-locate waste tire piles in Africa, which are a significant breeding ground for disease-carrying mosquitos.

Through discovery of these disease breeding grounds, healthcare teams can determine disease vectors to ultimately provide much needed vaccinations for diseases such as polio, West Nile virus, and malaria. Currently, nomadic tribes and camps are difficult to track, requiring locals and untrained health workers to deliver vaccinations in remote areas based on the seasonal migration of the tribes. Because of the difficulty in pinpointing the tribe locations and the nature of employing sometimes-corrupt locals for delivery, inoculations may end up on the black market and many people could remain unvaccinated. One in five children worldwide are not fully protected with even the most basic vaccines. As a result, an estimated 1.5 million children die each year—one every 20 seconds—from vaccine-preventable diseases. This application of technology provides better tools to track human migration, and to produce trends and reports that can make the vaccination delivery to humans in need more precise and timely. This same technology can be applied to find other

1. Maïke Krause-Traudes, Simon Scheider, Stefan Rüping, and Harald Meßner. "Spatial Data Mining for Retail Sales Forecasting." University of Girona, Spain. Agile-Online.org. 2008. https://agile-online.org/conference_paper/cds/agile_2008/pdf/118_doc.pdf. Accessed December 5, 2017.
2. Paul Duke. "Geospatial Data Mining for Market Intelligence." TDAN.com. April 01, 2001. <http://tdan.com/geospatial-data-mining-for-market-intelligence/4921>. Accessed December 6, 2017.

structures and bio-forms that function as breeding sites—information that can be provided to survey teams for validation and action.

The use of geospatial data and analysis provides impact and benefits to the healthcare industry daily. Geospatial tools are able to visualize and inform service providers about changes in patterns, environmental impacts, identification of and changes within high-risk areas, and where the greatest need for resources providing the greatest benefit should be deployed.

Geospatial Data in Financial Services

The financial services industry, which traditionally consumes data in the form of dollars, cents, credits, and debts contained within spreadsheets, balance sheets, or financial statements, has discovered value in geospatial data. Consider the world of investment banking, an industry whose success is built by betting on ventures that offer the best return on investment and avoiding ventures that have a high risk of failure. This industry has created a science out of making the right investments based on analysis of all available data. Certainly this includes accounting data, balance sheets, and financial forecasts. However, today many financial services providers are also including geospatial data and analysis in their decision process. By using geospatial data and employing experts in geospatial analysis, companies can access new elements of knowledge, including but not limited to:

- Visualizing real estate or land holdings tied to a particular investment.
- Tracking changes to corporate, industry, or regional construction or development over time.
- Visualizing geographic and demographic data of investments and the regions of the globe they occupy.
- Analyzing services and infrastructure in a geographic area that may have a positive or negative impact on an investment.
- Using geospatial data as one more source to avoid inaccurate or false financial information.

- Analyzing imagery data of current or prospective investments half a world away without the need for travel.

In all of these examples, the benefit is the same. Geospatial data provides a new type of information that promotes a better final decision. Geospatial data provides new information that at a minimum promotes a more informed decision process and, in many cases, a more profitable decision. Additionally, investment risk can be reduced in ways that were unheard of a decade ago.

Geospatial Data in Logistics/Transportation

Historically, geospatial data has been most commonly associated with transportation through the utilization of maps for navigation and transit. However, we have seen an abundance of new applications become available with digital maps that are changing the way that we understand our world. Would one ever think you could know exactly how much time it would take to get from Point A to Point B using the fastest route? Or, that we would be able to caution other drivers of a disabled car?

But beyond the common use of applications like Google Maps and Waze, companies and industries are leveraging geospatial data for transportation that provides better solutions.

Today's economy is focused on how to achieve results cheaper and faster while still maintaining high-quality products. Geospatial data has been a key influence in logistics and routing via roads/highways, railways, ports/maritime, and airports/aviation. Companies have been able to expand their businesses with this data by reducing the complexity of navigating large geographic areas. These operations can include:

- Using global positioning systems (GPS) for vehicle tracking and dispatch to expedite schedules.
- Conducting route analysis for better efficiency when transporting goods.
- Mapping operation/warehouse locations for the proper inventory of goods for transport.

By implementing geospatial data into business decisions, companies can see favorable results. Recent studies show that by using geospatial data, companies can help improve efficiencies and customer satisfaction as well as drive business strategy:

“Research carried out by Vanson Bourne on behalf of Google, shows that mapping technology has had a dramatic impact on the transport and logistics organizations that have embraced it. 67 percent are experiencing better customer engagement, 46 percent have improved productivity and efficiency, and 46 percent have seen reduced costs as a result. Over half (54 percent) of those surveyed say that it has led them to reconsider their organization and/or product strategy.”³

Internationally, geospatial data for transportation is in great demand. Data consisting of population densities, land uses, and travel behavior are valuable at the federal, state, and local levels to aid in transportation policy and planning. These data improve decisions made for highway management to ensure better use of limited funding.

During natural disasters, geospatial data plays an important role in risk management regarding transportation routes. Use of geospatial data informs strategic planners of potential routes that could be impacted due to the risks inherent to geography. These data also help identify evacuations routes. Emergency management organizations are able to identify road closures to help them navigate to people in need as quickly as possible.

Lastly, public transportation, fitness, and sport-based applications used for transportation should not be overlooked. There is an abundance of these applications available to the everyday user that helps provide information necessary to make timely decisions to improve schedules and results.

The Future of Geospatial Data

Innovation and cutting-edge research and development (R&D) in the field of geospatial data, geospatial science, and analytics continue to yield new ways to incorporate geospatial data into new

3. Balaji Swaminathan. “Geospatial Technology in the Logistics Industry.” Ramco. Ramco Systems, July 8, 2013. Accessed online September 17, 2017.

arenas and offer solutions to today's most challenging problems. Companies and academic institutions across the country are investing in developing geospatial technologies that will further extend the use of this valuable data outside traditional markets.

The fields of remote sensing and mobile drone platforms/sensors are expanding rapidly and providing consumer markets new levels of persistent and targeted geospatial data previously available only to the military and intelligence agencies. Geospatial data is a critical element to the operation of drones and small autonomous spacecraft, all of which depend on geospatial data to provide precise positioning. Numerous R&D activities are finding new ways to provide more accurate data to these platforms, thus enhancing their overall performance.

GIS research has also become a critical element in developing artificial intelligence (AI) and machine learning (ML) technologies, providing an important data element to the content libraries and algorithms of these systems. AI innovations offer groundbreaking ways to perform

topological data analysis, spatial analysis, change detection, and feature selection.

Geospatial data is also one of the foundational elements of virtual reality (VR) development. There is an increase in the use of geospatial data to inform policy-making. Spatial data related to urban sociology, demography, and statistics are becoming an essential element of many local, state, and federal government decision processes. The aforementioned is merely a sampling of the future of GIS. Other R&D activities that will further broaden the use of geospatial information include but are not limited to:

- Biosecurity and health informatics.
- Biostatistics and health risk appraisals.
- Geospatial patterns of health behaviors and outcomes.
- Geospatial patterns of disease treatment and outcomes.
- Urban health, education, crime, and economic development.
- Computation spatial statistics and social-environmental synthesis.

- Geospatial urban planning and development.
- Geospatial civil engineering.
- GIS for traffic analysis and engineering applications.
- Environmental and food security on both a regional and global scale.
- Transport of contaminants in soil and water.
- Geospatial trends in air pollution.
- Food and water security.
- Regional climate response and agricultural forecasting.

Geospatial data use has expanded beyond traditional consumers and is adding value to the retail, transportation, healthcare, and financial markets, to name a few. This expansion indicates that adding geospatial data to any data collection or analysis effort is beneficial. Furthermore, it speaks to the ever-present need to ensure geospatial data and related tradecrafts are properly governed to provide consistency in quality, accuracy, and security.

Modeling Outcome-Based Geospatial Intelligence

By Brian Collins, Intterra; Ofer Heyman, Ph.D., Levrum Data Technologies; Joaquín Ramírez, Ph.D., Technosylva Inc.; Trude King, Ph.D., U.S. Geological Survey; Brad Schmidt, Colorado Center of Excellence for Advanced Technology Aerial Firefighting; Paul M. Young, U.S. Geological Survey; KC Kroll, DigitalGlobe, a business unit of Maxar Technologies; Ryan Driver, DigitalGlobe, a business unit of Maxar Technologies; and Carl Niedner, Levrum Data Technologies

Society has tremendous capabilities to prepare, respond, and recover following natural disasters, emergency events, and security incidents—but these capabilities each require time, space, and energy to mobilize and focus. Geospatial intelligence (GEOINT) is a key element to engaging response capabilities in the right way, at the right time, and in the right place. In particular, the connection between GEOINT and modeling has emerged as a capability that decision-makers and response teams can rely upon to increase the correctness, reliability, and timeliness of their decisions.

Today, the most notable example of models in action occurs in the realm of hurricanes and severe weather. The impact of hurricanes on the United States

and across the globe continues to be a challenging part of our natural hazard landscape. We experience not only direct threats to life and property from such storms but also increased second and third order effects. Important tools to focus action (while simultaneously garnering public attention) include the ubiquitous European and United States hurricane models that we are accustomed to seeing. They enable us to track and predict where a hurricane may travel and its potential impacts. Similarly, we subsequently rely on flood and inundation models to predict storm surge and intensity.

As GEOINT systems collect additional data and decision-makers are exposed to more complex and useful models, the demand for modeled outputs in a variety of applications will likely grow. They present

data from spatial and dynamic sources as a unique combination of time and space in a format that decision-makers, the public, first responders, non-governmental organizations, and recovery experts all use to enhance and support their actions. This reflects a shift from simple data collection and display to a world where we ask and expect an answer to the question: "What does it all mean?"

The Integration of GEOINT and Mathematical Modeling

From a GEOINT perspective, the output of modeling can be used to analyze the projected path of a hurricane or wildland fire, depict and assess the impact of the event and on structures within that path, and prioritize evacuations. The objective of modeling is to create a simulation

of real-world events or conditions. By using modeling to focus on real-world outcomes such as population shifts or emergency services response times, the GEOINT Community is beginning to transform geospatial data from discrete data elements into the direct language of decision-makers and operations personnel.

While many think of modeling in terms of weather/hurricane models and Monte Carlo simulations, it is the application of those models into predictive situations that improve accuracy and the available time for decision-making. Delivering outcome-based modeling as a product of GEOINT allows policy-makers to more rapidly assess both risks and opportunities. Models allow us to investigate complex things by applying our knowledge of simpler things. Once a model is proven consistent with supporting evidence and therefore accepted, it can be confidently used to make reliable predictions.

“What if?” analysis is one of the most recognizable modeling outputs. Often called “predictive analytics,” these models encompass a variety of modeling and statistical techniques ranging from machine learning (ML) to linear regression to multivariate analysis. These models allow policy-makers to assess various decisions, predict uncertainty, and assess the impacts of one attribute versus another. They present insights into what may happen based on trends, combinations of data and patterns, or rule-based behaviors. Predictive models generally focus on outcomes rather than numbers. Decision-makers are far more likely to be asked when a river will reach flood stage, and what to do about it, than what the reading is on a particular stream gauge. The goal is to answer not only what may happen in the environment, but also what would be the impact of various decisions on the outcome.

Applying Models to Decision-Making

The majority of models are developed in academia or other technically sophisticated environments. Transitioning them from expert users to emergency service practitioners poses a variety of challenges. The development and

transition of models such as Hazus or the European and U.S. hurricane models into common tools used by responders requires consistent mentorship and stewardship by both the academic community and the targeted user community, typically including a centralized authority such as the Federal Emergency Management Agency (FEMA).

As demand for actionable GEOINT information increases, academia and GEOINT producers need to focus on ways to speed up the long-term adoption process (which exceeds five to eight years in some cases) that typical models take to transition from science into practice. One example of a recent effort to streamline this adoption cycle is the efforts of the State of Colorado to integrate a fire behavior model directly into fire operation. The Colorado Center of Excellence for Advanced Technology Aerial Firefighting (CoE) recently entered into a partnership with the National Center for Atmospheric Research (NCAR) to transition a weather-based wildland fire predictive model to operational use. As part of the project, the CoE not only provided training material to firefighters, but also engineered a separate training module to allow for multivariant simulations based on specific geographic and meteorological case studies. These enhancements improved the usability of the modeling system for non-experts and hastened potential adoption by the wildland fire community.

Current Uses of Modeling

Emergency Services Delivery:

Increasingly, fire and EMS leaders are applying quantitative standards, confronting complex problems, and seeking innovative deployment solutions. There is growing demand within fire and emergency medical services (EMS) communities for decision support systems that can answer “What if?” questions and allow for deployment planning based on future incident predictions. This confluence of factors is spurring the development of the kinds of hybrid GEOINT solutions described above.

A number of cities around the country are using hybrid modeling, geospatial

data, and ML techniques to evaluate performance and determine efficiencies. For example, the city of Palo Alto recently faced a daunting problem: optimizing paramedic unit placement, scheduling, and staffing to optimize five competing performance metrics within budget and physical constraints. A unique software solution that paired ML algorithms with discrete simulation and geospatial-temporal data identified eight near-optimal solutions out of millions of alternatives for command staff to evaluate. Nearby Redwood City addressed the problem of unprecedented growth by utilizing a hybrid system that combined a machine learner with geospatial-temporal analysis tools to generate an accurate, validated model of future incident profiles. This model generated future scenarios using discrete event simulation, enabling command staff to assess key performance metrics such as response time, utilization, budget impact, and system resiliency on both reasonably anticipated and extreme versions of future scenarios.

Fire Behavior: Fire behavior modeling projects the behavior and effects of fire activity to inform and guide prevention measures, response tactics, resource management, and safety decisions across all levels of the fire service—from wildfire to structure fire, from initial attack to sustained attack, and throughout the cycle of land and forest management. As a fire response increases in complexity, wildfire modeling is used for tactical planning, the assessment of future resource requirements, and evacuation planning.

Wildfire behavior models range from empirical fire spread estimation to physical models. They combine geospatial data (slope, fuel/land cover data) and dynamic data (weather measurements) to provide specific decision products including fire spread, intensity, and behavior. The State of Colorado is currently in the second year of a multiyear effort to deploy a wildland fire prediction system based on improved weather data provided by the High-Resolution Rapid Refresh (HRRR) model developed by the National Oceanic and Atmospheric Administration (NOAA). Rather than relying on a single point forecast, as was the case in previous

generations of fire models, the HRRR model provides a gridded forecast at three-kilometer spatial resolution across the state. The HRRR model creates a new 18-hour forecast every hour and uses radar data to model the propagation of existing storms. The fire prediction system creates a hyper-local forecast over 36 square kilometers at the location of the fire. This forecast is suitable for operational and tactical decisions of ground personnel based on micro-terrain and local winds.

In Southern California, a system called Wildfire Analyst simulates 10 million fires daily to evaluate the potential impact of wildfires on values at risk and utility lines, using a two-mile resolution local model and high-resolution five-meter fuels analysis. This massive analysis allows local utility managers to prepare in advance to address the potential impact of wildfires up to three days in advance. Similar systems are used in Chile by Corporación Nacional Forestal (CONAF), which uses real-time observations to calibrate modeling of large-scale incidents such as the Las Maquinas Fire in January 2017. CONAF uses the modeling not only to support incidents but also to communicate to the public what is intact after every big fire, comparing the resulting burned area versus simulated fire progressions that would have occurred without suppression efforts.

Land Use: Land use change modeling projects historic patterns into the future and visualizes alternative futures as a tool for decision-making by local or regional government officials. This type of modeling helps reveal the causes, mechanisms, and consequences of land use dynamics by modeling the interaction in space and time between humans and the environment. GEOINT data in the form of satellite images and maps play a key role.

One example of a land use change model is SLEUTH, which stands for Slope, Land Cover, Exclusion, Urban, Transportation, and Hill Shade—the input data to the model. For more than 20 years SLEUTH has been used in 18 countries to study land use change. The impacts to urban growth can also be examined. One such study assessed declining water quality in the Chesapeake Bay estuary due in

part to disruptions in the hydrological system caused by urban and suburban development. Land use change models will continue to be used to study the complex interactions of urban dynamics and can be used by local and regional governments to inform policy decisions.

Watershed: Providing water for human and ecological needs remains a challenge for local and regional government officials worldwide. As populations grow and demand for water increases, land and water resource management is evolving from simple, local-scale problems toward complex, regional ones. Such problems can be addressed with models that can compute runoff and erosion at different spatial and temporal scales. In 2002, the U.S. Environmental Protection Agency, U.S. Department of Agriculture, the University of Arizona, and the University of Wyoming first developed an automated, GIS-based watershed modeling tool. Now under continual development, the Automated Geospatial Watershed Assessment (AGWA) helps decision-makers manage and analyze water quantity and quality. AGWA utilizes the Kinematic Runoff and Erosion (KINEROS2) hydrologic model and the Soil and Water Assessment Tool (SWAT) to evaluate watersheds with varying soils, land uses and management conditions, and their related environmental and economic impact. AGWA has also been used to analyze land impacts of coalbed methane extraction, management of impacts from military training activities, and the evaluation of flow in streams on military bases in the southwestern U.S.

Sea-Level Rise: The effects of rising sea levels range from large-scale population displacement to critical infrastructure degradation due to saltwater intrusion. Coastal erosion is evident in many areas of the world, in the U.S. notably along the Louisiana coast. In 2014, the U.S. Geological Survey and the University of San Francisco published a new marsh accretion model, WARMER, to assess the risk of sea-level rise to salt marsh parcels around San Francisco Bay. The aim of this model is to provide site-specific sea-level rise predictions to land managers through the intensive collection of field data and innovative predictive modeling. WARMER indicates that most salt marsh around San

Francisco Bay will transition from high to mid marsh by 2040, to low marsh by 2060, and to mudflat by 2080, however, there is a great deal of variation around the bay.

What Makes a Good GEOINT Model?

A scientific model must not only generate predictions, but also generate results that are used and accepted by decision-makers. As observers of the natural world, we will only accept a model if its predictions stand up against outcomes we can observe. Although specific fields and disciplines may accept and use models with varying attributes, models that can be integrated as a GEOINT product must share some specific attributes. Here are some characteristics of good models:

Output that is linked to decision or analytical objectives: Models that support specific identifiable decisions or outputs support the entire GEOINT cycle. In this sense, they are “products” and must be aligned to an information need or decision point. They are the automated counterpart of manual analysis and reports.

Consistent, identifiable, and available data: The data that support a model can turn a good model into one that is inconsistent or irrelevant. GEOINT models are used to support decisions at all levels, from analysts to the public, and at frequencies that range from one to three times to common, automated runs. As a result, they should be aligned to consistent, accurate, and standardized geospatial data for which an analyst or automated system has a reasonable expectation of availability.

Ability to assess and compare the impact of inputs: The sensitivity of a model to changes and variation in input data is directly linked to decision-maker understanding, trust, and adoption. If a model appears to have wide swings in output based on small changes to inputs, it can limit the adoption and trust of outputs by decision-makers.

Consistent outputs: A model must produce output that is consistent with inputs. Although one of the benefits of modern modeling is that it goes beyond

pattern assessment, decision processes and trust in systems begin to wane when similar inputs result in different outcomes.

Ability to assimilate real-time

observations: Operational models need to provide answers in near real time and respond to the influx of massive amounts of data that can be captured from operators, citizens, and the wealth of sensors available through the Internet of Things (IoT) and remote platforms.

Produce results for advanced

visualization platforms: Traditional GEOINT results in maps, a tool for specialists to be used in planning and operations. But our audience (GEOINT professionals, decision-makers, the public) demands easy-to-understand information in a variety of formats (e.g., 360-degree

videos, 4D immersive environments, augmented and virtual reality).

Conclusion

Better and expanded application of modeling as a GEOINT product has the potential to enhance and focus the work of traditional analysis. To expedite the adoption and improve the relevance of modeling, the GEOINT Community should begin to revamp and refocus modeling advances on customer needs. The low adoption rate of modeling as a GEOINT product for some of the examples cited in this article can be refocused by addressing the core attributes listed above. Modeling should produce immediate, consumable results. Simultaneously, models need

modernization to take advantage of new practices and approaches as well as new and improved data sources. Modeling needs to decrease reliance on hard-to-find or outdated information, such as inconsistent, manually collected land cover data, and transition to the application of methods, such as automatically extracted data from satellite remote sensing systems.

Policy-makers must be able to depend upon a reliable, integrated, and continuously improving GEOINT framework to address the increasing challenges. Our future GEOINT framework should expand to include modeling tools as well as more data, processes, and visualization as we strive to support today's decision-makers.

Discipline-Based Education Research: A New Approach to Teaching and Learning in Geospatial Intelligence

By Camelia Kantor, Ph.D., USGIF; Narcisa Pricope, Ph.D., UNCW; and Susan Wang, Ph.D., USC

Education and Training as Personalized Learning

*“Training is for certainty, education is for uncertainty, and we are living in increasingly uncertain times.”*¹ This statement emphasizes the important role of education in times when training, a skill and task-oriented endeavor, is gaining increased attention. Education starts early in life and equally provides the arts and science behind the process of completing tasks. As we witness rapid transformation in the multidisciplinary field of geospatial intelligence (GEOINT), training and education are expected to complement each other. We educate people for critical thinking and train them to expand their knowledge base for increased performance. Combining both throughout one's career is especially valuable in addressing the problems of “being educated but poorly trained” or “well trained and poorly educated.”²

Today, rather than identifying occupation-specific knowledge and skills, the field of GEOINT uses USGIF's Essential Body of Knowledge (EBK) to define “what it means to be a GEOINT professional ... across multiple occupations.”³ As identified by the GEOINT enterprise (government, industry, and academia), the EBK was developed with input from a wide range of professions and provides a basic reference for anyone interested in or practicing the profession of GEOINT to include, but not limited to, GEOINT analysts, geospatial analysts, business market analysts, public health specialists, advanced visualization specialists, economic development specialists, emergency preparedness specialists, environmental scientists, geodetic surveyors, biologists, geospatial data stewards, etc. While GEOINT evolves into a stand-alone discipline that incorporates other disciplines, such as computer science, environmental science, physics, mathematics, etc., “geo” is fundamental

in providing students with geographic knowledge and skills during both GEOINT education and training.⁴

In such a fast-changing environment, the focus is more on preparing future GEOINTers and/or retraining current GEOINT practitioners than creating lifelong learners. Unfortunately, beyond some limited computer-based data collection and analysis, little to no efforts have been made in studying how these major technological transformations have affected or may affect the way students adapt to the shift toward a more cross-occupational and STEM-focused GEOINT discipline as compared to traditional geography. Moreover, while traditional students enter this new era of hard, data-focused geospatial sciences, returning students (including adult learners) find a very different world as compared to their earlier education. K-12 AP Human Geography education, which still falls under the social sciences and rarely sees

1. Tom Terry. Geospatial Intelligence Officer, Plans and Policy, Branch, Headquarters. USMC.

2. D. Burrus. “Teach a Man to Fish: Training vs. Education.” *HuffPost*. http://www.huffingtonpost.com/daniel-burrus/teach-a-man-to-fish-training-vs-education_b_7553264.html. Accessed October 10, 2017.

3. GEOINT Essential Body of Knowledge. http://usgif.org/certification/geoint_EBK. Accessed November 27, 2017.

4. R.M. Medina and G.F. Hepner. *Geography and Geospatial Intelligence: A Note on the State of Geography and Geospatial Intelligence*. <https://www.nga.mil/MediaRoom/News/Pages/StateofGeographyandGEOINT.aspx>. Accessed November 27, 2017.

any type of cross-pollination, is a good example of this educational gap.

To address such challenges, this article discusses the intermingled roles of education and training aided by observations of how teaching and learning occur (or should occur) while preparing the next generation of GEOINT practitioners. The article introduces a new concept to the GEOINT Community: Discipline-Based Education Research (DBER).

The Case for DBER in GEOINT

DBER is an emerging concept focused on studying how students learn the knowledge, concepts, and practices of a particular discipline such as geosciences, engineering, physics, chemistry, or astronomy. Much like the dynamic and large array of geospatial components that increasingly draw from or are being drawn into a variety of disciplines, DBER is also a collection of relevant research fields rather than a single unified field. High-quality DBER involves knowledge of the science, of the learning and teaching in that discipline, and the science of learning and teaching more generally.

There is a clear distinction between education specialists whose primary focus is on teaching and DBER scholars who conduct research on teaching and learning within an established discipline. Until it was embraced as a subfield of study within several STEM disciplines, DBER concepts were mostly used by “border crossers,” which remains true in many cases today. DBER is an emerging field with a growing network of scholars. While most DBER programs are housed within a single academic department, DBER is typically conducted by interdisciplinary teams.¹

GEOINT is essentially built on a similar framework as DBER. The GEOINT EBK created its blended set of competencies that incorporate tasks from a number of more established disciplines such as geography, earth science, computer science, engineering, political science, and the emerging field of visualization.

The GEOINT EBK was designed after conducting a cross-industry job analysis to identify the knowledge, skills, and abilities critical to the GEOINT workforce. Teaching GEOINT involves the use of tools from rapidly changing technologies such as geographic information systems (GIS), remote sensing (RS), geospatial database management, and visualization. Academic institutions currently offering GEOINT credentials usually have the GEOINT programs housed in geography or environmental science departments while increasingly using coursework or technologies from other disciplines. As the GEOINT field evolves, so will its educational and professional development stakeholders; the changing technology will continue to cross disciplinary boundaries and thus require different teaching and learning approaches to serve a more diverse student population in terms of technical background, liberal arts versus vocational prior education, age (traditional students versus adult learners), gender, race, and personal learning styles.

The GEOINT field is trying to attract a diverse and broadly educated and trained workforce from both STEM and non-STEM fields. But if considering the challenges largely acknowledged by the STEM scientific literature in diversifying its workforce, we may be looking at an enduring gap in the accessibility of education and training in the geospatial subfield. For example, while current labor statistics show important gains in female participation in the workforce, their share of computer workers has actually been declining since 1990, and both women and ethnic minority groups are still underrepresented in STEM occupations.² According to this year’s “Women in the Workplace” report from McKinsey and *LeanIn.org*, women account for 47 percent of entry-level employees. And, yes, these are jobs projected to be lost to automation. Such challenges may be partially mitigated through differentiated teaching/learning styles and approaches that focus on more inclusionary methods to reach a wider spectrum of society.

To maintain an influential role in the era of the Geospatial Revolution, the GEOINT Community needs to pause and reflect on how this field can continue to foster lifelong learning in a rapidly changing landscape. An integrative approach that weaves in personalized education and training could be instrumental to providing a GEOINT foundational framework under DBER. This framework would help learners plan their career pathways that still rely heavily on technical competencies while emphasizing crucial elements of human intelligence and allowing for creativity, innovation, and diversification based on each individual’s motivation and characteristics.

Education, in its dynamic forms (formal, self-directed, ad hoc, etc.), is fundamental to GEOINT practitioners as it provides a liberal arts background, methodologies, and depth as well as breadth of thinking. Training, on the other side, is necessary to circumvent the time lag between one’s education and technological changes. Training also allows for personal growth and development without sacrificing time and large amounts of money to pursue another degree. Unfortunately, there is no secret recipe to achieving a balanced combination of education and professional development. To effectively integrate education and training into personalized career pathways for a globally-oriented prospective GEOINT workforce, educators should direct more energy and resources into understanding how student learning progresses and what the most rewarding practices, applications, and techniques for training and educating such a workforce should be. This would allow them to proactively understand how to couple education with training in adaptive, dynamic, and responsible ways, both so student retention and satisfaction are maximized and also so outstanding professionals with appropriate depth and breadth of discipline are trained, broadly speaking.

Today, “career pathways”—to use the 21st century higher education buzz phrase—propose different modalities of integrating educational programs and

1. David Mogk. *Discipline-Based Education Research (DBER) Understanding and Improving Learning in Undergraduate Science and Engineering. Contributions and Opportunities for Geosciences.* <https://serc.carleton.edu/NAGTWorkshops/DBER.html>. Accessed on November 22, 2017.

2. U.S. Department of Labor. Bureau of Labor Statistics. *Women in Architecture and Engineering Occupations in 2016. March 10, 2017.* www.bls.gov. Accessed October 25, 2017.

training and/or continuing education to place students into the job market. The mechanism provided by these guided pathways into “hot jobs” usually involves intentional courses, experiential learning, cocurricular activities, career counseling, and the addition of minors and/or certificates as well as corporate—and possibly community—engagement. From teachers to counselors and advisory boards, everyone is engaged in guiding students toward what the labor market perceives as successful careers.

Also, more recently, advances in artificial intelligence (AI) allowed for the introduction of another buzzword: “adaptive learning,” a field that uses AI to draw upon diverse and rapidly changing domains such as predictive analytics, machine learning, cognitive science, etc., to actively tailor content to each individual’s needs.³ Similarly, “learning analytics,” a marketing research approach that gained popularity in K-12 education through support from venture capitalists,⁴ allows for data gathering and aggregation as early as kindergarten, where five-year-olds receive personalized learning experiences after interacting with a piece of software.

All these approaches are innovative, timely, and much needed. But they only focus on what are currently considered to be lucrative careers (career pathways) or rely on computer data collection and interpretation (adaptive learning and learning analytics). On the one hand, while following a pre-determined career pathway allows students to specialize early in a particular field of study, it may also cause students to easily miss a more holistic educational plan. Such approaches may contribute to discouraging the creativity and personal discovery that usually create pathways into future high-demand careers. On the other hand, while it is possible today to collect evidence of student thinking and learning via adaptive learning technology,⁵ the burden of making sense of this

dynamic data still rests on the shoulders of instructors. As those familiar with education in both academia and K-12 know well, the available time spent on assessment and providing feedback is quite limited.

Without having an established academic discipline with the mission to study learning types and provide educators with the appropriate models and tools, this cumbersome process still falls on the educators who are already struggling to keep pace with technological changes. Most likely, these educators do not also have a strong background in pedagogy, andragogy, and didactics or real interest/available time to pursue such professional development. This is why schools/ departments offering GEOINT credentials should follow in the footsteps of other multidisciplinary schools/departments and create venues for hiring DBER faculty interested in human learning and cognition within GEOINT.

This article recommends academic institutions offering GEOINT also create full-time, tenure track DBER positions. DBER faculty would enhance departmental/school capabilities by conducting research related to the improvement of student learning as well as developing and maintaining the current science of GEOINT learning to support fellow faculty. In STEM, several universities have already embraced this approach to opening full-time DBER positions (e.g., University of South Carolina, North Dakota State University, Auburn University, University of Nebraska-Lincoln, Middle Tennessee State University, University of Arizona, etc.). Carleton College, with its On the Cutting Edge program, leads the way in building a strong undergraduate geoscience teaching program with DBER.⁶ As the community grows, more knowledge becomes available to be shared and applied across disciplines.

To better understand individual learning abilities and address possible challenges

in grasping the unifying elements of GEOINT, DBER could help identify new pedagogical or adult learning (andragogy) methods. The DBER structure has already been proven successful in STEM areas currently embedded in geospatial teaching and learning (especially the geosciences). DBER led to the creation of effective professional development for those who mentor scientists-in-training, tools for measuring student learning, and curriculum and textbooks designed to fit differential student learning styles.⁷ DBER also helped address challenges related to students’ incorrect ideas and beliefs about concepts fundamental to the discipline, especially providing support with understanding how students are using representations such as equations, graphs, models, simulations, and diagrams to communicate science.⁸

It can take a considerable amount of time and effort for interdisciplinary teams with professional expertise across several disciplines to establish common ground and become productive, but such teams can be instrumental in tackling some of the larger problems in human learning soon to be faced by geospatial disciplines. A strong focus on differentiated instruction, tailored curricula, innovations in learning modules for both education and training, and the elevation of soft skills are just a few elements that should help ease some of the challenges currently or predictably faced by higher education in the GEOINT arena.

Challenges of DBER in GEOINT

When designing career pathways, the most difficult task is estimating the starting point based on predictions of where the tipping point would be and of what changes are likely to occur in terms of machine versus human-operated tasks. This is especially difficult in emerging disciplines such as GEOINT that rely on wrangling huge volumes and variety of data. Moreover, when the very definition of GEOINT is still challenged or its degree of professionalization contended, the

3. Zach Posner “What Is Adaptive Learning Anyway?” <https://www.mheducation.com/ideas/what-is-adaptive-learning.html>. Accessed November 22, 2017.

4. Hanover Research. “Emerging and Future Trends in K-12 Education.” October 2014. www.hanoverresearch.com. Accessed October 25, 2014.

5. “Intelligent Adaptive Learning Technology ‘Learns the Learner,’ Giving Teachers Insight about Student Thinking.” <http://www.forbes.com/sites/barbarakurshan/2016/07/26/technology-and-classroom-data/>.

6. On “On the Cutting Edge Strong Undergraduate Geoscience Teaching.” <https://serc.carleton.edu/NAGTWorkshops/DBER.html>.

7. E.L. Dolan, S.L. Elliott, C. Henderson, et al. “Evaluating Discipline-Based Education Research for Promotion and Tenure.” *Innovative Higher Education*. 2017. <https://doi.org/10.1007/s10755-017-9406-y>.

8. S.R. Singer, N.R. Nielsen, H.A. Schweingruber, editors. *Discipline-Based Education Research: Understanding and Improving Learning in Undergraduate Science and Engineering*. The Washington, D.C.: National Academies Press; 2012.

difficulty of carving out career pathways is further amplified.

While the GEOINT field relies heavily on its more established parent disciplines, there is no established underlying theoretical framework to map how disciplinary components connect under the umbrella of GEOINT. In addition, there are no assessments of how and to what extent learners perceive, understand, and embrace the critical connections among these cross-disciplinary competencies, which is a major drawback to establishing a unified approach to curriculum design to support GEOINT career pathways. Finally, the slow pace of transition in academia (moving curricula through the bureaucratic chain) versus the fast pace of change in the technical, commercial, and operational sectors of GEOINT makes it even more difficult to adjust teaching based on new human learning needs. Incorporating DBER in GEOINT may ease some of these pains, but it also comes with several challenges, namely:

- GEOINT is still an emerging field with limited fieldwork-based research and longitudinal studies.
- DBER is also emerging, and both DBER and GEOINT faculty still face publication and tenure challenges given the interdisciplinary nature of the fields.
- The rapidly changing nature of the GEOINT field requires flexible administrative support for professional development of DBER faculty, rarely found in today's academia.
- DBER requires a collaborative and supportive environment in which other faculty accept and encourage DBER scholars' class observations and are willing to embrace their recommendations to change their teaching styles.

Despite these challenges, there are a growing number of venues for DBER scholars in general to publish, share their work, and find jobs.

DBER in a World of GEOINT Automation

As early as 1997, Linda Gottfredson¹ highlighted reasoning, planning, solving problems, thinking abstractly, comprehending complex ideas, learning quickly, and learning from experience as the crucial elements of human intelligence. In an era of frenzy over AI, capturing the essence of what makes humans capable of performing the tasks mentioned by Gottfredson and learning how to consistently improve these capabilities is vital to advance the field. Learning the technology is necessary, but we believe these aforementioned elements of human intelligence are equal if not more valuable to GEOINTers and cannot be gained in a matter of days, weeks, or even months of training.

Intelligence means thinking and understanding, reflecting back to one's actions, and making sure the next "outputs" are better based on received feedback. But humans are now expected to do it all and do it fast while acting and behaving intelligently. Scholars have to teach, publish, bring in external funding, and provide community service. These expectations do not match the allocated time frame, which eventually results in an unbalanced allocation of time negatively impacting the "least" important task in academia: teaching to improve learning. DBER can help solve this problem by observing, investigating, measuring, assessing, modeling, and reporting on ways humans understand discipline-based concepts, practices, and how they interact with new technologies to produce intelligence.

Carl Bereiter defines intelligence as "what you use when you don't know what to do."² Intelligence not only draws the line between humans and their individual abilities to cope with challenging situations, but also points to the fundamental difference between humans and machines when programming has reached its limits.³ Today, daily job

routines involve a lot of emailing back and forth, phone calls, and e-conferences in a fast-paced environment in which decisions are made quickly based on sometimes disparate pieces of information. Modern professionals set goals, objectives, and ensure we check off the list of learning outcomes to justify our work. We barely find the time to think, read, analyze, share, and digest feedbacks and connections among the pieces of information accruing in our sphere of influence. A recent, highly cited book by Michelene Chi⁴ titled, "The Nature of Expertise," shows how experts (as opposed to novices) tend to first pause and reflect, thus demonstrating that qualitative analysis before attempting to solve a problem helps to "build a mental representation from which they can infer relations that can define the situation." One of the primary goals of DBER is to understand the nature and development of expertise in a discipline.⁵ As GEOINT has progressed toward becoming a stand-alone discipline, its success is also affected by a struggle to understand, define, and be willing to redefine the GEOINT student and future professional and, once defined, to help him or her build and rebuild expertise.

Conclusion

Both DBER and GEOINT are considered emerging disciplines. GEOINT changes very rapidly, thus the need for people who know both the discipline (the science) and the pedagogy/andragogy/didactics to observe teaching and learning and improve the process. These people exist in DBER, but they are still marginalized and not recognized for the value they bring. There are very limited venues for DBER publications, most without impact factor or no impact factor at all (similar to GEOINT), which negatively influences the sustainability of these positions (tenure track). It is also difficult to have DBER faculty evaluated throughout a tenure track process because education research is not quantified the same way as scientific, hard research. Fortunately,

1. L. Gottfredson. "Mainstream Science on Intelligence: An Editorial with 52 Signatories, History, and Bibliography." *Intelligence*. 1997;24:13–23.

2. R. Colom, S. Karama, R.E. Jung, and R.J. Haier. "Human Intelligence and Brain Networks." *Dialogues in Clinical Neuroscience*, 2010;12(4), 489.

3. J. Hawkins and S. Blakeslee. *On Intelligence: How a New Understanding of the Brain Will Lead to the Creation of Truly Intelligent Machines*. Macmillan; 2007.

4. M.T. Chi. *The Nature of Expertise*. Psychology Press; 2014.

5. David Mogk. *Discipline-Based Education Research (DBER) Understanding and Improving Learning in Undergraduate Science and Engineering. Contributions and Opportunities for Geosciences*. <https://serc.carleton.edu/NAGTWorkshops/DBER.html>. Accessed November 22, 2017.

things are changing and more schools have opened DBER positions in STEM. It is our recommendation that GEOINT education and training align with this movement.

From K-12 to higher education and beyond, the focus should be on ways to equip students with better understanding and control over their human competencies that would be impossible

or difficult to replicate in computers. While training can be designed to respond to the rapidly changing demands of the geospatial world, it should infuse, not replace, education. Changing technologies influence the definition of “expertise” in a discipline that relies on these changes. Both education and training are personal journeys that need to be observed, documented, and supported, and DBER can help achieve

that. At the same time, career pathways should be flexible enough to allow for change and personalized enough to encourage innovation. In the words of author John Steinbeck: “A journey is a person in itself; no two are alike. And all plans, safeguards, policing, and coercion are fruitless. We find that after years of struggle that we do not take a trip; a trip takes us.”⁶

Bridging the Gap Between Analysts and Artificial Intelligence

By Ben Conklin, Esri; Thomas Marchlewski, USAF; Tatyana Pasechnik, USAF; Scott Simmons, Open Geospatial Consortium; Joseph Sullivan, Ph.D., USC; Daniel Walton, Intterra; and Jeff Young, LizardTech

Artificial Intelligence (AI) has the potential to transform the role of geospatial intelligence (GEOINT) analysts, allowing analysts to expand capacity, create new analytic products, and get information out faster with more thorough and complete analysis. Successful transition from the commercial industry will require new user experiences for intelligence production and the introduction of new training and standards. The community will need to develop verification and validation processes to trust the results of these technologies. The final proof of success will be willing adoption by analysts. A major challenge for AI advocates is how to implement AI technologies in ways that do not require massive workforce retraining. Ideally, the technologies would go further and reduce the amount of specialized training needed to become a GEOINT analyst.

The GEOINT Community has also been long interested in AI-related technologies, but the excitement over AI has not lived up to expectations. AI technologies were too inaccurate to augment a human analyst, and the machine created more work for the human analyst. These early failures highlight that AI technologies must demonstrably improve life for analysts before being adopted into the mainstream.

Recent developments are more promising. Large companies such as Google, Microsoft, and Facebook are making major investments in AI, which covers many areas from reasoning, knowledge representation, perception,

natural language processing, robotics, and machine learning (ML). ML has surged forward with recent developments in new algorithms in an area known as deep learning (DL). Much of this research has been focused around object recognition within imagery. The promise of these new approaches has reinvigorated the GEOINT Community’s interest in AI.

Successful adoption of AI technologies has huge potential to assist the national security mission. Analysts are unable to keep up with the explosion in geospatial data. From small sats to the Internet of Things (IoT), the world is constantly generating new geographic knowledge. The challenge is to assist the analyst through use of AI, so instead of competing with a machine, they can compete with their main adversary: time—transforming the unknown into the known in time to impact decision-making. With the proper application of AI technologies, analysts can be more productive and ensure their observations and foundation intelligence are up-to-date and accurate. They can derive new connections and insights from the data during their daily workflows. When working on predictive analytics, they can include possible outcomes to better understand situations. Reports and standard product lines become more up-to-date and of higher quality when routine work is delegated to a machine. The machine does the heavy lifting on basic tasks, and analysts take on the unique cognitive work.

Information science and AI have undergone tremendous advances in the last 20 years. DL has proven transformational in e-commerce applications of imagery, voice, and text analysis, and owes its success to the development of new algorithms modeled on human and animal cognitive and sensory processes, (e.g., convolutional neural networks (CNNs)), faster processing with hardware exploiting highly parallelized graphics processing units (GPUs), and a massive increase in the volume of data available to train neural networks. Today, the pace of advancement is only accelerating due to the high availability of cloud-based AI platforms and the monetization of AI applications driving increased interest and investment.

Several benchmarks are used in the research of DL techniques. One specific annual challenge is the ImageNet Large Scale Visual Recognition Challenges hosted by ImageNet, which sets a benchmark for accurate image recognition. In 2012, the winning team’s accuracy rate jumped from 74 to 84 percent by leveraging CNNs and GPUs. By 2015, the rate climbed to 96 percent. This type of progress is happening in all the related DL technology areas. This level of accuracy, and perhaps higher, is required if ML approaches are to be viable for automating many intelligence collection activities. In commercial applications, it is acceptable for valid conclusions to be missed. In intelligence applications, there is much less tolerance for that, thereby requiring accuracies that exceed human performance.

6. J. Steinbeck. *Travels with Charley: In Search of America*. Penguin; 2012, 4.

Technology Drivers for AI

There are three primary reasons for this advancement in technology. Computing power is increasing; with new cloud computing and with big data processing technologies, we can harness problems of much larger scale. The IoT has made more data available to analytic processes. Finally, new algorithms like CNNs are being proven and shared across a growing community of developers. Each of these advancements creates unique challenges for the GEOINT Community to realize the potential of AI.

Computing Power: The major developments in AI harness enormous computing infrastructure that the GEOINT Community is just now beginning to leverage. The addition of computing power to sensitive or classified systems will provide the computing resources needed to make AI practical. And to the degree that the computing infrastructure is compatible with commercial use cases, the easier it will be to modify for GEOINT use cases.

Internet of Things: The IoT continues to be a major source of new geospatial information. Commercial companies are collectors and hosts for this type of information. The algorithms they produce are tuned to work with the data they collect and uniquely have access to. The new algorithms and use cases that emerge from IoT applications could prove very useful for government applications as well.

New Algorithms: The development of new algorithms holds great promise, but these algorithms are primarily being created to support consumer problems and are not specific to the intelligence mission. For these same promises to be realized, new algorithms will need to be developed capable of answering intelligence questions and leveraging multiple sources of intelligence data.

Challenges in Transitioning Commercial Technology

In addition to algorithm development, there is another hidden problem. Large commercial companies have an army of developers who can write code and

tune algorithms. They have a scaled development system. The government has experienced, trained analysts with advanced cognitive capabilities and intuition. A major challenge will be connecting these analysts with new user experiences for working with algorithms and datasets in easy-to-access ways. Making the technologies as transparent to the user as possible is ideal.

To make the transition to leveraging AI technologies for GEOINT, the analyst workforce and the specific objectives (productivity, new analysis, speed, completeness, etc.) must be at the forefront for those implementing. These new datasets and techniques will require a review of doctrine, organization, training, material, leadership and education, personnel, facilities, and policy. To gain value in AI, it must be integrated into the workforce and made a part of everyday life for analysts.

Changes in doctrine and organization will be required to create the correct structure for an AI-enabled workforce. The new types of data and technologies will stretch organizations that do not have adequate structure to support implementation. The new computing power will require cloud infrastructure with the personnel to manage and maintain. Improved productivity could result in smaller teams producing more output, or larger teams with fewer managers as exploitation functions become increasingly procedural.

Training and education will most likely have the largest potential impact on adoption. Implementation of these new technologies will shift some analysts from a processing role to a more cognitive one. They will have more time and access to more data to perform analysis and make inferences. This will be a new skill set for many analysts who have been trained in routine tasks such as feature identification. These new cognitive skills will have more value and will evolve as new algorithms are developed, requiring frequent retraining.

Facilities and policies will have to be adjusted; as more GEOINT comes from IoT sources, unclassified storage and processing environments will be essential.

Even with possible cross-domain solutions, the volume of data collected from unclassified sources will continue to grow. The ability to work in such environments will be mandatory. This impacts security policies and physical facility infrastructure. With increasing automation and growing delivery of results from AI, it will become important for analysts to understand the nature of the output information. Source data for AI will be increasingly diverse in complexity, accuracy, and provenance; analysts must understand in a meaningful manner the relative reliability of what goes into automated analysis. How does AI assign geospatial context to unstructured data and what assumptions go into that process?

AI technologies also vary in the types of algorithms used, how the systems are trained, the fashion in which poor results are pruned from the output, and what validation occurs to identify “good” results. Analysts will have new responsibilities to develop training and validation data and will select appropriate tools or algorithms best suited for the task at hand.

AI results must be verified, validated, and vindicated through the actions of the analyst. Critical to this process will be the establishment of a common set of terms and measures to describe the sources of information, the assumptions made by the AI, the mechanism to confirm or reject interim results, and the measure of accuracy of validation.

Finally, vindication of results must inform the AI process to improve workflow. Analysts have long been accustomed to developing clear metrics for spatial accuracy of analytic products from sensors; they will now need to develop similar metrics to rank and qualify AI-derived results.

The final test of AI’s value will be analyst adoption. The reality is AI hype has been present for some time. Automated feature extraction has been the great promise of computing for GEOINT since imagery was first stored on a computer. ML may be the solution that makes this a reality. A user-first approach to developing AI applications has the highest likelihood

of producing solutions analysts and their customers will accept.

Analysts will need access to the technology in an environment in which they can integrate it seamlessly into

their daily workflows. Instead of creating more work for them, the technology must reduce their challenges. This means it will need to be integrated into existing user experiences, augmenting current tools and processes. The workforce will not

be able to transform overnight; a gradual transition to proven technologies is more realistic. We will know AI has reached its potential when analysts demand it on their desktops instead of being dragged into the future.

The Ethics of Volunteered Geographic Information for GEOINT Use

By Steven D. Fleming, Ph.D., University of Southern California; Elisabeth Sedano, Ph.D., University of Southern California; Margaret Carlin, County of Los Angeles; Rex W. Tracy, Ph.D., Integrity Operations LLC; and James Walker, University of California – Los Angeles

VGI Defined

What is volunteered geographic information (VGI)? Renowned geographer Michael Goodchild coined the term in 2007 in response to the growing phenomenon of laypeople creating and sharing mappable data via the internet.¹ Since that time, geographers have debated the scope of the term and how it differs from related concepts, such as public participation GIS, which existed prior to Web 2.0 and its concomitant collection of user-generated content. VGI is a broad term, and one way to categorize types of VGI is to consider the intentionality of the volunteer. From most to least intentionality, we might identify five categories/levels of VGI: 1) a volunteer who is actively involved in framing the project; 2) a volunteer who helps devise the goals and collect data, but does not analyze data or make scientific findings; 3) a volunteer who knowingly contributes VGI for a particular purpose; 4) a person who contributes VGI for a different purpose; and 5) a person who unwittingly creates VGI.

Examples include persons involved in citizen science projects (Levels 1 and 2), OpenStreetMap users (Level 3), a Facebook user who knowingly shares a geotagged photo which is then downloaded and shared widely (Level 4), and a person who has unwittingly enabled cell-phone tracking on various smartphone apps (Level 5). Levels 4 and 5 might be considered contributed geographic information (CGI)² or ambient

geographic information (AGI),³ rather than true VGI. In such cases, while the contribution may technically be voluntary, the information is volunteered for a different purpose than it might ultimately be used or even unknowingly.

Broadening the discussion through further demonstrations, an example of VGI at the most collaborative levels is suggested by Dr. Mordechai Haklay, a leading researcher of GIS and citizen science: Professional and non-professional astronomers often work together on projects that are integrated at all levels, including the definition of the scientific question, field collection methods, and analysis.⁴ Haklay suggests that environmental justice projects often involve VGI at slightly less collaboration, wherein community residents work with environmental scientists to define the project goal and to collect data, but do not perform scientific analysis.

Another step down is seen in Dr. Elisabeth Sedano's study of outdoor advertising in Los Angeles, wherein residents helped to map billboards using a web map for a project whose goals and methods were shared with the volunteers but were defined by the researcher.⁵ The lowest level of collaboration in VGI is seen in projects based on geotagged social media posts, such as tweets, as users have voluntarily shared their location but without the specific intent to add to any project beyond their chosen social media platform.

Because there is no intentional collaboration, Dr. Anthony Stefanidis of George Mason University suggests such "volunteered" data should be characterized as ambient geographic information (AGI) rather than true VGI.⁶ In other cases, users may not realize an app is set to record their location, or their location contribution may technically be voluntary, but was volunteered only as a means to be able to participate in a particular web-based activity, where consenting to provide user location, for example, is a requirement to proceed. These categorizations are important to understand; ethically, they help define the intended use of the information as volunteered by the provider.

Current Thinking on the Ethical Use of VGI

With respect to VGI contributors, the discussion of ethics generally focuses on privacy. Regarding the aggregator and distributor of VGI, ethics might also involve legal liability, responsible use, and data quality considerations. Studies of VGI often focus on social media posts during disaster and crisis events, in which data accuracy can have vital consequences, whereas private sector data quality is less an issue than invasion of privacy. In the commercial sector, outdoor advertisers are combining location-based services, big data on consumer spending patterns, and digital sign displays to make real-time changes

1. M. Goodchild. "Citizens as Sensors: The World of Volunteered Geography," *GeoJournal*, 69:211-221, 2007.

2. F. Harvey. "To Volunteer or to Contribute Locational Information? Towards Truth in Labeling for Crowdsourced Geographic Information." In D. Sui, S. Elwood, and M. Goodchild (eds.). *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice*. 31-42. Springer Science+Business Media Dordrecht; 2012.

3. A. Stefanidis, A. Crooks, and J. Radzikowski. "Harvesting Ambient Geospatial Information from Social Media Feeds." *GeoJournal*, 2013:78(2), 319-338.

4. M. Haklay. 2013. "Citizen Science and Volunteered Geographic Information: Overview and Typology of Participation." In D. Sui et al. (eds.). *Crowdsourcing Geographic Knowledge: Volunteered Geographic Information (VGI) in Theory and Practice*, 105-122. Springer Science+Business Media Dordrecht; 2012.

5. E.J. Sedano. "'Sensor'ship and Spatial Data Quality." *Urban Planning*, 2016:1(2), 75-87.

6. A. Stefanidis, A. Crooks, and J. Radzikowski. "Harvesting Ambient Geospatial Information from Social Media Feeds." *GeoJournal*, 2013:78(2), 319-338.

in advertisements based on nearby individuals. One of the experts in the field of VGI is Dr. Peter Mooney of Maynooth University, Ireland. He states that private data in the VGI context are often any geographic data or information that can be linked to an individual contributor who created, collected, or edited it. A key aspect of project planning therefore is to consider whether data to be collected needs to be linked to its creator for the purposes of the project. Linkable data should only be collected if the project depends upon it and with the consent of the creator. When linkable private data are collected, protections should be established to ensure the data are only used according to the purpose for which the creator¹ consented or to take active steps to de-link data if linking is no longer required. If linkable private data are collected, it then becomes necessary to establish some protection that ensures the data are only used according to the original purpose defined before the collection of the VGI started. When VGI data collections are considered a resource for new and maybe unforeseen beneficial uses and research, it is arguably more important that these data do not provide linkable private data about the individuals who contributed it.

In a geospatial intelligence (GEOINT) context, the question that should be asked is whether location information in itself is private data or can be linked to individuals. The answer often then depends on the location accuracy. Many location data are accurate enough to be connected to one individual or to a small group of individuals (like an office or home). Sometimes this information is even combined with precise time and date. Mooney notes that there is no common solution; rather, the collection of point-based geographic data for a specific purpose may need to have high geographic accuracy which produces a possibility that the geographic features close to the collected points could be used to infer other information.² Supporting Mooney's work, Barbara Poore, a research geographer from the

United States Geological Survey, notes that the possibilities surrounding the use of location data associated with an identifiable contributor or embedded GPS information from cameras might entice an unethical use of the VGI.³ Finally, recognized methods to protect or hide information fidelity of data exist, such as making location information blurry or fuzzy and anonymizing the data by making private information available only per contributor's preferences.

Possible GEOINT VGI Use

The wide variety of VGI available today naturally leads to a myriad of potential uses for VGI as GEOINT. The use of VGI can be leveraged to significantly enhance conventional intelligence capabilities for Department of Defense (DoD) and homeland security organizations. The upsurge of web-based technologies that allow individuals to voluntarily develop applications and provide information offer numerous opportunities to improve GEOINT collection, management, retrieval, and dissemination. VGI technologies currently being developed and used by the mainstream population can likely be adapted for use with multi-echelon security access. In this, the use of VGI type sites as a structure for collection, management, retrieval, and dissemination of classified geographic information could provide the defense and intelligence communities with quickly evolving and continually improving technologies.

Recent lessons learned from operations in conflict areas such as Afghanistan and Iraq have demonstrated a need for improvements in GEOINT collection methods. VGI is a potential mechanism for increasing the number of sensors populating information databases. In this context, every person on the battlefield (including soldiers) is a sensor; therefore, all those on today's and tomorrow's battlefields are possible GEOINT providers. Careful investigation, however, into potential incentives for volunteering information is necessary to

fully understand the quality of the data provided. The management of intelligence using newly developed technologies and methodologies is significantly different from conventional schemes. In this, a number of questions arise:

- Should databases be populated without restriction and how is the accuracy of the information verified? Contributors may interpret the world differently. For example, what someone calls a bus terminal may be a bus station, stop, or bench to someone else.
- Is a database manager needed to supervise the data published? Some algorithms for data validation might not be able to reach common sense conclusions that a human monitor would be capable of reaching. New technologies now allow the users to become database managers. Websites such as eBay and Amazon allow users to rate each other. Wikimapia allows users to change previously submitted VGI.
- Is it possible for a VGI site to be self-correcting, self-improving, and self-assessing in order to continually judge the quality of the information? A meticulous study of the supervision methods for the provided information is required. In this, data comprehensiveness for VGI should be considered, as many people are not volunteering their information, which could lead to bias in the data or skewed datasets if some users submit multiple VGI. In some cases, a person's use of multiple devices could lead to the impression that the VGI is from multiple people.

LTC Ian Irmischer, Ph.D., from the United States Military Academy at West Point, noted that from these questions, it appears that GEOINT searches inherently arise from the possibilities of vast information collection. A powerful geospatial search engine that appropriately prioritizes information is essential for the efficient use of VGI. Recognizing that national security users often need geospatial information

1. P. Mooney, A.M. Olteanu-Raimond, G. Touya, N. Juul, S. Alvanides, and N. Kerle. "Considerations of Privacy, Ethics and Legal Issues in Volunteered Geographic Information." In G. Foody, L. See, S. Fritz, P. Mooney, A.M. Olteanu-Raimond, C.C. Fonte, and V. Antoniou (eds.), *Mapping and the Citizen Sensor*. London: Ubiquity Press; 2017, 119–135.

2. Ibid.

3. B. Poore. "Mapping the Unmappable: Is It Possible, Ethical, or Even Desirable to Incorporate Volunteered Geographic Information into Scientific Projects?" *Role of Volunteered Geographic Information in Advancing Science - GIST Workshop*, September 2010. web.ornl.gov/sci/gist/workshops/2010/papers/Barbara_Poore.pdf.

for immediate response situations, the search engine should be able to conduct network analysis of requested information and analyze the spatial components of the data. Standardization of automated metadata inclusion is likely required to allow the users to query and access needed intelligence. As a result, the compiled VGI must be able to be disseminated and visualized by the user facilitating interoperability between provided data formats and a common operating platform that can be efficiently interfaced by sensors and operators.

Defense and intelligence users would require limited training if currently existing VGI collection methods were integrated. Sites such as Google Earth and Wikimapia are intuitively designed, have widespread use, and are familiar to citizen sensors, organizational sensors, and operators in need of information.⁴ Resultant from all of this, VGI has many compelling uses for operators that require GEOINT for situational awareness. The use of citizens as sensors vastly increases the possible GEOINT collection capabilities by governmental organizations. A detailed examination of how VGI and associated technologies can improve the collection, management, retrieval, and dissemination for these organizations could advance local and national level crisis reaction and security.

The National Geospatial-Intelligence Agency (NGA) has progressed quickly into the VGI space through its creation of the NSG Open Mapping Enclave (NOME). NOME is an online tool kit that allows the National System for Geospatial Intelligence (NSG) to contribute and benefit from the power of open content. As a crowdsourcing method to harness tools to create, assemble, and disseminate geographic data provided voluntarily by individuals, crowdsourcing products such as Wikipedia and OpenStreetMap collect useful geospatial information for NGA analysts to produce GEOINT products. By allowing users to contribute their expert knowledge to maps, VGI opens up geospatial data to

communities that in the past would rely on their own limited collection resources and proprietary technologies. NOME challenges conventional geospatial collection and dissemination methods to reduce costs, improve accuracy, and enhance mission planning and execution.⁵

The use of VGI for GEOINT is also relevant to humanitarian assistance and disaster management operations and functions. In his work on crowdsourcing VGI, Flávio Horita concluded that the scientific literature about the use of VGI in disaster management is growing, with a significant increase in the number of publications since 2010, noting that the predominant research area was disaster response. Fewer studies were devoted to mitigation and preparedness, while none dealt with recovery. His explanation to this was that response is the most visible part of disaster management and is also more likely to attract the attention of volunteers. However, the challenge for researchers remains how to advance knowledge about methods that include VGI in mitigation and preparedness activities such as risk analysis and early warning systems, as well as in the recovery phase, by helping communities reorganize their routine and create mechanisms to prevent disasters from happening in the future. Horita continued, “This research also showed that VGI is commonly used to manage floods and fires. The prevailing media for sharing VGI was found to be social media (i.e., Twitter, Facebook, YouTube, etc.) and mobile devices. Interestingly, very few of the reviewed papers address VGI platforms like Ushahidi2, Elva 3, OpenStreetMap, and Wikimapia.”⁶

Ethical Use of VGI for GEOINT: Do the Rules Change?

There are ongoing discussions about the ethical use of VGI for GEOINT and whether the standard ethical considerations for VGI use apply. There is concern for targeted data analysis and use, and there appears to be potential for both positive and negative impact. Four

areas of concern are noteworthy:

- Data exploitation methods (including commercial, online, and offline use cases).
- Relevant, geographic scale.
- Bounded areas of data exploitation (geo-fences, group audience demographics, etc.).
- Individual protection considerations.

Stefanidis noted in his *GeoJournal* article that harvesting VGI and ambient information brings forward novel challenges to the issue of privacy, as analysis can reveal information the contributor did not explicitly communicate. Stefanidis said this is not a new trend. For example, Google uses the information it collects to improve its customer service. Similarly, Twitter makes money by licensing a tweet gateway to search engines, while companies can pay for “promoted tweets.” This trend has already spread to location information. For example, TomTom uses passively sensed data to help law enforcement determine the placements of speed cameras. iPhones store location data of which the user may be unaware. Stefanidis said the public is making progress in highlighting the issue of privacy-relinquishing when sharing location information. Sites and apps such as *pleaserobme.com* and *Creepy* (a geolocation aggregator) have demonstrated the potential for aggregating social media to pinpoint user locations. In this, trying to protect people’s identities in times of unrest is also a well-recognized concern. For example, the Standby Task Force suggests ways of limiting exposure and delaying information for the recent unrest in North Africa. Stefanidis further stated, “But the power of harvest AGI stems from gaining a deeper understanding of groups rather than looking at specific individuals. As the popularity of social media is growing exponentially, we are presented with unique opportunities to identify and understand information dissemination mechanisms and patterns of activity in both the geographical and social dimensions, allowing us to optimize responses to specific events, while the

4. I. Irmischer. *Volunteered Geographic Information Uses for National Security*. United States Military Academy; 2016

5. R. Cardillo. Statement for the Record before the House Armed Services Committee Subcommittee on Strategic Forces on the Fiscal Year 2018 Priorities and Posture of the National Security Space Enterprise. National Geospatial-Intelligence Agency. May 19, 2017.

6. F.E.A. Horita, L.C. Degrossi, L.F.G. de Assis, A. Zipf, and J.P. de Albuquerque. The Use of Volunteered Geographic Information (VGI) and Crowdsourcing in Disaster Management: A Systematic Literature Review. *Proceedings of the Nineteenth Americas Conference on Information Systems*. Chicago, Illinois; August 15-17, 2013.

identification of hot spot emergence helps us allocate resources to meet forthcoming needs.”¹

Although ethical concerns exist with the use of VGI for GEOINT, we posit some recommendations for going forward: 1) security and safety of the collective takes precedence; 2) personal information may and should be leveraged to ensure the security and safety of said person; 3) accepted, generalized, targeted information passing (aka advertising) should be used as a starting point when communicating general alert notifications; 4) VGI identification can and should be used for general (non-targeted) reverse information passing; 5) more descriptive VGI identification can and should be used for targeted information passing in response to a disaster/emergency/conflict; and 6) caution should be used when using VGI identification for psychological operations in a mission

plan (often connected to some form of a military, operational response).

Inherent in the recommendations is that security is a vulnerability, especially with advances in technical capabilities and increasing sophistication of sponsoring enterprises (criminal, opposing government, or otherwise). Security breaches are becoming more common (or more commonly reported), whether accidental (such as a lost, unencrypted laptop or careless disposal of old equipment) or intentional attack. At some point, security breaches are a possibility. In not knowing how the compromised data will be used, unpredictable consequences can ensue. From this and in concert with the recommendations above, targeted advertising and information passing (from the third recommendation above) represents a base level in which no personal information about an

individual is necessary. More descriptive VGI identification (from the fifth recommendation above) is recommended when safety is paramount and response time could be a life or death situation; the more information available to assist in evacuation and rescue efforts, the better. In this, one must keep in mind that first responders (in the field) may not have time to sift through data. Someone offsite (or resident within an app) would likely need to filter the information down to the necessary components for the responder to act quickly. More information can sometimes be too much information, depending on the context. Finally (from the sixth recommendation above), in conflict or psychological operations, deadly consequences could result if the opposing force acquires the information, whether or not the VGI aggregator/distributor is aware of the obtainment.

Individual Core Geospatial Knowledge in the U.S.: Insights from a Comparison of U.S. and UK GEOINT Analyst Education

By Daniel W. Steiner, Orion Mapping; Todd S. Bacastow, Dennis Bellafiore, Stephen P. Handwerk, and Ann Taylor, Pennsylvania State University; Robert J. Farnsworth; Justin Hoesman; and Ericka Sterns

The geospatial intelligence (GEOINT) discipline has arrived at an inflection point where its teaching methods must be changed. Adaptive learning can improve the learning of core geospatial knowledge which is essential for the integration of artificial intelligence (AI) with the work of humans. With increasing amounts of geospatial and imagery data, organizations may leverage AI in the image and data processing environment and then rely on the cognitive capabilities of GEOINT analysts to perform geospatial analysis and problem-solving. Compared to the United Kingdom, the United States GEOINT Community contains a pool of talent with widely varied education and backgrounds. UK education focuses more on essential core geospatial knowledge, thus new prospective students may see GEOINT as a career path earlier on. In

the U.S., students may not be aware of GEOINT until discovered through military service or later in their career path.

The interconnected relationship of the UK and the U.S. demonstrates an interest to examine the systems in place to educate GEOINT analysts. We’re talking about the differences in preparation with a goal to understand and improve the teaching of the GEOINT analyst. A recent Pennsylvania State University research seminar examined who the GEOINT analysts are, where they work, where their education takes place, and what foundation is developed.² Findings also highlighted the professional community as an underpinning in the preparation of the GEOINT analyst.

Geospatial Intelligence and Work Goals

GEOINT’s historic foundations are cartography, mapping, and imagery analysis. Currently, geospatial intelligence, as defined by the National Geospatial-Intelligence Agency (NGA), is the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth.³ It has been said that, “Geospatial intelligence—or GEOINT—is a highly evolved intelligence discipline that goes beyond telling you what is happening, where it is happening, and when it is happening—it also reveals how it is happening, why it matters, and what is likely to happen next.”⁴

1. A. Stefanidis, A. Crooks, and J. Radzikowski. “Harvesting Ambient Geospatial Information from Social Media Feeds.” *GeoJournal*, 2013:78(2), 319-338.

2. Drew Cavanagh, Steven Douglas, Jace Ebben, Zach Gordon, Justin Hoesman, Bryan Parent, Matthew Reynolds, Benjamin Smolansky, Daniel W. Steiner, and Ericka Sterns. “Comparative Professional Preparation of the Geospatial Intelligence Analyst in the United States & United Kingdom.” Penn State University; 2017.

3. National Geospatial-Intelligence Agency (NGA). “NGA Products and Services, GEOINT Standards.” <https://www.nga.mil/ProductsServices/geointstandards/Pages/default.aspx>.

4. NGA. “GEOINT Professional Certification Program 1-36.” <https://www.nga.mil/Careers/Pages/GEOINT-Professional-Certification.aspx>.

In contrast, in the UK, geospatial intelligence is defined as the spatially and temporally referenced intelligence derived from the exploitation and analysis of imagery intelligence (IMINT) and geospatial information (GeoInf) to establish patterns or to aggregate and extract additional intelligence.⁵

To overcome national differences in definitions of GEOINT, this research focused on principle work goals to compare analyst outcomes. The principles provide a benchmark to connect the work of analysts, design curricula, develop continuing education, and guide GEOINT analysts when encountering new challenges.⁶ These principles are:

- GEOINT seeks knowledge to achieve a decision advantage.
- GEOINT reveals how human behavior is constrained and/or enabled by the physical landscape, time, and human perceptions of Earth.
- GEOINT reshapes understanding by discovering relationships through space and time.

U.S. and UK Geospatial Intelligence Communities

An Intelligence Community (IC) is a system of separate government agencies that work both independently and together to conduct intelligence activities. Although differences in the organization of the national intelligence apparatus play a part, vigorous professional communities occupy a particularly central role in analyst learning. It is not hard to imagine a community in which those who teach geospatial analysts teach separately and together to prepare individuals in the IC based on common principles. Trainers and educators have a broad view to identify the organizations, outcomes, and pedagogies. Ideally, professional teaching communities within a national IC are fundamentally oriented to the classroom

practice and linked to a variety of external sources of knowledge and support.

The U.S. IC models a federation of government agencies working together to conduct intelligence activities to support the country's foreign relations and national security. The GEOINT Community is a social unit sharing a common place in this larger IC. It is a partnership among the government, business, and educational sectors known as the National System for Geospatial-Intelligence (NSG), developing an integrated approach to advance the GEOINT mission and tradecraft.

British intelligence didn't officially exist until the Parliament of the United Kingdom, Intelligence Services Act 1994. This act confirmed the existence of the Secret Intelligence Service (MI6) and the Government Communications Headquarters (GCHQ), declaring, "There shall continue to be a Secret Intelligence Service."⁷ The concept of the Single Intelligence Environment focused to support decision-makers at all levels is both a mind-set and method of operation.⁸ The design of the Defence Intelligence Fusion Centre (DIFC) creates collaboration with dynamic changes to teams depending on the mission and intelligence requirements.

U.S. and UK Geospatial Intelligence Educational Communities

Comparative education is an established field of study that examines education in one country by using insights from the practices and situation in another country or countries. It is believed that important educational questions can best be examined from an international and comparative perspective. The Bray and Thomas cube models the abstract systems of a nation, its education system, and society.⁹ The units of comparison provide a multilevel analysis of the preparation of GEOINT analysts.

A GEOINT Essential Body of Knowledge (EBK) was developed by the United States Geospatial Intelligence Foundation (USGIF) to describe competencies of remote sensing and imagery analysis, GIS analysis, geospatial data management, and data visualization. Research for this article was not able to uncover a UK Body of Knowledge relating to geospatial intelligence or geospatial sciences. The practice of GEOINT in the U.S. can be viewed as the overarching discipline encompassing many subcategories of the IC.

U.S. educational institutions have the unique ability to produce scholars, whose education exceeds the training received in government. A key to examining curricula for the education of GEOINT professionals can be found in geography, GIS, remote sensing, environmental science, and general science degree programs. Curricula in the geospatial community vary to some degree but share common foundational elements. There are other examples of universities offering degrees relevant to crowdsourcing, human geography, and visual analytics.¹⁰

More specialized training is available through university graduate programs, professional development programs, workshops, and short courses offered by professional and scientific societies. In the U.S., many universities offer courses in core/emerging areas of GEOINT, with recent growth in geodesy, geophysics, and remote sensing.¹¹ There are 190 universities that offer programs focusing on geodesy and geophysics, 15 offering a concentration in photogrammetry, 105 with a remote sensing related degree path, 189 offering degree tracks in GIS, and more than 400 community/technical schools with geospatial technologies courses.¹²

A majority of education is provided by universities that directly impact the supply of graduates researching relevant topics, breadth of knowledge, and overall

5. Ministry of Defence (MOD). *Understanding and Intelligence Support to Joint Operations. Joint Doctrine Publication 2-00*. <https://www.gov.uk/guidance/defence-intelligence-services>.

6. Todd Bacastow. "Viewpoint: A Call to Identify First Principles." *NGA Pathfinder*, Fall 2015. <https://medium.com/the-pathfinder/viewpoint-a-call-to-identify-first-principles-d5e21cb2ce40>.

7. Parliament of the United Kingdom. *Intelligence Services Act, 1994* No. 2734 (c. 60). <http://www.legislation.gov.uk/ukpga/1994/13/crossheading/the-secret-intelligence-service>.

8. MOD. *UK Joint Operations Doctrine. Joint Doctrine Publication 01*, 2014. https://www.gov.uk/government/uploads/system/uploads/attachment_data/file/389775/20141209-JDP_01_UK_Joint_Operations_Doctrine.pdf.

9. Mark Bray, Bob Adamson, and Mark Mason. *Comparative Education Research: Approaches and Methods*, 2nd ed. Switzerland: Springer International Publishing; 2014, p. 7, 95.

10. National Research Council. "Current Training Programs." *Future U.S. Workforce for Geospatial Intelligence*, Washington, DC: National Academies Press; 2012. <https://www.nap.edu/read/18265/chapter/8>.

11. *Peterson's Search of Colleges, Grad Schools and Online Schools*; 2017. <https://www.petersons.com/search/schools?searchType=26&searchTerm=geospatial>.

12. National Research Council. "Current Training Programs." 2012.

quality of candidates. Projected growth rates for graduates in a geospatial career field are expected to rise through 2030 as emerging technologies continue to grow.¹ One recent trend is the blending of specialties falling under GEOINT. Cartography, photogrammetry, GIS, and geospatial analysis are beginning to overlap due to technological developments and the digitization of maps and mapping products. Graduates potentially could have a specialty in cartography while maintaining a degree plan in a broader subject area.

An intelligence agency such as NGA has a major incentive to participate in, and sometimes fund, educational initiatives that will directly enrich the pool of potential GEOINT employees. One of NGA's initiatives is to partner with the U.S. Geological Survey (USGS) to identify Centers of Academic Excellence (CAE) in geospatial sciences (GS) that aim to grow the GEOINT career field by enriching educational opportunities. NGA employs thousands of analysts, many whom have already earned graduate degrees. As NGA standardizes the education and knowledge of future employees through opportunities with CAE for GS, this initiative does not support current employees. To ensure the knowledge standardization of current employees, NGA manages its Geospatial Intelligence Professional Certification (GPC) program. The GPC is available to cleared Department of Defense, civilian, military, and contractor personnel working in GEOINT-related positions throughout the NSG.

By charter, USGIF is dedicated to promoting the GEOINT tradecraft and developing a stronger GEOINT Community to address national security concerns. The foundation's accreditation of collegiate GEOINT Certificate programs at 14 national and international academic institutions demonstrates

this commitment.² USGIF maintains an academic board drawn from government, industry, and academia to advance geospatial education and connect new GEOINT analysts with professional opportunities. The USGIF Universal GEOINT Certification Program allows qualifying, experienced professionals to achieve certifications in GIS & analysis tools, remote sensing & imagery analysis, and geospatial data management.³

The Royal School of Military Survey (RSMS) is the predominant organization involved in the education of military geographers and fills a unique role unlike anything found in the U.S. Within the UK geospatial intelligence community, RSMS is positioned at the intersection of government and academia, offering multiple education programs developed in conjunction with and accredited by civilian universities to offer full degrees. It educates students from multiple government agencies in multiple locations around the country.

A major role of RSMS is to teach Military Engineer soldiers the key functions of their job roles, including collecting, processing, managing, exploiting, and disseminating geospatial information.⁴ All courses at RSMS are delivered in person and designed to meet the requirements of specific Ministry of Defence (MOD) customers.⁵ Since 2008, RSMS has been organized into three "training delivery wings," each with its own curriculum. Individuals assigned to the Geospatial Exploitation Wing at Chicksands are taught how to collect geospatial data using the latest digital capture methods and modern GIS software. Individuals assigned to the Geospatial Exploitation Wing and Geospatial Information Management Wing, both in Hermitage, are responsible for the fundamental principles of map science and cartography in an effort to ensure products of the highest quality.⁶

Education at RSMS yields multiple possible degrees for individuals that complete the flagship programs. Royal Engineer technicians attending soldier training are enrolled on a foundation (two-year) degree course accredited through Sheffield Hallam University. The Foundation Program was launched in 2001 and, according to RSMS, has been successful as a catalyst for soldier recruitment. As a result of the program's success, RSMS has entered into a contract with Sheffield Hallam University to enable soldiers to continue progressing and earn a full bachelor's (three-year) degree.⁷

Beyond the foundation degree, the Army Survey Course (ASC) at RSMS was accredited through Cranfield University to award a four-year Master of Science (MSc) degree in 1994. The ASC was revised in 2009 to better cover the needs of the UK IC and was re-accredited to award a MSc in geospatial intelligence. Cranfield University also developed a degree program related to geospatial intelligence to those outside government, offering a MSc in geographic information and a related postgraduate diploma and certificate. Ninety percent of graduates find employment within the geographic information or research sector.⁸

Research Findings

The scope of the U.S. and UK GEOINT entities are different: Our research found the scope of U.S. and UK GEOINT entities are different in size, funding, and design.⁹ The size difference is significant and impacts organization of the community, volume of GEOINT products, and scalability to address threats to national interest and geospatial analysis problems not related to security.¹⁰

The U.S. GEOINT Community is well funded. Just like the size of the community, the UK GEOINT community

1. Ibid.
2. USGIF. *USGIF 2016 Annual Report*. <http://usgif.org/about/annual-report>. Accessed June 26, 2017.
3. USGIF. "Universal GEOINT Certification Program," 2017. http://usgif.org/system/uploads/4829/original/about_USGIF_2017.pdf.
4. MOD. "Defence Intelligence: Roles," 2012. <https://www.gov.uk/guidance/defence-intelligence-services>.
5. Royal School of Military Survey. "About Us," 2017. <http://www.rsms.ac.uk/>.
6. MOD. "Defence Intelligence: Roles," 2012.
7. Royal School of Military Survey. "About Us," 2017.
8. Cranfield University. "Geographical Information Management MSc," 2017. <https://www.cranfield.ac.uk/courses/taught/geographical-information-management>.
9. Penn State University. "Comparative Professional Preparation of the Geospatial Intelligence Analyst in the U.S. & UK," 2017.
10. Department of Defense. "Fiscal Year 2017 President's Budget Proposal." <https://www.defense.gov/News/News-Releases/News-Release-View/Article/652687/department-of-defense-dod-releases-fiscal-year-2017-presidents-budget-proposal/>.

also has a much smaller budget. The difference in these budgets results in large differences in the scope of the work that can be accomplished by either entity.¹¹

A final difference between U.S. and UK geospatial entities is design. The U.S. GEOINT Community is layered. This design of different intelligence services overlapping and repeating efforts is a process of competitive analysis based on as many collection sources as possible. Conversely, UK GEOINT is steered by top-driven requirements.

Education of analysts shows differences between UK and U.S. universities:

Common principles, the formal standards for training GIS/geospatial intelligence in the UK, via the Quality Assurance Agency for Higher Education (QAA) and the Spatial Literacy in Teaching, are more well-defined and accepted compared to U.S. standards. The method of teaching GIS/geospatial intelligence in the UK has borrowed and mirrored a lot of the U.S. methods and standards.¹²

Both countries share similar attributes of geospatial science studies; but the preparation of analysts differs. The U.S. has a large pool of institutions, and, generally, geospatial sciences are presented via ad hoc curricula set by the institution or degree program. U.S. education prepares graduates for employment, often competency-oriented, focusing on skills and technical tradecraft of geospatial analysis.

The organized, sophisticated relationship between RSMS and UK universities is education-oriented to develop a student's cognitive thought. An integrated approach of civilian universities with RSMS and national quality standards represents where principles drive program design. UK education leads to certified or professional status for military geographers and civilians.

UK education of military engineers is unique:

Members of the British military

are trained through partnerships with universities to provide an education tailored to the soldier's or officer's branch, but with the rigors of the national education standards. Service members attend RSMS, where multiple formal universities oversee training to provide foundation, bachelor's, and master's degrees. Other UK geospatial intelligence analysts are educated from universities and/or formal military training.

The U.S. Military Academy and U.S. Air Force Academy resemble the RSMS system in educating military officers prior to active duty assignments. U.S. Army and Air Force officers are not specifically assigned to geospatial roles.

Relevance of the Findings

- Given the similarities and differences in the preparation of the GEOINT analyst between the U.S. and UK, the relevance of our findings suggests the UK focuses more on core geospatial knowledge.
- In contrast, the U.S. is establishing creditable GEOINT analysts based on course training (civilian and/or military) and certifications post traditional academia degree.
- The key difference between the two counties is foundation and awareness. For example, the UK offers schools centered on geospatial technical practices, thus new prospective students may see GEOINT as a career path early on. Whereas, U.S. students may not be aware of GEOINT until later discovered in the military or in their geospatial career path. As a result, U.S. students tend to gain higher education focused on GEOINT via accredited GEOINT program/schools, subsequently earning specific GEOINT credentials per employer or agency requirements.

Recommendations

The GEOINT discipline has arrived at the point where teaching methods must change to address the lack of individual core geospatial knowledge evident with

the ad hoc curricula of U.S. institutions and degree programs. Adaptive learning techniques and technology can help. The suggestion of adaptive learning is driven by a realization that the U.S. GEOINT community is far too diverse and complex for non-adaptive approaches. In other words, we need to allow the individual's learning needs to determine what they are taught.¹³ Adaptive learning is an educational method which uses computers to orchestrate the allocation of human and mediated resources according to the needs of each learner. Specifically, computers adapt the presentation of material according to students' learning needs.

Adaptive learning seems the best means to address the identified lack of core geospatial knowledge in the U.S. GEOINT Community. It is likely that this knowledge is essential for the integration of AI with the work of humans. The possible implications of new GEOINT technology affects communication, the way analysis is performed, and all aspects of imagery collection and data storage/manipulation. The community can be influenced through elements, links, and the environment—with technology adding a dynamic to the process. The elements are analysts, agencies, and academic institutions. The links include the ability to communicate and develop transferrable skills. The environment in this case is significantly influenced by the academic community's ability to adequately prepare the student with the essential knowledge that serves as the foundation of understanding. Applying adaptive learning to the core geospatial knowledge can change the environment for the better.

With a shared goal for the community to improve GEOINT curricula, the focus can't be on change at each institution. The path to changing the learning environment for GEOINT analysts is to change the way students are taught—to provide customizable education. Our comparison of U.S. and UK preparation of GEOINT analysts, including the RSMS case study, highlights the fundamental differences between the education systems in these

11. United Kingdom. "Civil Service Job Search," 2016. <https://www.civilservicejobs.service.gov.uk/csr/index.cgi?SID=Y3NvdX>.

12. Mehmet Seremet, Brian Chalkley, and Ralph Fyfe. "The Development of GIS Education in the UK and Turkey: A Comparative Review." *Planet*, 2013;27(1):14-20.

13. Alan Louie, Richard Balon, Eugene Beresin, John Coverdale, Adam Brenner, Anthony Guerrero, and Laura Weiss Roberts. "Teaching to See Behaviors—Using Machine Learning?" *Academic Psychiatry*, 2017;41(5):625-630. doi:10.1007/s40596-017-0786-1.

two countries.¹ The GEOINT Community must come together to improve the preparation of analysts. Focusing on the

environment, improvements to GEOINT curricula, program design, ways of teaching, and pedagogical methods may

significantly impact the foundation of professionals' critical thinking skills and ability to analyze complex problems.

Strengthening the St. Louis Workforce: USGIF's St. Louis Area Working Group

By David Berczek, NGA Office of Corporate Communications; Isa Reeb, Project Connect; Steven Thomas, Ball Aerospace; and Steve Wallach, consultant and former NGA West Executive

The importance of the geographic information system (GIS) within the modern world cannot be understated. The demand for geospatial data and geospatial intelligence (GEOINT) continues to grow exponentially year over year. Geospatial sciences and data have become critical elements in an ever-growing number of fields and an essential component to solving the most challenging problems and issues across a variety of industries. GIS can be found in almost every discipline from A to Z—from agriculture to zoology. The National Geospatial-Intelligence Agency (NGA) serves as the functional manager of GEOINT for the Intelligence Community (IC) and Department of Defense. NGA is charged with producing the geospatial information and intelligence that provide the eyes of our national security operations. The United States Geospatial Intelligence Foundation (USGIF) has always had at its core a commitment to advance GEOINT tradecraft through education and outreach, thus ensuring NGA always has plethora of well-trained candidates ready to enter its workforce.

The greater St. Louis, Mo., region has long hosted a number of companies, organizations, and government agencies that play a pivotal role in the world of GIS. Ball Aerospace, Boeing, Monsanto, Esri, and Boundless are just a few companies that develop or operate cutting-edge GIS systems and products. Many regional academic institutions such as the University of Missouri system, Saint Louis University, Washington University, and Harris-Stowe State University provide geospatial undergraduate and graduate programs as well perform innovative GIS-related research and development (R&D). This work is broad-reaching and includes,

but is not limited to, geospatial research in biosecurity, disease treatment and outcomes, urban health, education, crime, economic development, environmental and food security, air pollution, climate response, agricultural disease forecasting, water and food security, and urban development and social equity. For more than 70 years, NGA or its predecessors—such as the National Imagery and Mapping Agency or the Defense Mapping Agency and Aeronautical Chart and Information Center—have operated in the City of St. Louis. In June 2016, NGA announced it would construct a new “state-of-the-art” facility, known as the Next NGA West (N2W), at a 99-acre site in St. Louis city, just northwest of downtown. NGA Director Robert Cardillo stated, “The St. Louis City site provides NGA with the most technological, academic, and professional environment for this agency to develop the capabilities and solutions necessary to solve the hardest intelligence and national security problems entrusted to us by the American people.”

As NGA recommits itself to executing its national security mission from within the City of St. Louis and the city reaffirms its partnership with the agency, an opportunity arises. The City of St. Louis and the greater St. Louis region, on both sides of the Mississippi River, can become a core area of excellence for geospatial education and expertise. Seizing this opportunity means answering the agency's ever-growing need for a qualified workforce with the appropriate geospatial skill sets, credentials, and expertise. However, creating this environment presents a number of challenges. These include, but are not limited to:

- Perception by local communities and residents that there is no clear path to qualify for professional (i.e., analytic, management, etc.) careers at N2W.
- Complexity in coordinating with a variety of St. Louis city, county, and other surrounding local governments, academic institutions, and industry.
- Limited relationships with local school districts or academic institutions.
- Limited geospatial-related curriculum within local community colleges and some universities.
- Limited public awareness of geospatial-related professions and career opportunities.

Since 2004, USGIF has brought together government, industry, academia, professional organizations, and individuals to advance the geospatial intelligence tradecraft. This makes USGIF an ideal organization to help NGA satisfy its need for a qualified GEOINT workforce in St. Louis. As a 501(c)(3) educational nonprofit, USGIF has made education its top priority, exemplified by its Universal GEOINT Certification Program, scholarship program, Collegiate Accreditation program, outreach at K-12 schools, and other initiatives.

USGIF has formed and supports a variety of working groups, with members addressing issues and providing timely solutions to support needs across the GEOINT Community. USGIF working groups and outreach do not typically focus on a single city or region. However, to best address the specific needs of NGA and its transition to N2W, USGIF established the St. Louis Area Working Group (SLAWG). The SLAWG is the first

1. Penn State University. “Comparative Professional Preparation of the Geospatial Intelligence Analyst in the U.S. & UK,” 2017.

working group geographically based outside of USGIF headquarters in Herndon, Va., and is also the first working group that has a distinct geographic focus. It is this regional focus that makes possible the invaluable inclusion of local institutions such as the City of St. Louis, St. Louis University, and community groups such as Project Connect and SLATE. These groups provide the knowledge and expertise to take the working group's combined resources and effectively apply them across the greater St. Louis metro area.

The SLAWG was established to bring together key (government, industry, and academic) players in the region to develop lasting educational pathways for the community to achieve geospatial degrees and certifications, which lead to careers at NGA and across the GEOINT Community. The working group aims to support and build geospatial pipelines that integrate and amplify existing NGA efforts to educate and train individuals. The working group is also supporting NGA's plans to leverage more open source in St. Louis, both through the planned unclassified workspace at N2W and the agency's presence at one or more of the innovation centers (i.e., Cortex, T-REX, etc.). The end goal is to grow and sustain a populace with the necessary skills to qualify for and fill future needs for NGA and industry in technology, analysis, and management career fields. While NGA's government and contractor workforce is the focus, the positive impact of the SLAWG will be much broader, supporting and providing career opportunities in other federal, state, and local government agencies and across commercial industry.

To accomplish this, the SLAWG has established five primary objectives:

- 1) Improve geospatial and geographic literacy in the greater St. Louis area and surrounding regions.
- 2) Integrate with science, technology, engineering, and math (STEM) and other similar programs.
- 3) Introduce and/or advance geospatial curriculum at the K-12 level.
- 4) Create an engagement strategy between the greater St. Louis community and NGA.

- 5) Broaden engagement with St. Louis area industry, universities, colleges, and community colleges.

To achieve these objectives, the SLAWG brings together resources from NGA, local government and community leaders, and nonprofit, academic, and industry professional. These include:

- Accenture
- BAE Systems
- Ball Aerospace
- Boundless
- CACI
- CEdge
- Chameleon Integrated Systems
- City of St. Louis
- Continental Mapping
- Cortex
- CSRA
- Esri
- Flight Safety
- General Dynamics
- GEODataIT
- Harris
- Harris-Stowe State University
- InSequence
- Leidos
- ManTech
- Missouri University of Science and Technology
- NGA
- NJVC
- Planet
- Project Connect
- Raytheon
- SLATE
- St. Louis University
- Tera4D Systems
- T-Kartor
- T-REX
- University of Missouri Center for Geospatial Intelligence
- UrtheCast
- USGIF
- Washington University

This diversity, which is indicative of USGIF working groups, provides a wide range of expertise, perspectives, and resources to benefit the group's mission. This array of dedicated SLAWG partners has rapidly made significant progress against the group's stated objectives. Since its standup in August 2017, the SLAWG has established four distinct GIS pathways or engagement tracks: workforce, education, entrepreneur, and R&D. Each track is specifically focused and aligned with one or more of the strategic objectives of the working group.

The organizational structure of the SLAWG has followed the best practices of other USGIF Working Groups by establishing Sub-Working Groups to focus on and address high-priority tasks. These groups and teams are self-governed and cross-communicate to develop recommended strategies and solutions to present back to the larger SLAWG. Each Sub-Working Group is pursuing individual actions/efforts, all of which support the objectives of the greater working group.

The SLAWG has already become involved in a number of GIS-related events throughout the greater St. Louis region. The working group has supported numerous events, helping to raise awareness of geospatial-related sciences and careers within the community.

The first such event was the Inaugural GeoYou, which brought together GIS innovation leaders from government, industry, and academia to highlight cutting-edge capabilities in geospatial technology, big data, and real-time analytics. Experts discussed practical ways for high-tech entrepreneurs to enter the market. Throughout the event, St. Louis was highlighted as a key geospatial hub in the United States due to the long-term commitment of NGA and the vast GIS-related business interests throughout the area. The event was held in partnership with the Cortex Innovation Center, one of the Midwest's leading hubs for innovation and technology.

Next, the SLAWG supported the most recent GeoSTL Mapathon, a mapping event in which participants contributed to OpenStreetMap (OSM). The goal of the Mapathon was to add features to OSM to increase the digital geospatial footprint for the area of North St. Louis. Tasks were divided among the participants and both indoor and outdoor GIS and survey tools were used. Participants received on-the-spot training in basic geospatial skills and were exposed to the world of geospatial science through directly working with geospatial data.

The SLAWG also supported USGIF's most recent NGA Tech Showcase West. During the two-day event, participants had the opportunity to see the unique

work of the industry and NGA in St. Louis. During the unclassified day, the SLAWG hosted a panel discussion that focused on establishing the greater St. Louis region as a central hub for the geospatial industry.

The working group also supported Boundless, one of the group's partner companies, as it brought the first GeoPlunge tournament to the St. Louis area. The GeoPlunge tournament offers a great way for children to learn U.S. geography through a fun and easy card game. GeoPlunge can be played at school or at home, allowing children to develop critical thinking skills while gaining knowledge of U.S. geography.

Finally, the SLAWG was one of the organizations that participated in an open house for Project Connect, an action plan by the City of St. Louis to ensure coordination and collaboration between neighborhood revitalization, transportation, and other re-development efforts and the city's investments to

support NGA. The event engaged St. Louis residents, providing information and answering questions related to various projects. The SLAWG informed residents of the education and workforce development efforts underway and requested feedback on how to best engage youth in STEM education and geospatial careers.

Establishment of the greater St. Louis region as a core of geospatial education, expertise, and tradecraft will be of tremendous benefit to NGA, helping to ensure the long-term success of N2W. Accomplishing this vision will take a well-informed and combined effort across the public and private sector. USGIF and the SLAWG are committed to working directly with partners throughout the region to establish clear paths for people throughout St. Louis and surrounding communities to receive the necessary education and credentials to take advantage of career opportunities at

NGA or across the broader geospatial community. The SLAWG has already made significant progress in the short time since its formation. This success can be directly attributed to the diversity of its membership and their dedication and willingness to pool their wide array of knowledge and resources to achieve tangible results.

The working group's local geographic focus and its strong and varied partnerships have allowed USGIF goals and objectives to be pursued with boots on the ground in St. Louis. The accomplishment of the SLAWG's objectives and goals will require continued support from across the GEOINT Community.

The SLAWG is putting these pathways in place in the greater St. Louis area. If you would like more information on the SLAWG or are interested in becoming a member, please visit usgif.org/community/committees/SLAWG.

Geospatial Thinking Is Critical Thinking

By Katherine Hibbs Pherson, Pherson Associates; Robert J. Farnsworth; Steven D. Fleming, Ph.D., University of Southern California; Michael Hauck, Ph.D.; and William Lu, University of Southern California

In a world of swirling crises, ballooning data sources, and clever machines, cries for better thinking skills are universal. According to one popular bumper sticker, lack of critical thinking skills in America is akin to "the nation's second national deficit." The geospatial intelligence (GEOINT) Community is particularly sensitive about the role critical thinking plays in generating insights regarding time and space that set GEOINT apart from other intelligence disciplines. The community is keen to incorporate this recognition into its professional training and education.

The human brain's unique configuration to conceptualize, draw inferences from data, and anticipate is balanced by the dangers of being led astray by its biases and intuitive traps, e.g., being fooled by assuming all data are valid, or intimidated by the insecurity that automated algorithms might know more than people

do. The basic tenets of critical thinking provide a strong foundation upon which to evaluate the geospatial elements of space and time. Similarly, structured analytic techniques (SATs), popularized within the U.S. Intelligence Community (IC), help people make their thinking more explicit. Computational thinking helps people understand how to better interact with machines. These physical links to the real world can bridge empirical and experiential observation to help analysts make sense of their environment, solve problems, optimize their use of automated tools, and generate insights and actions.

Critical Thinking Enables Geospatial Problem-Solving

Successful critical thinkers are judged by results that almost always involve deliberation and intuition, logic and creativity, and interpreting data and anticipating situations that go

beyond available data. Longtime CIA methodologist Jack Davis recognized this in defining critical thinking as the "adaptation of the processes of scientific inquiry" to your environment and its special circumstances.¹ The key components of critical thinking include:

- Asking the right questions.
- Identifying your assumptions.
- Reaching out to sources of information beyond those readily available.
- Evaluating data for accuracy, relevance, and completeness.
- Assessing the data and forming hypotheses.
- Evaluating the hypotheses with an eye toward conflicting data.
- Drawing conclusions.
- Presenting your findings.

The study and understanding of critical thinking skills has come a long way

1. Katherine Hibbs Pherson and Randolph Pherson. *Critical Thinking for Strategic Intelligence*, 2nd ed. Washington, D.C.: CQ Press/Sage Publications; 2016, p. xxvi.

since Aristotle defined the principles of formal logic some 2,300 years ago. The concepts of logic as deduction, based on evaluating data to determine the single possible answer, evolved as 13th century thinkers such as Roger Bacon added concepts of induction or inferences based on incomplete data, and broadened even further to help account for the complexities of our changing world. Charles Sanders Peirce identified abduction as the part of the scientific method that enables the generation of multiple hypotheses whose consequences can be derived by deduction and evaluated by induction. All of these modes of logical reasoning are important for geospatial professionals seeking to make sense of situations, whether replete with hard data or simply indicators of possible events or activity. Some argue that observations foreseeing future options—which by definition are lacking in data and are characterized by uncertainty—may be yet another stage in contemplating how the human brain processes the human environment.

The first three steps imply successful critical thinking depends upon having a solid framework (well-posed questions, identified assumptions, broad sources of information) on which to base the thinking. Cognitive psychologists—ranging from Frederic Bartlett in the 1920s to Gary Klein and Daniel Kahneman today—have written extensively about the explanatory structures humans naturally create to account for the data, beliefs, and experiences that are unique to each of us. Klein² coined the term “sensemaking” to describe how humans form a frame or mental model based on few pieces of data and then adjust the frame as more data becomes available. Data that does not fit the frame may be ignored or discarded if it lies too far outside the frame or may even force fundamental changes to the frame if the data is compelling enough. Sensemaking is at the heart of telling good stories. After all, what makes a compelling story, if not the realization that the story helps us understand a topic in a new way?

Analysts often frame their stories with the journalistic questions that date back to Greek and Roman oratory traditions, namely, “Who?” “What?” “When?” “Where?” “Why?” and “How?” “When” and “where” are explicit in the geospatial domain, but the domain also uniquely captures the “who” and the “what,” in a sense, tethering events and intentions to the physical world. Geospatial reasoning matches the patterns of observed data to the models, oftentimes maps or other geospatial displays, to answer questions of what is or might be happening. Reasoned explanations for “how” and “why” require additional context and data.

Structured Analytic Techniques Make Thinking Explicit

SATs³ externalize internal thought processes to make them clear and transparent enough to be shared, improved, and critiqued. They save time in the long run and inject rigor, facilitate imagination, and infuse accountability by providing the means to examine, question, and collaborate with others to overcome mind-sets, creatively anticipate the potential for disruptive change, and focus on information that helps distinguish one working hypothesis or developing scenario from another.

SATs fall into four families:⁴

- 1) Innovation** techniques spur creative thinking. They enable us to generate new insights or discern all the aspects of the issue.
- 2) Diagnostic** techniques are used to understand what the information tells us. They help us best explain what has happened or is happening.
- 3) Reframing** techniques aid us in thinking about issues in a different way, challenge conventional wisdom, and mitigate groupthink.
- 4) Strategic foresight** techniques frame alternative ways for how a situation could evolve, identify key drivers, and assess the implications for each potential trajectory.

Richards Heuer began writing about techniques for externalizing thinking and considering multiple hypotheses in the 1960s, based on his efforts to apply the research of scholars such as Daniel Kahneman, Amos Tversky, and Robert Jervis to the real world of intelligence analysis and counterintelligence. In the past 15 years, these techniques have become broadly taught and used by intelligence communities across the globe. They are used increasingly within academic, business consulting, and industry settings. Their utility comes from providing analysts with guidance in how to “think through” or “unpack” difficult issues so they can assess the quality of sources and evidence, distinguish patterns and relationships, and justify the alternatives and judgments they make.

The role of SATs as aids in thinking—as opposed to predictive techniques—means they provide a bridge between the scientific method and the ambiguous realities of the intelligence world in which all facts are not, and may never, be known. To employ SATs well requires some knowledge and a little additional time. Nonetheless, making them a habit can save time in the end, prevent thoughtless errors, help integrate analysts into a collaborative process, and provide documentation for qualitative rigor applied to a wide range of problems.

As the GEOINT Community moves into increasing use of technology to help optimize use of large and varied datasets and think about situations in different ways, SATs are an important means by which we can bring the strengths of human cognition to intelligence problems. This is an important realization because postmortems of virtually every major intelligence failure in recent decades have identified engrained mind-sets as a key contributing issue.

Computational Thinking and Automated Tools

Computational thinking derives from the development of automated systems in the 1950s and reflects the process for

2. Gary Klein, et al. “A Data/Frame Model of Sensemaking,” in *Expertise Out of Context: Proceedings of the 6th International Conference on Naturalistic Decision Making*. ed. R.R. Hoffman. New York: Taylor & Francis; 2007.

3. Richards J. Heuer and Randolph Pherson. *Structured Analytic Techniques for Intelligence Analysis*, 2nd ed. Washington, D.C.: CQ Press/Sage Publications; 2015.

4. Randolph H. Pherson. *Handbook of Analytic Tools and Techniques*, 4th ed. Reston, VA: Pherson Associates, LLC; 2016.

the development of algorithms to express steps for solutions that could be carried out by machines. It gained strength as a concept with Jeanette Wing's¹ suggestion in 2006 that computational thinking should be a component of all education curricula.

Computational thinking is an expression of thinking that incorporates the critical thinking process and SATs to produce formulae for thinking—typically, a set of procedures that rigorously define a thought process. Without such discipline, it would not be possible to reduce the solution of meaningful problems to algorithms executable by a machine. For instance, the stages of forming the problem—expressing a solution that can be executed by a machine, executing it, and evaluating its effectiveness—is the critical thinking process applied to the specific domain of automation. The thinking skills of decomposition, pattern recognition, and identifying and testing multiple solutions are laid out in the step-by-step guidance in various SATs. This is not to say analysts should employ computational thinking as their exclusive—or even primary—approach to sensemaking and storytelling. Rather, analysts should develop computational thinking as a skill that enables them to frame problems in a way that allows them to define algorithms suitable for machine computation.

What is unique and particularly valuable to the evolving disciplines of geospatial thinking are the application of the specific types of logic used in creating computer programs and algorithms, including iteration, Boolean, and other logical operations, as well as the ordering of steps into algorithms. These skills bring a granularity and specificity to thinking processes that map well to manipulating the data details and measurements practiced in geospatial analysis.

These computational skills build another part of the bridge between the ambiguity of the real world and the carefully defined data fields and manipulations machines require to yield insights of value to intelligence consumers. Incorporating these skills more overtly in geospatial

processes will help analysts work within both worlds by understanding the human thinking and machine thinking processes and leveraging the strengths of both in their observations and judgments.

Applying Thinking Regimens to Geospatial Analysis

Many continue to debate whether intelligence analysis is an art or a science. This discussion takes on additional significance in light of advances in availability and scale of data sources, new ways to process and manipulate them, and the extraordinary progress in machine learning. The field of geospatial information science (GISc) is going through a similar evolution as did computer science in the 1950s and 1960s. Critics claimed there could be no “computer science” because sciences are derived from natural phenomena and computers are simply man-made tools used to extract that information.² Like many intelligence domains, GISc spans several traditional disciplines, principally geography, computer science, and mathematics. Geospatial principles are taught in several liberal arts curricula (for example, international relations and sociology) because of the ease with which geospatial visualizations can display data specific to those areas of study.

Geospatial science distinguishes between the skills required to produce accurate geospatial assessments and the use of information technology to display data without expert knowledge in the discipline. This is a critical point—today's geospatial tools can be so powerful and intuitive, it can be easy to produce misleading visualizations that compellingly lead to false conclusions. Reliable geospatial product creation and analysis requires the individual to understand the common pitfalls in geographic data. Creating an accurate buffer map, for instance, requires awareness of the differences between a geographic coordinate system that displays the Earth as a curved surface and a projected coordinate system that displays it as a flat surface. For the

foreseeable future, no matter how smart the machine, expert tools wielded by analysts who lack critical thinking skills will result in “nonsensmaking.”

Geospatial analysis, like other forms of intelligence analysis, requires practitioners to employ critical thinking processes to identify and assess significant data to arrive at a conclusion. Geospatial analysis is unique in that it does so through the exercise of spatial reasoning, which focuses on matching data to frames that involve the location, extent, distribution, pattern, association, interaction, or change of data within a geospatial sphere or “space.”³ The geospatial contexts within which data are interpreted and transformed into meaning include:

- **Life space** that enables thinking about the world in which we live and is exemplified by “patterns of life.”
- **Physical space** that enables thinking about geographic space and the ways in which the world works to understand and model natural phenomena such as earthquakes.
- **Intellectual (or cognitive) space** that involves abstract concepts that occur in space, such as a cultural model that describes the significance of a religious place.

In particular, geospatial analysts seek to gain a sense of the data through imagery and maps. The data are presented in an automated model processed within their mental model, which is an amalgamation of the data, beliefs, experience, and collaboration that makes up their expertise. In Klein's data-frame concept of sensemaking, analysts are questioning the data and the frame, and consciously reframing to better explain relationships among the data. Diagnostic SATs such as an analysis of competing hypotheses, or reframing SATs such as remotem analysis and structured self-critique, can guide analysts through reconsidering their assumptions, seeking additional perspectives and data, considering other alternatives, and questioning how they might be wrong.

1. Jeanette M. Wing. “Computational Thinking Benefits Society.” *40th Anniversary Blog of Social Issues in Computing*, 2014.

2. Peter J. Denning. “Remaining Trouble Spots with Computational Thinking.” *Communications of the ACM* 60, no. 6 (2017):33-39. doi:10.1145/2998438.

3. Contribution from Todd Bacastow, Pennsylvania State University.

These models can be applied in all aspects of life with problem sets ranging from national security to retail supply chains. Models can be so simple to use that they require setting only a few parameters, while other models are incredibly complex, such as those that forecast the weather based on millions or billions of inputs. In criminal justice, for instance, risk terrain modeling can identify areas of high risk for criminal activities by gathering data on risk layers such as drug houses, crime hot spots, and population density, and then valuing the risk layers

and mapping them. In epidemiology, disease vectors can be mapped for prevention programs by gathering data on desirable mosquito habitats, overlaying it on a geospatial format, and summing it to display areas most likely to expose humans to mosquito-borne disease.

The community needs exquisite collection, adept data handlers, automated assistance to manipulate and visualize, and the ability to put all this together into insights that lead to effective actions. The common thread needed to weave all these things together is rigorous thought. It takes

thinking skills that make for rational thought, collaboration, and learning.

Critical thinking and SATs operationalize thinking processes and best practices while computational thinking helps analysts interact better with machine data, models, and applications to translate intent and capability into geospatial models that make sense of our environment and solve difficult problems. No matter how advanced technology becomes, humans still seek to convey our understanding in the most natural of ways—by telling stories about things that matter.

Improving GEOINT Access for Health and Humanitarian Work in the Global South

By Victoria M. Gammino, Ph.D., U.S. Centers for Disease Control and Prevention; Vincent Seaman, Ph.D., Bill & Melinda Gates Foundation; and John Steed, Tesla Government

The “Global North” and “Global South” are generally distinguished by their respectively higher and lower economic and development profiles.⁴ With respect to geospatial intelligence (GEOINT), they also exist as parallel yet distinctly different worlds. The marked dominance of the U.S. within the GEOINT sphere diminishes our appreciation for operational challenges in the Global South, where critical authoritative data and geospatial infrastructure are lacking. Humanitarian activities, including disaster mitigation, service delivery to refugees and internally displaced people, and multinational efforts such as the Global Health Security Agenda’s mission to secure the world from “global health threats,” are constrained by that region’s variable geospatial capacity.⁵ Spatial data, also known as geospatial data, is information about a physical object that can be represented by numerical values in a geographic coordinate system. The increasing availability of geographically referenced base layer data, geo-referenced imagery sources, improved processing, and crowdsourced data enable rigorous and complex analyses with more granular outputs that allow analysts to target specific locations and populations. However, owing to a dearth of

geospatial expertise, core data layers, and technical and financial resources, GEOINT capabilities remain out of reach to many countries. Such resource inequity presents a significant challenge that is further amplified in conflict areas, where current, precise, and, wherever possible, verified ground-reference data are mission-critical.

In the Global North, discussions on the “state of the art” reflect the ubiquity of fundamental GEOINT capacities including automated feature extraction and change detection; big data analytics and geospatial presentation; access to topical, relevant, and quality geospatial data; the tools and knowledge required to execute fundamental geospatial processes; and to a lesser but increasing degree, machine learning (ML) and artificial intelligence (AI). While there are notable exceptions, outside of capitals and major cities, a significant part of the Global South is bereft of basic information and communications technology (ICT) prerequisites—such as consistent electricity and internet access—needed to routinely and accurately conduct geospatial work.

National and local government support for health and humanitarian efforts vary, and the onus of procuring quality geospatial data may be left to aid and health agencies,

few of which have the capacity to meet this immense need. Additionally, GEOINT fundamentals, such as current census data or authoritative base layers, are often outdated or non-existent, sometimes at the country-level, and especially below second- or third-order administrative-level boundaries. Further complicating access to authoritative data, governmental and other institutions may restrict data for a variety of reasons (which may run counter to their missions to improve the well-being of their constituencies). Restriction of these authoritative datasets may arise from political sensitivities, protection of funding streams through data dominance, or deflection of questions concerning data quality.

Similarly, commercial satellite and unmanned aircraft systems imagery for many developing countries—particularly for remote or sparsely populated areas—has relatively no commercial value outside of intelligence arenas and entities such as the mining industry, and thus is refreshed less often and is of lower quality than imagery of urban areas.⁶ Even where these data do exist, the cost of purchasing and processing imagery is frequently beyond the financial reach of those in the humanitarian and

4. Generally signified through the human development index (HDI). <http://hdr.undp.org/en/content/human-development-index-hdi>.

5. Global Health Security Agenda website. <https://www.ghsagenda.org/>.

6. P.F. Uhler, R.S. Chen, J.I. Gabrynowicz, and K. Janssen. “Toward implementation of the global earth observation system of systems data sharing principles.” *Data Science Journal*, vol. 8, October 2009.

development circles. This divide in remote sensing capacity mirrors the overall digital divide, wherein, according to the United Nations (UN), 90 percent of the population in the world's 48 poorest countries remains offline.¹ Thus, there is the least capacity to take advantage of GEOINT where it is most needed.

In the absence of open-source, authoritative data, crowdsourcing platforms such as OpenStreetMap, HealthMap, Wikimapia, and CrisisMappers fill important gaps by providing egalitarian scaffolding that supports data aggregation, curation, and management. However, it is important to recognize the intrinsic limitations of user-generated and “found” data.² Free and open-source geospatial platforms such as Google Earth and QGIS have had a similarly democratizing impact on geospatial software utilization within the minority of Global South countries with dependable internet access. However, while data and tools are necessary, they are not sufficient to enable true access. Geospatial expertise is the third leg of the access “stool” required to maximize data utilization. In the Global South, the preponderance of technical capability and data dwells among national-level government, multilateral, and academic institutions rather than among implementing staff or non-governmental organizations (NGOs) that operate at the subnational level.

Given this divide in geospatial resources, improved collaboration is critical among private, bilateral, and multilateral stakeholders that have access to data, expertise, and imagery. Recent examples from the global health arena illustrate how GEOINT practitioners have contributed to effectively target service delivery through a combination of imagery analysis and

inexpensive, creative, low-tech ground-referenced datasets. Further field and sky coordination of GEOINT capabilities in conjunction with activity-based analytics hold significant potential to strengthen disaster mitigation response as well as civil and military humanitarian actions. We discuss the role of data access and recent achievements targeting infectious disease and humanitarian responses in remote and conflict-ridden areas as examples of successful collaborative and multidisciplinary approaches to GEOINT of benefit to the Global South.

Case Studies

The resource inequity with respect to GEOINT that the Global South faces necessitates a continuous stream of outside financial, technical, and human resources to establish and maintain parity with the Global North. To some degree, this may account for the prominent rise of crowdsourced labor and online data sharing platforms (e.g., Ushahidi, Swift River, OpenStreetMap, Tomnod) for near real-time reporting. There have been several recent public-private efforts, however, to create sustainable solutions by investing in GEOINT infrastructure and expertise that illustrate the long-term value proposition to both donors and countries. The following case studies illustrate how providing access to authoritative base layers as well as specialized knowledge and resources such as imagery classification tools and automated feature extraction can solve problems, leverage further investment, and highlight new opportunities to bridge the North-South GEOINT divide.

1) The Global Polio Eradication Initiative (GPEI), a public-private partnership³ with the goal to eradicate polio worldwide, exemplifies the application of geospatial

data and analysis to solve a humanitarian problem while building technical capacity to create sustainable geospatial infrastructure. The use of GIS has significantly changed the trajectory of GPEI since 2007, when Google Earth was first used to develop “the river strategy”—a tactic devised to interrupt transmission of poliovirus along the Congo River in the Democratic Republic of Congo.⁴ This effort used imagery to identify settlements along the river, visualize potential trade routes and related population movement patterns, and facilitate vaccine distribution logistics by examining navigation patterns. Analytics were subsequently used to evaluate the geographic coverage of house-to-house vaccination teams;⁵ assess team performance and campaign coverage;⁶ collect location coordinates for all suspected polio cases; track post-campaign coverage surveys; and collect microcensus data to support imagery-based population estimates.⁷ The granular geospatial reference data collected in Nigeria for polio eradication also resulted in the Vaccination Tracking System (VTS) platform, which is arguably the most complete synthesis of population and health program data in Sub-Saharan Africa.⁸ In 2015, this system was adapted and successfully repurposed to avert the spread of Ebola within Nigeria.⁹

The VTS has also provided the foundation for a major breakthrough in the field of demography, resulting from a collaboration among the Geographic Information Science and Technology (GIST) Group at Oak Ridge National Laboratory, the Bill & Melinda Gates Foundation, and Sweden-based Flowminder Foundation. This group developed population estimates for gender and standard 0-12-month and five-year age groupings at a resolution of 90 meters, based on settlement feature

1. The Broadband Commission for Digital Development. *The State of Broadband 2015: Broadband As a Foundation for Sustainable Development*. <http://www.broadbandcommission.org/Documents/reports/bb-annualreport2015.pdf>.

2. K. Crawford and M. Finn. “The Limits of Crisis Data: Analytical and Ethical Challenges of Using Social and Mobile Data to Understand Disasters.” *GeoJournal*, 201:80(4), 491–502.

3. The Global Polio Eradication Initiative is a public-private partnership led by national governments with five partners: the World Health Organization (WHO), Rotary International, the U.S. Centers for Disease Control and Prevention (CDC), the United Nations Children's Fund (UNICEF) and the Bill & Melinda Gates Foundation. <http://polioeradication.org/>.

4. R. Kamadjeu. “Tracking the Poliovirus Down the Congo River: A Case Study on the Use of Google Earth™ in Public Health Planning and Mapping.” *Int J Health Geogr*, 2009;(8):4.

5. V.M. Gammino, A. Nuhu, P. Chenoweth, R. Young, D. Sugarman, S. Gerber, A. Abanida, and A. Gasasira. “Using Geographic Information Systems to Track Polio Vaccination Team Performance: Pilot Project Report.” *J Infect Dis*. Suppl 1:S98-101, 2014.

6. B.I. Inuwa, M. Zubairu, M.N. Mwanza, and V.Y. Seaman. “Improving Polio Vaccination Coverage in Nigeria Through the Use of Geographic Information System Technology.” *J Infect Dis*. Suppl 1:S102–S110, 2014.

7. E.M. Weber, V.Y. Seaman, R.N. Stewart, T.J. Bird, A.J. Tatem, J.J. McKee, B.L. Bhaduria, J.J. Moehl, and A.E. Reith. “Census Independent Population Mapping in Northern Nigeria.” *Remote Sensing of Environment*. In press.

8. Vaccination Tracking System online platform. <http://vts.eocng.org/>.

9. R.G. Vaz, P. Mkanda, R. Banda, W. Komkech, O.O. Ekundare-Famiyesin, R. Onyibe, S. Abidoye, P. Nsubuga, S. Maleghemi, B. Hannah-Murele, S.G. Tegegne. “The Role of the Polio Program Infrastructure in Response to Ebola Virus Disease Outbreak in Nigeria 2014.” *J Infect Dis*. Suppl 3:S140-6, 2016.

extraction and microcensus data.¹⁰

The creation of this extensive GIS infrastructure in Nigeria led to additional base-mapping efforts in the other Lake Chad Basin nations of Cameroon, Chad, and Niger, as well as the Democratic Republic of Congo, Mozambique, and Somalia. These activities revealed significant data gaps such as the identification of hundreds (Mozambique, Somalia) and sometimes thousands (Nigeria) of previously unrecorded place names and error rates in authoritative data that have been known to exceed 50 percent.

This work also spurred the formation of two informal, virtual stakeholder GIS working groups with representation from the U.S. government, UN, and private organizations and NGOs for East and West Africa. These working groups afford an important opportunity to exchange information on planned and completed regional activities and a professionally curated library through which geospatial data, tools, and analyses can be shared among partners. This activity has facilitated the exchange of base layer data among local humanitarian efforts with regional and supraregional organizations in remote environments in Cameroon, Mozambique, and Somalia.

2) Civil and military conflicts also pose an obvious barrier to humanitarian and disease control efforts. In the face of limited authoritative geospatial and census data, a number of multilateral, humanitarian, and academic groups have designed innovative, multisourced solutions to conduct needs assessments, deliver services, and monitor human rights violations in the region. For example, Boko Haram insurgents have occupied and destroyed villages throughout Northern Nigeria since 2008. Airstrikes and military raids have wrought further destruction, leaving humanitarian agencies reliant upon imagery and analysis from donors and commercial entities to maintain situational awareness in non-permissive areas.^{11,12} Even with myriad resources used to identify locations and estimate

populations, remotely sensed data have limitations and a network of reliable human informants is required to validate information gleaned in these high-threat areas. By fusing imagery analysis and fresh key-informant data, villages can potentially be described as sustaining complete structural damage or partially/fully intact—and potentially whether inhabited—informing how the flow of internally displaced populations and refugees is monitored within the region.

3) A combination of geospatial data, imagery, and activity-based analysis has also been used to investigate and respond to outbreaks of guinea worm disease in humans, dogs, and baboons. Individuals are infected through the consumption of water contaminated with the parasite's larvae. Breaking the transmission cycle requires the treatment of water sources to kill the larvae in the intermediate host, identification of other cases in the area, and preventive efforts through education and water filtration. Mounting a comprehensive response thus requires identification of all stagnant water features proximal to areas inhabited by infected humans, dogs, and baboons. In remote areas of Ethiopia, where the disease was detected in a baboon troop, authoritative geospatial data are sparse, and, while maps displaying water features may be available, seasonality plays a major role in water level, flows, etc. Thus, seasonally accurate, high-resolution imagery granular enough to reveal large game trails and walking paths used by baboons and humans to reach water sources was critical to formulate a response plan. Two-dimensional printed paper maps, rather than tablet- or computer-displayed imagery, also played a key role in communicating with local guides unfamiliar with digitally displayed data. In this case, the provision of technical assistance in addition to geospatial assets has not simply supported guinea worm eradication efforts in southwestern Ethiopia, it also increased GEOINT capacity where there was little and introduced new ways to approach a complex logistical problem.

Capacitating Access and Utilization

In addition to these examples, potential use cases with benefits that extend beyond the Global South are plentiful. For example, service delivery to refugee and internally displaced persons (IDPs) could benefit significantly from improved data fusion. While the United Nations High Commissioner for Refugees (UNHCR) and NGOs strive to maintain current maps of IDP and refugee camps, these data are not always geo-referenced and thus opportunities to integrate multiple data types may be missed. The creation of “neighborhood” level maps that enumerate households would facilitate linkage of specific populations with appropriate services and follow-up. In the absence of such granular data, it may be incumbent upon residents to seek social, health, and protection services, which may be difficult for the infirm, aged, unaccompanied children, or women without freedom of movement. Geo-referenced, neighborhood-level, multilayer IDP and refugee camp data could also be used to evaluate the equitable distribution of services and, in conjunction with human activity patterns, monitor security incidents within the camp, while simultaneously assisting with situational awareness throughout the host area. Finally, this type of data affords an extension of services for returnees and protection monitoring as people transition from the care of agencies, such as UNHCR and implementing partners, back to their areas/countries of origin.

The increasing role of GEOINT as a form of social, political, programmatic, and technical currency is a countervailing influence on multilateral efforts to build sustainable technical and human capacity. In the absence of an incentivized sharing culture, a unified effort by the global development community can be successful in breaking this data-sharing impasse. One such effort is the Geospatial Reference Information Database (GRID) project, which aims to create open-source geospatial reference layers in priority developing countries selected by donor-partners, along with building local capacity to use,

10. E.M. Weber, V.Y. Seaman, R.N. Stewart, T.J. Bird, A.J. Tatem, J.J. McKee, B.L. Bhaduria, J.J. Moehl, and A.E. Reith. “Census Independent Population Mapping in Northern Nigeria.” *Remote Sensing of Environment*. In press.

11. <https://www.hrw.org/news/2013/05/01/nigeria-massive-destruction-deaths-military-raid>

12. <https://www.hrw.org/news/2017/01/19/nigeria-satellite-imagery-shows-strikes-settlement>

manage, and sustain the datasets at the country level. Co-funded by the United Kingdom's Department for International Development, GRID will engage the United Nations Population Fund to support geo-referenced national censuses in all countries, which represent the "gold standard" in reference data. A key requirement of GRID is countries must be willing to expose their base reference data layers to include settlement names and locations, key points of interest, validated administrative boundaries, and GIS-modeled population estimates to a global, public platform. Such significant and freely available GIS infrastructure can directly improve digital democracy and potentially attract further investment, which could bolster the labor market for geographers, GIS specialists, and related expertise.

Additionally, several for-profit firms such as DigitalGlobe, Planet, Google, and Esri facilitate access to the imagery, data, tools, and expertise required for humanitarian and other activities consistent with their missions. In the non-profit sector, organizations such as Radiant Earth offer free access to open-source satellite, aerial, and drone imagery archives from across the globe, alongside the analytic tools that enable greater access for organizations with less technical and financial resources. Other opportunities to link sky and field lie in the integration of geospatial data with complementary computational capabilities such as AI and ML—as Palantir and the Carter Center have effectively demonstrated through the Syria Conflict Mapping Project.¹

Through these efforts, the playing field is slowly being leveled to create parity between those with the greatest capacity and those whose access is currently dependent upon educational institutions, donors, or fee-for-service expertise. Access to free imagery, geospatial data, and analytic capacity alone is a social good in that it moves forward academic research on modeling and methods for validation. However, significant unmet needs awaiting creative and synergistic solutions remain, so continued support for robust, open-source GEOINT tools and expertise is essential to provide effective and sustainable support to the Global South.

The Cross-Flow of Information Across Federal Communities for Disaster Response: Efficiently and Effectively Sharing Data

By Dan Opstal, NGA; Frank Toomer, NRO; and Hayden Howard, CompassData

The flow of geospatial information and services across organizational boundaries is ultimately the fulfillment of the social contract, or the expectations between the government and its people. In a humanitarian assistance/disaster response scenario, there is an expectation that an element of the government, whether federal, state, or local, will show up and provide some kind of situational awareness. This can range from hard copy maps to an application displaying the location of critical infrastructure.

Recently, we've learned a lot about the operations of the Federal Emergency Management Agency (FEMA), but the lead federal agency in disaster response situations varies depending on the specific statutes governing the response. The focus needed to satisfy federal, civil, and non-governmental needs involves the evolution of policies and tools. Policy issues include (but are not limited to)

federally controlled unclassified data dissemination guidance and awareness of the guidance available to invoke Defense Support of Civil Authorities (DSCA). Tools include both specific databases and aggregation services for situational awareness data such as the Pacific Disaster Center's EMOPS tool and many more.² These are tools that enable the sharing of aggregated geospatial data—a need the public demands of its government in disaster situations.

Aggregation is arguably one of the most important functions to fulfilling this social contract. There must be a place to have threaded, focused discussions at a controlled unclassified level over a mobile device complementing all of the other communication methods used. Understanding the data within government and how it is managed is one part of this complex puzzle. Yet U.S. society demands that these approaches be designed and

smartly executed as part of the services, or contract, paid for by taxpayer dollars.

The previous administration's Executive Order 13556, issued in 2010, established a Controlled Unclassified Information policy, but the implementation of this effort to corral the wide range of differing unclassified control systems (including "For Official Use Only" and "Law Enforcement Sensitive") requires the replacement of "hundreds of different agency policies and associated markings."³ This policy issue must be resolved as the geospatial community as a whole strives to understand the sharing paradigm in fulfilling the social contract. Commercial industry does a tremendous job supporting disasters, especially when one of the sponsor nations invokes the International Disaster Charter, a UN-derived agreement among 16 nations to share remote sensing information during major disasters, opening the spigot for

1. <http://fortune.com/2016/03/09/syria-big-data-analysis/>

2. Pacific Disaster Center Emergency Operations (EMOPS) website. <https://emops.pdc.org/emops/>. Accessed October 17, 2017.

3. General Services Administration Controlled Unclassified Imagery Policy.

<https://www.gsa.gov/about-us/organization/office-of-the-chief-information-officer/office-of-enterprise-planning-and-governance/enterprise-architecture-policy-planning/controlled-unclassified-information-cui>. Accessed October 17, 2017.

all manner of geospatial data to flow into data lakes such as the Hazard Distribution Data System to assist first responders.⁴ Yet, the cross-flow of data can always be improved through the use of tools in concert with an awareness of how different elements of government work, especially civil-military relations in a disaster context.

One way to understand how the federal-civil community works with the Department of Defense (DoD) is to review Joint Publication 3-28, Defense Support of Civil Authorities.⁵ Analyzing the multifaceted dynamics of policies, however, tells only one part of the story. The real key is some kind of focus on shared access among first responders and other users of geospatial data during a crisis—people who leverage and use these data outside the world of theory and in the chaotic environment that is the modern world. The crucial component is having data at the point of need, which includes hard copy of the type provided during the recent hurricanes by the National Geospatial-Intelligence Agency (NGA) and the U.S. Geological Survey (USGS) in concert with the Defense Logistics Agency.⁶

Point cloud-based visualizations complement powerful analysis provided by web-based analysis tools such as the National System for Geospatial-Intelligence Open Mapping Enclave during any kind of disaster response scenario or other geospatially referenced problem.⁷ Yet, despite the success, the challenge remains control. Not just control for security's sake, but also program control to understand usage and system metrics in an agile programming environment. Or, managing shareholder/user expectations and ensuring profit while providing a cyber-resilient community service in a fast-paced geospatial intelligence (GEOINT) economy that demands

success. Approaches to solve these problems must be tethered to a set of users ranging from novice to advanced, requiring uniform cataloguing of data and easy dissemination. This includes GIS-ready data lakes for the advanced user to manipulate complementing simple visualizations to provide key decision-makers with at-a-glance updates. Implementing rules that incorporate all data, categorized by confidence of quality (spatial and thematic) in a common language will allow decision-makers access to all data available and to take action accordingly.

At a minimum, a properly designed tool should incorporate source (state data, authoritative, ancillary, etc.), accuracy, projection/datum, classification/category, credential/permissions, and temporal. Yet the time to observe this information is also at a premium given the tyranny of the immediate need on mobile devices. Shared access, then, is more than simply providing geospatially-ready data and services. It is about understanding the consumer base and the psychology of the user at multiple points of need. It also means moving beyond the comfort of email into shared spaces to communicate.

Collaboration between the federal-civil, DoD community, and leaders of existing data aggregation programs/tools is imperative to the successful implementation of the suggested cross-flow of information. The existence of programs like the Federal Aviation Administration's (FAA) Airport GIS is an example of such a program, and much can be learned and duplicated/avoided as a result of this effort. Airport GIS offers funding to airports that are already required to submit electronic airport layout plans (eALPs), and who submit such plans in a way that is digestible to the geospatial repository. This results

in data that is already required to be captured, attributed, and delivered in a common format that can be stored in the FAA's database as well as be used by the airport operations themselves for enhanced functionality and increased operational efficiency. Social business software also sets the stage for the aggregation of data and services, but this can only be accomplished if the user base complements their dependence on email communications.

Email is a useful tool, and yet, it ruins so much productivity in wasted communication. Users benefit from migrating to "complementary" services that reduce this wasted time, such as Dropbox and Jive.⁸ Fortunately, the geospatial community has access to many tools that can help link various datasets. One example is the Structured Analytic Gateway for Expertise (SAGE), a Jive-based platform for social business communication.

A DoD Inspector General report from 2013 highlights a powerful capability to share data among various users within the academic community. The recommendation is to create varied methods of communication for a range of users as part of the National Centers of Academic Excellence program such as through the use of the SAGE environment.⁹ This is a powerful capability that enables controlled, unclassified, and mobile access to data sponsored by a DoD component. It complements and, in some cases, replaces the need for email, especially in the arena of the federal civil community's engagement with the Intelligence Community/DoD. The U.S. Geological Survey's Civil Applications Committee (CAC) facilitates this effort, creating a disaster hub to share data previously sent out only via a large email alias.¹⁰ This data provides a hub for complex information sets that previously

4. International Charter: Space and Natural Disasters. <https://disasterscharter.org>. Accessed October 5, 2017. Hazard Data Distribution System (HDDS). <https://hdds.usgs.gov/hazards-data-distribution-system-hdds>. Accessed November 15, 2017. The Charter is an international collaboration between the owners and operators of Earth observation missions to provide rapid access to satellite data to assist rescue authorities in the event of a natural or manmade disaster. The HDDS is an event-based interface that provides a single point-of-entry for access to remotely sensed imagery and other geospatial datasets as they become available during a response.

5. Joint Publication 3-28, Defense Support to Civil Authorities. U.S. Joint Chiefs of Staff, July 31, 2013. http://www.dtic.mil/doctrine/new_pubs/jp3_28.pdf. Accessed October 5, 2017.

6. DLA Aviation Public Affairs. "DLA Partners Provide Map Support for Hurricane Relief," October 25, 2017. <http://www.dla.mil/AboutDLA/News/NewsArticleView/Article/1352988/dla-partners-to-provide-map-support-for-hurricane-relief/>. Accessed December 7, 2017.

7. Will Mortenson. *National System for Geospatial-Intelligence Open Mapping Enclave*. https://s3.amazonaws.com/gpccb/wp-content/uploads/2017/01/10163403/GP_Mortenson.pdf. Accessed October 17, 2017.

8. Gerald Kane. "Are You Part of the Email Problem?" *MIT Sloan Management Review*, May 5, 2015. <http://sloanreview.mit.edu/article/are-you-part-of-the-email-problem/>. Accessed October 17, 2017.

9. Department of Defense. *Audit of the Centers of Academic Excellence Program's Use of Grant Funds. Inspector General Report*, October 22, 2013. <http://www.dtic.mil/dtic/tr/fulltext/u2/a588830.pdf>. Accessed October 17, 2017, p. 6.

10. Melanie Kaplan. "Inside the CAC." *United States Geospatial Intelligence Foundation Trajectory Magazine*, September 21, 2014. <http://trajectorymagazine.com/inside-the-cac/>. Accessed October 17, 2017, p. 1-3.

operated in the purview of large email aliases. Field data can also be leveraged by increasing deployment of software to the various app stores and through the use of shared software code facilitated by GitHub. One example of this is the Mobile Awareness GEOINT Environment (MAGE), recently used to support FEMA operations in Puerto Rico. This app was previously only available on the GEOINT App Store inside the DoD firewall but is now openly available for consumption by Apple or Android devices.¹

For example, these capabilities allow volcanologists dealing with an erupting volcano to quickly get data on their mobile devices, potentially bringing to bear the shared expertise of hundreds of imagery and other geospatial-services professionals. Similarly, a disaster manager working issues associated with Puerto Rican hospitals severely

damaged in the wake of Hurricane Maria can receive and share appropriate geospatial datasets from a multitude of communities. This approach does not solve access problems associated with data management protections, but it does expose data efficiently to allow for shared discussion of a problem set. Questions can be posed and answered quickly without resorting to emails that often unintentionally leave crucial individuals out of the loop. All of these initiatives complement overarching and unifying efforts across the geospatial civil and military communities, such as the GeoPlatform developed under the auspices of the Federal Geographic Data Committee.²

The cross-functional competencies within USGIF's GEOINT Essential Body of Knowledge (EBK) are "synthesis, reporting, and analysis." The description

of synthesis is to identify, locate, and obtain essential information efficiently and effectively.³ Social business tools such as SAGE and MAGE under the auspices of full-spectrum geospatial support committees such as the CAC and Federal Geographic Data Committee (FGDC) allow the union of controlled, unclassified, and mobile access, and are an ideal venue to enable this aspect of the EBK. Policies will change and morph, but proper communications enabling a free-flowing exchange of ideas among a wide group of users is a definite path to the fulfillment of the social contract. Many tools have limited costs as long as the purpose of the endeavor is to support a federal agency or department's statutory mission set, such as homeland security, disaster response, or even scientific and academic research. Continued funding is needed to provide the best possible support using taxpayer dollars.

Everything, Everywhere, All the Time—Now What?

By Edward Abrahams, Tesla Government, Inc.; Patrick T. Biltgen, Ph.D., Vencore; Peter Hanson, Concurrent Technologies Corporation; and Shannon C. Pankow, Federal Aviation Administration

A near-clairvoyant ability to develop knowledge on everything, everywhere, all the time is fictitiously portrayed in TV shows such as *24*, *Person of Interest*, *The Wire*, *Alias*, and *Homeland*. However, recent proliferation of new sensors, the integration of humans and machines, and the advent of big data analytics provide new opportunities to translate this portrayed drama and excitement of intelligence fiction into intelligence fact. The persistence and depth of data now readily available allows new products to be woven together out of three basic threads or classes of information: vector-based knowledge (everything), locational knowledge (everywhere), and temporal knowledge (all the time).

As we move to an era of ubiquitous, real-time information, economists, first responders, business intelligence analysts, scientific researchers, intelligence officers, and many other

analysts have the potential to answer questions previously unimagined. However, reaching this potential future vision will require the geospatial intelligence (GEOINT) Community to overcome several distinct challenges.

New GEOINT Sources for a New World

Where analysts previously relied on only a few sources, today's GEOINT professionals have a plethora of new, non-traditional sources from which to choose. Increasingly proliferated and persistent small satellites, drones, and other emerging commercial capabilities contribute greatly to the wealth of information by complementing traditional airborne and spaceborne GEOINT collection systems. At the same time, the convergence of sensing, communication, and computation on single platforms combined with the ubiquity of the internet

and mobile devices have further increased the variety of data available.⁴

Traditional and proven imagery capabilities based on large government and commercial aircraft and spacecraft have been augmented by increasingly capable small satellites that cost less to produce and are easier to launch. Small sats, picosats, and even smaller versions being created in the past decade have proliferated new remote sensing capabilities that increase revisit rates and cover larger portions of the electromagnetic spectrum. Closer to Earth, affordable commercial drones with high-resolution imaging, multi/hyper-spectral sensors, high-definition video, and other capabilities have revolutionized all aspects of data collection, from hobby photography to agriculture to archaeology. Small sats also contribute to the U.S. military mission by providing easier and faster

1. "Create, Share Geotagged, Media-rich Field Reports with New NGA App." *NGA Mediaroom*, July 5, 2016. <https://www.nga.mil/MediaRoom/PressReleases/Pages/NGA-mobile-app-allows-for-creating,-sharing-geotagged,-media-rich-field-reports.aspx>. Accessed December 7, 2017, p. 1-2.

2. <https://www.geoplatform.gov/>

3. United States Geospatial Intelligence Foundation. "Essential Body of GEOINT Knowledge." http://usgif.org/system/uploads/4828/original/USGIF_EBK_.pdf. Accessed October 17, 2017, p. 6.

4. National Research Council. *Future U.S. Workforce for Geospatial Intelligence*. Washington, DC: The National Academies Press; 2013. <https://doi.org/10.17226/18265>.

access to communication, positioning, navigation, timing, and weather data.⁵ As these sensors become more affordable, pervasive, and persistent, new users across industry, academia, and government will be able to leverage increasingly capable systems to improve access to all forms of GEOINT.

Crowdsourcing, or “participatory sensing,” is defined in the 2011 *Merriam-Webster’s Dictionary* as “the practice of obtaining needed services, ideas, or content by soliciting contributions from a large group of people and especially from the online community rather than from traditional employees or suppliers.” Crowdsourcing plays a major role in creating information-rich maps, collecting geo-localized human activity, and working collaboratively. This relative newcomer to the GEOINT tool kit has been utilized effectively in crisis mapping efforts such as DigitalGlobe’s Tomnod, a volunteer, public crowdsourcing community that gained popularity during the 2014 search for Malaysian Airlines Flight 370 and the aftermath of the 2015 Nepal Earthquake.⁶ In the commercial sector, companies like Findyr, Native, and Spatial Networks provide high-fidelity, street-level, near real-time contextual data from a worldwide, hyper-local audience of participatory geographers.

While intelligence revolutions often rely on the advent of new collection systems, a dominant driver for the future of GEOINT includes multisource data persistently generated and processed by intelligent machines. National Geospatial-Intelligence Agency (NGA) Director Robert Cardillo recently named artificial intelligence (AI) and machine learning (ML) technologies a top priority for U.S. GEOINT Community analysis: “If we attempted to manually exploit all of the imagery we’ll collect over the next 20 years, we’d need 8 million imagery analysts.”⁷ Cardillo also noted automation is needed to augment human analysts. The development of ML algorithms for

automated change detection to handle the increasing load of imagery data will free up human analysts to continue working on “higher-order thinking to answer broader questions,” said Scot Currie, director of NGA’s Source Mission Integration Office.⁸ Such algorithms also have the potential to discover unknown relationships invisible to cognitively biased humans, generate unconventional hypotheses, and anticipate potential outcomes based on continuously learned causal models.

Included in these techniques are automated feature-based image registration, automated change finding, automated change feature extraction and identification, intelligent change recognition, change accuracy assessment, and database updating and visualization. The GEOINT analyst of the near future will operate as a member of a blended human-machine team that leverages the best skills of each to answer more questions with more information over a wider range of issues on a shorter timeline.

Living and Working in a Persistent Knowledge Environment

Highlighting *The Economist’s* description of “data as the new oil”—a valuable commodity driving our economy, NGA Director of Capabilities Dr. Anthony Vinci has challenged industry partners to “turn it into plastic.”^{9,10} The tradecraft of a GEOINT analyst now lies in the ability to quickly synthesize this highly adaptable resource into intricate, creative, and useful products previously unforeseen or unimagined.

In a persistent information world, every object and entity on, above, or below the surface of the Earth may be represented as a vector of its attributes—i.e., all the metadata about that entity. This extends the analytic paradigm to a knowledge environment in which every property of every entity is always available in real

time. Analysts will be able to create comprehensive datasets about specific vectors of interest—be it individuals, groups of people, a particular building, or a particular type of infrastructure. To know “everything” in this sense means being able to perform a deep dive on any person, place, or thing and gain insight on how their attributes are distributed spatially. In addition, this new wave of data allows us to dispense with the old pick-and-choose mentality and perform this level of examination on all subjects at the same time. If this capability sounds far-fetched, the proliferation of sensor-enabled, internet-connected mobile devices—the so-called Internet of Things (IoT)—seems poised to introduce a paradigm in the not-too-distant future in which almost every entity on Earth beacons vectorized metadata into a ubiquitous data cloud.

In this world, it is also possible to create a complete dataset about any location on Earth. For a given place, we can gather data about topography, weather and climate, population density and demographics, local populations, recent conflicts, infrastructure, land cover, and 3D renders and imagery of buildings. Aggregating these data allows for a complete snapshot not only of any given area, but of the whole Earth at once. Imagine a spinning Google Earth globe with an infinite number of layers and an infinite level of detail at every altitude from the Mariana Trench to geostationary Earth orbit updated in real time. The challenge for the analyst holding such a globe is simply where to start.

As persistent data providers blanket the Earth and index data in accessible, online repositories, analysts build upon the immense place- and vector-oriented datasets over long periods of time. This exposes movements of population and demographic shifts, changes in weather and climate as well as land cover, destruction or construction of infrastructure, and the movement

5. M. Holmes. “Small Satellites Set for Prosperous MILSpace Future.” Via Satellite 2017 Show Daily. <http://interactive.satellitetoday.com/via/satellite-2017-show-daily-day-2/small-satellites-set-for-prosperous-milspace-future/>.

6. T. Bacastow T and K. Ellis. “Reflections on GEOINT 2017: From Manual to Automatic—Leveraging Crowdsourcing for Machine Learning Training.” <http://blog.digitalglobe.com/news/reflections-on-geoint-2017-from-manual-to-automatic-leveraging-crowdsourcing-for-machine-learning-training/>.

7. Robert Cardillo. Remarks at the 2017 USGIF GEOINT Symposium. June 2017, San Antonio, TX.

8. Matt Alderton. “NGA Eyes Analytic Assistance.” *Trajectory Magazine Online*. 2017, Issue 3. <http://trajectorymagazine.com/nga-eyes-analytic-assistance/>.

9. “The World’s Most Valuable Resource Is No Longer Oil, but Data,” *The Economist*. May 6, 2017.

10. Colin Clark. “NGA to Offer Data to Industry for Partnerships.” *Breaking Defense*. June 6, 2017. <https://breakingdefense.com/2017/06/nga-to-offer-data-to-industry-for-partnerships/>.

of conflict hot spots over time. By integrating all of these datasets, we can connect patterns between any number of variables across time. The concept of real time extends to *all time*.

With persistent knowledge across vector, location, and temporal domains, analysts can instantly exploit extremely high-resolution data about every concept of interest in every location, and refresh it on a daily basis, if not more frequently. However, the question remains, “So what?” It certainly seems interesting to have persistent data, but what can we do with them that we couldn’t do with simple big data? Are there questions we can answer now that we couldn’t before?

Answering New Questions

As anyone with a five-year-old child can attest, the most dreaded word in the English language is “why.” Children approach the world with relentless inquisitiveness, but “why” questions are taxing to answer. Early GEOINT collection and analysis capabilities constrained analysts to answering questions of what, where, and how many, but modern analytic advances open new avenues for who, how, and most importantly, why. The GEOINT environment of the future will reinvigorate the curious five-year-old in all of us.

The ability to rapidly ask questions and instantly receive answers from a near-infinite amalgamation of information gives analysts a Google-like ability to comprehend the world. New analysts will develop a deep understanding of geospatial and cultural issues in a fraction of the time required with infrequent, periodic collection and multiyear analytic efforts. Using app-based micro-tasking capabilities, an intelligence analyst in Virginia might interact in a video chat session with a protester in Cairo to understand why people are protesting and anticipate future areas of violence.

Analysts in the past operated in a sparse data environment where they waited to get data that in some cases was never collected or not processed in time. In an environment of instant, persistent data, it is likely that many knowable facts might be sensed by multiple phenomena that don’t always generate the same

interpretation. The pace of weighing, judging, integrating, and verifying information will increase dramatically. Decision-makers will require an unrelenting operational tempo and a near-superhuman expectation of omniscience. It now falls to analysts and analytics to make sense of everything in context.

Integrating cultural, social, and economic information within GEOINT analysis significantly enhances analyst understanding over object-focused analysis. Human geography, while not technically a new source, is being used in new ways to provide fresh insights. By applying the who, what, when, why, and how of a particular group to geographic locations, analysts can create maps to track the social networks of terrorist groups, documenting complex interactions and relationships. By mapping the evolution and movement of ideas, activities, technologies, and beliefs, analysts develop deep contextual maps that combine “where” and “how” to convey “why” events are occurring (e.g., the rise of the Islamic State).

By integrating information about a specific area, such as who is in charge, what language they use, who they worship, what they eat, etc., analysts can create information mash-ups on the web that help planners and decision-makers safely and effectively anticipate potential future violence, deliver humanitarian aid, or improve regional stability. Human terrain information, introduced at broad scale during the Iraq and Afghanistan conflicts, will increasingly become part of a standard foundational GEOINT layer included in all cartographic products.

Collaborative analytic teams will extend existing operating procedures based on text-based Jabber sessions to “always-on” telepresence where geographically dispersed analysts interact as though they are in the same room and time zone. Perhaps these teams will even break down collaboration barriers across organizations, time zones, cultures, languages, and experience levels. Multidisciplinary teams working in a persistent knowledge environment can change their mind-set and answer new questions, especially the elusive “why.”

Overcoming New Challenges

While the proliferation of sensors and big data seemingly on demand may lead us to believe omniscience is truly within reach, several distinct challenges currently impede our vision for the future. First, if the data exists, can everyone access it? Should they? Data’s democratization has made excessively large volumes of data available to anyone who can search and download from the internet. But, as the saying goes, you get what you pay for. Thousands of websites offer free investment advice, but can you beat the market when everyone has access to the same free data? For example, the much-touted *data.gov* repository boasts nearly 200,000 free public datasets, but data are not always well described or easy to navigate.

Even when freely available data points to a logical conclusion, skepticism should arise. We cannot always know the origin of openly available data, be sure it has not been altered, assume scientific correction factors have been applied appropriately to raw data, or confirm metadata has been tagged correctly. Additionally, we may not know the intent of the person who made the data available or the biases that may have been introduced. In short, data veracity can be questioned when one does not fully control the data supply chain. Constant verification and vetting of sources may take over a majority of the analytic time bought back by advanced automated algorithms.

Freely available data’s omnipresence can overwhelm any analytic workflow, even with powerful big data processing, thereby quickly becoming an analyst’s self-imposed analytic quagmire. Many analysts will brave the overwhelming to ferret out insight that hides within this deluge. Data can be conditioned and formats standardized for compatibility. But to what benefit if the combined dataset is impossible to search, filter, fuse, and explore in a realistic time frame?

As commercial market demand for remotely sensed data and knowledge products continues to evolve and expand and barriers to market entry become lower, new vendors continue to emerge. A critical question arises: Can

the government afford to pay for data and will commercial companies survive if they don't? In 2010, NGA awarded two 10-year contracts for commercial imagery to DigitalGlobe and GeoEye with a combined value of \$7.3 billion,¹ but two years later, funding shortfalls caused the companies to merge.²

Social media harvesting and sentiment mining is popular, but Twitter aggregator Sifter charges users a simple pricing model of \$50 per 100,000 tweets. (Twitter estimates there are about 200 billion tweets in a year.) The Intelligence Community's noble attempt to connect all the dots to ensure the U.S. does not experience a surprise terrorist or military attack underscores the desire to acquire and examine "all" available data. Whether government or commercial, it may be cost-prohibitive to purchase and examine all collected data to ensure competitive advantage—going infinitely and indefinitely global might carry a similarly infinite price tag. Overly narrowing the focus of collection might limit opportunities to stumble upon the singular "missing dot."

Additionally, licensing and usage rights that protect commercial business often inhibit redistribution of data to other individuals, departments, or agencies. The U.S. government's contract with DigitalGlobe limits imagery use to within federal agencies to "minimize the effects on commercial sales."³ NGA's 2017 \$14 million contract to San Francisco-based imagery start-up Planet tests a subscription-based model to "access imagery over 25 select regions of interest" for one year.⁴ Despite its widespread use as a source of human activity data, the Twitter Terms of Service prevent usage of data "for surveillance purposes" and "in a manner inconsistent with our users' reasonable expectations of privacy."⁵ Key issues of perpetual data ownership, lineage to source data and processing settings, privacy protections, and long-term archive requirements will challenge traditional concepts of data ownership.

Finally, the ubiquity of spatial data of all kinds raises new privacy concerns. Policies have been developed to govern how different "INTs" can be used, but when source data can be worked into

new products and discoveries, protection of citizens from continuous monitoring becomes increasingly difficult. A GEOINT savvy workforce must also include lawyers, psychologists, law enforcement personnel, and even politicians.

Succeeding in a Persistent World

The democratization of GEOINT and the expectation of omniscient, instant knowledge of every activity, event, and object on Earth puts new pressures on the GEOINT workforce. Similar pressure exists in commercial industry, such as in the financial sector, to ensure better knowledge than competitors about issues such as trade volumes, raw material supply, and transportation networks. In the business of intelligence, competitors are threats that evolve across changing geopolitical and economic environments. The stakes are more than financial—they are existential. As GEOINT becomes more persistent, pervasive, and accessible, it will also become increasingly able to answer new questions, develop new products, and enhance the GEOINT workforce with new tradecraft.

An Orchestra of Machine Intelligence

By Mark Sarojak, GeoNeo Inc.; Daniel Kepner, BAE Systems; Rex Tracy, Integrity Operations; Cordula A. Robinson, Ph.D., Northeastern University; Craig Gruber, Ph.D., Kostas Research Institute for Homeland Security; and Dan Feldman, Planet Insight

Imagine a near future in which complex intelligence questions such as "Where is Osama bin Laden?" could be posed as simple textual queries, with answers automatically generated in milliseconds rather than months. Analysts wouldn't spend countless hours searching for data to help answer their complex questions, nor would they spend many more hours waiting for large datasets to download and process on local computing resources. In this future, analysts would simply type a query, then an orchestra of machine intelligence (MI) systems would present a short list of high-probability answers with supporting information for

each response. Let's look into our crystal ball to see if we can catch a glimpse or two of what the future might hold for intelligence analysis. Before we do, here are some of the ground rules:

- We refer to the following group of technologies collectively as machine intelligence (MI): classical artificial intelligence (AI), machine learning (ML), deep learning (DL), multitask learning, reinforcement learning (RL), data mining (DM), decision analysis (DA), and large-scale stochastic dynamic optimization (metaheuristics).
- We believe MI is critical to answer

demanding intelligence questions quickly and effectively due to the volume, velocity, and variety of data involved, but in this article, we do not advocate for one technique over another for any particular purpose.

- Accurately answering complex questions often requires a broad spectrum of intelligence disciplines. Because of this, we are not constraining this discussion to geospatial intelligence (GEOINT) alone.

1. Peter De Selding. "EnhancedView Contract Awards Carefully Structured, NGA says," September 10, 2010. <http://spacenews.com/enhancedview-contract-awards-carefully-structured-nga-says/>.

2. Steven Overly. "GeoEye, DigitalGlobe Agree to \$900 Million Merger." *The Washington Post*. July 23, 2012. https://www.washingtonpost.com/business/capitalbusiness/geoeeye-digitalglobe-agree-to-900-million-merger/2012/07/23/gJQAgA2G5W_story.html.

3. National Geospatial-Intelligence Agency. "NextView License Information Paper." May 3, 2017. https://www.nga.mil/ProductsServices/NextView%20Public%20Release%20Documents/NextView_License_Information_Paper_20170503.pdf.

4. National Geospatial-Intelligence Agency. "NGA Purchases \$14 Million Subscription to Utilize Small Satellite Capabilities." Press Release. July 19, 2017. [https://www.nga.mil/MediaRoom/PressReleases/Pages/NGA-purchases-\\$14-million-subscription-to-utilize-small-satellite-capabilities.aspx](https://www.nga.mil/MediaRoom/PressReleases/Pages/NGA-purchases-$14-million-subscription-to-utilize-small-satellite-capabilities.aspx).

5. Twitter Developer Agreement and Policy. <https://developer.twitter.com/en/developer-terms/agreement-and-policy>. Accessed December 2017.

- A sample scenario will help illustrate how ML is applied to answer complex intelligence questions. As such, we will attempt to show how the analysis of finding a high-value target (HVT), like Osama bin Laden (OBL), is accelerated and enhanced through use of MI. Note: The scenario described herein is a hypothetical application of how an MI-enabled system could have been used in the search for OBL. The scenario we describe is not intended to be historically accurate and is used only to illustrate the use of MI in an intelligence scenario.

The Orchestral Ensemble

Analysts are ever engaged in answering intelligence questions: Who was that and where did they come from? Where are they now? What are they planning and when will they strike? Although seemingly simple questions, unearthing the answers is often challenging due to the mountains of raw data involved and the extensive skills and experience required. The Intelligence Community (IC) has come to know this broad spectrum of domain-specific data and skills by many names, such as geospatial intelligence (GEOINT), signals intelligence (SIGINT), human intelligence (HUMINT), measurement and signatures intelligence (MASINT), and open-source intelligence (OSINT), among others.

Earlier, we introduced the concept of “an orchestra of MI systems” that could aid in answering these challenging questions. In a broad sense, we are talking about a system of humans and instruments working together to make beautiful music—especially if saving lives and ensuring national security is music to your ears. MI encompasses a broad set of computer science techniques dedicated to developing systems that can perform complex skills that generally require human intelligence, including advanced visual perception tasks like automated target recognition (ATR), natural language comprehension, and other complex decision-making processes. Given the vast quantities of intelligence data that have outpaced the growth of human resources, the community needs intelligent computer systems that analysts can use to automate functions they cannot or should not perform manually—tasks such as searching for, downloading,

selecting, deleting, moving, processing, re-processing, and sharing data. When analysts are free from inefficient tasks, they can focus their time doing what they are best at—activities that require human creativity and critical thinking, such as asking insightful sequences of questions, collaborating with other analysts, and evaluating which potential answers are most plausible to the human decision-makers. This is the true value of highly trained analysts.

The Path Forward

How does the GEOINT Community get there from here? We can best illustrate our vision by examining a sample intelligence scenario. We envision the user of this system would compose a question in plain language by asking something like, “Where is Osama bin Laden?” Asking this question would initiate an intricate series of activities to decompose the query, identify the applicable data sources, perform complex data analysis via disparate MI-enabled subsystems, fuse data and query results, and ultimately generate a series of highest probability responses for the analyst to consider. In our envisioned orchestra, MI is important as both composer and conductor, and our system can be conceptualized as these two main parts:

Query Composer: The first role of the query composer is to determine what the analyst is asking. The MI system uses natural language processing (NLP) to disambiguate and identify the specific interests of the analyst’s query as the name of the HVT as “Osama bin Laden” (referenced to a unique entity identifier), and the most probable current location. The query composer is additionally responsible for identifying which data sources are applicable to answering the analyst’s question. Data suitability assessments are required to identify which data sources provide relevant information with respect to the questions asked, as well as an assessment of each source’s accuracy and reliability. For our example, the query composer determines various intelligence sources are likely to contribute to answering this question, including all-source reports, field reports (HUMINT), cell-phone logs and voice recordings (SIGINT), satellite imagery and

video (GEOINT), and information found on open-source sites such as real estate records and social media (OSINT).

Query Conductor: When the analyst’s question is clearly understood and relevant data sources are identified, the query conductor begins orchestrating federated queries across domain-specific information subsystems, such as GEOINT libraries and SIGINT databases, and fusing results from MI-enabled analysis engines.

For our scenario, the query conductor initially prioritizes all-source analysis reports generated by leading analysts. Discovered reports indicate several experts believe OBL is hiding in either Pakistan or Afghanistan. The query conductor uses these initial findings to query SIGINT databases to analyze cell-phone data recorded from those countries, looking for voice recognition patterns of OBL or his known lieutenants. While no direct matches are found for OBL’s voice signature, cell-phone activity of his known associates is used to create a pattern of repeating locations and times, known as a “pattern of life.”

Using these patterns, the query conductor initiates anomaly detection algorithms and quickly detects an unusual call originating from a public pay phone booth to the cell phone of one of OBL’s lieutenants. Using the call time and phone booth location, the query conductor cross-correlates this information with GEOINT databases to identify potentially relevant datasets and queue them for automated processing. Facial detection/recognition algorithms automatically identify video footage from an unsecured web camera nearby containing the face of a person in the phone booth at the time of the call. However, due to low video resolution, the algorithms are unable to pinpoint the specific identity of the unknown caller. Simultaneously, a wide-area motion imagery (WAMI) collection acquired during the time of the phone call is found to also contain the phone booth’s geographic coordinates. Motion tracking algorithms are applied to the WAMI data.

The caller’s movements both before and after the call are revealed, showing numerous stops throughout the day. The

query conductor cross-correlates the stops to geographic information system (GIS) foundational databases, and one of the locations is identified as a residential compound of unknown ownership. Initiating a scan of available OSINT real estate websites reveals a senior military officer owns the property. Additional OSINT scans of social media posts by this military officer reveals fervent support for OBL's activities and his ideology. Pattern analysis identifies the officer's high-velocity series of social media posts suddenly ceases on the same date as the last known public appearance by OBL.

The query conductor then initiates GEOINT analysis techniques to analyze the residential compound over a series of high-resolution satellite imagery, and automated analysis techniques identify unusual movement behaviors within the property. At this point, sufficient evidence has been collected to generate a high confidence score, and the query conductor presents the findings and supporting materials to the analyst for review. Upon confirmation by the analyst, the query conductor flags the compound's address as a possible location of OBL in relevant interagency databases and includes it for tasking of future multisource surveillance activities.

This scenario presents a single thread that MI algorithms might follow. However, we believe the system would best serve the analyst if several possible results, along with confidence scores and links to the supporting data, were provided in a format such as the following:

#	Possible Answer	Confidence
1	XXXX	90
2	XXXX	82
3	XXXX	76
4	XXXX	40

The confidence scores are generated using weighted analysis across all contributing information sources and would vary depending on the pedigree and provenance of the source information and timeline data. Analysts would interact with each answer and confidence score to display the supporting data. This enables analysts to visually traverse the logic associated

with the recommendation, and to either "agree" or "disagree" with the individual assessments. Based on this feedback from the analyst, the MI algorithms would automatically update to re-assess the weight of the recommendations, thereby learning from the analyst's assessment of the supporting data. This information can be used to drive future data collection priorities and methodologies in preparation for the same or a similar question being posed in the future.

Additional Assertions:

- A flexible framework is needed in which new domain-specific algorithms can be plugged in, trained, and validated easily and effectively. Data from many information sources would require automated data conditioning and source preparation to assist in conflating, normalizing, providing metadata to, and contextualizing the collected intelligence. These conditioning services must exist as flexible and discrete services to allow processing workflows that drive conditioning and preparation of content.
- Analytic tradecraft is associated with the interpretation of errors, including their nature, magnitude, direction, and associated consequences. Therefore, MI calculations must articulate their accuracy in a manner that is easily understandable by the analyst. As MI algorithms improve, the accuracy of the responses to posed questions should trend upward. Measures of effectiveness and performance will be established and followed for various algorithms. For example, a 40 percent accuracy threshold may be sufficient for recommending the likelihood that an entity is at a specific location, but is not suitable for situations involving kinetic effects.
- Validating MI algorithms requires cross-industry approaches that facilitate the credibility of the algorithm. Datasets should minimize bias of model performance estimates and provide a mechanism for evaluating various model-tuning parameters. Model validations should occur upon the preparation of the model. Analyst feedback is important to improve the confidence in the algorithms.

- Many analyst questions will revolve around scenarios with little training data available or lower confidence predictions. For these scenarios, we believe the techniques described remain valid. Less mature data and training will require additional human expert involvement to better train the MI systems.
- It is imperative the knowledge and expertise of senior analysts is retained before they transition out of the analytic workforce. To facilitate this, MI techniques should be employed to watch and learn as expert analysts perform their tradecraft. This will capture expert tradecraft within the MI knowledge base without placing an additional training burden upon the analysts.

Conclusion

This article describes a future GEOINT system that employs MI technologies to supplement and support human analysis. Though creation of a fully functional MI system would require significant advances in technology, governance, and policy, the result would be highly valuable—a revolutionary advancement in intelligence analysis. Allowing analysts to do what they do best (thinking critically and creatively) is crucial to maintaining national security, and freeing analysts from rote and repetitive tasks would enable them to reach key decisions faster. Additionally, incorporating learning into the system will improve where, when, and how intelligence data is collected.

The Human Factors “Why” of Geospatial Intelligence

By Laura D. Strater and Susan P. Coster, Raytheon; Dennis Bellafiore, Stephen. P. Handwerk, Gregory Thomas, and Todd S. Bacastow, Pennsylvania State University; and Daniel Steiner, Orion Mapping

This article addresses the underlying human factors (HF) of geospatial intelligence (GEOINT) by examining the “why” of GEOINT using the Data/Frame Model of Sensemaking.^{1,2} The article is based upon recent HF research we conducted about the fundamental human factors of GEOINT (Hoffman, In Press).

HF engineering studies interactions between humans and technology to improve overall human-system performance. Formally, the International Ergonomics Association defines human factors as “... the scientific discipline concerned with the understanding of interactions among humans and other elements of a system ... in order to optimize human well-being and overall system performance.”³ The definition we use applies the concept of human factors beyond the design of systems to the study and design of ways to improve “cognitive work.” To do this, we examine the cognitive basis of GEOINT by considering why the analyst completes tasks.

GEOINT Automation

As we are coming to appreciate, the GEOINT Community is overwhelmed with data.⁴ The thousands of new small satellites projected in the next few years and the Internet of Things (IoT) are but a few reasons for the data avalanche. This creates a particular problem for the analyst. The collection of geospatial information is the most easily and often automated component of the intelligence cycle. Thus, while the data glut is problematic for intelligence and any big data analytics, some of the most extreme problems exist in the GEOINT arena. The prospect is the data glut will grow and increase analyst uncertainty since systems are now collecting megabytes of data for each human on the earth each minute of the day.⁵

GEOINT’s Cognitive Work

Our research investigates the challenges of GEOINT analysis through the lens of human cognition, focusing on how operators think rather than what specific tasks they perform. By looking at operator goals within the context of a human sensemaking model, we decompose the analytic problem space in a way consistent with human cognition, an important consideration for improving instructional methods, analytic tools, and gaining an advantage in analytic decision-making. This can form the basis for understanding how tools and automation can better integrate with the analyst. In considering how automation can support or extend the GEOINT analyst’s goals, we can create tools that work more effectively with their human counterparts, building a more effective human-systems team.

The human is ultimately where knowledge work is done and insights are produced in intelligence analysis, thus geospatial intelligence is dependent on the geospatial analyst’s know-how. Though often confused for a workflow, the analyst’s cognitive actions are not a sequence of steps through which work passes; however, cognitive activities may be associated with parts of a workflow. The cognitive actions of analysts can generally be classified as “sensemaking,” a concerted cognitive effort to understand the relationships among disparate objects and events to place them within a context or frame that has explanatory power.

Geospatial analysis, sensemaking with geography, begins with the conceptualization of space-time to frame the problem. The nature of the frame is critical because it ultimately determines the interpretation of the analyst’s observations—how they make sense of the geospatial relationships. These are generally considered within the three geographic frames: physical spaces, behavioral spaces, and cognitive spaces.⁶ The frame provides the interpretive context that gives meaning to the geospatial data. The three geospatial frames are described as follows:

- **Physical space** is built on the four-dimensional world of space-time, but focuses on the physical.
- **Behavioral space** is the four-dimensional space-time that focuses on the spatial relations and interactions between individual actors and objects in the physical environment.
- **Cognitive space** focuses on concepts and objects that are not themselves necessarily spatial, but the nature of the space is defined by the particular problem. In the geospatial sciences, this is called the “mental map” that exists in the analyst’s mind.⁷

The sensemaking process teaches us that machines automate processes that increase the efficiency in the human performance of sensemaking using the three geospatial frames, and, that at its most basic core component, the data, systems, and humans work in concert. As such, this requires an understanding of the synergy between the human cognitive thought processes involved and the technical systems used.

1. Gary Klein, Brian Moon, and Robert R. Hoffman. “Making Sense of Sensemaking 1: Alternative Perspectives.” *IEEE Intelligent Systems*, 21(4), July/August 2006, 70-73. doi:10.1109/MIS.2006.75.
2. Winston Sieck, Gary Klein, Deborah Peluso, Jennifer Smith, Danyele Harris-Thompson, and Paul Gade. “FOCUS: A Model of Sensemaking.” *US Air Force Technical Report 1200*, 2007. <http://www.dtic.mil/get-tr-doc/pdf?AD=ADA469770>.
3. International Ergonomics Association. “Definition and Domains of Ergonomics,” July 12, 2017. <http://www.iea.cc/whats/index.html>.
4. Alex Young. “Too Much Information: Ineffective Intelligence Collection.” *Harvard International Review*, 35(1), 2013, 24-27. <http://hir.harvard.edu/article/?a=10382>.
5. EMC. “Executive Summary: Data Growth, Business Opportunities, and the IT Imperatives.” *Digital Universe with Research & Analysis by IDC*, April 2014. <https://www.emc.com/leadership/digital-universe/2014iview/executive-summary.htm>. Accessed April 9, 2017.
6. National Research Council. *Learning to Think Spatially*. Washington, D.C.: National Academies Press; 2006. <https://doi.org/10.17226/11019>.
7. Peter Gould and Rodney White. *Mental Maps*. New York: Rutledge; 1993.

Sensemaking

Cognitive research on intelligence analysis has highlighted that analysts engage in an iterative sensemaking process that involves considering the data available from different viewpoints and perspectives.^{8,9} Sensemaking is a human cognitive function that has been studied and is not to be confused with specific structured analytic techniques. Sensemaking has been defined as "... a motivated, continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively."¹⁰ Moreover, Gary Klein, et al.,¹¹ posit a generic Data/Frame Theory of Sensemaking, which suggests analysts collect sufficient data to establish an initial frame (or mental map) for making sense of the data. The data used to create the frame are "the interpreted signals of events" and frames are "the explanatory structures that account for data."¹² This frame can be considered an organizing entity—a specific instance of a mental model of the elements and relationships under analysis.

We conducted a cognitive task analysis using an abbreviated, goal-directed task analysis methodology. The output of the cognitive task analysis is a goal hierarchy describing the analyst's goals and subgoals as he or she seeks to understand the situation, which creates a framework for understanding the cognitive work of the geospatial analyst. GEOINT analysts may work with any branch of the department of defense, intelligence community, or law enforcement, for example. Though the problems they analyze may vary across domains, at some level of abstraction, the goals and decisions, and, of course, the analytic methods are common. We chose to focus on the commonalities across domains rather than the differences.

The "Why" of GEOINT

Research conducted during the summer/fall 2017 for the preparation of a book chapter¹³ on human factors indicated the overall goal for a GEOINT analyst is to *use geospatial analysis methods to "find truth" in response to requests for information*. The goal of finding truth is not always achievable, particularly in any area of intelligence analysis, where there is often an opponent seeking to hide that truth from view.¹⁴ Finding truth is still the high-level goal, despite the difficulty in attainment. At its core, finding truth is the goal of all sensemaking, though the professional domain operational reality may be that getting close enough to truth to defeat the opponent is sufficient. Sensemaking is the cognitive process of iteratively fitting data to a frame, and fitting a frame to the data.^{15,16,17,18} The data-frame model of sensemaking provides a working description of how the geospatial analyst performs at the most rudimentary level. The model describes how people construct and revise internal mental structures when they make sense of events, and the goal of this sensemaking process is to find truth by selecting the right frame to interpret the data.

The primary subgoal identified during the 2017 research project cited above was to *complete intelligence tasking in accordance with schedule and priority*. This involves finding the answer to a GEOINT question, and the analyst will incorporate the necessary constraints for schedule and priority within their tasking requirements. This indicates that while the goal is to complete all tasking on schedule, higher priority tasks may bump lower priority tasks. Again, sensemaking is always done for a purpose, and this goal reflects the reality that GEOINT professionals are often tasked with

multiple requests, and balancing schedule and priority across multiple competing demands requires effort. To achieve this higher-level goal, the analyst also has three subgoals to consider: *evaluate geospatial collection requirements; evaluate the best sources for needed GEOINT data; and analyze how and why locations of objects of interest change over time*. The analyst determines the requirements of the collection tasking and the best opportunities and options for collecting the data, and will begin the process of geospatial analysis by investigating the geospatial relationships among the objects of interest and looking at activity over time.

Next, analysts strive to *identify information needed to respond to requests for GEOINT information*. This is analogous to the "representing the situation" facet of sensemaking, the first facet in which the sensemaker tries to pull relevant data from the stream of information, while discarding data deemed not applicable to the current problem. The related subgoals are: *identify relevant available GEOINT data; evaluate available GEOINT data for quality, timeliness, and applicability; identify gaps in current data; and request information to fill gaps in the data*. To achieve these goals and effectively represent the situation, the analyst will determine what information is available, analyze the quality of that data, identify critical gaps in information needed to meet the tasking, and then determine how to fill those data gaps.

Our research result goal hierarchy next shows that analysts have a subgoal to *analyze the available data using GEOINT methodologies*. This includes considering and presenting the geospatial and temporal data relationships then trying to extract meaning from these relationships.

8. Susan G. Hutchins, Peter Pirolli, and Stuart Card. *A New Perspective on Use of the Critical Decision Method with Intelligence Analysts*. Monterey, CA: Naval Postgraduate School; 2004.

9. Gary Klein, Brian Moon, and Robert R. Hoffman. "Making Sense of Sensemaking 2: A Macrocognitive Model." *IEEE Intelligent Systems*, 21(5), September/October 2006, 88-92.

10. Gary Klein, Brian Moon, and Robert R. Hoffman. "Making Sense of Sensemaking 1: Alternative Perspectives." *IEEE Intelligent Systems*, 21(4), July/August 2006, 71-71.

11. Ibid.

12. Gary Klein, Jennifer K. Phillips, Erica L. Rall, and Deborah A. Peluso. "A Data-Frame Theory of Sensemaking." *Expertise Out of Context: Proceedings of the Sixth International Conference on Naturalistic Decision Making*, 2007, 120.

13. Raechel White, Arzu Coltekin, and Robert Hoffman. "The Human Factors of Geospatial Intelligence." *Human Factors of Remote Sensing Imagery*. Boca Raton, FL: CRC Press, In Press.

14. What is truth in intelligence? We believe Anamaria Popescu said it best in her blog (<https://www.linkedin.com/pulse/philosophy-intelligence-what-truth-anamaria-popescu/>). "The truth is an ideal representation concept of basic reality. It will never be completed, is infinite in perspectives, and relevant not for the past, not for the present, but for... the future. It is an illusion of certainty. It is dynamical knowledge, that may be assembled in models, patterns, and algorithms for intelligence purposes (promotion, operation, prediction)."

15. Gary Klein, Brian Moon, and Robert R. Hoffman, "Making Sense of Sensemaking 1: Alternative perspectives." *IEEE Intelligent Systems*, 21(4), July/August 2006.

16. Gary Klein, Jennifer K. Phillips, Erica L. Rall, and Deborah A. Peluso. "A Data-Frame Theory of Sensemaking." *Expertise Out of Context: Proceedings of the Sixth International Conference on Naturalistic Decision Making*, 2007.

17. Gary Klein, Brian Moon, and Robert R. Hoffman. "Making Sense of Sensemaking 2: A Macrocognitive Model." *IEEE Intelligent Systems*, 21(5), September/October 2006, 88-92.

18. Gary Klein, Jennifer K. Phillips, Erica L. Rall, and Deborah A. Peluso. "A Data-Frame Theory of Sensemaking." *Expertise Out of Context: Proceedings of the Sixth International Conference on Naturalistic Decision Making*, 2007.

In the sensemaking model, this is when the analyst examines the relationships in the data to find an initial frame that fits the relationships then continues iterations via elaborating and questioning the frame. Data that has been discarded may be considered again, as the analyst questions the frame to determine whether another frame can better explain the geospatial relationships among the data. As a subgoal, the analyst will *define and visualize data relationships*, including analyzing the spatial, temporal, and multidimensional aspects of the data. This analysis of relationships assists the analyst in understanding the data to select a frame.

Through a process of pattern matching to domain knowledge familiar frames, the analyst selects a frame, then questions whether the frame really fits the current data. This may involve seeking additional information, or seeking to better understand how the elements are related, as the analyst elaborates the frame and documents the current frame to preserve it. The analyst has a goal to *build and test hypotheses to identify “truth.”* During the process of elaborating and questioning the frame (testing), the analyst will apply a variety of domain knowledge obtained models (which are often maps), theorems, and axioms to search for patterns and meaning (frames) in the data. In particular, GEOINT analysts seek to gain a visual sense of the data. The analyst strives for reliability and precision in the data as even small variances can affect the perceived relationships among data points. In sensemaking, this corresponds to questioning the frame and reframing when a different frame better explains the relationships among the data. In addition, the skilled analyst considers other possible frames using a method such as the analysis of competing hypotheses (ACH), in which he or she attempts to either validate or nullify the current frame. Depending on the outcome, the analyst may select another frame (reframing) that better explains the geospatial relationships and activity that has been identified.

To complete the intelligence tasking, the analyst must *synthesize and disseminate information into comprehensive, organized, prioritized intelligence products*. This requires that the analyst is satisfied, for the moment, with the selected sensemaking frame, and is willing to present the final data within a frame that offers explanatory value as an analytic work product. The information is integrated within the final frame, and storytelling is used to create a product that explains the data in a way that targets the needs of the report’s consumers. The work product will include an assessment of the quality and error precision of the data and the related analysis, and will be shared in accordance with their domain-specific quality guidance. It is important to note GEOINT analysts often develop expertise in a specific geographic area, and the delivery of a report is never the end of the analysis. In fact, if additional information is uncovered that causes a shift in the frame, or adds additional explanatory value to the existing frame, the analyst will revise the report to capture the additional data.

In addition, the analyst has a goal to *collaborate with others in a team environment*. Collaboration is increasingly common within the GEOINT Community, with multiple analysts working together to provide an integrated product that is more complete than any one expert analyst can provide and spans multiple analytic specialties. Collaboration in intelligence extends beyond human to human. As discussed earlier, technology is prevalent within GEOINT, and the GEOINT analyst uses a number of tools to better perform the analysis tasks. Many of these are of benefit, and have extended geospatial analyst capabilities tremendously such as with machine-aided object recognition within imagery. However, as tools become more automated, the challenge is to maintain the analyst’s ability to determine the accuracy and reliability of the data provided. As systems become more autonomous, they become more independent entities that can contribute more directly to team analysis and success—but they can also contribute to breakdowns in communication and may lead to longer decision cycles, rather than shorter.

Conclusion

This article identified the challenges of geospatial intelligence analysis through the lens of human cognition, focusing on how operators think, rather than the computer tasks performed. By looking at the operator’s cognitive actions, we can improve instructional methods, analytic tools, and gain an advantage in analytic decision-making. Perhaps most importantly, this helps develop automated tools that can better integrate with the analyst. In considering how automation can support or extend the GEOINT analyst’s goals, we open the door to machines working more effectively with their human counterparts and building a more effective human-systems team.

The human “why” of GEOINT is to compare observed patterns of details to better understand them. Our research identified HF concepts and methods of GEOINT analysis with the potential to significantly improve the overall “why” of the human-systems team. Something makes sense because the analyst has seen a similar pattern, and the similarities between the two patterns help the analyst make non-obvious inferences and draw conclusions. GEOINT analysis can be said to be the process of fitting geospatial data into a frame, and fitting a frame around the geospatial data. GEOINT insights are developed within a system of humans and machines, in which machines play a role in selecting and preparing information for the analyst’s consumption. The geospatial analyst’s frames are mental maps that account for the data. We suggest a community discussion that adds human and machine refinements and domain knowledge to an analyst’s framing and testing skill set to increase analysts’ ability to explain “why.”

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