2019

STATE AND FUTURE OF GEOINT REPORT

USGIF United States Geospatial Intelligence Foundation

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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.

2019 State and Future of GEOINT Report

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INTRODUCTION

The United States Geospatial Intelligence Foundation (USGIF) provides leadership to the geospatial intelligence (GEOINT) Community via the three pillars that define the Foundation's mission: Build the Community | Advance the Tradecraft | Accelerate Innovation. As an educational Foundation, we are passionate about advancing tradecraft within our ever-expanding community as people and innovative technology align to advance mission capabilities.

USGIF's annual State and Future of GEOINT Report is one of the Foundation's capstone projects. It is widely digested, downloaded, and discussed, generating an improved understanding of this ever-evolving profession. The report helps define and drive thought leadership to renew and extend the GEOINT discipline. Each year, through the lens of people, process, technology, and data, the report offers insights about the state and potential of our community and its tradecraft. Please thank the many leaders and subject matter experts who contributed their time and talent to achieve the quality represented in this report.

Through USGIF Working Groups, the Foundation creates yet another forum to harness the potential of rapid technological advances while helping the community quickly discern the applications, understand the potential unintended consequences, and address any contracting, legal, or ethical issues. USGIF Vice President of Programs Ronda Schrenk engages our working groups to help drive their products and events to have relevant, timely, and meaningful advances. These efforts are but small steps in our journey to serve as a convening authority and together define the future.

Our recipe for this report is straightforward: member volunteers, facilitated by USGIF staff, form teams and brainstorm to best define the GEOINT future across the fields of practice and innovation. This year's report demonstrates the power of collaboration across academia, industry, and government to make informed statements about the possible. Our volunteer Editorial Review Board importantly challenges the authors to strengthen their arguments and better support their convictions.

The 2019 report marks the fifth document in this series. Each provides a timestamped cornerstone of tradecraft understanding. The GEOINT tradecraft and associated skills are increasingly central to the connected and interoperable world—finding nuanced substance about entities across location and time. USGIF's shared mission and mandate is clear. Through our K-12, undergraduate, graduate, and young professional offerings we witness both the excitement and the new ideas joining the conversation—whether it be junior GEOINTers taking advantage of all our annual Symposium has to offer, impressive and robust scholarship applications, or children advancing their STEM skills on USGIF's giant portable map.

On behalf of USGIF members, academic affiliates, staff, and the Board of Directors, we will continue collaborating on important efforts such as these to deliver on our shared educational mandate by leveraging our community's collective skill and wisdom.

The Honorable Jeffrey K. Harris
Chairman, USGIF Board of Directors

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The Geo-Atom for GEOINT: A Network Science Application

By Micah L Brachman, Ph.D., University of Maryland; Zachary Mostowsky, NT Concepts; and Ian Jonesi, BlackSky Corporation

Delivering timely and accurate geospatial intelligence (GEOINT) requires collecting data from multiple sources ranging from satellite imagery to ground reports. This geospatial data is often collected, processed, and shared using different data models, leading to many persistent challenges within the GEOINT Community such as ensuring systems interoperability, performing data fusion, and delivering a common operating picture (COP) to end users. The geo-atom is a geospatial data model that defines an association between a location in space-time and a property.[1] This simple model incorporates both discrete object (i.e., vector) and continuous field (i.e., raster) data, and can be extended to represent nearly any feature or phenomenon on the Earth's surface.[2] In this article, an emergency evacuation scenario is used to demonstrate how adoption of the geo-atom data model could help address challenges related to collecting, processing, and disseminating GEOINT.

The emergency scenario developed for this article is based on an evacuation of the Houston, Texas, metropolitan area due to a hurricane. While this particular scenario is hypothetical, there is significant historical precedent given the devastation and loss of life previously wrought upon this area by Hurricane Harvey (2017), Hurricane Ike (2008), and Hurricane Rita (2005). The basis for this scenario is a map of hurricane evacuation routes and evacuation zones developed by the Harris County Office of Homeland Security and Emergency Management.[3] The data from this map is fused with other geospatial datasets to create a network science model that can predict areas of traffic congestion, and the geo-atom is used to develop the model and deliver a COP to emergency management decision-makers.

Background

The geo-atom has previously been applied to many geospatial problems relevant to the GEOINT Community. For example, the geo-atom has been used to improve the exploitation of remotely sensed imagery by building image-objects that resemble real-world objects rather than using raw pixels as the basis for classification.[4] Another interesting application of the geo-atom is using it to create standardized cartographic products.[5] Work has been conducted to integrate the geo-atom data model into a four-dimensional model that simulates particle dispersion,[6] but to date, there are no known research efforts to integrate the geo-atom with a network science model.

Network science is the study of network representations of physical, biological, and social phenomena leading to predictive models of these phenomena.[7] In USGIF's *2018 State and Future of GEOINT Report*, Collins et al. state that "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."[8] The goal of the following research is to demonstrate how integrating the geo-atom with a network science model can enhance the ability of decision-makers to make timely decisions related to the planning and/or execution of an emergency evacuation.

The basic design of the research presented is as follows: First, geospatial data from several sources is used to develop a network science model. Next, this model is applied to a section of the road network in the Houston area, and the model results are used to predict areas of traffic congestion during a hypothetical hurricane evacuation. The geo-atom is then used to add new input variables to the network flow model, and new model results are produced that show how factors such as flooding and large debris might affect traffic flow. Finally, the model results are disseminated as geo-atom data and are displayed on several software platforms to demonstrate interoperability. This network science application shows how adoption of the geo-atom can improve the decision support capabilities provided by GEOINT models.

Data

The most important data used in this research is a map of hurricane evacuation routes and evacuation zones developed by the Harris County Office of Homeland Security and Emergency Management. This map is shown as Figure 1.

Several GIS datasets were used as well: a polygon shapefile of ZIP Codes and a polyline shapefile of evacuation routes. An additional dataset of hypothetical real-time flooding data was developed and stored as geo-atom data.

Methods

The most common way to create a network science model is by using nodes to represent a set of discrete objects and arcs to illustrate the connections among these objects. For the emergency evacuation model for Harris County, the arcs represent the roads shown in Figure 1 and nodes

1. Michael F. Goodchild. "Geographical Data Modeling." *Computers & Geosciences*, 1992:18(4):401-408.
2. Michael F. Goodchild, May Yuan, and Thomas J. Cova. "Towards a General Theory of Geographic Representation in GIS." *International Journal of Geographical Information Science*, 2007:21(3):239-60.
3. Harris County Hurricane Evacuation Map, Harris County Office of Homeland Security and Emergency Management. http://prepare.readyharris.org/Evacuation-Map. Accessed May 12, 2018.
4. Ivan Lizarazo and Paul Elsner. "From Pixels to Grixels: A Unified Functional Model for Geographic-Object-Based Image Analysis." *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 2008:38(4/C1).
5. Robert G. Cromley, Shuowei Zhang, and Natalia Vorotyntseva. "A Concentration-Based Approach to Data Classification for Choropleth Mapping." *International Journal of Geographical Information Science*, 2015:29(10):1845-63.
6. Anthony Jjumba and Suzana Dragicevic. "Integrating GIS-Based Geo-Atom Theory and Voxel Automata to Simulate the Dispersal of Airborne Pollutants." *Transactions in GIS*, 2015:19(4):582-603.
7. National Research Council. *Network Science Committee on Network Science for Future Army Applications*. The National Academies Press. Washington, D.C.; 2005.
8. Brian Collins, Ofer Heyman, Joaquín Ramírez, Trude King, Brad Schmidt, Paul M. Young, KC Kroll, Ryan Driver and Carl Niedner. "Modeling Outcome-Based Geospatial Intelligence." *State and Future of GEOINT Report*, The United States Geospatial Intelligence Foundation; 2018.

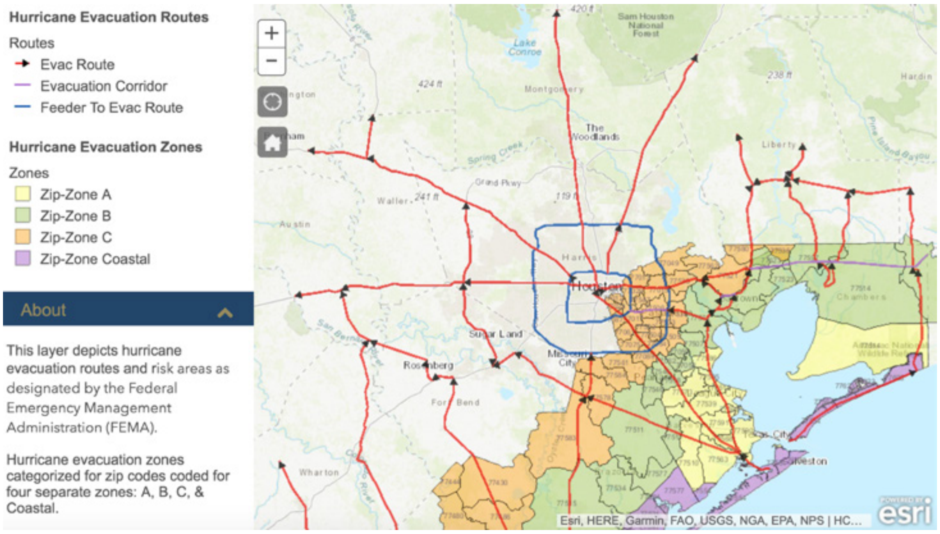

Figure 1. Harris County Hurricane Evacuation Map (Image credit: Harris County Office of Homeland Security and Emergency Management preparedness website http://prepare.readyharris.org/Evacuation-Map.html).

represent either the start or end point of an evacuation route or a road intersection. The location and number of people who require evacuation from the area is determined using the attributes of the ZIP Code shapefile, and the distance of each road segment is calculated using GIS. A network science model is solved using these data, and the outputs show where areas of traffic congestion may occur. This network science model was originally developed by Micah Brachman and Suzana Dragicevic.[1]

Incorporating real-time data into models is a challenge both within the GEOINT domain and in the broader domain of geographic information science. By using the geo-atom, new variables that represent real-time hurricane impacts can be seamlessly incorporated into the network science model. The model can then generate new outputs, which show how traffic congestion can change as real-time conditions are taken into account. The specific method for encoding the hypothetical real-time flooding data as a geo-atom is shown below:

$g = \{p, A, a(p)\}$

where

g = *flooding*
p = (*WGS84 Latitude*, *Longitude*)
A = *water depth* (*cm*)
$a(p) = 170$

An example of record for a flood event is:

flooding = {(30.012, -95.806), *water depth* (cm), 170}

The hypothetical real-time flooding data was then input as new variables in the network science model. It was assumed several roads would be impassible due to flooding. The network science model was then solved again with these new variable inputs and produced results showing how evacuation traffic congestion could change if areas of the roadway became flooded.

Results

The outputs from the network science emergency evacuation model are shown in Figure 2. This map shows areas of traffic congestion forecast by the network science model that utilizes the geo-atom to incorporate real-time flood depth data that could be reported by an observer on the ground. Emergency managers could use such results to decide how to re-direct vehicles in response to a hazard such as flooding or to help identify locations for alternative evacuation routes.

There are many different software platforms used within the GEOINT Community, thus data interoperability is essential for providing a COP. By transforming the outputs of the emergency evacuation model into geo-atoms, the data can be easily disseminated and visualized using nearly any platform.

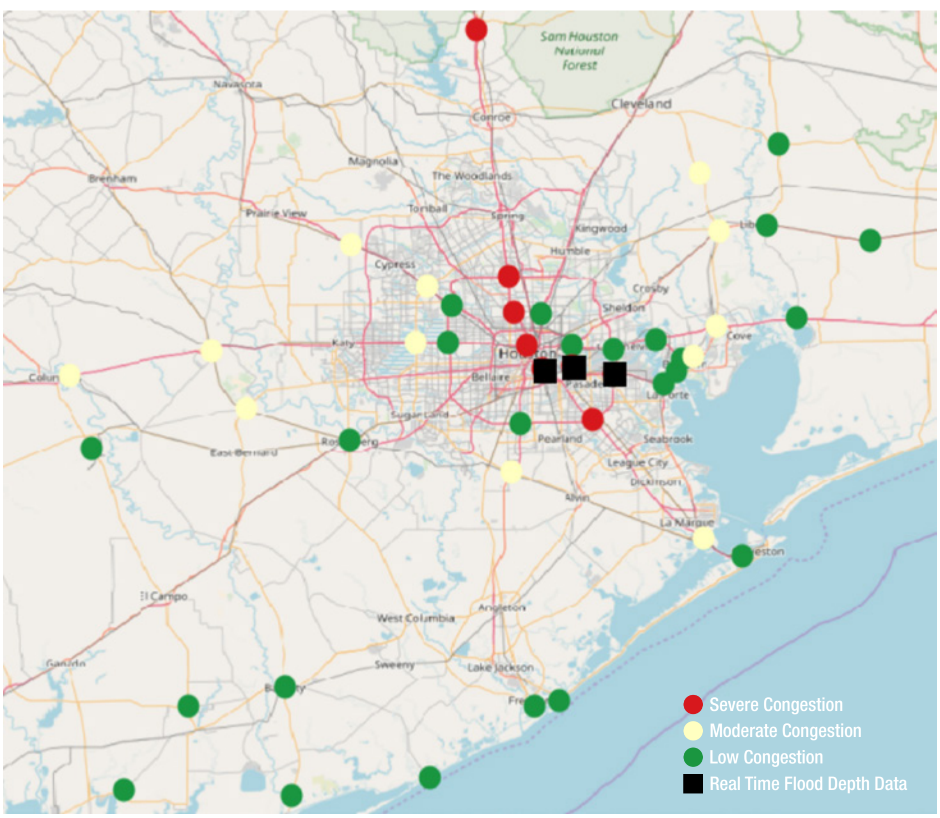

Figure 2. Potential areas of traffic congestion in the Houston area during a hurricane evacuation (Image Credit: Micah Brachman).

1. Micah L. Brachman and Suzana Dragicevic. “A Spatially Explicit Network Science Model for Emergency Evacuations in an Urban Context.” *Computers, Environment and Urban Systems*, 2014:44:15-26.

The Way Forward

One common critique of geospatial modeling and simulation is that it can be difficult to translate the results into real-world decision-making. To avoid this and other pitfalls, it is useful to evaluate the modeling approach presented above using the characteristics of a good GEOINT model identified by Collins, et al.:[2]

Output that is linked to decision or analytic objectives:

The model outputs presented can be used by emergency managers and other decision-makers tasked with managing traffic flow during an emergency evacuation. Incorporating real-time, geo-atom data into the model allows these decisions to change to account for developing conditions on the ground.

Consistent, identifiable, and available data:

ZIP Code and road network data is available for the entire United States, and open-source road network datasets such as OpenStreetMap have global coverage. The availability of emergency evacuation maps varies, but most major metropolitan areas that are under a consistent threat from one or more hazards have an evacuation plan in place.

Ability to assess and compare the impact of inputs:

For this particular emergency evacuation model, the geography of the road network, designated evacuation routes, and the location of the people who will evacuate can be considered fixed inputs. The impact of real-time, geo-atom data inputs can therefore be easily assessed by comparing the outputs of an instance of the model that does not account for real-time data to the outputs of an instance of the model that does.

Consistent outputs:

The network science emergency evacuation model produces a map showing where traffic congestion may occur. The generalized mathematical formula for this model presented by Brachman and Dragicevic can use many different types of road networks and population data inputs and will still produce a traffic congestion map as the output.

Ability to assimilate real-time observations:

One of the major advantages of the geo-atom is it can be used to represent nearly any type of geospatial data. As new real-time sensors are developed and new sources of geospatial data are leveraged for analyses, adoption of the geo-atom will help ensure these observations can be rapidly incorporated into models that support decision-makers.

Ability to produce results for advanced visualization platforms:

The flexible and scalable design of the geo-atom ensures it can be used to incorporate new, real-time observations into models as well as to share the model outputs. The simplicity of the geo-atom allows these outputs to be visualized on many different types of platforms, ranging from desktop GIS and remote sensing software to mobile devices.

The research presented in this article demonstrates how adoption of the geo-atom data model can help address many persistent challenges related to collecting, processing, and disseminating GEOINT. While the integration of real-time, geo-atom data into a network science model is limited to a hypothetical hurricane emergency evacuation scenario, there are many avenues for future research.

One such avenue is further exploring the potential for the geo-atom to become a widely used standard for geospatial data. Organizations such as the Open Geospatial Consortium could play an important role in facilitating this. Another is designing and implementing an emergency evacuation decision support system that can use nationally or globally available road network data and directly incorporate real-time data from a variety of sensors. Network science is only one possible application of the geo-atom; additional applications that can support the GEOINT decision-making process abound, including cutting-edge machine learning and artificial intelligence capabilities.

Assessing the Army Brigade Combat Team GEOINT Enterprise

By CPT Zach Bowers, 46th Engineer Battalion Senior Intelligence Officer; CPT Patrick Ortiz, Department of the Army G-2 (Intelligence) Initiatives Group; and Ben Gildner, formerly of the 2nd Cavalry Regimental Geospatial Cell

Army GEOINT Enterprise

From the dawn of warfare, a commander's ability to visualize the battlefield and direct his or her forces has often meant the difference between victory and defeat. Defined as the "fusion of imagery with geospatial information to describe, assess, and visually depict physical features and geographically referenced activities in the battlefield," GEOINT has evolved to help satisfy this intelligence requirement.[3] By allowing everyone to "'see' the map" and understand pertinent details about the enemy and terrain in time and space, the commander's and staffs' visualization of the battlefield is enhanced.[4] Through this enhanced visualization, commanders can make appropriate and timely decisions resulting in successful mission execution thus leading the National Geospatial-Intelligence Agency's (NGA) Director of Strategic Operations to recognize that GEOINT has become "literally

2. Brian Collins, Ofer Heyman, Joaquín Ramírez, Trude King, Brad Schmidt, Paul M. Young, KC Kroll, Ryan Driver, and Carl Niedner. "Modeling Outcome-Based Geospatial Intelligence." *State and Future of GEOINT Report*. The United States Geospatial Intelligence Foundation; 2018.
3. CW4 Thomas R. Dostie. "USAIC&FH Geospatial Intelligence Enterprise Initiatives," *Military Intelligence Professional Bulletin*, 2006:32(1):44.
4. LTG Michael T. Flynn and BG Charles A. Flynn. "Integrating Intelligence and Information: Ten Points for the Commander," *Military Review*, 2012:4.

indispensable."[1] In contrast to this recognized value, the commander of the Army GEOINT Battalion recently revealed that Army commanders are still unaware of GEOINT's full potential due to GEOINT being "underrepresented in the Army."[2] To evaluate this claim, a current examination of the brigade combat team (BCT) GEOINT enterprise is necessary.

When implementing the Army GEOINT structure, military intelligence research identified the "role of geospatial engineering in GEOINT" as well as the need for "MI and engineer partnership."[3] In response, the Army developed BCT GEOINT cells to combine the capabilities of geospatial engineers and imagery intelligence analysts into one organizational entity, but the merger was not without difficulties. Engineer officers still recommended the development of courses within the engineer school house that are nearly identical to courses already offered in the intelligence school house.[4] Military Occupational Specialties were not combined to form a holistic GEOINT position but continue to be distinct with geospatial experts remaining in the Engineering Branch and imagery experts remaining in the Intelligence Branch.[5] Finally, the lack of integration was most pronounced in comparing two leading GEOINT organizations. This lack of cohesion between the key aspects of the GEOINT discipline has and will continue to impede complete integration of the enterprise for the foreseeable future.

In order to gain a full understanding of the potential ramifications of this lack of cohesion, an objective survey of the BCT GEOINT structure must be conducted. While the Army recognizes the importance of strategic (NGA) support to BCTs—as evidenced by the Army devoting an entire chapter of only three chapters to NGA request procedures within its GIS regulation—the scope of this survey will be limited to the BCT's organic systems and personnel.[6] With regard to necessary elements of a GEOINT enterprise, GEOINT's Basic Doctrine: Publication 1.0 identifies three components: data, tradecraft, and products.[7] For the purposes of this examination, tradecraft will be divided into two subcomponents: data communication processes and data analysis processes. Thus, the BCT GEOINT enterprise will be evaluated based on availability of geospatial data, status of communication systems, data processing procedures, and product visualization. After analyzing these four criteria, this article will summarize its findings in a holistic assessment of the BCT GEOINT enterprise.

Analysis

Geospatial Data

Geospatial references "the relative position of things … [on] our Earth."[8] Given this definition, any information with a referenced location on Earth can be utilized for GEOINT purposes. As such, GEOINT "incorporates data from other intelligence disciplines … to corroborate and provide context to geospatial data and information."[9] Aerial observation of enemy tanks, scout platoon identification of enemy elements, engineer reconnaissance assessments of bridges, and reported locations of friendly units would all fit within the definition of geospatial data. Given this expansive definition, the amount of geospatial data readily accessible to a BCT outside of NGA databases is immense. Identifying potential GEOINT collectors organic to a BCT is somewhat more manageable.

Historically, GEOINT can trace its intelligence roots back to the desire to "control the high ground [… as this] gave the possessor an observational advantage."[10] This historic recognition widens the potential GEOINT sensors within a BCT to all scouts, forward observers, and additional reconnaissance and surveillance assets. Additionally, given the preponderance of GPS devices, any soldier can now determine his or her current position and report on information within their vicinity. Based on this expansive definition, BCTs appear to have a plethora of GEOINT sensors. Determining how this geospatial data is then fed into the overall GEOINT enterprise becomes imperative.

Communications Systems

Data is only useful if it is transmitted to the appropriate individual for further processing. This analysis involves two parts: an analysis of available communications systems and an analysis of the end users of geospatial data. In terms of communication (i.e., mission command systems), the Army has a wide variety of capabilities spanning the Command Post of the Future (CPOF), Advanced Field Artillery Tactical Data System (AFATDS), Distributed Common Ground System-Army (DCGS-A), Next Generation FBCB2 Joint Capabilities Release (JCR), and FM radio.[11] While each of these systems has tremendous potential, there is a significant time and resource cost associated with the communications architecture development, systems maintenance, and operator training.[12] Of particular importance to GEOINT, LTC Keith Carter, 1st BN, 26th INF REG Commander, noted DCGS-A has significant problems operating in field conditions with a high "level of austerity."[13]

1. Alderton. "The Defining Decade of GEOINT." 36.
2. Quinn, "Army GEOINT: A Team Sport." 13.
3. COL Thomas R. Crabtree. "The Role of Geospatial Engineering in GEOINT," *Military Intelligence*, 2007:16-18.; Dostie. "USAIC&FH Geospatial Intelligence Enterprise Initiatives," 44-47.
4. Jared L. Ware. "Developing a Tactical Geospatial Course for Army Engineers," *ESRI*, 2016:1-10.
5. U.S. Army Recruiting Command. "Career and Jobs." *GoArmy.com*; 2018. https://www.goarmy.com/careers-and-jobs/browse-career-and-job-categories/intelligence-and-combat-support/geospatial-intelligence-imagery-analyst.html. Accessed April 8, 2018.
6. United States Army. "AR 115-11: Geospatial Information and Services." Headquarters Department of Army Washington D.C.; 2014. 10-16.
7. Cardillo. "GEOINT Basic Doctrine: Publication 1-0." 2018. 1-2.
8. Keith J. Masback, *State of GEOINT Report*. United States Geospatial Intelligence Foundation; 2015:9.
9. Conway, Cromer, and McDonough. "Leading the Way in Geospatial Intelligence." 9.
10. Robert M. Clark and Mark M. Lowenthal. *The 5 Disciplines of Intelligence Collection*. London: Sage Publications; 2016. p 121.
11. John Bolton. "Overkill: Army Mission Command Systems Inhibit Mission Command," *Small War Journals*. http://smallwarsjournal.com/jrnl/art/overkill-army-mission-command-systems-inhibit-mission-command. Accessed November 1, 2018.
12. Gary Lawrence. "A Layered Approach for Training Battle Staffs within Digital Tactical Operations Centers," *Infantry*, 2013:34-38.
13. Jen Judson. "Rethinking the Battlefield: Army Drives Toward Lighter, Smaller, Mobile Systems at NIE," *Defense News*, August 1, 2017. https://www.defensenews.com/it-networks/2017/08/01/us-army-drives-toward-lighter-smaller-mobile-systems-at-network-integration-evaluation/. Accessed April 20, 2018.

Even if connectivity is assumed to be sufficient, the question of successful receipt of geospatial data by the necessary recipient remains. Each mission command system caters to a different set of individuals. AFATDS is traditionally associated with artillerymen; DCGS-A is maintained by intelligence professionals; JCR encompasses the majority of mounted friendly forces. As each of these different systems is a conduit of useful geospatial data, the BCT GEOINT cell must have a means of accessing this data. While attempting to operate each of these systems with organic personnel would be impossible, integration of the entire Army Battle Command System would prove useful to the GEOINT cell. As a result, the Army has begun development of a comprehensive solution focused on the CPOF. Through the use of a data distribution system, the CPOF will be able to consolidate all information into one COP. Of note, the success of these efforts has been limited, and alternative approaches are already being considered.[14] In short, while geospatial data is accessible to BCTs and entered into its communications infrastructure, the probability of the GEOINT cell acquiring and fusing all of this information appears minimal in its current design.

Geospatial Data Processing

To effectively evaluate how well GEOINT analysts transform data into intelligence, two requirements are necessary: tools and knowledge. Through DCGS-A, GEOINT analysts appear to have wide variety of tools at their disposal. In 2009, analysts used at least three pieces of hardware and numerous software programs to view and manipulate extensive file formats, intel reports, data files, and imagery.[15] Software packages have since been updated with even more advanced computational algorithms and terrain reasoning tools to facilitate faster automation processes and analytic procedures.[16] Although these tools are extremely powerful, the main requirement is that data coming into the system must be in the proper format to be usable. In spite of this limitation, GEOINT analysts are fully resourced with the proper tools to provide actionable intelligence.

The second and more important factor is the degree of knowledge analysts have at transforming geospatial data into GEOINT. While this attribute is more difficult to assess given the already identified separation of GEOINT training in two different institutions—Fort Leonard Wood for engineers and Fort Huachuca for intelligence—a general assessment can be made. Given both the unified nature of NGA as the proponent of GEOINT as well as the Army's Foundry Program, which provides commanders with outside funding to train organic intelligence soldiers, GEOINT training would appear to be well resourced and managed.[17] Outside of initial institutional training, mobile training teams, contracted system upgrade training, and additional schooling opportunities exist to ensure professional GEOINT standards and expertise are maintained.[18] While a detailed assessment of GEOINT analyst training is outside the scope of this survey, a cursory survey reveals that training opportunities both exist and are resourced. In combination with a wide set of advanced geospatial tools, the BCT GEOINT enterprise has the capability to produce relevant, actionable GEOINT.

Product Visualization

As discussed earlier, "the most important result of GEOINT [… is] situational awareness."[19] This has led to an abundance of different types of both standard and specialized products. Many of the more recognizable GEOINT products include line of sight, cross-country mobility, route analysis, IED density plots, obstacle overlays, etc.[20] While GEOINT products may have a reasonable amount of variance, one unique aspect of these products and this intelligence discipline is the concept of "value-added." Value-added is the process of continually updating products and databases with current information and purging obsolete information to ensure the product is as up-to-date and relevant as possible.[21] This attribute of GEOINT is exceptionally important to ensure situational awareness is maintained.

While the above products and value-added concept are laudable, the COP is noticeably absent. A COP is a "single display of relevant information within a commander's area of interest tailored to the user's requirements and based on common data and information shared by more than one command."[22] Scholars have already identified that "GEOINT, using multiple and advanced sensors as well as the integration of various intelligence disciplines, has proved to be able to create a common operational picture."[23] Traditionally, the COP is "owned" by the operations section as much of the COP contains friendly locations. While JP 2-03 does recognize that GEOINT supports the development of the COP, BCT structure does not inherently facilitate this as the intelligence section is distinct from the operations section.[24] The BCT GEOINT enterprise's role in the development of this product should be more clearly articulated by the chief of staff or operations officer.

Assessment

Of the four criteria necessary for a successful GEOINT enterprise—data, communications systems, processing, and visualization—access to geospatial

14. Devon Bistarkey. "The Big 'Common Operating' Picture," *Army.mil*, May 6, 2016. https://www.army.mil/article/167488/the_big_common_operating_picture. Accessed April 20, 2018.
15. Conway, Cromer, and McDonough. "Leading the Way in Geospatial Intelligence." 14-15.
16. *Intelligence Support for Military Operations Using ArcGIS Platform. Redlands*, CA: ESRI; April 2016. 5-8.
17. United States Army. *AR 350-32: Army Foundry Intelligence Training Program.* Washington D.C.: Headquarters Department of Army; 2015. 1-29.
18. Conway, Cromer, and McDonough. "Leading the Way in Geospatial Intelligence." 15.
19. Clark and Lowenthal. "The 5 Disciplines of Intelligence Collection." 132.
20. Richards. "Integrating the Army Geospatial Enterprise: Synchronizing Geospatial-Intelligence to the Dismounted Soldier." 56.
21. JP 2-03, IV-8.
22. Keith Hibner and Mike Previous. "The (Un)Common Operational Picture," *Connected* 3, 2011(3):1.
23. Roberto Mugavero, Federico Belloni, and Valentina Sabato, "Geospatial Intelligence, Technological Development, and Human Interaction," *Journal of Information Privacy and Security*, 2015:11:244.
24. JP 2-03, I-2.

data was the only component clearly sufficient for supporting BCT GEOINT operations. Given the variety of advanced geospatial tools, unity of training efforts through NGA, and resourcing through the Foundry program, this cursory assessment contends that the third criteria is also satisfactory. This assessment is caveated with the acknowledgment that the full impact of GEOINT education and training being split between the engineer and intelligence branches has yet to be fully assessed. The final two criteria of communications systems and visualization products will encompass the duration of this assessment.

The most immediate issue that must be addressed is the GEOINT cell's ability to access all geospatial information. The optimal solution would be an easy-to-implement and easy-to-maintain technological solution that both provides connectivity as well as file transformation software packages between each of the different Army mission command systems, but this does not appear to be a feasible solution in the short term. A more reasonable policy would be a structural change. As identified earlier, the CPOF system has been the focus of integrating each dispersed mission command system. It is also traditionally located on the current operations floor among the wide array of mission command systems. The GEOINT cell should maintain a presence within this space for the purposes of acquiring all relevant geospatial data. As the GEOINT cell's personnel strength is limited, this may require education of the current system operators on what constitutes relevant geospatial data and the format that it needs to be delivered to the GEOINT cell.

The second recommendation is related to the first. The GEOINT cell's role must be clearly articulated with relation to COP development. While this article does not necessarily advocate that this responsibility should be placed entirely on the GEOINT cell, there should be no ambiguity regarding the expectations of the GEOINT cell. As GEOINT provides indications of how friendly and enemy forces can and are using the terrain to their advantage, the GEOINT cell should at a minimum be responsible for capturing geospatial data corresponding to the enemy and terrain in a holistic visual product that the entire staff and command can use to enhance decision-making. As the COP also incorporates friendly force information, this product must be a collaborative product rather than a separate intelligence product. The GEOINT concept of value-added through continual refinement makes the GEOINT cell particularly suited for this task.

The final recommendation is much more difficult to implement. It involves cultural change and education. As the commander of the Army GEOINT Battalion pointed out, many in the Army only view GEOINT as a section that can "make me a map or […] get me a picture."[1] Even the GEOINT cell itself often becomes fixated with "traditional" GEOINT assets such as unmanned aerial vehicles, Ground moving target indicators, satellite imagery, or existing strategic databases. Both GEOINT professionals and Army leaders need to reference GEOINT's actual purpose: the analysis of geospatial data to "describe, assess, and visually depict physical features and geographically referenced activities on the Earth."[2] This definition is much more encompassing than what has traditionally been expected of BCT GEOINT cells. While this should not be confused with all-source analysis, which encompasses every intelligence discipline for predictive assessments of enemy actions and intentions, GEOINT still has a wide range of responsibilities. A shared understanding of this role must be developed across tactical Army organizations if GEOINT is to be fully utilized.

Conclusion

While the need for geospatial intelligence has always existed, the relatively recent attempt to merge the culturally distinct organizations of geospatial engineering and imagery intelligence in 1996 led to friction within the resulting organization. Given the U.S. Army's even more recent GEOINT merger, the potential for lack of cooperation and integration is high. While the existing literature readily reveals discrepancies between the engineering and intelligence communities with regard to the discipline, a holistic assessment of the current BCT GEOINT structure was necessary to objectively ascertain the resulting inadequacies that could be improved upon.

The article analyzed the current BCT GEOINT architecture through four criteria: geospatial data, communication systems, geospatial data processing, and visualization products. While the current GEOINT architecture appears to meet both the requirements for access to geospatial data as well as to possess the appropriate tools and expertise, this survey did highlight failures in both the current communications architecture as well as product development to enhance situational awareness across the staff and command teams. Through limited structure changes, COP development clarification, and GEOINT awareness and emphasis, many of these issues could be potentially mitigated.

While this article limited the scope of its research to an exploratory survey, some insights developed here should be further explored by future research projects; for example, a more thorough assessment of geospatial tools and expertise concentrated on the separation of elements within the GEOINT Community between differing Army branches. Additionally, given the expansive role of GEOINT, research should be conducted on the feasibility of expanding the GEOINT cell's role within a BCT given personnel and resource constraints. Through continued research and analysis into this area of research, the BCT GEOINT enterprise can be more effectively realized and reach its full potential.

1. Quinn. "Army GEOINT: A Team Sport." 13.
2. Murrett. *GEOINT Basic Doctrine: Publication 1-0.* 5.

Public and National Technical Means in the Digital Age: The Implications for GEOINT in the Monitoring of International Nonproliferation Agreements

By Pia Ulrich and Chris Bidwell, Federation of American Scientists; John Lauder, Nuclear Verification Capabilities Independent Task Force; Harvey Rishikof, American Bar Association Standing Committee on Law and National Security; and Valerie Lincy, Wisconsin Project on Nuclear Arms Control

A vital task for the geospatial intelligence (GEOINT) community remains collecting, analyzing, and exploiting data for the monitoring of international agreements and informing verification decisions concerning compliance with those agreements.[3] The fundamental challenge of monitoring and verification was a staple of Cold War intelligence—and one of its greatest achievements. This essential role has gained renewed urgency due to the demands of recent negotiations and compliance issues concerning Iran, North Korea, Syria, Russia, and potentially China.

During the Cold War, the United States and the Soviet Union sought to view each other's nuclear delivery arsenals, conventional military forces, and industrial infrastructure from space. The U.S., in particular, built eye-watering intelligence capabilities for monitoring that made arms control agreements possible and reduced the risk of strategic surprise and miscalculation. International treaties and other agreements referred to these capabilities as national technical means (NTM) and prohibited interference in their use for monitoring. The agreements did not define specifically what NTM included. This intentional ambiguity provided useful flexibility among the parties as to what methods of technical monitoring would permissibly be applied. NTM was understood to include more than remote sensing from space, but satellite imagery was clearly viewed as a major component of NTM. These NTM were later adapted for use against a host of other national security issues and have continued to improve in terms of sensor types, spatial and temporal resolution, and accuracy.

Since the Cold War, a major evolution in remote sensing data has been the increase in publicly available data and the number of available observation platforms, including those operated by private entities. Less expensive technologies and new business paradigms yielded a robust industry and marketplace. The National Geospatial-Intelligence Agency's (NGA) Commercial GEOINT Strategy[4] observes that the remote sensing industry continues to evolve in terms of global coverage, rapid revisit rates, diverse spectral content, aggregation from open-source venues, and analytic capabilities with increasing dynamism. The impact on the nonproliferation and monitoring communities is threefold:

1. The accelerating quality, quantity, and timeliness of imagery and other forms of remote sensing available outside of governments.

2. The growing volume and availability of worldwide transactional data related to commerce.

3. The ease of both accessing the data (including imagery) and communicating findings, observations, and assertions about illicit activities related to nuclear programs and proliferation (with varying degrees of accuracy and truthfulness) through an increasing number of traditional and emerging social media outlets.

Overlaying these developments is the introduction of new forms of data analytics, including artificial intelligence (AI)[5] approaches such as machine learning, which serve to speed up both the process and pace at which these developments can affect monitoring and verification activities. The sheer volume of available data, imagery, and analysis, some of it conflicting, has made the monitoring process more challenging. In addition, confidence in the result of data analytics is moderated by a lack of understanding regarding the logic basis (algorithms) that produced the result and the extent to which it can be generalized. Additionally, there is a risk to data integrity due to a dependence on the digital cloud, data storage, web browsing, and online communication.

Commercial Imagery and NGOs

Enabled by these increases in the speed and quantity of open data sources, non-governmental organizations (NGOs) are playing an enhanced role in commenting on nonproliferation agreements, facilitating greater transparency, and helping to identify options, opportunities, and challenges. Use of enhanced open-source tools by the NGO community is likely to increase as the technologies continue to improve and costs decline. Dr. Christopher Stubbs of Harvard University and Dr. Sidney Drell of Stanford University, in "Public Domain Treaty Compliance Verification in the Digital Age," described these new tools collectively as "public technical means (PTM)."[6]

One significant change that has emerged from less expensive and more accessible geospatial information is the emerging private sector business market. Unlike legacy aerospace firms that focused on national security clients, many new private firms are financially incentivized to sell their products to as many customers as they can, including businesses, foreign governments, and NGOs.

3. In this article, the term "monitoring" refers to the gathering of information relevant to compliance assessments, including imagery and other forms of remote sensing tools. "Verification" refers to the process of reaching policy judgments about the extent and significance of compliance or noncompliance.
4. *Commercial GEOINT Strategy – 2018 Update*. National Geospatial-Intelligence Agency. https://www.nga.mil/Partners/Pages/Commercial-GEOINT-Strategy.aspx. Accessed August 20, 2018.
5. Artificial intelligence (AI) is usually defined as the science of making computers do things that require intelligence when done by humans. It is an evolving nascent technology. Machine learning is a subset of AI that involves algorithms that can learn to make predictions over time without being explicitly programmed to do so.
6. Christopher Stubbs and Sidney Drell. "Public Domain Treaty Compliance Verification in the Digital Age," *IEEE Technology and Society Magazine*, Winter 2013.

Investors are now purchasing geospatial technology, once used to monitor adversaries' missile launch sites, to count cars in Walmart parking lots and to monitor crop yields in order to gain a competitive edge in investment decision-making. Imagery-focused commercial enterprises have found innovative ways to explain to new customers how these technologies can affect their bottom line. Moreover, these enterprises are now fusing satellite imagery with other data sources such as social media, allowing users to assess business risks (e.g., geopolitical conflicts, energy resources, natural disasters) or to obtain data feeds organized by location (e.g., ports, pipelines, borders).

This new business model presents several challenges for government. First, the technological growth and innovation in components of the commercial imagery sector, such as AI, may significantly outpace that of the national security arena. Much AI innovation will be focused, funded, and developed primarily for highly profitable commercial uses. Despite successful examples of public-private partnerships, national security uses of a company's AI products may be a secondary objective for a growing number of businesses engaged in geospatial production and analysis. Second, the government is at risk of losing the battle for top AI talent. The private sector can pay more and offer more attractive and flexible workplaces than the government. Third, attempts to secure, classify, or restrict emerging AI technologies on national security grounds will be met with stiff resistance by the commercial sector, which has made significant research and development investments in anticipation of significant monetary returns. Another end result of these developments is that it will be easier for foreign governments to work with and acquire new technologies.

An implication of high-quality and affordable GEOINT is that NGOs, and an increasing number of U.S. and foreign government entities at all levels, are now able to use compelling imagery to put forward plausible analysis and interpretations about world events. In turn, these analyses and perspectives are easily broadcast via the internet and can reach ever-growing audiences at negligible cost. This new capability results in competing narratives with regard to developing security issues that must be sifted through and adjudicated by policy-makers worldwide. One example of how this phenomenon plays out can be seen in the various narratives offered up by different entities regarding territorial claims in the South China Sea.

The Growing Role of NGOs

As PTMs evolve and grow, NGOs will increasingly influence policy conversations leading to verification determinations. An example of this new phenomenon is the work of the James Martin Center for Nonproliferation Studies at the Middlebury Institute of International Studies at Monterey.[1] The center's analysis of and publications on its discovery of a North Korean missile production facility received wide dissemination both through traditional and social media outlets. The center has published several studies that have influenced the policy debate and expanded general public awareness about proliferation.[2]

Despite the improvements in imagery analysis and interpretation, the techniques employed by NGOs may lead to faulty analysis and misinterpretation. Using overhead imagery effectively requires not only specialized supporting software but also geospatial expertise. The complex nature of working with satellite data and the lack of standardization of data is a challenge even for skilled imagery analysts. It is essential that users have the expertise to analyze the imagery and interpret the data, which includes choosing the best type and resolution of imagery for the intended illustration, along with the need to properly process the raw data. These requirements pose serious obstacles to NGOs that are often operating on a shoestring budget but eager to embrace the opportunities that geospatial information, data analytics, and social media present. Another challenge for NGOs is navigating complex commercial licensing arrangements that may limit public distribution of images due to restrictions found in government contracts with industry. On a positive note, some NGOs have arranged for discounted pricing on imagery used for non-commercial purposes. Nonetheless, the biggest risk to NGOs can come from publicizing faulty conclusions that can potentially tarnish their credibility and the reputations of those relying on their analysis.

As NGOs establish expertise in the use of GEOINT, they are increasingly organizing their approach to information using methods similar to those of government intelligence services. NGOs face many of the same policy decisions about information access, control, and influence as government intelligence services, and must decide when and how best to disseminate satellite imagery and geospatial analysis on a particular policy question or situation.

Although most nonproliferation-focused institutions rely on basic electro-optical imagery, some are beginning to make wider use of radar, infrared, other spectral imaging, and advanced processing techniques. A decent proxy for capacity among these institutions is whether they can process imagery in-house, or whether they must rely on others to process the image. Groups can draw conclusions from visually examining images processed by others, but the ability to conduct in-house processing offers significant advantages. Some institutions working in this area include:

1. Richard Engel and Kennett Werner. "Open-Source Material Offers Hints on North Korea's Missile Capabilities." *NBC News*. March 1, 2018. https://www.nbcnews.com/news/north-korea/open-source-material-offers-hints-north-korea-s-missile-capabilities-n850246.

2. See for example: Ellen Nakashima and Joby Warrick. "U.S. Spy Agencies: North Korea Is Working on New Missiles," *Washington Pos*t, July 30, 2018. https://www.washingtonpost.com/world/national-security/us-spy-agencies-north-korea-is-working-on-new-missiles/2018/07/30/b3542696-940d-11e8-a679-b09212fb69c2_story.html?noredirect=on&utm_term=.c0311e1b4e0c; Jeffrey Lewis and Dave Schmerler. "North Korea Expanding Key Missile Site," *Arms Control Wonk*. July 2, 2018. https://www.armscontrolwonk.com/archive/1205558/north-korea-expanding-key-missile-site/. Accessed August 30, 2018; Catherine Dill. "Open Silos," *Arms Control Wonk*, August 22, 2018. https://www.armscontrolwonk.com/archive/1205826/open-silos/. Accessed August 30, 2018.

- 38 North (focuses on North Korea)
- AllSource Analysis
- The Atlantic Council's Digital Forensic Research Lab
- The Center for Strategic and International Studies (CSIS) ("Beyond Parallel" focuses on North Korea)
- The Institute for Science and International Security
- The James Martin Center for Nonproliferation Studies, Middlebury Institute of International Studies at Monterey
- The Verification Research, Training and Information Centre
- Bellingcat

Monitoring and Verification

The U.S. government is beginning to explore ways of collaborating with these institutions. One such partnership is between CSIS and NGA.[3] This collaboration reflects the realization that NGOs and the U.S. government can do a better job of analyzing threats in cooperation with each other as opposed to proceeding independently, and is driven by the Intelligence Community's (IC) goal to provide greater transparency that enhances public understanding and promotes collaboration with those outside the IC.[4] Moreover, if NGOs like CSIS can conduct expert analysis without using classified data, their analysis can be more easily shared with allies and even adversaries.

In addition, international organizations like the International Atomic Energy Agency (IAEA) and the Comprehensive Nuclear-Test-Ban Treaty Organization (CTBTO) see value in the use of GEOINT to support their work. IAEA has an in-house capacity to use satellite imagery and referenced this resource together with other open sources in its most recent report on North Korea.[5] Several NGOs have worked with IAEA to build the agency's capacity in this area. CTBTO has a more restrictive mandate but is currently exploring how to build greater capacity in this area to support on-site inspection. Adding to seismic and other data collected and analyzed by CTBTO, commercial satellite imagery provides the precise geolocation of underground nuclear tests. Analysts at 38 North have used this capability in their work monitoring North Korea's Punggye-ri Nuclear Test Site.[6]

Ultimately, the impact of technology acquisition in the commercial sector and the use by NGOs of more complex and powerful tools will yield a more robust offering of geospatial and related data analysis, fueling international debate. This debate may be amplified by NGOs, which regularly publicize their findings in traditional media as well as through blogs and websites. The ability to appropriately evaluate a multitude of claims and counterclaims will be more difficult in the future, as there may be much more noise (all data and analysis) than there is signal (relevant and reliable analysis). In short, the job of GEOINT professionals working with and in government will become more difficult as the private sector and NGOs increasingly offer analysis of their own and compete for the dominant narrative. The days of government monopoly of the monitoring process are waning.

Still, the emerging capabilities of NGOs, as significant as they are, do not diminish the primacy of governments in monitoring and, more importantly, making verification determinations of compliance and national interest. These are policy judgments that can only be performed by the state parties to international agreements. Governments have a far greater capacity—largely through intelligence sources and methods as well as negotiated inspection, information-sharing, and confidence building measures—to discover and penetrate weapons programs of concern. Governments are well positioned to facilitate the participation of international organizations and NGOs in the monitoring process and to assess the credibility of their contribution to verification judgments.

The increasing influence of geospatial and other open-source information to the monitoring and verification process will pose challenges as well as opportunities for governments. Although such open-source information provides valuable data, it may introduce spurious information that complicates efforts to penetrate denial and deception in monitoring. It also creates opportunities for the manipulation of the policy process of verification. The verification process is increasingly taking place in a political environment in which suspicions, "fake news," disinformation, and unfounded accusations flourish. The geospatial and nonproliferation communities will need to cooperate more closely to produce and authenticate data that must be seen as objectively unbiased and impartial, which is the lifeblood of effective verification decision-making.

3. CSIS Korea Chair Announces Research Partnership with National Geospatial-Intelligence Agency (NGA). May 22, 2018. CSIS Press Release. https://www.csis.org/news/csis-korea-chair-announces-research-partnership-national-geospatial-intelligence-agency-nga. Accessed August 20, 2018.
4. Intelligence Community Directive 107. Office of the Director of National Intelligence. https://www.dni.gov/files/documents/ICD/ICD-107.pdf. Accessed August 30, 2018.
5. Application of Safeguards in the Democratic People's Republic of Korea. International Atomic Energy Agency. August 20, 2018. https://www-legacy.iaea.org/About/Policy/GC/GC62/GC62Documents/English/gc62-12_en.pdf.
6. See for example: The Punggye-ri Nuclear Test Site: A Test Tunnel Tutorial. 38 North. May 23, 2018. https://www.38north.org/2018/05/punggyetunnel052318/.

The Frontier of Multimodal Mapping and the Future of Secure, Integrated Data Visualization

By Ashley M. Richter, AECOM; Rupal Mehta, Ph.D., the University of Nebraska-Lincoln; and Michael Hess, Ph.D., Alutiiq, LLC

What will data visualization and knowledge interaction look like in the future? We don't need a crystal ball to guess. Between the exponential growth and confluence of extant and emerging technologies, and our species' tendency to reverse engineer the systems we dream up in our science fiction, the hazy shapes of future mechanisms are already visible.

There are intersecting features across the sci-fi spectrum that provide clues: the fully immersive virtual reality of *Ready Player One*; the augmented reality of *The Expanse*; the more popular mixed reality of *Avatar*, *Passengers*, *Prometheus*, and *The Hunger Games*; and the incoming wave of speculation regarding brain-computer interfaces. These future, integrated, analytic data systems all share a need for multidimensional and multispectral 3D+ data capture as a base with layers of geospatial and activity-based intelligence at multiple scales—landscape, building, and human.

Likewise, the co-registration of this data yields interesting opportunities for a more robust computer vision and machine learning/artificial intelligence automation paradigm. Such a system implies a much-needed bump up in how we secure our digital data infrastructures and how we ethically access such an amalgamation of live-streaming and historic data.

Where previous years were spent lamenting lack of processing power, shortage of expertise, weak multimodal data co-registration mechanisms, or the "black box" nature of machine decision processes, recent progress has highlighted the new challenges to a digitally twinned world. Cybersecurity, data privacy, and control issues as well as a need for interdisciplinary/silo collaboration, and an improvement in the business practices with respect to data management are now at the forefront.

As more industry and academic groups build out the base levels of a global digital twin, it is essential that we consider not just what the future 3D-mapped, ubiquitous sensor-driven, annotatable, and tracked multimodal "Internet of Everything" will look like in its assorted mixed reality visualization hardware, but also how and why such an integrated data schema needs to be constructed, accessed, and securely maintained.

An ubiquitous sensing paradigm and the inevitable data economy posited by the smart cities of the future rely on this same digital scaffold at their base. The spaceships and space colonies of the future will depend on real-time decisions made from ever-expanding, integrated, and authenticated intelligence platforms. To develop these types of automated operations, we must be able to 7D+ map space, time, assets, life cycle, collaboration, financials, and more on top of 3D surroundings for our cities, buildings, and selves—otherwise we won't to be able to reproduce it into any form of useful off-planet construction and maintenance at scale. But long before we get to that point, we must ensure that when (not if) these systems are put into inevitable mainstream use, the right balance of international powers are involved in their development and security from the start. A living, 3D+ blueprint of the world and the movement of humans and objects through it is both a security asset and a threat.

Where will these systems come from?

Just as so many other "emerging" technologies have actually been around for quite a while, the pieces of such a sci-fi-integrated visualization schema have lurked in the background for some time.

Ultimately, any arena that is considering how to map time and space is at the edges of the proposed unified theory of cyber-physical spatialization—exploration and survey geospatial intelligence (GEOINT) in the government; the architecture, engineering, and construction industries' expanded use of building information modeling; the digital heritage community's cultural heritage diagnostic efforts to digitize and annotate historical monuments and landscapes; the self-driving car industry's labors to map and monitor roadways and vehicle context; and the augmented, virtual, and mixed reality industries and GIS communities that are increasingly a part of public awareness, education programs, and mainstream career paths. Even progress in the gaming industry to map digital realms or Hollywood special effects efforts to use real-world data captured via sensor instead of drafted digitally should all be considered relevant efforts to build a digital scaffold upon which to drape and access all of our other data streams in a grand system of systems.

Match spatial visualizations with increased intensity and science communication efforts toward analytic annotation layers, and, voilà, the pieces begin to take shape. As different arenas across industry collide and conspire toward applied use cases, more and more aggregate data will be visually and analytically entangled.

Everything—from the increased miniaturization and decreased cost of terrestrial LiDAR and multispectral data capture tools, public awareness of GIS systems, the rise of gaming engines capable of uniting interactive datasets, increased interest in establishing automation policies for the future of work, quantum computing simulation possibilities, indoor mapping, Wi-Fi mapping, medical imaging and training devices, etc.—are all related to the evolution of a unified digital twin. This singularity of sorts will be a constantly evolving digital representation of time and space that allows us to spatially record our lives on the landscape we inhabit, and subsequently derive further analytics from the accumulated data of those lives lived.

Why put all the pieces together?

Technology should not be developed for technology's sake.

Historically, technology has evolved and become ubiquitous practice because it served a need—even when that need was not immediately apparent to anyone but early adopters and creators. When the search engine was first introduced, the need to query a digital encyclopedia was infamously questioned. The trajectory of GPS from government to public use followed a similar quixotic pathway—and yet few among us would dare to head somewhere new today without the use of a mapping application. We are lost, both literally and figuratively, without our smartphones.

An integrated, visual, spatiotemporal system of analytic, multimodal data yields even greater opportunities to chart and share the world around us for present and future use: when a field engineer in a disaster zone can receive automatic alerts to maintain an asset, be guided to the damaged area in augmented reality, and collaborate in virtual reality with additional experts; when the warfighter can automatically track changes projected directly onto the landscape for situational awareness; when a construction team can move through digital annotated blueprints actively layered over their real world; when a teacher can access the relevant, authenticated strata of scientific and crowdsourced anecdotes layered onto each painting to answer the questions of curious school kids; when a real estate agent or engineer can query the building itself for its maintenance records; when your medical history is visually tied to your body; when a future descendent can tour the world and be prompted to take a photo at a certain spot because their great-great-grandparent stood in that exact spot decades ago; when these are all the same, ubiquitous system—then we will have the beginnings of a mechanism to record and assess our species over the "longue durée" of our assorted civilizations and derive even greater analysis from our aggregate.

In the long term, a unified ecosystem of multimodal data is a living, collaborative multidimensional atlas of humanity accessible online in 2D via our assorted smart devices, and viewable in the ubiquitous mixed reality systems on the horizon in its 3D+, hopefully holographic form.

A spatial representation of everything can be utilized to not just preserve our brief existence and connect us constantly to the past as the ultimate of our historic archives—but as training data for future levels of automation and optimization to ongoing society.

In the short term—this living, global, multidimensional digital twin is a tool to provide context to our activities—be they the maintenance and operations of a smart facility, the negotiation of a smart city's labyrinth, the automated highways to come, or out in the field for research, reconnaissance, or disaster relief—on planet or off.

How will a global digital twin come into being?

Integrated, spatially visualized systems are an inevitable confluence, but they also represent a new challenge. One that will require mass collaboration and significant reworking of how government, industry, and academia share data and build systems together. But enough puzzle pieces are on the proverbial table to get started if an applied use can be decided upon to focus concerted efforts.

Previous work by some of the authors focused on the use of cultural heritage monuments as test beds for the development of multimodal data visualization platforms, most notably for the Florentine Baptistery of San Giovanni and the Duomo under the care of the Vatican's Opera di Santa Maria del Fiore. Subsequent efforts have been focused on critical infrastructure and secure facilities operations and maintenance for the U.S. government as sandboxes to establish best security practices for these future platforms. It is important that the construction of a working, ubiquitous digital twin of this nature be dominated by the security concerns present at monuments and secure government assets to ensure data security issues are part of the recipe from the start. But whether a sandbox of these issues will be best handled by government or industry is up for debate given that both arenas can lay conflicting claim to cybersecurity supremacy.

As more and more elements are mapped together, it will be necessary for some element of the world's government to take responsibility, not just for the future end system, but for the increasing layers of building, street, and subterranean 3D mapping elements already in play. Aerial LiDAR at the landscape level has set a precedent for data collection and sharing mechanisms. But as more and more annotated 3D blueprints at building level make their way into the public domain, a security mind-set is essential. A 3D archive of critical infrastructure, world monuments, or local housing is part education resource, part commercial driver, and part terrorist planning guide. The ability of a real estate agent to use a 3D annotated version of a home to sell it could also result in a well-planned home invasion. Digitized highways and self-driving cars mean hackable training data at multiple levels. A digital twin of a secure facility can be optimized by spatially mapping its asset management system, but it can also be compromised more significantly if it is breached.

What does this mean for the future of data privacy and security?

In a constantly replicated virtual version of the world, our physical movements would ideally be digitally live-mapped for best case data extrapolation. But while it's one thing for our standing buildings to be represented and improved upon by their digital copies—what does an activity-based intelligence layer tracking individuals and populations over time and cross-referencing their actions mean? Philosophers and statesmen have pondered such a surveillance state for millennia. But as we find ourselves not just on the cusp, but already wading into a technocratic variant of a temporally and spatially tracked society, what are we doing and what can we do to ensure citizens maintain individual rights and their data cannot be compromised and used for nefarious purposes? Given how often recent waves of technological progress have failed to address this before being implemented, it's important that such dialogue take place up front rather than be addressed ad hoc.

The return on investment to spatially layering data exceeds the security risk—but that security risk cannot get lost in the shuffle or go unmonitored by government agencies—even when it is with respect to publicly or privately collected data. Which begs the questions: Who ought to control the assorted levels of data and their interaction? What area will set its governance? Who will monitor compliance? How will the best version of a model or a user contributing data be authenticated? How will an individual's data in the system be controlled—by third parties as is, by the individual's aggregate self-sovereign identity of all of their data, by a new regime of data bankers to come, by government? The National Geospatial-Intelligence Agency is most likely to kick off handling this quagmire of data—but industry is not far behind and may come up with something more accessible and quicker in an effort to create and control the data economy at all levels. Society is struggling to answer these questions with respect to 2D data—how will 3D+ and multispectral data confuse and exacerbate these issues?

But the accumulation of 3D data on our bridges and houses, the tracking of our movements via GPS or Wi-Fi or health-monitoring devices, the thermal assessment of our bodies in public spaces, the nature of our very genes—are all being aggregated in one database or another as individual puzzle pieces and trends. We don't actually know how much is out there, already mapped, or how it's being used. But it's likely only 1 percent of what has been collected thus far has been connected. We need to agree on a place to start. We need to determine a baseline of what exists already and establish systems for aggregation, access, and security to the inevitable sync of the world's data before it's too late and someone nefarious does so first.

Though we are struggling to make all of the base systems actively work—to turn machine learning into something more complex and yet understandable, to sync asset management systems into 3D building models, or to easily layer high-resolution building models into landscape-level imagery—we cannot and should not ignore the potential to get ahead of incoming systems and ensure American and ally control of the inescapable, data-driven, user-centric future.

Often, progress, innovation, and security are stunted and threatened by our inability to flexibly implement, act, or build policy and better business practices in relation to new technologies. We need to shift the current paradigm of disruptive technology even further to encompass how we're handling global data strategy. For all that we may be able to estimate the shape and approximate nature and base data layers of future data visualization and knowledge management systems, we cannot predict them or their repercussions in full. We must be ready for anything.

The Significance of Convergent Technology Threats to Geospatial Intelligence

By Robert McCreight Ph.D.; Suzanne Sincavage Ph.D.; Tim Stephens; and Kimothy Smith Ph.D.

Today, serious security researchers who devote their energies assessing the realistic threats of 2020 and the immediate decade beyond may well consider the quiet, unrecognized but revolutionary developments in future evolution of modern technology. Such developments include synthetic biology, artificial intelligence (AI), enabled robotics, and complex biochemical compounds to enhance human health. Many of these contain essential elements that are inherently dual-use, possessing enough significant military applications to dramatically affect the strategic balance.

It is one thing to consider the linear growth and extrapolation of unique scientific technologies such as nanoscience, neuroscience, and synthetic biology out another decade. Here, we can soon expect breakthroughs in brain chemistry, uncovered neural pathways to more effective perception and clearer thought, and find cures for persistent diseases via the benefits of synthetic biology. All are of enormous societal and economic value to the human condition.

It is quite another thing to imagine and assess the strategic risks which may accrue globally as covert mixtures and deliberate blends of nanoscience, neuroscience, and synthetic biology evolve into outcomes which may be inimical to our national security and upend our understanding of how geopolitical leverage is measured. Experience has already revealed the dark, malevolent, and nefarious side of dual-use scientific endeavors from which either immediate, gradual, or long-term military applications are attainable and exploitable. We have also discovered that nuclear energy, complex cyber systems, and biochemical engineering contain as much risk of onward weaponization as they are a net benefit to society. It doesn't take much to imagine that mixed results and research—which we term "convergent technologies"—could trigger ominous developments that lead to unexpected weapons systems, nullify deterrence and defensive measures, trigger a call for new doctrine, and ultimately change the global strategic calculus in a decade. Imagine, for example, deliberate mixes of genomics, AI, and robotics. Defensive doctrine, strategy, and countermeasures are not obvious.

When we remember the 1970s and 1980s in terms of emerging weapons systems and newly revealed threats, we can point to better satellites, lasers, jump-jet technologies, and any number of new systems which redefined our nation's offensive capabilities or provided a distinct offensive or defensive edge.

The advent of military aviation, the tank, the missile, and the atomic bomb all provided in their own way evidence of progressively more sophisticated weaponry that heralded in an entirely new age of geostrategic threats, opportunities, and defense policies.

The chief challenge of the 21st century is to determine whether advanced technologies, especially as they are deliberately engineered to converge apart from, and in addition to, their ongoing linear sophistication, symbolizes an entirely new threat of interest to the GEOINT enterprise. Will it be largely benign and beneficial to modern global society and community of nations or instead will convergence inadvertently, or willfully, launch entire groups of sinister future weapons we cannot yet imagine or adequately prepare for. If new, more dangerous, and strategically significant weapons emerge, it makes sense to ask a few basic questions, including: Will future advanced weapons technologies remain in the hands of peaceful nations, or will they be available to all? Will they be restricted or controlled in any way? Will the nonproliferation and tech transfer set of security dilemmas become even more inscrutable, opaque, and impossible to trace for the U.S.?

For the geospatial intelligence (GEOINT) leadership, assessing and analyzing convergent technology threats (CTT) realistically requires a rigorous analytical process and potential pathway to derive useful GEOINT insights about estimating, ranking, and preparing for possible combinations of future linear and convergent threats. CTT embraces all the known and nascent advanced technologies that have both linear and convergent potential. This would include, at a minimum—lasers, nanotech, neurotech, synthetic biology, AI, robotics, genomics, autonomous systems, cybertechnology, stealth tech, hyperspectral tech, and many others with obvious and latent strategic value. Dangerous blends of AI, neurotech, and cybertechnology might result in standoff weapons that redirect, alter, or diminish normal brain functions as is suspected to have occurred at our embassy in Havana, Cuba. Nanotech robotics and AI could be engineered to become covert metabolic time bombs if inserted clandestinely with ordinary vaccination or nasal spray.

The decade beginning in 2020 will likely witness more frequent examples of both linear and convergent advanced dual-use technologies that outline the new frontiers of intelligence and threat assessment activity. If unhindered and unchecked, CTT could lead to unforeseen strategic outcomes and revolutionize every aspect of our arsenal or even render some existing systems obsolete. Anticipating these changes and devising approaches to deter, divert, or minimize their worst effects makes sense.

GEOINT Frontiers

The advent of CTT in many ways has already become one of the technical dilemmas and strategic goals of U.S. leaders. CTT emerges as a prime objective because, as we approach the edge of the arguable fourth offset era, keeping the technological edge and superiority the U.S. has traditionally enjoyed means intense global competition may put our own leadership in that domain at risk. We suggest that government, generally as the sponsor, developer, and overseer of CTT research, must confront a major governance challenge: promoting positive CTT outcomes globally while being aware of and neutralizing those deemed negative and harmful. This is a staggering technological dilemma because U.S. security leadership must reckon with the simultaneous linear extrapolation of cutting-edge technology as well as the results of malevolently engineered convergence. As the weapons systems and technologies advance and the dual-use landscape becomes wider and more complex, the factors that define, shape, and support strategic advantage are at stake.

Immediate GEOINT Opportunities

GEOINT leadership and experts face five-dimensional opportunities as the new threat frontier emerges which displays both linear and convergent technology developments. These five dimensions are merely a starting point for gauging the extent to which resources, projects, and personnel should be directed toward an immediate assessment of the CTTs and their strategic implications. These five areas of initial focus are:

1. Determining via experts which linear and convergent threats are imminent.
2. Assessing U.S. capacity to neutralize, respond, or overcome these threats.
3. Identifying U.S. high potential CTT research and development efforts that leverage GPS, remote sensing, and geospatial information sciences for defensive and deterrence purposes.
4. Devising appropriate doctrine and strategy for the emerging CTT battlespace.
5. Determining where and when the most strategically urgent CTTs will emerge.

A Path Forward

The locus of strategic responsibility for corrective action is shared equally among interagency players such as private sector science and technology incubators, the U.S. Intelligence Community, and the U.S. Departments of Defense, Homeland Security, Agriculture, Health and Human Services, and Energy. Overall leadership, control, and policy focus rests with the federal consortium of security agencies who reckon that CTT offers nothing less than a wholesale revolution in global security dynamics. Sharp, focused, comprehensive, and integrated assessments are needed today to understand both immediate and long-term CTT threats. The exact process for conducting these calibrated assessments would likely require a series of in-depth expert reviews, strategic simulations, white papers, expert seminars, and scientific conferences. This may require some preliminary classified agreements with think tanks, universities, and research foundations with an eye toward publishing papers, studies, and seminars to appropriately discuss and analyze the immediate and long-term implications of CTT on national security.

Examples include the Commercial GEOINT Activity (CGA) in partnership between the National Geospatial-Intelligence Agency (NGA), and the National Reconnaissance Office (NRO). Borne of a collective vision of NGA and NRO leadership, CGA will position both agencies to take full advantage of legacy and emerging commercial GEOINT capabilities to satisfy mission needs and maximize the efficiency and effectiveness of the overhead architecture. Technology advances are spurring better imagery collection and analysis and fueling worldwide demand for GEOINT. NGA and NRO joint assessment of observable and detectible technology convergence activities involve nefarious and benign mixtures of robotics, genomics, nanotech, and neurotech ventures with an emphasis on sorting out weapons design and configuration research.

NGA and NRO will direct CGA to lead the development and application of a framework to assess the technical capabilities of emerging commercial providers. It will advise each agency on the value proposition related to mission utility and help inform and synchronize NGA and NRO decisions related to the acquisition of commercial imagery capabilities. CGA will help shape U.S. remote sensing policy given emerging commercial capabilities and the new space environment. An example of this would be commercial and government-sponsored research that entails explicit technology convergence involving dual use activities such as robotics, genomics, and nanotech that drives the acquisition of enhanced imagery capabilities to further intensify and modernize NGA/NRO remote sensing, GPS, and GIS platforms and policy. The remote sensing community has spent considerable effort demonstrating many of these applications and has significant potential to provide useful information to analysts. Approaches that apply for the military, civilians, and Intelligence Community considerably overlap and use similar applications in various parts of the globe but for different purposes, for example, grouping by common functions such as reconnaissance (wide area survey) and surveillance (monitoring). Locating objects and events for the military (surface-to-air missile materials) and those used for the civilian community (weather, human/animal, plant, environment, social) produce different target outcomes but use similar applications to accomplish it.

Exploring new phenomenologies to exploit the full potential of new national, commercial, airborne, space, and ground technologies and transitioning their applications to the National System for Geospatial Intelligence (NSG) will address and support NGA in solving hard problems for the Intelligence Community and the military. Sensors of different modalities will be tested by models, simulations, and actual demonstrations to assess their potential contributions. With the focus on dual use convergent technology growth and complex integration, NGA will explore new technical phenomenologies to exploit the future operational evolution of national, commercial, airborne, and ground sensors and instruments aimed at capturing long-term complex problems for the IC and military.

Enhanced GEOINT analytics will enable analysts to quickly process voluminous and heterogeneous data inputs to determine their significance, extract relevant information, and discover subtle patterns and change detection indicators that may be critical to solving pressing intelligence problems. Focusing technology convergence on future, multidimensional dual use threats will enable NGA to generate new GIS products rapidly, and to develop visualization and presentation tools and displays to enhance the analyst and end user's ability to easily and intuitively understand and interact with spatio-temporal data.

There is an acute risk of hesitation, hyper-analysis, and stalemate if the questions of interagency leadership, funding, and policy direction are left unresolved. Agencies might compete for being the "lead agency" without regard for the damaging effects and negative influences such behavior might inflict on a time-sensitive strategic undertaking.

GEOINT leaders, and the intelligence and defense communities at large, should establish a multiyear plan for addressing CTT in terms of their potential to alter global security and usher in strategic surprise. They should outline appropriate steps for the U.S. to adequately and effectively anticipate, prepare, and respond to the array of CTT issues and challenges expected and unexpected. Efforts should be launched in FY 2019 to provide for capability milestones five years out. Annual CTT assessments (classified and unclassified) may be needed to increase chances for wider public and Congressional support and funding. This recommended multiyear plan would target the decade 2020–2030 for intensive analysis to determine how future CTT discoveries and developments would affect the Future Years Defense Program (FYDP) and the Intelligence Community budget, and to begin immediately recruiting the necessary talent and scientific expertise to properly assess onward CTT breakthroughs and activities.

This should be a truly bipartisan science and technology venture and program equivalent in strategic scope and impact as the Manhattan Project or NASA's Race to the Moon. Global CTT activities are likely to increase during the next decade, and the U.S. should retain the leverage necessary to monitor and ultimately influence its strategic outcomes and effects in the interests of our own security.

The Rise of Augmented Analysis: Defining Levels of Automation for Machine Learning Applied to Geospatial Intelligence

By David Lindenbaum and Ryan Lewis, CosmiQ Works; Todd M. Bacastow, Radiant Solutions; and Joe Flasher, Amazon Web Services

Machine Learning Applied to Remote Sensing

Since the release of AlexNet[1] by Alex Krizhevsky, Ilya Sutskever, and Geoffrey Hinton in 2012 to compete in the ImageNet Large Scale Visual Recognition Challenge, there has been an explosion of computer vision research focused on deep learning. There have been marked improvements in computer vision tasks such as image classification, object detection, and instance segmentation. Improvements in these computer vision tasks have profound implications for geospatial intelligence (GEOINT).

In recent years, there have been several data science competitions that aim to direct more computer vision research and development toward remote sensing applications. These competitions have generated new analytic techniques, ranging from general object detection to feature segmentation and classification (see Figure 1), that combine state-of-the-art computer vision with geospatial problems. As remote sensing-focused machine learning techniques mature, GEOINT practitioners need to understand and engage the research community to help structure the application of these new techniques against geospatial problems.

Currently, it is difficult to translate mission requirements to machine learning evaluation metrics and vice versa. For example, in the computer vision community, most results are described by certain image-specific metrics such as mAP, F1 Score, Precision, and Recall. Alternatively, a GEOINT practitioner may want to incorporate machine learning capabilities into his or her workflow, but not know what level of performance (or augmented support) is necessary for a specific mission.

In 2013, the automotive industry addressed this challenge for autonomous vehicle capabilities by establishing a taxonomy for levels of autonomous driving. The levels were defined from zero (no automation) to five (full automation). In this article, we will explore parallels of this framework relevant to GEOINT practitioners and propose a framework for defining levels of analyst augmentation. We hope this will allow geospatial end users and machine learning researchers to better understand each other, and perhaps help direct the application of these algorithms against geospatial problems.

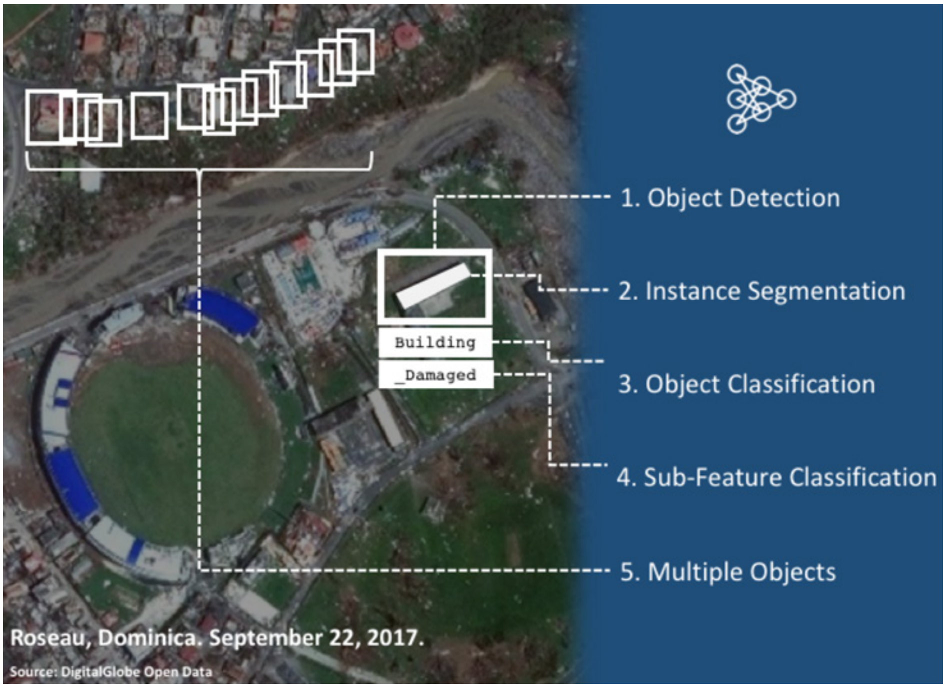

Figure 1. A visual depiction of the different types of computer vision techniques that can be applied to remote sensing data.

The use case of foundational mapping requirements, before, during, and after a hurricane is relevant given recent natural disaster events. We will define a taxonomy similar to the Society of Automotive Engineers' (SAE) Levels of Automation[2] to understand which capabilities are nearing readiness and which require more directed research.

Hurricane Disaster Response Use Case

Disaster response scenarios present a challenge for geospatial analysts and geographic information systems (GIS) professionals. Throughout the preparatory, response, and recovery phases of a disaster, analysts and aid organizations are charged with providing mapping solutions that are timely, dynamic, and accurate in order to support aid functions such as the delivery of critical supplies and services. Yet, the complexity, volatility, and sheer geographic scale of many natural disasters may limit the speed, and in some cases the accuracy, of manual mapping annotation techniques. While global crowdsourcing initiatives such as Humanitarian OpenStreetMap Team (HOT)[3] have significantly increased the speed and robustness of dynamic mapping data generation

1. https://papers.nips.cc/paper/4824-imagenet-classification-with-deep-convolutional-neural-networks.pdf
2. https://www.sae.org/standards/content/j3016_201806/
3. https://www.hotosm.org/

and dissemination, rapidly maturing machine learning techniques, specifically computer vision, can help accelerate the development of timely maps over large geographic areas.

Hurricanes Irma and Maria wreaked near record-level economic and humanitarian devastation across a large portion of the Caribbean in September 2017. Some of the hardest hit areas, such as Puerto Rico, are still recovering from the storm's effects more than a year later.[1] The large number of affected areas along with the speed of the storms, particularly Hurricane Maria, pushed open-source, manual mapping processes to the limit. For example, HOT leveraged more than 5,300 mapping volunteers to produce more than 950,000 building footprint labels and upward of 30,000 kilometers of roads labels in approximately five weeks for locations affected by Maria.[2] This was truly an amazing feat, but it presents the question: How could machine learning accelerate this map generation process? More specifically, what are the map key features (layers) contributors are labeling and which features could benefit from automation?

During the early response to Maria, the most important map feature was arguably building footprints as they represent the foundational infrastructure of where people live and work. Since there were limited preexisting quality data on structure counts, locations, and classifications (i.e., purpose of the structure), first responders did not have detailed information on the number of people potentially in vulnerable or remote locations.[3] As a result, it was difficult for responders to prioritize aid missions. For instance, when authorities decided to evacuate areas downstream from the Guajataca Dam in Puerto Rico due to the dam's potential for collapse, officials needed to know the size of the surrounding population.[4] Counting and classifying structures was one method for approximating population size. From the American Red Cross' request for updated building footprints on September 22 to the release of the "first pass" map on October 25, HOT, in conjunction with its mission partners, conducted 12 separate labeling campaigns for buildings in Puerto Rico.[5]

Although there were existing road network maps for a majority of Puerto Rico, the dynamic nature of Hurricane Maria required timely updates to the road network. More than 1,500 roads were damaged, blocked, or washed out from the hurricane. As a result, first responders needed rapid updates to transportation maps to determine where supplies could and should be sent.[6] Given the widespread damage to the road network, initial mapping efforts were primarily focused on identifying which routes were passable.[7] Efficient logistics and route planning were particularly important during the first days of the response phase because Puerto Rico did not have sufficient aid supplies such as generators and water filtration systems warehoused locally.[8] Analysts and mapping volunteers completely updated the labels for Puerto Rico's road network during a five-week period.

The third map feature category analysts provided were critical infrastructure points of interest (POIs). Since the entire island of Puerto Rico lost power when Maria made landfall, an important classification feature was power infrastructure. The island's prolonged blackouts, and the associated catastrophic effects including loss of life, highlight the complexity of identifying specific types of infrastructure.[9] Puerto Rico also experienced severe communications challenges in the days following Maria. To make matters worse, officials and responders had an insufficient supply of satellite phones. Analysts were also asked to identify communications infrastructure such as microwave towers in an effort to assist responders and local utility providers.

Lastly, identifying medical facilities and infrastructure was important due to power outages, flooding, and damage at some of the area's largest hospital centers.[10] The identification of POIs was particularly challenging for analysts because it required them to both identify a particular structure, classify the type of structure, and then determine the presence and severity of damage. Based on previous studies looking at remote sensing imagery after the 2010 earthquake in Haiti, accurate classification of structures and subsequent damage only using satellite imagery or airborne datasets was not possible because a damaged building was not necessarily visible from directly overhead.[11] In order to detect and verify building damages, a site survey and/or off-angle image were required in order to adequately collect imagery showing characteristics of building damage, particularly collapsed or partially structures.

The scale and diversity of mapping tasks associated with disaster response scenarios such as Hurricane Maria present several potential functions for emerging machine learning technologies. First, and most generally, machine learning can assist in the provision of labeling assignments by determining the level of complexity in each image assignment prior to tasking. More complex scenes could be assigned to experienced mapping analysts and labelers while simpler scenes could be directed toward novice analysts. Second,

1. https://www.theguardian.com/world/2018/aug/08/puerto-rico-hurricane-maria-electricity-ten-months
2. https://wiki.openstreetmap.org/wiki/2017_Hurricanes_Irma_and_Maria
3. https://www.philanthropy.com/article/Podcast-Nonprofit-Creates/244125
4. https://www.dw.com/en/puerto-rico-evacuates-thousands-as-dam-breach-threatens-floods/a-40650400
5. https://wiki.openstreetmap.org/wiki/2017_Hurricanes_Irma_and_Maria
6. https://www.pbs.org/newshour/nation/volunteers-helping-puerto-rico-home-map-anyone-can-edit
7. https://www.wsj.com/articles/inside-puerto-ricos-struggle-to-recover-a-month-after-hurricane-1508491811
8. https://www.npr.org/2018/07/14/629131912/fema-internal-report-cites-problems-with-agencys-response-to-hurricane-maria
9. https://edition.cnn.com/2018/08/29/us/puerto-rico-growing-death-toll/index.html
10. https://www.humanityroad.org/situation-reports/caribbean/hurricane-maria
11. The Development and Uses of Crowdsourced Building Damage Information Based on Remote-Sensing.

object detection algorithms could be used to perform quality control on the mapping annotation data submitted by analysts. The primary role of algorithms in this function would be as an assistive technology to ensure analysts do not miss key features. Third, object detection (and potentially classification) algorithms could provide an assessment of each image before being assigned to a mapping analyst for human inspection. While this implementation could greatly increase analyst performance and speed, it requires a high level of algorithmic performance that may not be realistic in some complex scenes with today's technology.

Defining an Automation Taxonomy

In January 2014, SAE released its first version of *J3016: Taxonomy and Definitions for Terms Related to Driving Automation Systems for On-Road Motor Vehicles*. This document was instrumental in unifying the language and providing clarity about the intended capabilities of products in design. It describes six levels of automation from no driving automation (Level 0) to full driving automation (Level 5). As autonomous driving capabilities have evolved, this taxonomy has gone through two revisions and has grown from 12 to 35 pages.

Building a similar taxonomy for geospatial problems would allow the GEOINT Community to move from a technology-centric definition to a use case-centric definition. This would help the community better understand what it is asking of new technology and the types of performance that should be expected.

Figure 2 is a proposed taxonomy for moving toward automated building extraction for foundational mapping in the context of a disaster response scenario. It separates two equally difficult tasks, localizing objects in an image, and fine grade classification of objects in that image.

Current State of the Art

In the last two years, several open-source datasets designed to move the state of the art forward in applying machine learning to the challenges of accurate building maps were developed. The SpaceNet Buildings Dataset has more than 800,000 building footprints across six cities (Atlanta, Khartoum, Las Vegas, Paris, Rio de Janeiro, and Shanghai)[12] and is designed to improve the performance of extracting building footprints from satellite imagery.

In July 2017, the Intelligence Advanced Research Projects Activity (IARPA) released its Functional Map of the World (fMoW) dataset, which includes more than 1,000,000 DigitalGlobe satellite image chips covering 63 categories such as airport, police station, hospital, shopping mall, and single unit residential building, and is designed to improve the classification of already identified buildings and structures.[13]

The SpaceNet dataset enables the creation of Level 1 or Level 2 automated systems. The fMoW dataset enables the creation of a Level 2 system for building classification. To enable Level 3 to Level 5, systems trained from both datasets would be required or, ideally, another dataset created to enable assessment of Level 3 to Level 5 systems for creating foundational maps of a region.

Conclusion

Innovations in machine learning continue to benefit the GEOINT Community by providing automation to enable mapping and analysis at unprecedented speed, scale, and efficiency. The application of this technology to drive improved mission outcomes should remain the focus of the community. To this end, understanding what level of performance or augmented support is necessary for a given mission remains a challenge and opportunity for GEOINT practitioners. We proposed a taxonomy and definition analogous to the six levels for autonomous vehicle driving with the goal of helping to enable the application of advanced machine learning algorithms against geospatial problems. Improving the community's understanding of what levels of automation are possible and how much automation should be applied in a given scenario is essential to gaining advantage during mission-critical situations such as natural disaster response.

Level	Description
Level 0	No automation from machine learning. Traditional desktop or web-based GIS software would commonly be used with standard cartographic functions and tools.
Level 1	Machine learning is used to create a general count of an object in a broad feature class in an area. This should be used in situations for which large errors in count can be tolerated.
Level 2	One single specific task is automated to provide a suggestion to a human. For example, providing a geo-located bounding box or polygon, or providing a recommended label for a specific feature such as a residence, office, police station, or hospital.
Level 3	The complete labeling activity is automated and a complete footprint and narrow feature label is sent to a human labeler, and a recommended label for a specific feature is provided for a human to assess.
Level 4	The complete labeling activity is automated and a complete footprint and narrow feature label is sent to a human, and a recommended label for a specific feature is automated for a geospatially confined area.
Level 5	The complete labeling activity is automated and a complete footprint and narrow feature label is automated for the entire globe.

Figure 2. Proposed Taxonomy for Foundational Mapping Levels of Automation.

12. https://spacenetchallenge.github.io/
13. https://arxiv.org/pdf/1711.07846.pdf

Knowing Your Opponent and Knowing Yourself: Lessons from Comparing U.S. and Russian Geospatial Intelligence

By Dr. Todd Bacastow, Penn State; Dan Steiner, Orion Mapping; Stephen Handwerk, Penn State; Dr. Dennis Bellafiore, Penn State; Dr. Greg Thomas, Penn State; and the Penn State Comparative Geospatial Intelligence Seminar[1]

Geospatial intelligence (GEOINT) is known to be practiced by nations other than the U.S. but not called by the same term.[2] These nations might be partners, friendly competitors, or threatening foes. GEOINT's intent is to disadvantage your opponent with information they do not have or they do not know you have. Sun Tzu, an ancient military strategist, writer, and philosopher, articulates the notion as the principle of knowing your enemy while knowing yourself:[3]

> *"If you know your enemies and know yourself, you will not be imperiled in a hundred battles; if you do not know your enemies but do know yourself, you will win one and lose one; if you do not know your enemies nor yourself, you will be imperiled in every single battle."*

This article speaks to the necessity of a comparative view of yourself and an opponent in GEOINT. We illustrate the need for a comparative approach in education by examining GEOINT in the United States and the Russian Federation (RU). Our example is to illustrate that reliable GEOINT demands knowing both your opponent and yourself. The results of the study are more relevant to GEOINT educational goals and the comparative process than informative of RU GEOINT capabilities since there is little open source and explicit information about RU GEOINT doctrine.

Identifying Geospatial Intelligence

GEOINT is easy to distinguish in the U.S. (it's called GEOINT by law) and its governmental structures. Since few other countries have such openness, use similar definitions, or mirror the U.S. structure, it is essential to identify the reasoning and basic behaviors of people performing GEOINT.

Research suggests that GEOINT reasoning uncovers how human action is constrained by the physical landscape and perceptions of the Earth.[4] As such, GEOINT has the organizational behavioral characteristics of being polymorphic,[5] metadisciplinary,[6] craft-based, and competitive. The polymorphic nature of GEOINT is apparent in RU's different organizational forms. In RU, there is not an agency whose primary mission is GEOINT as with the National Geospatial-Intelligence Agency (NGA) in the U.S. Metadisciplinary appears as expertise from two or more disciplines around a shared problem. In both nations, GEOINT encompasses many disciplines to answer basic questions. The U.S. and RU utilize craft-based processes in which thinking is through the senses and deeply entangled.[7] Such craft practice creates knowledge from the researcher-practitioner's experience. Competition is when one entity seeks to gain an advantage over a rival. Applying these concepts, we found that RU performs GEOINT.

Comparative Process

As part of a summer 2018 research seminar, Penn State graduate students and faculty applied comparative methods to examine GEOINT in the U.S. and RU. Our process was modeled after that used in comparative education, which is a long-established academic field that examines abstract units of a system of systems. Our units of comparison were aspects of the GEOINT Community and work. A nine-cell table was used to compare the work of GEOINT communities. The major aspects of community that were examined included mission, organization, and business processes. This was compared in the table to GEOINT work, which included tradecraft, people, and technology.

U.S. GEOINT

Oversight of the U.S. Intelligence Community (IC) is shared by both the elected executive and legislative branches of the government to ensure public accountability. Transparency is a key policy and goal of the U.S. GEOINT Community.[8] Transparency includes the legal, political, and institutional structures that make information about the internal characteristics of government available to those inside and outside the political system.[9]

Congress created the National System for Geospatial Intelligence (NSG) to integrate GEOINT within the U.S. IC. The Geospatial Intelligence Basic Doctrine Publication 1.0 defines NGA's mission and the agency director's role as functional manager of the NSG and coordinator of the global Allied System for Geospatial Intelligence (ASG).[10] NGA is responsible for managing the GEOINT Enterprise with a mission of acquiring, developing, and maintaining the proper technology,

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1. The Penn State Comparative Geospatial Intelligence Seminar participants included Ericka Kato, Raven Bowden, Scott Kanzelmeyer, Cathryn Sacs, Joshua Smith, and Jonathan Thompson. July 23, 2018.
2. Todd Bacastow (2016a). "Viewpoint: A Call to Identify First Principles." *NGA Pathfinder*, January 2016. https://medium.com/the-pathfinder/viewpoint-a-call-to-identify-first-principles-d5e21cb2ce40.
3. Lionel Giles. *The Art of War by Sun Tzu (1910).* Allandale Online Publishing; 2000. p 45.
4. Todd Bacastow (2016b). "Comparative Geospatial Intelligence (GEOINT) Professional Communities." *European Conference of the International Association for Intelligence Education*, Netherlands Military Academy, Castle of Breda, The Netherlands on June 23, 2016.
5. GEOINT is polymorphic, meaning that it occurs in different forms in difference organizations and might not use the same lexicon.
6. Metadisciplinary is a discipline that transcends traditional field boundaries to create an integrated discipline uninhibited by familiar academic limits and barriers. Instead of merely linking fields at their margins, metadisciplinary means working simultaneously in multiple fields both theoretically and practically.
7. Nithikul Nimkulrat. "Integrating Craft Practice into Design Research." *International Journal of Design,*.2012:6(3):1. https://www.researchgate.net/publication/278367044_Hands-on_Intellect_Integrating_Craft_Practice_into_Design_Research.
8. Todd Bacastow, Stephen Handwerk, Gregory Thomas, Dennis Bellafiore, Susan Coster, Larri Rosser, and Mark Tapee (2016c). "Bringing Transparency to Transparency" *2016 State of GEOINT Report*, The United States Geospatial Intelligence Foundation.
9. Bernard Finel and Kristin M. Lord. "The Surprising Logic of Transparency," *International Studies Quarterly*, 1999:43(2):315-339.
10. National System for Geospatial Intelligence (NSG): Geospatial Intelligence (GEOINT) Basic Doctrine Publication 1-0. NGA. 2018.

people, and processes to produce GEOINT.

A key goal of U.S. GEOINT is to enhance geospatial situational awareness. Consumers of GEOINT include the military, policy-makers, the IC, the U.S. Geological Survey, the Federal Emergency Management Agency, law enforcement, allied countries, and other federal agencies and civil authorities. Through NGA, GEOINT supports humanitarian assistance, disaster recovery, land reclamation, historic preservation, and domestic security at special events.[11] U.S. GEOINT is a unique intelligence discipline. As a metadiscipline it includes geodesy, geophysics, photogrammetry, remote sensing, human geography, physical geography, GIS, geospatial analysis, cartography, data fusion, crowdsourcing, visual analytics, and forecasting.[12] These varied disciplines influence the U.S. GEOINT tradecraft.

The U.S. GEOINT Community is comprised of varied professionals, most of whom have college degrees. NGA and industry contractors train their GEOINT analysts, require certifications, and provide professional development. Geospatial foundational knowledge, as well as an ability to apply emerging technologies, are important, as are soft skills such as cognitive thinking, creativity, and communication. The cultural diversity of the U.S. GEOINT workforce is valued to maintain varied perspectives.

The U.S. uses technology to achieve an advantage, continually seeking to gain more information than opponents. A critical task is to disseminate GEOINT products to decision-makers in advance of events. Important technologies are military Distributed Common Ground Systems (DCGS), aircraft and onboard sensors, secure servers and computers, and Earth orbiting satellites. The loss of secure communications, precise positioning and navigation, and intelligence and surveillance would dramatically affect U.S. ability to conduct GEOINT operations.[13] The use of artificial intelligence (AI) is being increasingly applied to activities such as image object analysis, processing raw data into usable imagery, and GIS data collection, management, analysis, and dissemination. Future mission success suggests extracting intelligence from large volumes of inconsequential data and images. The application of emerging technologies complements commonly and widely used active and passive sensors.

RU GEOINT

Since the collapse of the USSR in 1991, RU geography has experienced new borders, political leadership, security challenges, an economic crisis, degradation of infrastructure, privatization, globalization, de- and reindustrialization, demographic changes, and migration.[14] This chaos notwithstanding, in 2016, RU had more billionaires than the United Kingdom.[15] RU has a free education system with a literacy rate of more than 99 percent, and competitive entry makes advanced schooling some of the world's best.[16] Politically, RU faces challenges to Moscow's rule in the majority-Muslim North Caucasus region including Chechnya, Dagestan, Ingushetiya, Kabardino-Balkaria, and Karachay-Cherkessia.[17] All these changes impact RU GEOINT. The effect is difficult to determine since RU intelligence organizations work under conditions of strict secrecy because of the tendency to treat the outside world with "maximal suspicion."[18] Add to this RU's history of fabricating events to serve political goals, and the challenge of understanding RU GEOINT is significant.[19]

The RU GEOINT community appears to be substantial. Since the 1970s, the Soviet Union progressed from making cartographic products using human intelligence to electronic processes. RU has a strong legacy of geographic thought and cartography, compiling detailed maps for its global sphere of influence.[20] The RU GEOINT community employs the same academic disciplines as the U.S. but lacks the same organizational concentration in a single agency such as NGA. Their use of GEOINT provides RU ministries, agencies, and directorates with information to mitigate and respond to natural disasters, civil matters, and perceived military threats.

In RU, GEOINT appears to be an amalgamation of defensive and proactive missions performed within military intelligence, federal security, and interior ministry organizations. The goal of RU GEOINT, in addition to providing geographic information, is to modify the human landscape. This mission is the result of the internal political culture and the perceived threats to the state. The scope of RU activities is further motivated by the perspective that peripheral countries of the former Soviet Union have limited sovereignty. High priority is placed on economic and technological development to counter Western actions.[21]

11. Robert Cardillo. *Statement for the Record Before the Senate Select Committee on Intelligence*. September 2016. https://www.nga.mil/MediaRoom/SpeechesRemarks/Pages/Director-Cardillo-Senate-Select-Committee-on-Intelligence-open-hearing.aspx
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RU intelligence leadership includes government officials, heads of state-owned enterprises, and private corporations. The Ministry of Defense answers to the RU president. RU Foreign Intelligence Service is comparable to the U.S. Central Intelligence Agency, relying on its Main Intelligence Directorate (GRU) to collect foreign military intelligence. The Federal Security Service (FSB) is a domestic security and counterintelligence agency.[1] Also under Ministry of Defense control are the Aerospace Defense Forces tasked to launch military and civilian spacecraft using separate integrated satellite systems to provide RU Armed Forces with military-related information.[2]

RU collects imagery from satellites, manned aircraft, and unmanned aerial vehicles using electro-optics, LiDAR, hyperspectral and multispectral, full-motion video, and various other sensors. RU has more than 130 civilian and military spacecraft performing communication, Earth observation, navigation, geodetic survey support, reconnaissance, and intelligence gathering missions. RU's current systems provide an array of capabilities including high-resolution imagery, terrestrial and space weather, missile warning, electronic intelligence, and scientific observations to develop detailed GIS and GEOINT products.[3] RU uses international open-source and commercial vendors to supplement imagery requirements.

RU has identified the need to keep pace with other modernized countries' GEOINT communities. A specific RU goal in future war scenarios is to eliminate an opponent's satellite systems.[4] RU is modernizing its space capabilities and has developed new counterspace weapons, including direct-ascent and co-orbital kinetic anti-satellite systems, an airborne lasing platform, advanced jamming and spoofing capabilities, and formidable cyberattack capabilities.[5]

RU's goal to once again become a world power has shaped RU GEOINT tradecraft, seeking to achieve an advantage over opponents who threaten the balance of conditions. RU's operational philosophy promotes using propaganda, disinformation, denial, and deception to influence internal, regional, and global political actors.[6] The RU doctrine of maskirovka—denial and deception—includes measures such as concealment, decoys, denial of information, and disinformation. Maskirovka causes confusion, doubt, and mistrust.[7]

RU's First Deputy Minister of Defense expects AI to aid RU military to obtain a "library of goals," which will help supplement weapons recognition and guidance.[8] Specifically, AI is intended to:

- Automate the analysis of satellite imagery and radar data by quickly identifying targets and picking out unusual behavior by enemy ground or airborne forces.
- Perform change detection, predictive analysis, and real-time weather and ocean monitoring.

Comparing GEOINT in the U.S. and RU

The U.S. and RU have obvious similarities in their GEOINT activities. Both countries use GEOINT to achieve a decision advantage. Both the U.S. and RU use GEOINT to reveal how human action is constrained by the physical landscape. Both have craft-based approaches. There are, however, striking differences:

- RU performs GEOINT in the environment of "maximal suspicion;" the U.S. performs GEOINT under a policy of transparency.
- RU has no single identifiable agency responsible for GEOINT; the U.S. has NGA.
- RU applies GEOINT in an environment of protracted political control; the U.S. adjusts objectives with election cycles.
- RU proactively uses GEOINT to influence the human landscape; the U.S. views GEOINT as a situational awareness tool.
- RU's GEOINT activities are limited by internal leadership; in the U.S., oversight is driven by public sentiment.

These differences are manifested in a nation's tradecraft. Since RU tradecraft is guided by political goals, RU is using GEOINT not only for military and humanitarian purposes but to achieve economic and geopolitical goals. This includes using GEOINT to reshape the human landscape to their advantage. This is contrasted with the U.S. GEOINT tradecraft, which is focused on providing information about environmental elements to project their future status.

Maskirovka belies the RU GEOINT tradecraft and provides a range of preemptive, non-kinetic actions. RU tradecraft furthers goals by distracting an opponent's attention to other geographies, disguising what is happening on the ground, and creating confusion with false information. RU's leverage of proxy governments and their military forces in Ukraine, Syria, and Afghanistan are working examples designed to undermine Western objectives. In Syria's civil war, RU-backed, pro-regime forces threaten to attack U.S. and U.S.-backed Syrian Democratic

1. Mark Galeotti. "Russian Intelligence Is at (Political) War." *NATO Review Magazine*, 2017. https://www.nato.int/docu/review/2017/also-in-2017/russian-intelligence-political-war-security/EN/index.htm.
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5. Todd Harrison, Kaitlyn Johnson, and Thomas Robert. Space Threat Assessment 2018; A Report of the CSIS Aerospace Security Project. Center for Strategic & International Studies. 2018. p 12-13. https://www.csis.org/analysis/space-threat-assessment-2018
6. Emilio Iasiello. "Russia's Improved Information Operations: From Georgia to Crimea." *Innovations in War & Strategy*, 2017. p 55. https://ssi.armywarcollege.edu/pubs/Parameters/issues/Summer_2017/8_Iasiello_RussiasImprovedInformationOperations.pdf
7. Timothy C. Shea. "Post-Soviet Maskirovka, Cold War Nostalgia, and Peacetime Engagement," *Military Review*, 2002:82(3):63-67. Retrieved from http://ezaccess.libraries.psu.edu/login?url=https://search-proquest-com.ezaccess.libraries.psu.edu/docview/225321191?accountid=13158.
8. Samuel Bendett. "In AI, Russia Is Hustling to Catch Up," *Defense One*. 2018. https://www.defenseone.com/ideas/2018/04/russia-races-forward-ai-development/147178/.

Forces. RU appears to be shaping post-conflict negotiations over Syria in line with RU geopolitical goals. The Institute for the Study of War (ISW) researchers observe "these condition-setting activities would allow Putin to escalate militarily to challenge U.S. interests in multiple theaters simultaneously if he so chose."[9]

Implications and Recommendations

In summary, RU understands the competitive nature of GEOINT. However, this research also showed the importance of understanding the GEOINT capabilities of competitors. This essential element of comparative advantage must be incorporated in the U.S. GEOINT educational community's body of knowledge. Without it, the U.S. educational community is limiting its effectiveness. The U.S. GEOINT educational community needs to adopt a view embodying the philosophy of knowing your opponent while knowing yourself.

U.S. academic institutions awarding GEOINT certificates through the United States Geospatial Intelligence Foundation (USGIF) use USGIF's GEOINT Essential Body of Knowledge (EBK) to guide teaching and learning.[10] The current EBK does not explicitly address the competencies where a student would learn and practice the skills of analyzing the GEOINT capabilities of a competitor or foe in another country. Without this, students in the U.S. are open to falling into the intelligence trap of assuming that the people being analyzed think like they do. This is not to suggest that some or most of the USGIF-accredited programs do not teach about understanding an opponent. This is to suggest that the way the EBK is structured and was implemented does not emphasize understanding an opponent. Specifically, the EBK has seven core competencies—four technical and three cross-functional knowledge areas. The technical competencies were implemented first, and the cross-functional GEOINT knowledge, skills, and abilities, which generally reflect the human aspects of the discipline, are just now being realized. This fosters an impression that GEOINT values technology over the human cognitive thought process.

Based on this research, the U.S. GEOINT educational community should use the comparative approach to give equal balance of the human geographic aspect of GEOINT with that of the technologic aspects of the discipline. The following recommendations are made to achieve the balance:

- Represent and teach GEOINT as a discipline focused on rendering advantage over an environmental or human opponent.
- Develop and share with the community a method of teaching comparative GEOINT that instills the philosophy of knowing your opponent while knowing yourself.
- Balance the learning of GEOINT's technical and non-technical knowledge, skills, and tradecraft by emphasizing how the technical tools are explicitly applied to examine and understand the interrelationships among people, place, and environments.

Conclusion

Success in GEOINT is to combine the utilitarian aspects of technology with a sophisticated understanding of ourselves and our rival. Knowing these things, we can develop and apply GEOINT based on knowledge and skill rather than on speculation and blind action. Since comparative studies are neither common in U.S. GEOINT curriculum nor is there a specific competency pertaining to the skill of knowing an opponent, the community cannot be certain the advancing student has the skills to understand their opponent. Without the depth and agility of this comparative thinking, the U.S. GEOINT Community is opening itself to failure. Not knowing how to examine an opponent, the analyst cannot penetrate their "geospatial mind;" the analyst cannot anticipate how the opponent might attempt to stymie their progress. Until we formalize the competency of analyzing how others think and/or act geospatially, GEOINT education in the U.S. is incomplete.

Rapid Terrain Generation for Geovisualization, Simulation, Mission Rehearsal, and Operations

By Steven D. Fleming, Ph.D., and Ryan McAlinden, the University of Southern California; Matt S. O'Banion, Ph.D., Christopher Oxendine, Ph.D., and William Wright, Ph.D., the United States Military Academy at West Point; and Ian Irmischer, Ph.D., the United States Air Force Academy

Geospecific 3D terrain representation (aka reality modeling) is revolutionizing geovisualization, simulation, and engineering practices around the world. In tandem with the rapid growth in unmanned aerial systems (UAS) and small satellites, reality modeling advancements now allow geospatial intelligence (GEOINT) practitioners to generate three-dimensional models from a decentralized collection of digital images to meet mission needs in both urban and rural environments. Scalable mesh models deliver enhanced, real-world visualization for engineers, geospatial teams, combatant, and combat support organizations. In this, reality modeling provides a detailed understanding of the physical environment, and models allow installation engineers and GEOINT practitioners to quickly generate updated, high-precision 3D reality meshes to provide real-world digital context for the decision-making process.

9. Catherine Harris, Jack Ulses, and Mason Clark. *Russia in Review: August 28 – September 13, 2018.* Institute for the Study of War. 2018. http://iswresearch.blogspot.com/search?q=russia+in+review
10. United States Geospatial Intelligence Foundation (USGIF). "GEOINT Essential Body of Knowledge." 2015. http://usgif.org/system/uploads/3858/original/EBK.pdf. Accessed on July 20, 2018.

On the facilities engineering front, projects can be planned, designed, and completed more quickly and easily with lower costs. These models integrate with existing CAD tools to save time and money in facility design. Facility operations and maintenance, construction site inspection, asset management, environmental management, and management of military training ranges all benefit from this technology. In deployed environments, ground commanders, military planners, engineers, and practitioners can use 3D models for mission planning and rehearsal, terrain generation, route mapping and clearance, base layout and design, infrastructure planning, IED-modeling and post-blast assessment, cover/concealment, and more. For post-attack recovery efforts, practitioners can quickly send drones to capture existing conditions, then model the damage and map unexploded ordnance to assess the situation and develop a recovery plan—while minimizing exposure to deployed troops. Operational units such as infantry and special operators can produce models to map the battlespace and to enhance defensive preparation efforts or model assault objectives. Units can now quickly determine mission conditions and answer questions such as: Can our vehicles fit in that alleyway? Can we land a helicopter on that roof? What is my line of site at this location?

Modeling and Simulation Possibilities

The use of non-traditional, decentralized data collection sources supports next-generation digital Earth representation and the desires to achieve unique 3D visualization and terrain development for many U.S. government modeling and simulation (M&S) communities, including the Department of Defense (DoD) and the Intelligence Community (IC). Work is being done for U.S. Joint Staff-funded projects designed to assist the DoD in creating the realistic, temporarily accurate, precise, and informative representations of the physical and non-physical landscape. In addition, and as a part of the Army Synthetic Training Environment (STE) Cross Functional Team (CFT), reality modeling is helping to establish a next-generation government/industry terrain standard for M&S hardware and software for use in training and operational applications. To this end, the following goals are being advanced:

- Construction of a single, authoritative, updated 3D geospatial database for use in next-generation simulations and virtual environments.
- Utilization of commercial cloud-front solutions for storing and serving geospatial data.
- Protocols for procedurally recreating 3D terrain using drones and other collection equipment/sensors.
- Reduction of cost and time for creating geospecific datasets for M&S.
- Utilization of non-traditional, open, and market sources of geospatial data.

There are anticipated impacts of potential applications enabled by this work. The One World Terrain (OWT) effort is principally centered around understanding and planning for the next-generation of M&S technology. More specifically, OWT relates to the feasibility of turning collected terrain data into simulation-usable terrain features that can be employed in real-time by simulation platforms. This work hopes to demonstrate how rapid terrain generation and user-driven social media data may be incorporated in real- or near-real-time into a virtual or constructive environment for geovisualization and simulation applications.

Data Challenges

As more and more data saturates the digital landscape, we have become increasingly reliant on technologies to help sift, sort, analyze, and visualize. One example is the way one collects, processes, and uses geospatial data. The field has evolved rapidly from paper maps with acetate overlays, to the digital 2D maps of the 1990s and 2000s, to the 3D immersive representations we see today. This data continues to grow in abundance and requires a new breed of cross-disciplinary collaboration and research to ensure its utility is maximized.

Identifying and developing ways for users to exploit and better understand the 3D world through automation is becoming increasingly popular and relevant. Virtual and augmented reality continue to proliferate and are now mainstays in society. Map-based data are used in many of the most popular applications on common devices, from consumer review apps (like Yelp), to ride sharing, to games. However, the ability to produce and visualize 3D geospatial content for these devices remains elusive. The process for generating such content is existentially a human-intensive process, and, as a result, time-consuming, inefficient, and inconsistent. Spatial scientists are attempting to ease the burden of creating and using 3D terrain content in electronic devices as quickly and cost-effectively as possible. Ultimately, the research goal is to achieve complete automation of how one creates the digital world around us, removing the human from the loop.

Cutting-Edge Processes

In order to understand the challenges with 3D geospatial terrain, the problem is best decomposed into its constituent parts: collection; creation (processing); storage and distribution; and application. More precisely, the questions often asked when assessing 3D terrain include: How is source terrain data collected? How is that data processed into a form digestible by an application? Where is it stored and how is it distributed? And how is it used by consumers?

Research has been conducted on the challenges presented by 3D terrain data for several decades, harkening back to the days of the Topographic Engineering Center (TEC). In the DoD, tremendous efforts have focused on building the Army's suite of next-generation interactive simulation and training platforms. Years ago, terrain was often considered the "Achilles' Heel" of simulators. Its generation is time-consuming, expensive, manpower-intensive, and fraught with vagaries that result in unrealistic, unsatisfying, and often uncompelling synthetic experiences. Simulation environments are often created with entities floating above the terrain because of correlation issues, or virtual characters passing through walls because the models were not attributed correctly. And until recently, creating the virtual terrain in applications was purely a manual activity, with artists, modelers, and programmers spending significant time and money to create one-off terrain datasets that were rarely able to be repurposed in other rendering environments. Limitations in processing and artificial intelligence (AI) and poor-quality source data compounded the problem for decades, stalling attempts to fundamentally change the way terrain is created for virtual applications.

However, over the past 5 to 7 years, the introduction of cloud computing, better and cheaper processors and graphics processing units, and new sources of high-resolution terrain data (unmanned systems, airborne and terrestrial LiDAR, small satellites, crowdsourcing, photogrammetry, and commercial industry mapping resources such as Bing or Google Maps) have provided new procedures for terrain generation. The opportunity has arisen to reduce the time and cost for creating "digital dirt" by automating what were previously manual efforts. Automated functions include procedurally-generated textures and polygons, the correlation and linking of datasets, and adding application-specific attribution to models that allows the simulation to reason with colliders, navigation meshes, and other entities. Leveraging these advancements and combining them with specific research areas has allowed the M&S community to exponentially grow its capabilities and output.

Unlike traditional geospatial research (which often falls to academic geography departments), this line of research incorporates the disciplines of geomatics (e.g., remote sensing, surveying, navigation, and positioning) and computer science (e.g., AI, computer vision, image processing, and computer graphics). The ability to automate from "source to runtime" requires algorithmic approaches that can add, manipulate, and preserve data attributes and qualities that allow the data to be rendered and simulated in 3D. This collaboration is crucial as disciplines seek to exploit data, computational resources, and knowledge. Collaboratively, much of the current work is focused on automating the workflow from collection to application. Specifically, the steps to this end include:

Collection:

How can one organically collect and fuse their own 3D geospatial data, use existing open and market-based sources, and leverage previously-collected data? To accomplish this, one relies on automatic geo-referencing and correlation of the data using traditional GIS techniques such as ground-sampling distance as well as newer techniques for 3D terrain data collection such as automated photogrammetric reconstruction.

Creation (Processing):

This dynamic work with the data entails manipulating source GIS data into a form that a runtime application can not only display but reason against. Techniques rely heavily on machine learning as well as more traditional AI techniques to analyze and segment the data into its constituent parts (elevation, vegetation, roads, buildings, etc.).

Storage & Distribution:

3D terrain data can be very large, on the order of several petabytes to cover the Earth's surface at one-meter resolution. Storing all of the data in the cloud is cost-prohibitive, and storing it locally is impractical for bandwidth and throughput reasons. Researching strategies and techniques for storing and serving the data is central to addressing these challenges. Basic research centers on identifying intelligent storage means (dynamic load balancing and cloud instancing; hot versus cold storage) that allow for a cost-effective, yet efficient 3D storage and distribution mechanism.

Application (Rendering & Simulating):

Displaying terrain data is where the most fundamental research challenges remain. Adding semantic labels and metadata to the underlying data is critical so the engine can differentiate how the data is to be used at runtime (e.g., whether something will drive on it, shoot through it, move through it, hide behind it, etc.). This is where some of the most manually intensive activities continue to be centered, such as adding colliders around buildings, navigation meshes, lighting properties, and higher-order metadata for AI agent reasoning. Moreover, much of the investment for automating the terrain workflow has been in processing, with rendering and simulation often relegated to the sidelines because they are viewed as production activities.

Advanced Applications and Future Use

This research need stretches across the workflow from collection to application. Early efforts have led to many outcomes, including the purchase of tactical decision kits for the U.S. Marine Corps that allow small units to organically manage their own geospatial holdings. Unit operators now regularly collect image data and provide it to others in the force, as well as researchers for additional classification and segmentation experiments. Agriculture, architecture, and law enforcement professionals have also applied these techniques. Work is also being done in mapping the commercial infrastructure (sports venues, college campuses, and many other urban locations) to assist these and other communities with specific challenges such as infrastructure protection, flood analysis, site surveys, structural integrity, and historical/anthropologic research activities. Ultimately, researchers hope to revolutionize the way the world collects, processes, and serves 3D geospatial data with long-term goals being to obviate the need for human intervention, and to use automation to more quickly and cost-effectively deliver terrain data to the point-of-need. In aggregate, focused research hopes to continue and evolve with outcomes including:

- Machine learning for additional classification and segmentation of meshes and point clouds.
- Alternative sources of data collection and fusion.
- Algorithmically adding attribution to 3D data for use in runtime applications.

Conclusively, 3D geospatial data will continue to increase in abundance and quality. Therefore, its use and the research to ensure its utility, integrity, and production are critical so the GEOINT Community can produce more accurate and reflective digital representations of the physical world. These representations service the reality modeling community as a conduit to revolutionizing geovisualization, simulation, and engineering practices around the globe.

Economic Competition and the Role of GEOINT

By David Gauthier, NGA; Mark Phillips, The MITRE Corporation; and Steven Truitt, Descartes Labs

Headlines concerning the use of national levers of power are increasingly focused on economics, relationships, and nuance. While diplomatic, information, and military levers of power are often showcased for obvious effect, it is frequently the unheralded lever of national power—economic power—that has a profound global effect and is now taking its place at the forefront of national debates. With nations flexing their strength, it is vitally important for decision-makers to be fully informed of the challenges, uncertainty, opportunities, and risks inherent in this complex, interrelated world. Our leaders "must come to grips with the reality that the geopolitical landscape is populated with countries content to use the modern tools of economics and finance without regard"[1] for the societal norms we take for granted. After all, the use of these national levers of power can precipitate worldwide successes or calamities.

Likewise, in the boardrooms of the corporate world and the dorm rooms of the start-up world, the focus on the interconnectedness of the economy is proliferating. Discussions about micro-shifts in the economy, incentive hacking, and massive scaling of applications are common in the commercial world. This new focus is a direct parallel of what plays out among nation-states, and increasingly the commercial and governmental economic moves converge. However, while disruptive capabilities in the commercial world often spell financial success, disruptive events among nation-states can rapidly devolve into more overt threats to national security. And the lack of economic stability in one region can have detrimental effects to U.S. national security.

Therefore, framing the question: How does the U.S. use geospatial intelligence (GEOINT) to understand the world economic stage, predict behavior, and broaden the trade space associated with national security for U.S. and partner decision-makers?

The role of GEOINT has been applied infrequently to economic analysis, especially on a global scale. Secure and masked supply chains, secretive business relationships, and illicit demand for goods further complicate the challenges facing GEOINT analysis. Maps and charts are not yet being made to reflect these global economic forces and the context that accompanies them; GEOINT services do not currently publish and update maps with detailed economic data placed in context for improved decision-making. This is a severe limitation to geospatial analysis and global understanding. However, geospatial technology is a powerful tool to assess context, monitor activity, and provide understanding—the fundamental components needed for decision-makers. Understanding impact and forecasting responses through geospatially integrated data provides a common operating picture of economic actions and effects.

GEOINT may be the new key element to enable nations and companies alike to understand the world economic stage, predict outcomes, and broaden the trade space for more diverse actions. The increased availability of GEOINT provides insights that support the integration of information and decision-making across diplomatic, information, military, and economic levers of power.

The Effects of GEOINT

The drivers of competitive advantage are becoming everywhere and nowhere at the same time. Whether the competition is in the boardroom or the war room, it is increasingly important to uncover this information in time to act and seize an advantage. Data is the leverage point and the greatest weapon in our arsenal. Whomever controls the right data—and knows how to use it—will have an unmatched advantage. Organizations have picked up on this trend and are learning to exhaustively mine data sources for insights. But when data is being created at a rate far beyond our comprehension, it is difficult to know how to mine the most value out of our vast data resources.

In the economic arena, our nation's mission is to understand where to put leverage, or how to execute policies, actions, and deals for the best macro position possible. We need to discover and understand long-term financial trends hidden below the noise in the global economy. To make these discoveries a single information domain—nor a single analytic formula—is not sufficient as the complexity is too great and our natural human comprehension too lacking.

GEOINT is not simply the analysis of any particular medium such as imagery, but today refers to any data which is or can be geo-referenced. Most data, within all domains, can be both temporally and geospatially referenced, giving that data unique exploitable features and enabling it with greater context. Time scales are a significant factor since unlike the immediacy of military actions, economic actions may take years for true impact to be identified. If we apply the techniques of GEOINT collection and analysis, the

1. Robert D. Blackwill and Jennifer M. Harris. *War by Other Means: Geoeconomics and Statecraft*. Cambridge, MA: The Belknap Press of Harvard University Press; 2016, p 13.

analyst and decision-maker can begin to understand the impact of economic actions through time, space, and context.

Geo-referencing every piece of data and linking it with any other information contained in the data is the fundamental first step in understanding the vast sea of data available. The value of GEOINT is apparent once all available data is aligned against one frame of reference. Waldo Tobler, a noted geographer and cartographer, stated as his first law of geography:

> *"Everything is related to everything else, but near things are more related than distant things."*[2]

The ability to gather and aggregate data in a single environment allows one to see more connections, leading to a richer understanding of activities and events. Connected data contributes to the depth of the subsequent analysis by allowing analysts and decision-makers to examine and evaluate the data through time and space to understand the spatiotemporal effects of their actions.[3] Connected data leads us to Tobler's second law of geography:

> *"The phenomenon external to an area of interest affects what goes on inside."*[4]

Here, we affirm a hidden power of spatiotemporal reasoning is to understand and predict economic action and activities across and beyond geographic boundaries. Analytic frameworks, underpinned by GEOINT, provide a unique perspective through which to understand the extended economic landscape.

The nature of GEOINT enables cross-domain analysis so experts from diverse fields can easily work together. The differences among them lies in the application of the data analytics and the skill sets of the analysts. Data scientists, regional experts, traditional geospatial analysts, and most significantly economic analysts can collaborate to create information advantage. These teams must explore the data for causality and trends, the goal of which is to provide decision-makers with a superior understanding of the economic environment, a perspective on the impacts and implications of economic actions, and the ability to see global effects. By gaining global geospatial and temporal understanding of an economic action, the government can realize a multitude of options. For instance, we might predict a response to an economic action, understand systematic weak points to stimulate a "telling" action for future exploitation, or build resilient economic systems that benefit multiple parties through long-term prosperity.

No one nation can do this alone; the U.S. must work with partners and allies who have access to data and analytic skills otherwise unavailable. Other entities will have different economic concerns and levers which may be in alignment or in contention with others' policies and action. Regardless, the benefits far exceed the disadvantages when economic insight is the shared goal.

The World Economic Landscape

The nature of the world today, especially in the economic realm, is summed up in two words: "global interconnectivity." Changes in economics on a local scale can have regional or global effects while global changes can have real, and often detrimental, effects on a local level. The world saw this global effect several years ago as the collapse of the economy in Greece almost brought down the economic stability of the European Union. World economic systems are changing; some collapse and are reborn with new partners, some are founded from whole cloth as a technology or service appears. U.S. ability to understand, engage, and influence these economic systems is vital to national interests.

As the nation looks at economics as a means of projecting national will, we must be able to detect and understand the context within which a nation's actions will be taken and the global and local implications for those actions. As futurist Parag Khanna writes in his book *Connectography*, "Economic coercion precedes military hostilities in today's geopolitical maneuvering. Even though interdependence can be weaponized through financial sanctions, cyber-attacks, and supply chain disruptions, escalation is far costlier for both sides today than a century ago because they immediately harm one's own businesses operating in the rival country."[5]

The understanding of context, be it local, regional, or global is fundamental to understanding the influences of diplomatic, information, military, and economic levers of national power. Context is defined as "the interrelated conditions in which something exists or occurs."[6] The underlying nature of the human domain (who we are, what we do, who we do it with, and under what conditions)[7] so permeates decision-making that it cannot be ignored.[8] The global context for economic activity is inextricably tied to the application of the other levers of national power, and most commonly to shifts in military preparations and action. Using GEOINT analysis to understand these global shifts is important as it indicates changes in regional context; context that has the potential to alter the desired effect of an economic action on the part of a nation-state.

By way of example, the analytic team will assess the economic impacts of over-population, resource constraints, and climate change. The geospatial analyst needs to be aware of local violence, disease, and famine. As the population shifts to urban areas and megacities, the geospatial analyst will need to quantify the local effects of sanctions or tariffs—will the population shift elsewhere if a

2. "Tobler's first law of geography." www.wikipedia.org. Accessed December 6, 2018.
3. Patrick Biltgen and Steve Ryan. *Activity Based Intelligence: Principles and Application*. Boston: Artech House; 2016.
4. "Tober's first law of geography." www.wikipedia.org. Accessed December 6, 2018.
5. Parag Khanna. *Connectography: Mapping the Global Network Revolution*. London: Weidenfeld & Nicolson; 2016. p 150.
6. Merriam-Webster Online Dictionary. https://www.merriam-webster.com/dictionary/context. Accessed October 16, 2018.
7. *The Human Dimension: Analyzing the Roll of the Human Element in the Operational Environment*. Arlington, VA: United States of America: Office of the Under Secretary of Defense for Intelligence; 2010.
8. *Activity-Based Intelligence Knowledge Management. Arlington*, VA: United States of America: Office of the Under Secretary of Defense for Intelligence; 2011.

factory closes or reduces production? Finally, with China, Russia, and other nation-states taking economic and military action in the "gray zone," the state between peace and war, it is even more important that geospatial data be analyzed for adversary effects and for counteractions to help protect the economies of the U.S. and its allies.

The World Economic Landscape: The Security Perspective

The U.S. National Security Strategy[1] and National Defense Strategy[2] both emphasize nations are part of a competitive space; not at war and not at peace. A whole of government approach leveraging the diplomatic, informational, military, and economic instruments of national power must be considered to gain an advantage. The fact of continuous competition somewhere between peace and war now more than ever demands an outsized emphasis on the understanding and use of deliberate economic actions to further national strategy. Frequently underutilized, GEOINT is vital to providing options to decision-makers as they pursue different courses of action, frequently with unintended consequences.

As economies change, so do the power structures within a country or region. Shifts in traditional regional boundaries, demographics, and opportunists are all manifest in economic forces. As Khanna also writes in *Connectography*, "Countries run by supply chains, cities that run themselves, communities that know no borders, and companies with more power than governments—all are evidence of the shift toward a new kind of pluralistic world system. The ranks of such global authorities that belong on our maps."[3]

The situation has only become more exasperated in the new global economy, where everything from blood diamonds, coffee, munitions, computer software and hardware, prescription and illegal drugs, retail goods, and organic foods are traded globally. This creates immense challenges as the U.S. and its partners attempt to understand these activities.

Within the competitive space, the U.S., our partners, and allies face new threats, old threats in disguise, and complex new classes of threats behaving in unexpected ways. Threats take on new meaning in the world of economic influence. The recently released Joint Concept for Integrated Campaigning by the Vice Chairman of the Joint Chiefs of Staff[4] provides the following example as an illustration of how the levers of power are employed:

> *"Russia's aggressing against Ukraine in 2014 highlights how Moscow employs a combination of diplomatic, informational, military (both conventional and irregular), and economic means to achieve its aims, the precise mixture varies with the situation but seems calculated to achieve maximum effect without provoking a direct military response by the West."*

Another example was recently published in a U.S. Financial Crimes Enforcement Network Advisory indicating how GEOINT analysis could take a primary role in generating understanding of the economic impacts of a nation-state's actions:

> *"The Iranian regime has long used front and shell companies to exploit financial systems around the world to generate revenues and transfer funds in support of malign conduct, which includes support to terrorist groups, ballistic missile development, human rights abuses, support to the Syrian regime, and other destabilizing actions targeted by U.S. sanctions."*[5]

Another recent advisory stated:

> *"Red flag of illicit activity: Inconsistencies between shipping related documents and maritime database entries that are used for conducting due diligence. For example, the maritime database may indicate that a vessel is docked in an Iranian port, even though this information is not included in the shipping documents submitted to the financial institutions for payment processing."*[6]

The U.S. Intelligence Community needs to detect and understand the shifts in demographics, loyalties, and resources in the virtual and physical world that are frequently the first indicators of the long-term implications of a nation's economic actions. It is also vital that GEOINT be used to unmask economic activities and reveal deception in the economic space when it occurs. Finally, the government needs this visibility for clarity to provide decision-makers with the understanding needed to take additional actions or to assess the effects of a recent action. It is within this economic landscape that GEOINT can be most powerful.

The World Economic Landscape: The Growth Perspective

The counterpoint to the security perspective on economics is one of growth and general improvement. The underlying thesis of a competitive environment stays constant, however, the outcome of multiple parties competing can result in universal improvements. In market competition, the steady tide of improvement stemming from this competition lifts everyone over time, even if the relative successes change.

This view of the world economic landscape is as a game with relative scoring and universal successes. There is incentive to win and out-compete other players, as the winner is first to newfound riches, comforts, and experiences. However, all other parties also benefit as evidenced by the near elimination of extreme poverty,[7] the increasingly rapid adoption and diffusion of new technologies, and progress eradicating or mitigating many diseases. At first glance, these may seem the accomplishments

1. *National Security Strategy of the United States of America*. Office of the President of the United States. Government Printing Office; December 2017. p 2.
2. *A Summary of the 2018 National Defense Strategy*., Office of the Secretary of Defense. Government Printing Office; December 2017. p 2.
3. Parag Khanna. *Connectography: Mapping the Global Network Revolution*. London: Weidenfeld & Nicolson; 2016. p 58.
4. Joint Concept for Integrated Campaigning. Vice Chairman of the Joint Chiefs of Staff; March 16, 2018. p 3. Approved for Public Release.
5. FinCEN Advisory, FIN-2018-A006. October 11, 2018. The Financial Crimes Enforcement Network. U.S. Government. p 1.
6. FinCEN Advisory, FIN-2018-A006. October 11, 2018. The Financial Crimes Enforcement Network. U.S. Government. p 13.
7. https://ourworldindata.org/extreme-poverty#historical-poverty-around-the-world

of governments and nonprofits, however at the core they have all been driven by technologies made inexpensive and easily available through profit-seeking behaviors.

To see the effects of technology, demographics, and overall context on the economy and regional stability, Africa is a prime example. In order to increase communications and speed the stand-up and stability of businesses, nations in Africa are using technology to great effect. For instance, rather than install traditional phone lines, many nations have skipped several iterations of technology and installed cellular service. African nations have rapidly moved toward digital currency in order to participate in the global market. African nations are also making strategic moves with regard to their natural resources with nation-state partners, increasing regional stability, solidifying trading partnerships, developing infrastructures, and increasing quality of life for their populations. These actions, which also reduce the loss of skilled populations to other nations, has placed these regions on the world stage as global strategic influencers, something unthinkable 15 years ago. The use of geospatial analysis to monitor and assess these changes is an obvious choice.

Conclusion

In the era of great power competition, the U.S. and its allies increasingly face a wide spectrum of threats across political, military, and economic elements. Today, more than ever before, macroeconomics and microeconomics are levers of national security that can be influenced by nation-states, corporations, and illicit networks. Subtle changes to global economic systems and power structures may work in favor of malicious actors and undermine democracy and the free action of the people. We must be increasingly vigilant with respect to economic indicators and activity at both the national and local levels. These threats may only become visible through the lens of geospatially integrated data. It is vitally important that the whole of government apply the discipline of GEOINT as part of their normal processes to shed light on underlying relationships, to understand the nature of supply lines fueling the global economy and military operations, and to discern shifts in economic power, addressing dangerous threats to our livelihood and national security.

Activity-Based Intelligence in Mixed Reality: What Can Be Done to Improve Global Humanitarian Outcomes

By Robie Mitchell; Patrick Kenney, Whitespace Solutions; Jacqueline Barbieri, Whitespace Solutions; John Bridgwood, Vricon; and Stephen Hodgson, Valorem

Hidden among more than 82 billion data points gathered in the past five years—the last of which were ingested seconds ago at 6:32:12 GMT on May 3, 2023—a Rohingya fishing village in Myanmar is likely in the crosshairs of Buddhist paramilitaries, intent on setting it alight. Supported by the nationalist government, they operate with impunity.

8,260 miles away in a nondescript office a few metro stops from the Pentagon, the symbol of the U.S. national security community, an analyst is working for a non-governmental organization (NGO) that aims not just to record war crimes of the past, but to warn of war crimes in the future. She wears a sleek visor and fingertip sensors that let her see and manipulate a broad, virtual landscape of three-dimensional imagery, icons, relationships, and timescales. Her simple cubicle would blend into any office, but the "view" in her cubicle is out of this world. To the uninitiated, her virtual view is as colorful and overwhelming as the Las Vegas Strip. However, for this analyst, properly trained in the right mind-set and methods, this 3D analytic environment is a wealth of knowledge—a book waiting to be read. She focuses her eyes on a particular bit of data and blinks twice, summoning relevant details and attributes into view. The analyst has been tracking a paramilitary leader via four proxies across 19 datasets during the past 13 months, and she has identified recent aberrations in his "normal" pattern-of-life, indicating his intent to attack the Rohingya fishing village within days.

With her sensor-tipped fingers, she seamlessly integrates additional contextual data and generates a 3D augmented reality experience to convey her facts and findings. This presentation will be dispatched to contacts at the U.S. Department of Defense, the United Nations, and partnered NGOs in Southeast Asia. Just as the adoption of video and digital slideshows surpassed static photos and flip charts as the means to convey the outcome of complex intelligence and research work to great effect, so will this 3D immersive tool allow analysts to better make their case and explain their conclusions.

VR and ABI: A Path to the Future

Virtual reality (VR) and activity-based intelligence (ABI) are both buzz terms used imprecisely and hyperbolically. But those familiar with the disparate technologies, methodologies, and mind-sets that underwrite their contributions to traditional analysis have experienced the substance behind the hype. Together, they are particularly powerful and make the aforementioned hypothetical scenario feel tantalizingly real. Synthesizing the described technological and methodological innovations is not a simple task, but it is happening successfully in industry and government alike and will be a foundational element of analyst workflows in the not-too-distant future.

Given the current pace of change in technology, the synthesis is only a matter of time, but to what ends is it taking place? Can the resultant analytic efficiencies and exponentially increased information advantage be brought to bear outside of traditional intelligence problems, and also applied to problems NGOs are tackling? If so, what does this mean for their outcomes? Before diving into these important questions, we will first establish a brief foundation in virtual, mixed, and augmented reality (AR) as well as ABI.

Virtual, Mixed, and Augmented Realities

Paul Milgram and Fumio Kishino introduced the concept of a "virtual reality continuum" in the 1990s, and the idea has held sway since.[1] The continuum refers to the relative mix of object types—real and artificial—visible in any display environment. At one extreme, everything visible is artificial (i.e., virtual reality). And at the other, only few virtual objects are laid over the real world (i.e., augmented reality). Whereas Milgram and Kishino used "mixed reality" to refer to the entirety of the continuum, nowadays, it often refers to the spectrum's middle ground.[2] Today, other than for gaming and recreation, mixed reality technology has been used mainly as a presentation tool. But such capability can do much more than enable high-tech conference calls and heightened consumer engagement.[3] Properly leveraged, mixed reality experiences afford users a level of engagement and understanding that is impossible with traditional displays.[4]

For analytic purposes, mixed reality experiences offer enhancements that consider user experience, comfort, and ease without sacrificing cutting-edge visualization. Moreover, the ability to toggle between an immersive VR experience enabled by a set of lightweight glasses and an augmented one projected via a tablet potentially drives more efficient, accurate, and timely analysis more so than a set of capabilities predicated on a particular device. Mixed reality solutions must be hardware agnostic to avoid challenges related to hardware upkeep, lock-in, and interoperability, which can cause as many headaches as their capabilities will be worth. Imagine being able to visualize 3D problems in 3D space—seeing chemical plumes and wildfires spread in real- or near real-time, tracking the spread of cyber threats through complex data infrastructure schematics, or training to breach a room for law enforcement, counterterrorism, or counter-narcotics purposes. The analytic dividends gained by going from 2D geographic information system (GIS) tools to 3D mixed reality capabilities will be like the leap to 2D GIS from static maps and charts.

Activity-Based Intelligence

ABI emerged from the counterterrorism fight in Afghanistan and Iraq and, as such, was organically defined and refined by operator-analyst teams in the field. Its bottom-up origins have led to contentious debates over ABI's definition. It is important to understand that at its core, ABI is not just a methodology, but a mind-set. While the proper mix of method to mind-set required to maintain rigor varies across the three ABI sub-disciplines, its four constituent pillars—geo-reference to discover, integrate before exploitation, data neutrality, and temporal neutrality—are foundational to all variants of the ABI approach.[5]

First, all data, to the extent possible, should be geo-tagged so it can be viewed spatially and temporally. Second, all data should be folded together and only exploited after it has been integrated. This means not assessing the various intelligence disciplines, or INTs, in silos. Third, all data can yield significant information no matter how old or new it may be (i.e., one must resist the urge to privilege that which is newly-collected or obtained over that which resides in older stores). Fourth, and relatedly, data from flashier "exquisite" sources should not be privileged over data with humbler origins.[6] A tweet or a piece of battlefield pocket litter can yield an answer as readily as satellite imagery with creative analysis.

These foundational pillars not only provide answers for pre-existing questions, but also enable the discovery of entirely new questions based on the interrelations deeply embedded within data. This includes seemingly irrelevant patterns of life and anomalies contained therein that are invisible without ABI's unique temporal, spatial, and network analysis. This significant analytic innovation hinged on the adoption of 2D GIS environments in which all your data can be brought together. Transitioning analytic work into 3D environments will bring the next wave of analytic innovation, unlocking a richer capability to model and understand complex issues.

Geospatial Analysis in Humanitarian Relief

The literature on applying mixed reality technologies to humanitarian workflows is neither practical nor up-to-date. This is understandable because much of the innovation that has increased analytic rigor and allowed for creative problem-solving has come from within government, and much of the technological progress in mixed reality capabilities has come from within the entertainment industry. As a result, academics lack the insider perspective needed to accurately assess the impact of combining the two phenomena. We compare the ability of NGOs to use geospatial data to the Intelligence Community's (IC) still-dominant tasking, collection, processing, exploitation, and dissemination (TCPED) paradigm.[7] There are widely acknowledged issues with this process, including a lag in the delivery of final analytic products and a lack of

1. Paul Milgram and Fumio Kishino. "A Taxonomy of Mixed Reality Visual Displays." *The Institute of Electronic, Information, and Communication Engineers (IEICE) Transactions on Information Systems*. 1994:E77-D(12):3.
2. Lucas Matney. "Magic Leap Details What Its Mixed Reality OS Will Look Like." *Tech Crunch*. July 27, 2018. https://techcrunch.com/2018/07/27/magic-leap-unveils-what-its-mixed-reality-operating-system-will-look-like/, par. 7.
3. Jeff Miller, Christian Dieckmann, Dario Raciti, Shauna Heller, and Craig Dalton. "Building Virtual Reality Experiences to Maximize Brand Awareness and Prestige" (presentation). VRX Immersive Enterprise Conference & Expo. San Francisco, CA. November 2015.
4. Alejandro G. Iñárritu. "Carne y Arena: Physically Present, Virtually Invisible." https://carneyarenadc.com.
5. "NGA GEOINT CONOPS 2022." *National Geospatial-Intelligence Agency*. p 7.
6. Patrick Biltgen and Stephen Ryan. *Activity-Based Intelligence: Principles and Applications*. Norwood, MA: Artech House; 2016. p 16.
7. The authors acknowledge that several IC agencies have made strides toward replacing TCPED with alternatives, such as object-based production (OBP). However, given that TCPED is still the doctrinal paradigm, we elected to use it as our comparative lens for this paper.

integration among human, geospatial, signals, and open-source intelligence.[8] Despite TCPED's shortcomings, the framework provides a useful metric for evaluating NGO performance and mapping a path forward.

NGO responses to natural disasters, along with academic after-action analyses, demonstrate the level at which geospatial understanding and technologies are currently leveraged. These responses provided a baseline with which to evaluate the NGO community's views and uses of geospatial analysis.[9] During an exceptionally severe drought in the Iberian Peninsula, wildfires broke out in 2005 near Coimbra, Portugal's third-largest city. Not until the activation of the "International Charter"—an informal cooperative agreement among the world's premier governmental space agencies—did Portugal request satellite imagery to aid in the disaster response.[10] This delay, coupled with limited data integration, showcased shortcomings in NGO tasking and exploitation processes.[11]

In another example, a rain-induced landslide on the Southern Leyte Island of the Philippines on February 17, 2006, killed 1,126 people and displaced approximately 19,000.[12] Continual rainfall impeded rescue operations, and Rosette Lerias, the governor of Southern Leyte, ended them on February 24.[13] A widely cited assessment by Voigt et al. confirms the disaster response was inadequate but frames the problem as a lack of information sharing with government entities that have access to exquisite data sources and ineffective information fusion among those entities.[14] The assessment states that greater awareness of the landslide extent—derived from timely production and dissemination of analysis—could have informed evacuation routes and emergency response and notes similarly deficient responses to earthquakes in Pakistan and a tsunami in the Indian Ocean region. Yet, this understanding of how geospatial information could inform action against humanity's most daunting challenges lacks imagination—so much more can be done to improve outcomes than faster analysis and better information sharing.

What Can Be Done?

The capacity of NGOs to leverage geospatial information represents fertile ground for organizational leapfrogging—with proper adoption of ABI-infused VR, these sometimes nimbler and less bureaucratically constrained entities can surpass what the government has accomplished with TCPED.[15] The intersection of mixed reality technologies, analytic innovation, and humanitarian outcomes remains largely speculative and theoretical. Despite the nature of our research question, we found it imperative to derive experimental data using mixed reality capabilities and industry expertise to better assess the utility of cutting-edge tradecraft and tools within NGOs. Partnering with Amnesty International, our research team selected relevant crisis-affected geographies. Demonstrating the potential of ABI and other elements of tradecraft, we collected a wide range of open-source data that provided insights into political violence, social media, infrastructure, natural resources, population, geographic features, and epidemiology. Layering and geo-referencing this data allowed us to demonstrate how analytic innovations could enhance humanitarian outcomes.

Using ABI, we discovered links among the data that allowed us to infer culpability in Syrian violence, track aid worker movements in Myanmar, and map the spread of election-related civil unrest in Zimbabwe. Incidentally, while we were collecting our live data, the database we used to track politically motivated violence, the Armed Conflict Location & Event Data Project (ACLED), stopped refreshing data for August. So, some of the events that were referenced via Tweets and news articles were not represented in arguably the best open-source database on conflict. Nonetheless, we were able to determine that a neighborhood in Aleppo was currently controlled by rebel forces, meaning that recent violence was more likely perpetrated by non-government actors. We were able to observe differences in the relationship between natural resources and violence in Syria and Myanmar. Namely, that oil fuels violence in Syria but has little effect in Myanmar. Finally, we discovered that unrest from Zimbabwe's disputed election on July 30 was not centered in the capital of Harare as many open-source datasets suggested, but rather was steadily spreading southward.

These findings are speculative to some extent because of the limitations of open-source data collection, but with enough data points they can have real-world implications and in VR they could be leveraged to lifesaving effect. Although we investigated geospatial capabilities primarily at a specific NGO—Amnesty International—and showcased how tradecraft can improve situational awareness and humanitarian outcomes, our findings are applicable to use cases beyond refugee flows in Myanmar, war crimes in Syria, or election monitoring in Zimbabwe. Given the severity of the events NGOs often respond to, there is a good chance that no matter the use case there will be a wide variety of

8. NGA GEOINT CONOPS 2022. National Geospatial-Intelligence Agency. p 3.
9. Stefan Voigt, Thomas Kemper, Ralph Kiefl, Klass Scholte, and Harald Mehl. "Satellite Image Analysis for Disaster and Crisis-Management Support." *Transactions on Geoscience and Remote Sensing*. 2007:45(6):1525.
10. *The International Charter Space and Major Disasters*. The International Charter. https://disasterscharter.org/web/guest/home;jsessionid=DF479CC8AB623E78C289173FA37A1B95.jvm1.
11. Stefan Voigt, Thomas Kemper, Ralph Kiefl, Klass Scholte, and Harald Mehl. "Satellite Image Analysis for Disaster and Crisis-Management Support." *Transactions on Geoscience and Remote Sensing*. 2007:45(6):1524.2.
12. Gisela D.A. Luna, Jesusa Grace J. Molina, and Fatima Gay J. Molina. "The Southern Leyte Landslide 2006: Recovery Status Report." *International Recovery Platform*. December 2011. p 1. https://www.preventionweb.net/files/26098_26098recoverystatusreportleytemarch.pdf.
13. ibid. p 4.
14. Stefan Voigt, Thomas Kemper, Ralph Kiefl, Klass Scholte, and Harald Mehl. "Satellite Image Analysis for Disaster and Crisis-Management Support." *Transactions on Geoscience and Remote Sensing*. 2007:45(6):1520.
15. José Goldemberg. "Technological Leapfrogging in the Developing World." *Georgetown Journal of International Affairs*. 2011:12(1):135. https://www-jstor-org/stable/43133873.

means across available sources to collect data, track bad actors, and act upon information in new and meaningful ways.

Ethics

A growing body of evidence suggests that people's exposure to technology is positively correlated with overconfidence in their analysis.[1] When the capabilities we investigated make their way to routine use by governmental and non-governmental actors, it will be important to seriously consider the role of observers in the events they are omnisciently "seeing." Whether they are making decisions that affect resource allocation or post-conflict justice, NGOs will have to reconcile with issues the IC has long contended with. The life-and-death nature of the issues at hand leave them inextricably linked to questions of ethics, morality, and values. In addition, performing ABI requires collecting and integrating massive volumes of data, which raises critical privacy questions when done outside of the purview of the strict laws that govern U.S. government activities. Integrating visualization capabilities such as VR into routine analytic workflows should be coupled with processes that compensate for these issues.

Conclusion

There are two interrelated takeaways from our research and discussions. First, geospatial data and advanced analytic approaches are underused among NGOs—which is unsurprising given that their adoption within government is still developing. Institutional inertia, tight budgets, and insufficient technical expertise explain why this gap exists and persists. Second, mixed reality capabilities could allow NGOs to leverage their geospatial data in new ways as disparate as fundraising (by showing potential donors scenes from the ground) and imagery exploitation (through faster and more efficient analysis).

At Amnesty International, for example, volunteers have sorted through imagery and marshalled evidence showing where and when war crimes were committed. In 2016, Amnesty used this model to credibly assert that the Sudanese government had targeted its own citizens in Darfur.[2] Professional and volunteer analysts can be trained in ABI analytic techniques even at an introductory level quickly and economically to get to these meaningful conclusions and outcomes faster and more efficiently. Amnesty and other NGOs can leapfrog their analytic skills and technology through dialogue with government actors who have suffered the long, expensive trial-and-error phase of moving analysis into the 21st century. Likewise, NGOs will be able to stand on the global security community's shoulders as VR technologies advance, are tested, and fall in price through government initiatives.

By sharing their respective problems, potential solutions, and methodological and technical innovations around ABI and VR technologies, these groups could create a collaborative nexus that lowers the cost of doing good for both NGOs and the national security community. This new equation would have tremendous impact for both humanitarian and security outcomes.

The Geo-Singularity

By Chuck Herring, AllSource Analysis; John Goolgasian, GeoSpark Analytics; and Steven Truitt, Descartes Labs

Human decisions and the information that feeds them are the basis for modern success. Throughout many industries, automation and complex adaptive systems—artificial intelligence (AI)—have steadily improved the quality, efficiency, and timeliness of human decisions. Humans are inherently sequential and relational thinkers; we enjoy anecdotes and stories. This method of thinking, along with a relative lack of technological progress in spatial analysis, saw a stagnation in spatiotemporal analysis. A new collaboration is realizing the opportunity to connect complementary attributes. Broad, deep data-wrangling by machines and human analysis is merging into a new, bold, real-time processing movement honoring the best application of both capabilities.

The simultaneous availability of useful, new technologies has created what we call the "geo-singularity." In this new paradigm, human analysts and machines work side-by-side to ask and answer critical questions using tremendous datasets in real-time. This capability has already been demonstrated to speed up and deepen decision-making. The future is now.

In this article, we describe scenarios that provide an understanding of what is viable using current tools. We also predict what is immediately possible given smart adoption and full application of capabilities. The principles of the new movement are shown by detailing the geo-singularity's main processes of data analysis and decision-making.

Activity Monitoring

Informed decisions require clear information and context. Improved satellite datasets and the spread of remote sensors have enabled powerful, reliable data collection. This data requires both processing and the application of learning models to be useful.

Building and using data refineries makes a clear set of conclusions and insights possible. A data refinery takes huge datasets and turns them into relevant signals an organization can use to make decisions. Three primary functions continuously update a relevant image set:

1. **Data Ingest and Harmonization:** Platforms ingest a variety of remote

1. Brent B. Clark, Christopher Robert, and Stephen A. Hampton. "The Technology Effect: How Perceptions of Technology Drive Excessive Optimism." *Journal of Business and Psychology*. 2016:31(1):87. https://doi.org/10.1007/s10869-015-9399-4.
2. "Decode Darfur." Amnesty International. https://decoders.amnesty.org/projects/decode-darfur.

sensing data and pre-processes to support machine learning and massively scalable computer vision.

2. Development of Machine Learning Capabilities: Classifiers are trained on known sample data to develop signatures for site and target identification, classification, and change detection.

3. Search and Classification: Classifiers are run at scale to identify sites and label their purpose. These classifiers are run over the entirety of the region or associated areas and through time using a combination of medium- and high-resolution data sources.

As the data refinery runs, the results are available as a shared resource among human data scientists, operational staff, and the machine learning tools they employ. AI starts the assessment process by identifying signals and creating semantic information. The data team completes the analysis feedback loop by ensuring the validity of this information before updating the models and repeating the process. The continuous outputs are used in real-time to inform decisions and conclusions made by executives and analysts.

Identification and Development of Context

Establishing context is the next step to provide a high-value dataset. Fully refined data of one variety is not sufficient to meet most analysis needs. The use of many datasets in context with each other to identify correlations in space and time is critical.

Areas of Interest (AOIs) can be identified for new development prior to traditional GEOINT analysis. AOIs are detected by machine learning analysis of nontraditional GEOINT sources. News stories, social media, financial data, and other social and cultural indicators all carry signals of places to watch.

Machine learning models for context development look globally at indicators of change. Anomalies are identified by comparison to "normal behaviors" whose descriptions must also be continuously updated. The models must monitor a range of complementary data sources to avoid surprises.

A wide area search is possible when the entire Earth is turned into pixels—a broader digital twin. If changes in a facility signal danger or abnormal production, efficient signature identification is crucial to realize risk and loss before a disaster occurs. Point signatures and shifts in the operating environment are detectable across borders with the right models.

Leveraging the right individual's expertise at the right time makes a huge difference in the outcome of any situation. A network of spatial and subject matter experts available to provide the intelligence answer is ideal. Sourcing and plugging the right expert into current AI results and detection creates a highly efficient system to run and finish actionable assessments. Automation makes it possible for people to think clearly and act fast.

Human Finish Assessments

Human expert analysts are critical to ensure end users get a complete, understandable geospatial intelligence (GEOINT). The analysts provide meaning and context to "finish" the assessment from the output of AI monitoring and data processing. The geo-singular organization leverages a network of imagery, geospatial datasets, and subject matter experts. The expertise is critical for the intelligence call. Machines do more of the heavy lifting in data analysis, allowing humans to focus on giving the results meaning and steering the intention of the assessments. This approach amplifies the expertise of any one analyst, resulting in high output and quality analysis.

Data refinement and assessment is the first element of the geo-singularity. It leads to the next questions: How is this intelligence used? How do we apply the new power of the geo-singularity?

Monitoring Energy Development

As a broad example, energy infrastructure development offers a use case for the geo-singularity. It starts with developing context relevant to the energy industry. Automated broad-area search and existing models bootstrap analysts to identify new energy development sites of interest all along the supply chain. Rather than manual scanning, AI tools see opportunities and threats faster.

Once identified and contextualized, development is monitored and efforts are adapted as development progresses. What used to require literally an army of military intelligence gatherers can now be accomplished with powerful AI platforms directed by a handful of humans on a data team, or even a single engineer. Using automated observations of key signals, machines can tip off and efficiently use the attention of human analysts. Decision-makers avoid surprises and react fast and early.

Change detection in energy operations can range from picking up ground disturbances to flare activity. Refinery

Figure 1. Identifying potential anti-aircraft sites based on low-quality raw data sources.

production tracking can be accomplished by quantifying output and shipments of finished resources. All of this is detectable with the unblinking eye of a constantly scanning satellite monitoring system.

Abnormal activity is often associated with abnormal language. Hot spots are found by detecting shifts from normal operation, often seen in unusual and unscheduled production and logistics changes.

We are rarely surprised when we know where to look and what to look for. Machine learning models that pattern human behavior globally are required to drive current government and commercial intelligence, security, and business operations. A model continuously assesses activity levels, defines normal patterns of behavior, and identifies anomalous activity. The system alerts users to actions that may pose a threat, risk, or opportunity to their operations, people, or investments.

Human teams built around automation can triage, respond, and focus on real events, in real-time, and at scale. Along with lag time, the need for damage control is reduced. Reactive mind-sets give way to proactive strategy and preparation. The more the teams consistently know, the more efficient and targeted the response. Small teams can monitor a large corpus of signals to prioritize key activities and incidents for further investigation. For example, widespread site monitoring across several perspectives establishes forewarning of disruption in the energy sector.

There is a balance to be struck here. Experience has shown that models hold up well over time when properly designed, however, there is always drift and change that threatens to change our understanding of how the world works. For example, identifying facility activity is reliable up until the underlying facility or workflow changes. Correcting models to match these changes in the real world can be autonomous, but people must be involved to communicate and adapt the model properly to new goals.

Global Threat and Risk Assessment

Few organizations understand the risks for their employees and operations at a global scale. Industrial-age processes still rule most of the risk assessment industry. Hundreds, if not thousands, of analysts toil away scanning newspapers, trying to cull through a growing mountain of social media, and reading field reports. These tasks steal precious time from strategic thinking, overwhelm analysts with a volume of data, and offer only a small glimpse into what is happening across the globe. Static reports are written on a monthly or quarterly basis and sold at high costs.

Machine learning models in advanced analytic platforms are gradually replacing the old process. These models record billions of calculations of activity and stability. They visualize those findings graphically and textually in accessible platforms and through automated prompts. Alerts show changing patterns and present ratings of current and forecast potential stability levels on a global level.

Again, these models do not replace the human analyst. Instead, they augment his or her ability by a factor of 10. They enable the analyst to have a full picture of global events as they break and offer a glimpse into future potential scenarios.

This trend is being seen across verticals like trading and supply chain management. It is directly tied to modeling actions in the physical world. Those with a strong profit motivation are moving first, of course. Yet even within the environmental/non-governmental organization (NGO) world, there is a move toward the use of automated monitoring systems backed up by sophisticated human analysis.

Moving into the Future

The improvements from augmentation and collaboration with machines in the geo-singularity is clear. Realizing this new state prompts the question: How is all of this built from current processes?

An effective transition begins with a bootstrap of what is already known by human-driven search and filtering strategies. A campaign is built to understand and monitor, and to use leading indicators to get ahead of the problem before it gets out of control. An organization begins to operate at a deeper level of integration and feedback with technology when understanding increases the performance of the system and the system increases understanding.

Recently, new technical abilities such as deep learning, large-scale data processing, and highly connected models have simultaneously created a huge opportunity to aid human decision-making. We now have the computational tools to tell stories in geospatial terms, at scale, and across different disciplines.

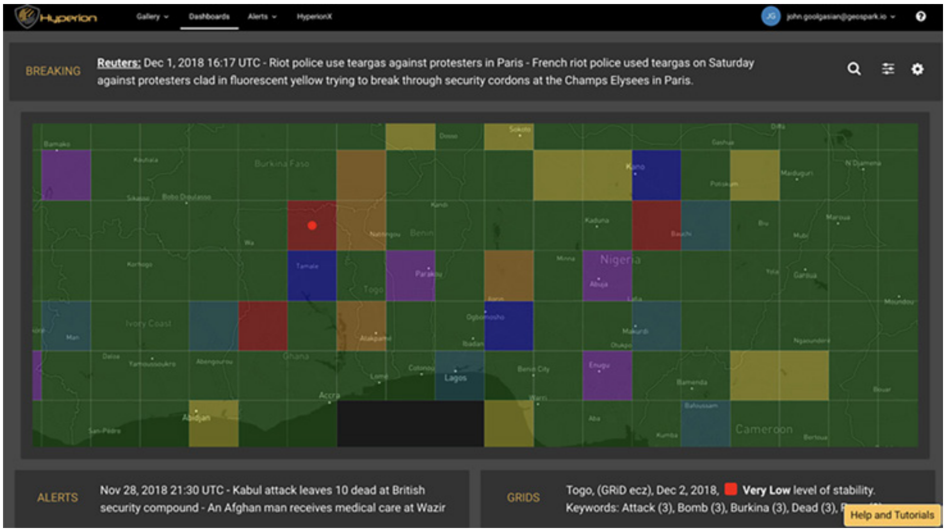

Figure 2. An integrated picture of assessed risk and underlying interpretation.

This rapid expansion of technical capabilities has outpaced the application of these technologies to our human endeavors—and created opportunities.

The adaptive organizations of today are creatively applying these new technologies. Iteration cycles are accelerating. Entirely new ways of conducting business are being developed, enabling humans to be more informed, effective, and successful in their choices.

There is merited discussion, shown in this larger USGIF report, about what the future will bring for the GEOINT Community. But the future is already here.

Our current technical capacities often outpace our ability to use them effectively, and additional technology will not solve this problem. The promise of the geo-singularity is to become a focal point to change the way we work. We will emerge on the other side of the transition with new ways of operating in and thinking about the world.

Open-Source Collaboration as a Model to Supercharge GEOINT Success

By David Gwynn, Boundless; Scott Clark, Radiant Solutions; Justin Bennett, Geodata IT; and Tony Bryan, Midwest Cyber Center

The ability of an organization to stay ahead of its competitors requires continuous innovation and the rapid integration of best-of-breed tools, workflows, and business processes. For geospatial intelligence (GEOINT) practitioners faced with the prospect of vast increases of geospatial data in the next five years—as noted by National Geospatial-Intelligence Agency Director Robert Cardillo[1]—there is an unprecedented urgency to explore creative approaches to efficiently leverage all resources and stay ahead of the game.

Integration of GEOINT activities across all practitioners in the Global GEOINT Enterprise is fundamentally based on efficiently leveraging the breadth of all resources, including human analytic capabilities. The cross-functional competency of collaboration outlined in the United States Geospatial Intelligence Foundation's (USGIF) GEOINT Essential Body of Knowledge[2] realizes the powerful potential for accelerating knowledge exchange to maximize the value and efficiency of human analysts.

Using the methodology employed in open-source collaboration, this article outlines the tools, workflows, and business processes that result in rapid cross-team innovation. Discussion of how these can be leveraged within the GEOINT Community to supercharge collaboration to rapidly achieve success is outlined.

Defining the Problem: The Need for Knowledge Sharing to Achieve Rapid, Continual Success

Across every industry, one may find the same flawed approach: several disparate groups developing their own tools/technologies, methods/workflows, and strategies to meet local decision-making information gaps. Typically, these groups are unaware that the same gaps exist elsewhere in their enterprise. This flawed structure results in duplicative efforts, inefficient innovation, lack of interoperability, and a dependency on the individual heroics of a few people. As a result, there exists a need to formalize methods to seamlessly share knowledge and efficiently leverage all human resources to accelerate innovation. Such methods are desired to establish a culture of continuous evolution and excellence that benefits the enterprise. For GEOINT, adoption of new methods offers great potential to increase the ability of the enterprise to systematically innovate, evolve, and cull vast amounts of data to stay ahead of threats.

The Customer Success Perspective

The "outcome economy" dominates the software industry today. In contrast to prior economic eras—product, service, subscription—the focus on the outcome economy is the achievement of customer goals. As defined by the World Economic Forum, the outcome economy is a marketplace in which businesses compete on their ability to deliver quantifiable results that matter to customers rather than just selling products or services.[3] Business success in this economy requires deep understanding of customer needs, solutions that address their needs, and metrics that document the value added by your software solution. According to Chris Carrington, CEO of ServiceSource, the following actions lead to business growth in an outcome economy:

- Understanding the customer's job via proactive engagement, prescriptive conversations, and personalized interaction.
- Letting data drive decision-making, including collecting, analyzing, and acting on data.
- Orienting around outcomes by aligning, allocating resources for customer success, and accepting shared risk and reward.[4]

The "customer success" model directly addresses the needs in the outcome economy. According to Nick Mehta, CEO of Gainsight, customer success is a business methodology that ensures customers achieve their desired outcomes while using your product or service. It is relationship-focused client management that aligns client and vendor goals for mutually beneficial outcomes.[5]

1. Quote during keynote address by NGA Director Robert Cardillo at USGIF GEOINT Symposium 2017 in San Antonio, TX on June 4, 2017.
2. https://usgif.org/certification/geoint_EBK
3. World Economic Forum, Industrial Internet of Things: Unleashing the potential of connected products and services. http://reports.weforum.org/industrial-internet-of-things/.
4. Key takeaways from TSIA, Gainsight, and Service Source's Executive Symposium, Tim Hoag, July 26, 2018. https://www.gainsight.com/blog/key-takeaways-tsia-gainsight-servicesources-executive-symposium/.
5. https://www.gainsight.com/guides/the-essential-guide-to-customer-success/

Customer success requires a proactive, holistic, across-client vision focused on user-defined outcomes. It also requires continuous evaluation of customer outcomes measured empirically from performance metrics and feedback data from users to quantify improvements introduced by your solution.

Collaboration within an organization and between an organization and its customers is critical for customer success. Building upon the maxim, "the whole is greater than the sum of the parts," collaboration unleashes an organization's ability to reduce time to solutions and efficiently marshals all human resources. The embrace of collaboration within and beyond an organization achieves two goals. First, it increases the speed of innovation by ensuring that advances made by any person or group quickly propagate across the enterprise. Second, it formalizes and establishes an environment in which exchange of ideas and information focused on discovery and sensemaking is the norm. Collaboration is a skill that needs to be deliberately taught, fostered, and rewarded via tools, methods, and practices.

Deliberate planning is required to establish and maintain a new mind-set for actualizing continuous innovation and GEOINT success. Establishment of a new strategic vision focused on customer outcomes can be achieved through the formal adoption of the customer success model, and the incentivization of personnel can be made by quantifying their ability to provide added value to the customer.

Open-Source Methods Unleash Structured Creativity and Innovation

The communities and organizations that have coalesced around open-source geospatial software practice collaboration across highly distributed volunteer teams to successfully deliver software, tools, processes, and even data. Examples of these organizations include OSGeo, LocationTech, and OpenStreetMap. Software from OSGeo and LocationTech are used widely in government and commercial environments. OpenStreetMap has been such a successful model that the software and processes form the basis of the National System for Geospatial Intelligence's (NSG) Open Mapping Enclave (NOME). But it's the actual processes by which these communities organize, self-govern, and release capabilities that offer key practices worth emulating in GEOINT.

Many organizations are coupling development and analytic teams, and therefore the common lexicon that comes from these often developer-oriented organizations is helpful to GEOINT analysts. In this scenario, developers become more educated about GEOINT and analysts become more proficient with coding tools and workflows, but each continue to focus on their primary area of expertise, thereby ensuring each make the most efficient use of their time as they pursue the team goal.

In the publication, "Producing Open Source Software,"[1] Karl Fogel points out critical habits that enable an open-source software project to become a true community project. These principles are useful for other communities of practice as well, even if there are no developers involved. Critical communication practices such as mailing lists ensure the entire community can see conversations (including debates and professional disagreements) among team members. The principle of having "public" conversations may be uncomfortable for some at first, but this ensures agreements aren't formed in back channels. It also ensures that conclusions are preserved for future reference, so the same debates aren't rehashed unless necessary. Sharing software code, processes, and algorithms is a necessary function of developing a community. The open-source software community is strong and the principle of "with many eyes, all bugs become shallow" also fits for complex analytic problems that require multidisciplinary backgrounds. This communication transparency expedites troubleshooting, eliminates redundancy, and accelerates innovation, all while enabling structured creativity that is laser-focused on the team goal.

Open-Source Communities Are Connected and Self-Motivated

The members of open geospatial communities include developers, analysts, subject matter experts, project managers, and professors from across industry, government, academia, and nonprofit organizations. Open geospatial communities share and co-contribute to projects and knowledge bases. They also participate in special interest groups and governing foundations, all in the name of collaboration. Collaboration involves an easy interchange of ideas among many perspectives to produce a better result than any one of them could achieve separately. Organizations that choose to adopt these principles gain the following benefits: group-derived knowledge, information, analytic findings, and data, all made instantly available to executives, policy-makers, concept developers, trainers, system engineers, and analysts; and instant feedback on lessons learned from successes and failures during in-office, day-to-day activities (internal analysts) and out-of-office operations (mobile users) where GEOINT is planned, created, and used.

Software foundations such as OSGeo and LocationTech have a governance/business process that allows for the incubation of new capabilities. Even if there is overlap in a capability, it is not squashed by the organization, but rather given the opportunity to evolve and thrive. There is a recognition that one size does not fit all with technology and geospatial challenges. The incubation process is a mechanism that increases collaboration because it makes early capabilities available to the wider community to experiment with and evaluate. It also provides visibility to those who may become interested in contributing directly to the evolution of a new project. The incubation process provides a top-down

1. Karl Fogel. Producing Open Source Software. 2017. https://producingoss.com/.

set of guiding principles and resources that allow for bottom-up creation of new capabilities that benefit the entire community.

Open-Source Tools Facilitate Transparency and Efficiency

Several web-based tools facilitate enterprise collaboration across remote teams of diverse experts. Among the most important of these are management tools supporting the agile development methodology. Agile is a systematic, transparent, repeatable methodology that tightly couples product development with end user outcomes. Agile management software enables input from all key stakeholders to be documented in a highly transparent manner. All end user requirements and technical tasks undertaken to achieve requirements are recorded, edited, tracked, and archived. These data as well as other data such as team performance metrics are available to stakeholders who regularly perform reviews to determine if the capabilities developed appropriately achieve the outcomes the end user requires. Adjustments to requirements can quickly be made by stakeholders as needed because the time between "sprint" reviews is relatively short (two to six weeks). In this way, constant feedback from the end user during the stepwise creation process enables iterative corrections to be rapidly incorporated into the evolving capability. The agile methodology decreases the time required to innovate and increases the probability that the developed capability meets end user goals.

Role of Community of Practice

The idea of communities of practice (CoP) is relatively new even in industry. Pioneering work by Étienne Wenger[2] and others in the 1990s noted that large businesses had within them communities that self-organized around specific functional areas all without formal sponsorship, recognition, or even interaction with the front office. It was during an efficiency study that IBM first noticed members of some communities were spending a lot of time having "conversations around the water cooler," where, for example, sales representatives shared stories of their day and associated successes and failures. While IBM originally saw this time as idleness that could be recovered to core business practices, closer analysis determined this was where IBM salesmen were professionalizing. Sharing anecdotes of the days' challenges and opportunities allowed members of the community to collectively learn best practices, avoid pitfalls, and coalesce around ideas or efforts. This allowed individuals to outpace their competition and to make IBM money.

CoPs, as defined in the business community, are:

- Peer-to-peer collaborative networks.
- Driven by willing member participation.
- Focused on learning and building capacity.
- Engaged in knowledge-sharing, developing expertise, and solving problems.

CoPs will be the common thread that ties together the most critical resource of the GEOINT Community—its people—by empowering them with insight and awareness. As enterprise professionals conduct their daily business at corporate and headquarter-level offices, they gain insight into how a company wishes to evolve as an organization across its different business functions. For example, the U.S. federal government will learn how military services, the Intelligence Community, and even other nations address their intelligence challenges, and whether these organizations are meeting obstacles or exposing opportunities.

A CoP provides a means for this highly strategic information to be provided back to the professionals at the tactical echelons whose physical or organizational location prevent them from knowing this information. The "top-down" distribution of cross-enterprise vision will subsequently inform a workforce about a wide variety of actions taking place within their community; they can tailor their "bottom-up" goals to achieve the vision. By removing communication barriers and increasing transparency, the CoP ensures the rapid cross-pollination of ideas. This is the same role that modern IT architectures and open-source technologies provide for geospatial data and products.

Discussion and Recommendations

The GEOINT enterprise has the critical mission of staying ahead of the game in a world where ever-growing volumes of complex and diverse data require rapid exploitation. In this environment, the importance of adopting methods that accelerate innovation across the enterprise cannot be understated as they drive mission success. Efficiently harnessing the breadth of talent, skill, and experience across the GEOINT Community has great potential to positively impact a range of missions.

Like the open-source development community, the GEOINT enterprise is dispersed among multiple organizations around the globe. Any duplicative efforts within the GEOINT enterprise result in precious loss of time, and procedures that prevent collaboration increase the time required to innovate. Lessons learned from the open-source community offer great potential for improvement.

Leveraging the methodology employed in open-source collaboration, this article outlines a series of actions the GEOINT enterprise can take to expedite cross-team innovation.

Three recommended actions are:

1. Provide strategic vision and reward/promotion mechanisms that incentivize GEOINT excellence and customer success methods as the norm. Create and foster a work environment committed to cross-enterprise collaboration, continuous innovation, and creative problem-solving that is laser-focused on ensuring customer

2. Étienne Wenger. Communities of Practice: Learning, Meaning, and Identity. Cambridge, MA: Cambridge University Press; 1998.

goals and outcomes are rapidly achieved.

2. Adopt best practices from open-source software development by leveraging best-of-breed tools, workflows, and business processes across the enterprise to facilitate collaboration among remote teams of diverse experts. Utilize the highly structured agile software development methodology to formalize transparency, constant communication, and stakeholder engagement to rapidly achieve customer goals.
3. Establish and foster one or multiple GEOINT communities of practice in which motivated individuals self-select to participate because of their high levels of interest in GEOINT. These CoPs will ensure cross-pollination of ideas across the enterprise and up and down the chain of command, thereby ensuring custom-tailored, "bottom-up" goals achieve "top-down" vision.

Adoption and implementation of these actions within the GEOINT enterprise offer a viable mechanism to accelerate knowledge transfer and innovation to supercharge GEOINT success.

The Future of Foundation GEOINT: How Technology, Procurement, and Cultural Changes Are Transforming the Business Model for GEOINT Data

By S. Carter Christopher, Ph.D., NGA Foundation GEOINT Group; J. Edward Pickle, Radiant Solutions; and Nathan Frantz, Geospatial Research Laboratory, U.S. Army Corps of Engineers

Creating and maintaining a "foundational map" of the world is no small feat. While the National Geospatial-Intelligence Agency (NGA) has functional management authority to produce Foundation GEOINT for the National System for Geospatial Intelligence (NSG), the creation of Foundation GEOINT is a team sport. That team is expanding to transform Foundation GEOINT and the business processes/models by which it is compiled. New data options such as crowdsourcing, do-it-yourself data collection from drones and other sensors, and machine learning approaches are coming to supplement traditional foundation products with truly on-demand content.

If GEOINT is formally defined as "the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth,"[1] then Foundation GEOINT is the global representation of those physical features in the form of maps, charts, and data. Foundation GEOINT generally describes natural and man-made features of the world as vector data through points, lines, and polygons. Traditionally created through mono- or stereo-imagery extraction, those points, lines, and polygons are then cartographically styled to create products supporting a range of missions, from U.S. Department of Defense (DoD) operational planning, to aeronautical and maritime navigation, to base maps providing geospatial context in intelligence centers around the globe.

While Foundation GEOINT is inclusive of other mapping, charting, and geodesy (MC&G) components such as surveying, elevation modeling, and gravity modeling; Global Navigation Satellite System/GPS monitoring and processing; and satellite and aerial imagery, LiDAR, and radar collection; this article will focus primarily on vector mapping components. Foundation GEOINT is truly the foundation upon which all geospatially referenced intelligence analysis is built: it provides the cartographic backdrop and location referencing that enables imagery, signals, human, and all-source intelligence.

The origins of Foundation GEOINT in the U.S. can be found in the military services. The Army, Navy, and Air Force all performed portions of the nation's MC&G needs until the Defense Mapping Agency (DMA) was created to consolidate significant portions of this in the 1970s. Responsibilities for defense and intelligence mapping further converged with the creation of the National Imagery and Mapping Agency (NIMA) in 1996 and have remained as such with the creation of NGA in 2003. Foundation GEOINT has evolved during the history of DMA and NGA, shifting from highly disaggregated (functionally, organizationally, and physically) to highly aggregated. Additionally, while technological advances during this period have been revolutionary across all industries, the accuracy and precision advances in remote sensing now make it possible to map the world at sub-meter resolutions from space, with horizontal and vertical error at less than five meters globally. Combined with aerial assets at much higher resolution and accuracy, medium-resolution/accuracy small sats, and low-resolution but spectrally dense government satellites—such as the U.S. Geological Survey's LandSat 8 and the European Space Agency's Sentinel-2—it's clear the U.S. ability to collect and provide Foundation GEOINT is the best it has ever been.

Even with the significant aggregation of responsibilities at NGA, the agency relies on a team of partners to fulfill the Foundation GEOINT mission. U.S. military services, combatant commands, and intelligence agencies provide data for Foundation GEOINT holdings. Additionally, NGA manages international partner agreements for sharing Foundation GEOINT data and products, and none of this would be possible without the talent and

1. GEOINT Basic Doctrine. Publication 1.0. National System for Geospatial Intelligence. April 2018.

technology of commercial partners and service providers. This article discusses the opportunities NGA and its partners are beginning to leverage in technology, business processes, and acquisition to transform Foundation GEOINT production and delivery, with a purposeful shift toward on-demand access to mission-relevant Foundation GEOINT.

Blurred Lines

> *"The future is already here—it's just not very evenly distributed." – William Gibson*

The emergence of user-generated content in the form of customer-produced and crowdsourced data enhances the geospatial inventory, but simultaneously blurs lines between traditional Foundation GEOINT and non-authoritative data. Imagery and elevation data collected by drones and tactical aerial assets, and crowdsourced data, such as OpenStreetMap (OSM), add to the capabilities of users to collect data "on demand" for their areas of interest. This new generation of user-generated content supplies current and locally specific data to the geospatial community.

One such innovation is the Tactical Full Motion Video to 3D (FMV-2-3D) program currently in development at the U.S. Army Engineer Research and Development Center's Geospatial Research Laboratory. Using structure from motion, researchers created the FMV-2-3D tool to ingest live FMV feeds and produce customer-sourced Foundation GEOINT products within minutes. These point clouds, digital elevation models, and orthomosaics are available in near-real-time for mission planning and execution at the point of need. No longer are remotely placed teams bound by bandwidth to make critical mission decisions with limited or outdated maps. We are experiencing an era in which end users will collect, process, extract, and visualize geospatial products without touching the GEOINT pipeline.

This evolution of GEOINT product creation has the potential to flip dissemination of GEOINT products to a new model by which the ingestion of field-collected data may outpace the foundation products it seeks to enhance. These soldier-deployed GEOINT collection technologies will only intensify growing content delivery challenges. As more content is required to pass to tactical users on stretched connectivity pipelines, soldiers need intelligent support to reduce the load to only what is necessary for successful mission execution.
A critical step forward will take a user- and content-centric approach to support disconnected, intermittent, and limited (DIL) environments.

The emergence of crowd-oriented approaches presents more options for production (and consumption) of Foundation GEOINT. Beginning in 2004 with the development of OSM, map-making expanded from a producer-centric paradigm to a user-centric model. The dominion of highly trained geospatial professionals directed by mapping agency priorities became open to users with a range of skillsets and mapping objectives.

Crowdsourced mapping enables near-real-time access to data and cartographic products. Cartographic products take time to update, and traditional production is difficult to track and monitor. Intermediate data and products that may be fit for use are difficult to access until they are made available as final deliverables. Capabilities such as OSM change this paradigm by enabling access to data and maps as content is created, so consumers are able to evaluate, enrich, and use data when they deem fit.

Tec(h)tonic Shifts

Maturation of Open-Source Alternatives

OSM and similar volunteer mapping efforts would have limited impact on Foundation GEOINT if not for the rise of open-source software. OSM's global adoption made it a testbed for software improving data editing and curation. This aspect of OSM accelerated in 2010, when a devastating earthquake in Haiti led to the creation of the Humanitarian OpenStreetMap Team (HOT) and a wave of open-source, collaborative mapping tools. HOT's mission required real-time engagement among disparate mappers—including the military, NGOs, civil government, and citizens—and spurred creation of real-time web mapping and mobile software tools. Open-source software engineers in the geospatial community substantially improved the ability for OSM projects to distribute map editing tasks across volunteer mappers, while enabling data quality assurance and curation processes.

OSM's success was not lost on the U.S. government. NGA began a research and development version of OSM's user-focused mapping, editing, and curation model five years ago, and this has grown to more than 1,000 domestic and international users. The NSG Open Mapping Enclave (NOME) brings the crowd mapping model to the NSG by allowing NGA's defense, intelligence, and international partners to crowdsource data needs, enabling approved government users to contribute features and datasets in support of campaigns established based on mission requirements. NOME's promise is to provide users a "workforce" of mapping collaborators who can work on a project remotely to answer common data needs. NOME offers users both individual and collective ownership of data, allowing anyone to lead a campaign and providing new sources of current map data.

Some Foundation GEOINT missions remain difficult to adapt to the crowdsourcing model or to high levels of machine-derived data. Safety of Navigation (SoN) is one such mission. In the U.S., due to statutory restrictions, aeronautical and maritime SoN data at NGA require a tight chain of custody as well as vetting and approval by certified professionals in those fields.

However, new ground is being broken in these domains. NGA is demonstrating how machine learning and automation technologies can help triage and process global notices to mariners. Additionally, OpenSeaMap and open flightmaps platforms use crowdsourcing models to build global, open navigational maps for the maritime and aeronautical communities.

While these platforms present exciting opportunities, there remain significant hurdles to broad adoption of crowdsourced SoN approaches.

First, accurately mapping and updating features (especially non-land-based features) that are not clearly visible in satellite imagery is difficult and requires significant amounts of collateral material to locate, identify, and validate features. Second, the crowd for these types of data is significantly smaller than the crowd interested in mapping land-based features. Lastly, SoN is first and foremost about safety. NGA and other national and defense mapping organizations around the world have strict guidelines and timelines for publishing updates to navigation charts.

Bring on the Microservices

The need for crowdsourced mapping services allowing map editing and review across myriad mappers led to the development of software enabling OSM to harness crowds and update map data with unprecedented speed. A new generation of software is making crowdsourced data more accurate, reliable, and fit for Foundation GEOINT: cloud-based software microservices.

The microservice approach to software development improves the architecting of complex software processes. For Foundation GEOINT, a positive characteristic of the microservices approach is that it allows organizations to flexibly evolve software stacks. For example, for crowdsourced data to contribute to Foundation GEOINT, innovations in software microservices enable NOME and OSM to improve data conflation at scale, mapping campaign management and tasking, map editing, map quality assurance, data publication, and more. This is not to negate the legacy strength and staying power of commercial software that enables the majority of foundation mapping today; no doubt traditional commercial applications will remain central to the toolkit of Foundation GEOINT. However, the opportunities presented by open-source software and custom microservices development vastly expand that toolkit and provide workflow opportunities that are unreachable in legacy applications.

New microservices are on the horizon that allow managers to tailor mapping campaign presets and validations. A manager can limit edits mappers might make, allowing only point or certain types of facility collection. These rules can be embedded into map editing software, providing end users a simple, integrated solution. Other microservices are envisioned that allow Web Feature Services (WFS) to stream data such as points of interest from social media and websites, and to copy/paste features and attributes from the WFS to crowdsourced editing environments. By limiting input error, increasing data for enrichment, and conflating many sources automatically, microservices improve fidelity and enrichment of crowdsourced map resources and make them ready for Foundation GEOINT products.

The Machines Are Coming

The ability of cloud-based computer processes to automatically generate high-quality geospatial products on demand and for large areas is among the most transformational aspect of Foundation GEOINT's future. This is another example of how the future is already here in some places: At the GEOINT 2018 Symposium, NGA Director Robert Cardillo showed how the "Beachfront" shoreline detection process, developed by NGA's GEOINT Services, can rapidly draw new coastline vectors as new satellite imagery becomes available.

Processes like Beachfront have the potential to take the time and burden of hand digitization off analysts, enabling them to complete geospatial products in a fraction of current times. NGA partners are using cloud technology and distributed computing to automatically extract building footprints, roads, and more. NGA's ability to procure these rapidly produced, intermediate products quickly and at lower costs will create an "auto-extraction" services market, featuring agile acquisition and shorter production times that can reshape the Foundation GEOINT market.

World of Data

NGA recently underwent a strategic shift from being primarily a data (and product) provider for the defense and intelligence communities to serving as a broker connecting defense and intelligence users with data and products meeting unique mission needs, some of which NGA may not have a hand in creating or quality checking. This is a marked shift, but necessary due to the massive growth in commercial data providers and in geospatial literacy across NGA customers.

What used to be a tightly controlled data environment almost wholly owned and governed by NGA has shifted to one in which coverage, relevancy, and prevalence of commercial data and products has overwhelmed and outstripped NGA's, or any government's, mapping ability. Coupled with expectations for data availability, currency, and coverage by a geospatially literate community of customers, it was imperative NGA reassess its value proposition. As a broker, NGA retains its high-accuracy data and product creation mission while embracing the range of commercial, open, and other government sources that meet customer mission needs, then helps customers reach those data.

With innovative contracts along with organizational shifts, NGA is setting the landscape to enable the agency and its customers to get to the right data, product, or service as quickly as possible. NGA is also exploring ways to evolve acquisition approaches to allow for more competition, quicker execution, and smaller taskings. If success from NGA's GEOINT Pathfinder program is any indication, the agency's next step may be hyperlocal microtaskings for Foundation GEOINT updates over priority areas.

As a key example, U.S. Army has examined the ability to merge NSG authoritative datasets with commercial and open-source products to provide on-road route analysis and navigation at the point of need. As the nation's principle land force, navigation is a key technology enabler that has changed in focus, emphasizing decentralized operations in dense urban environments. These new warfighting paradigms have stressed current Foundation GEOINT products to provide accurate and timely route analysis at a tactical scale.

With unique mission requirements and specific vehicle movement parametrics, a single routing network and topology source has not been a viable production method. Multiple approaches are being examined, focusing on the ability to populate the operational data models and leverage commercial and open datasets simultaneously. While there exists an accurate geospatial layer to build from, detailed route network attribution (e.g., road directionality, turn restrictions) and temporal information (e.g., road closures, traffic) key to accurate navigation are lacking. Using NSG-procured HERE trucking data, NGA's NOME road topology, and the Army's existing road networks, a hybrid solution is being assessed to gather a best-of-breed dataset. While some route attributes will be conflated with other operational schemas, the Army is also investing in technology that will seamlessly switch between government, commercial, and open-source routing networks to provide user-based route analysis across the globe.

The Shift to On-Demand Foundation GEOINT

The future is here for customer-driven and crowdsourced contributions to Foundation GEOINT, enhanced by cloud technology and machine learning. Although these approaches are not distributed equally across the enterprise, they are having notable impacts and are proving successful in pockets across NGA and its community of partners. These approaches will continue to scale horizontally and vertically, and they will necessitate (and in many cases may be drivers of) tighter technology integration across the DoD and the Intelligence Community.

As the NSG continues to embrace more collaborative approaches to Foundation GEOINT mapping and leverages more automation, as NGA grows into its broker shoes, and as the ground warfighter (along with sailors and airmen) produces near-real-time Foundation GEOINT products in theater, NGA and the NSG will need to invest in focused shifts to technology architectures. This includes a protected unclassified production, integration, and collaboration environment for Foundation GEOINT that is globally accessible and scalable to support a global user base. Technology changes, however, will only go as far as culture and policy allow. The NSG will need to invest significantly in shaping these three pillars of transformation simultaneously to fully realize the shift to on-demand Foundation GEOINT data and the operational advantage this provides.

The Tradecraft of Artificial Intelligence and Machine Learning

By Mike Rampino, Preferred Systems Solutions; Steven R. Thomas, Ball Aerospace; Stephen H. Tupper, Missouri University of Science and Technology; Marion Neumann, Washington University in St. Louis; and Peter Morosoff, Electronic Mapping Systems, Inc. (E-MAPS)

The tradecraft of geospatial intelligence (GEOINT) is always evolving. However, the integration of artificial intelligence (AI) and machine learning (ML) into GEOINT tradecraft presents a significant paradigm shift, and like previous technical innovations that dramatically change and advance the tradecraft, a thoughtful, broad-reaching approach to the adoption of these technologies is necessary. AI and ML go beyond the introduction of technical innovation such as the conversion of film and print media to digital media or 3D stereoscopic capabilities.

The introduction of AI and ML into GEOINT will cause analysts and practitioners to interact with technology in a new way. In addition to learning new technical skills they will learn to teach geospatial science to AI. They will also oversee geospatial workflows and practices to determine where AI and ML can be inserted into processes to provide automation and augmentation. The merger of AI and ML within the GEOINT tradecraft will continue to advance toward a place in which its practitioners possess the knowledge and skills to be a steward of the GEOINT practice and the practitioner can leverage AI and ML to create new points of innovation. In the early stages of this inclusion of AI and ML we can already identify strong steps being made where Data Scientists work alongside GEOINT analysts to achieve mission outcomes.

Incorporating Innovation

The defense and intelligence communities have previously described enhancements of system performance and functionality in existing or deployed capabilities by inserting new or significantly improved technology. A vertical insertion enhances a single capability from bottom to top at components, equipment, subsystems, systems, system of systems, and kits. A horizontal insertion is the utilization of a new or improved technology in similar but distinct platforms or disciplines. The GEOINT Community should view the incorporation of AI and ML as the latter.

Historically, horizontal insertion of new technology can require a full generation to achieve. This is caused by an insertion model that waits for senior personnel to retire and entry-level personnel are the focus of training on the new technology. The GEOINT Community does not have a full generation to incorporate AI/ML technology. Insertion of AI/ML within the GEOINT tradecraft must move faster to keep pace with the exponential growth of data collected and to stay a step ahead of U.S. adversaries. If the GEOINT Community waits a generation to fully incorporate AI/ML, we will become irrelevant (and perhaps be dominated by our adversaries). Thus, new and aggressive education and insertion models must be adopted.

Recent history provides many examples of new technologies being adopted for national security purposes. Often, complex scientific and engineering concepts have been translated into layman's terms to enable training forces to employ new weapons or new enabling capabilities. For example, maritime navigation is based on geophysics and other scientific principles that might require an advanced degree to fully comprehend. Yet, the National Geospatial-Intelligence Agency (NGA) and its predecessor organizations have for years produced a widely used reference for laymen without such advanced degrees who successfully navigate the world's oceans.[1] The adoption and operational employment of RADAR in World War II and the operational deployment of nuclear weapons after World War II provide other examples. In each case, doctrine, training, and procedures had to be developed and implemented to allow airmen, sailors, marines, and soldiers with relatively little scientific or engineering knowledge to successfully operate complex and potentially lethal systems.[2]

To be successful, the GEOINT Community must create a culture within the tradecraft in which analysts and practitioners come to trust automated systems. It must cultivate a culture that has an eagerness to use AI/ML to replace manual, human-driven processes. The GEOINT Community must grow beyond its current educational programs and credentials to include new skills and knowledge. It must integrate the skills that support AI/ML within existing education and training programs. To achieve accelerated adoption of AI/ML, the GEOINT Community requires a multi-echelon educational offering related to AI/ML technology.

Education Echelons

These echelons are nested such that tradecraft practitioners at various seniority levels and of varying types of expertise receive tailored education and training that provide them the skills to employ AI/ML approaches such as using database platforms, structuring data warehouse environments, information storage and retrieval systems, web search engines, text mining, collaborative filtering, and recommender systems. These entry-level tasks may be appropriate subjects for instruction at the associate degree-level or in the form of industry certifications focused on specific hardware and software. These base-level skills in both hardware and software have a shorter shelf life due to constant improvement and rapid expansion.

At the next level up are the data scientists. They are likely to need a mix of bachelor's and master's degree-level understanding of regression, classification, resampling methods, model selection, regularization, decision trees, support vector machines, principal component analysis, and clustering. Analysts who draw on data science talent must first know the GEOINT domain and will succeed through collaboration with data science models and tools. GEOINT analysts in collaboration with data scientists will need to draw upon their combined talents and expertise to operate AI/ML comfortably across the GEOINT mission.

Beyond analysts, the top-echelon of decision-makers will require special instruction and education. Executives are drawn from many disciplines and don't necessarily lead the ranks they grew up in. It is more likely they have a variety of experiences in many fields and will have to be coached, more than educated, in how to best understand AI/ML-derived interpretations. Here the transition state equals the end state. High-level decision-makers are to be helped by learning an overarching understanding of the tradeoffs of using AI and ML, understanding the nuance associated in accepting AI/ML-augmented processes and products, and being prepared to invest in the maturation of the art and science of interpreting data via machines.

At the outset of using AI/ML within GEOINT processes, analysts, engineers, supervisors, and executives all need to understand that a product or recommendation for decisions based on AI/ML-dependent analysis should be treated with caution, possibly needing more verification by experienced humans until a consistent record of prediction has been statistically correlated with established tradecraft techniques. At the same time, these practitioners must be given training that allows them a depth of understanding that supports a willingness to invest in refining processes, algorithm development, datasets, etc. Additionally, this education needs to provide the fundamental acumen on which they can measure the maturity of the inserted AI/ML technology.

At another scale, an analyst should have a very different training in the AI/ML system—perhaps how it is coded, or the selection of filters, the segmentation of data, the speed of analysis, and the comparison of error. Within the GEOINT Community each practitioner (i.e., manager, engineer, data scientist, and analyst) must work together, leveraging their different skills and expertise to improve the technology through methodologies such as mining, scraping, manipulating, transforming, cleaning, visualizing, summarizing, and modeling large-scale data as well as supervised and unsupervised machine learning algorithms applied in various mission scenarios.

AI and ML have the potential to greatly improve the productivity, capacity, and capability of GEOINT analysts, enabling them and their organizations to capitalize on the ever-increasing amount of data available. In the near-term, advances in computational power, artificial neural networks (ANNs), and computer vision enable new approaches to GEOINT tradecraft. NGA Director Robert Cardillo has said eight million more GEOINT analysts would be needed to analyze all the data expected to be available as remote sensing systems and other

1. "The American Practical Navigator" was first published in 1802 and was most recently published by NGA in 2017. It had been published by NGA predecessor organizations for decades. NGA provides access to the material on line at https://msi.nga.mil/NGAPortal/MSI.portal?_nfpb=true&_pageLabel=msi_portal_page_62&pubCode=0002.
2. The United States Air Force initially used highly-educated contractors to staff its first Atlas Intercontinental Ballistic Missile (ICBM) system but then transitioned to less-technically sophisticated and educated military operators after a Strategic Air Command crew completed a successful training launch. Jacob Neufeld, "Ballistic Missiles," (Washington, D.C., Office of Air Force History, 1990), 103, 208, 252-253.

geospatial data sources proliferate.[3] Since educating, training, and employing millions of additional GEOINT analysts is unlikely if not impossible, incorporating AI and ML into GEOINT tradecraft might help us keep up. But discussions of how to best incorporate AL and ML into GEOINT tradecraft can reveal disparate views.

Some assert that anyone wishing to apply AI/ML must have an advanced degree in computer science, math, or statistics and be proficient in coding and writing software. The thinking is it would be dangerous for anyone without such education and skills to apply AI and ML. Such an approach would certainly provide practitioners greater confidence in applying AI/ML to GEOINT tradecraft, but it would likely also significantly slow speed of adoption. We might also find that people eager to be GEOINT analysts don't necessarily have the same passion for being computer scientists or mathematicians.

In order to successfully determine where AI and ML can be inserted into GEOINT processes, engineers and practitioners tasked with its implementation or development need to gain a substantial understanding of the fundamentals of AI/ML algorithms. This typically requires a solid background in probability and statistics, linear algebra, and calculus. Proficiency in probability and statistics is not only important for engineers who want to understand and implement AI/ML methods, but it is also a critical skill for analysts and end users who apply AI/ML methods—even if the methods themselves are treated as a black box. Users of AI/ML techniques need to understand, interpret, and judge both input and output to AI/ML algorithms applied to practical problems.

The educational echelons of the GEOINT Community will need to ensure fundamentals such as linear algebra and calculus, which are foundational to the understanding of AI/ML algorithms. Conversely, the developers and engineers tasked with implementation of AI/ML technology, whether from scratch or existing implementations, are approaching AI/ML from a computer science perspective. They require proficiency in data structures and algorithms (including complexity analysis).

As there is no one ML method that solves all problems, engineers will have to acquire a basic understanding of the strengths and weaknesses of the state-of-the art methods. Further, it is important to understand the ML workflow and how to evaluate and compare algorithms in a sound and scientific manner as well as how to internalize the process of comparing and evaluating algorithms on various application domains. Engineers will have to dive deeper into the learning algorithms that typically leverage non-linear optimization and advanced calculus. At the core is a focus on understanding, implementing, and analyzing AI/ML algorithms, however related fields of study such as computer vision, big data processing, and cloud computing should be considered in a holistic AI/ML education.

By recognizing the different needs of GEOINT Community, a multi-echelon educational approach advocates teaching AI/ML as a series of courses or programs that allow students to achieve the level of familiarity with AI/ML methods their role within the GEOINT Community requires. Providing multiple courses, paths, and tracks covering the introduction of AI/ML at undergraduate and graduate levels ensures the variety of roles, positions, and seniority levels within the community are provided the education and training needed to successfully adopt AI/ML.

Growing Confidence in AI/ML

The community is in the early phase of applying AI/ML to GEOINT tradecraft. Defense and intelligence organizations such as NGA have pilots underway that should shed light on the best approaches. These pilot programs have helped reveal and identify challenges in inserting AI/ML into GEOINT workflows. Some of these challenges include but are certainly not limited to data scarcity, lack of data diversity, difficulty in scaling AI/ML, and legacy systems that were designed around human perception and performance. Each of these challenges must be overcome to fully realize the benefits of AI/ML.

However, perhaps the greatest challenge from the perceptive of the GEOINT tradecraft is that of confidence in use of the emerging technologies. AI/ML offers a future in which analysts are freed from much if not all of the manual data management tasks that consume a large amount of their time. They are freed from tasks such as data labeling and allowed to focus on mission-related analysis and production. However, those analysts must have confidence in the AI system.

In these early days of applying AI/ML to GEOINT tradecraft, it seems teaming analysts with data scientists is yielding successes. The GEOINT analysts have seen significantly increased productivity and are confident in applying ML to their analytical problems. Today, GEOINT analysts participating in these pilot programs depend on close collaboration with data scientists. The data scientists develop models and implement ML algorithms. GEOINT analysts work with the data scientists to help validate the models but the data scientists do the development and write the code. The collaboration seems to be instilling a level of understanding and confidence in AI/ML. In the longer-term, when AI/ML tools and processes are implemented at an enterprise scale, the GEOINT Community will need to determine how to build confidence in its analysts and leadership and determine whether constant collaboration with data scientists will diminish over time or become an institutionalized change within the community's tradecraft.

3. Robert Cardillo, Director of the National Geospatial-Intelligence Agency, remarks delivered at the GEOINT 2018 Symposium, 23 April 2018, available at https://www.nga.mil/MediaRoom/SpeechesRemarks/Pages/GEOINT-2018-Symposium-.aspx.

Bridging GEOINT and IoT for Secure Smart Cities

By Chip Hathaway, TerraGo; Mike Mullen, Deep Water Point; and John Torres, Security & Technology Consulting and Guidepost

As the GEOINT Community expands beyond traditional defense and intelligence arenas, so do innovations that marry geospatial intelligence (GEOINT) technology with the Internet of Things (IoT) and cybersecurity to create smart cities and smart military bases.

A National League of Cities report, "Trends in Smart City Development," defined a smart city as "one that has developed technological infrastructure that enables it to collect, aggregate, and analyze real-time data to improve the lives of its residents."[1]

Today's smart cities embrace fully connected networks of IoT sensors and sensor nodes, smart devices, mobile applications, and social networks that generate location-based data to optimize energy efficiency, security, traffic, infrastructure, public safety, emergency response, and more. The underpinning of the network is geospatial technology that provides a framework for data collection, language for analysis and decision-making, a method for decision implementation, and a means for communication with a public that increasingly drives smart cities.

Smart cities are the next big thing in a technological continuum that has stretched more than a quarter century and looks ahead to transformation. But what makes a city smart? What does a smart city look like? Ask several practitioners and each will have a different answer, depending on personal involvement. Often the response is, "I don't know, but I recognize it when I see it."

Some point to applications to find available parking spaces. Others to streetlights that vary in intensity in response to public safety needs, and snowplows strategically placed to cope with storms. Still others note the power grid. Or busses and trains that run on time, or traffic signals timed strategically with rush hours. Some stakeholders will add elements of "economic development." Others want to include "resiliency" and "sustainability." Still others mention automation, machine learning, or artificial intelligence (AI). More enlightened respondents point to public interaction that drives decisions and their implementation.

More properly, smart cities are about the art of the possible, limited by the budget of the practical but not by the imagination of the creative. They're about an industry generating solutions to problems some cities didn't know they had, and other cities believed were insoluble as merely the high price of growth. They're about quality of life, but also increasingly about concerns of threatened privacy and fears of cybersecurity breaches that could shut down critical infrastructure and cause chaos.

Smart cities technology is being used to cope with a population migration to urban areas. The infusion of people brings increased public and private resource and amenity requirements and quality-of-life demands, as well as potential effects on climate and weather.

The United Nations reported in 2018 that 55 percent of the world's population lives in cities, and that the percentage would rise to 68 percent by 2050.[2] In the United States, 82.7 percent of the population lives in urban areas, and that number is expected to grow to 87.4 percent by 2050.[3]

An estimated $80 billion was spent on smart cities in 2018, largely driven by priorities in transportation, public safety, and energy, according to International Data Corporation, which predicts expenditures will rise to $158 billion in 2022.[4]

While the U.S. military talks of moving toward smart cities technology for bases, budgets remain focused on personnel and weaponry, with less emphasis on funding facility updates. Still, the Army uses smart energy to reduce costs up to $160 million a year. A 250-acre solar farm at Fort Stewart, Ga., provides 30 percent of the facility's needs. Cameras and other sensors are being more closely integrated in some facilities to tighten security.

The Army plans to launch a series of pilot programs over the next 12 to 18 months to see how smart cities concepts can improve facility services, according to Lt. Gen. Gwen Bingham, assistant chief of staff for installation management. Public-private partnerships have been suggested to overcome budget issues.[5]

The U.S., which lagged behind Europe and Asia in embracing smart city concepts, led the world in 2018 with $22 billion spent on smart cities technology, followed closely by China's $21 billion. But the countries are spending differently. The U.S. is retrofitting mature cities with tools aimed at infrastructure and quality-of-life issues such as transportation, health, education, and safety. China is building cities with smart cities technology, addressing some of the same issues, but also with facial recognition and movement monitoring technology as part of the security apparatus. Many Americans would find those measures intrusive.[6]

But smart cities and bases are about more than money and investment. They're about geospatial analytics that shape the future.

1. National League of Cities. https://www.nlc.org/find-city-solutions/city-solutions-and-applied-resources/urban-development/trends-in-smart-city-development/.
2. United Nations. "The 2018 Revision of World Urbanization Prospects." http://www.un.org/development/desa/publications/2018-revision-of-world-urbanization-prospects.html.
3. statista.com. https://www.statista.com/statistics/678561/urbanization-in-the-united-states/.
4. International Data Corporation. https://www.idc.com/getdoc.jsp?containerId=prUS44159418.
5. Federal News Network. https://federalnewsnetwork.com/army/2018/07/army-plans-smart-city-technology-pilots-to-move-toward-installations-of-the-future/.
6. zdnet.com. "Cisco CEO Chuck Robbins on Smart Cities Architecture: Step by Step." https://www.zdnet.com/article/cisco-ceo-chuck-robbins-on-smart-cities-architecture/.

GEOINT for the Internet of Cyber Assets

When you speak with many smart cities advocates, their emphasis is on building the network “now” to enable a future in which connected devices will proliferate, bringing new data sources online that enable new services, real-time analytics, and infrastructure optimization.

Security demands will increase with the growth of smart cities networks, devices, and sensors, as well as a future that includes fleets of automatic vehicles (AVs). There were 2.1 billion machine-to-machine (M2M) connections added to an already crowded cybersphere last year, according to Cisco CEO Chuck Robbins. He also said another 27 billion M2M connections will be added in the next five years.[7] Put simply, that’s 27 billion networked cyber assets.

This is where geospatial intelligence (GEOINT) technology has another unique, enabling role to play. IoT cyber assets need vigilant chain of custody and location tracking during installation, commissioning, and maintenance, and, ultimately, a secure disposition. Like traditional corporate networks, smart cities networks need robust access controls and threat intelligence. Unlike traditional networks, IoT sensors represent a geographically dispersed population of network devices that can’t be housed in secure data centers. A GEOINT-enabled security framework tracks the location of all network devices to prevent the risk of physical exfiltration along with illicit network penetration.

GEOINT, including spatial analytics, enables many of the economic benefits of today’s smart cities networks. New and broader GEOINT technology will be required to help secure those networks, and GIS practitioners with smart cities skillsets will be needed to apply that technology as part of the security process to meet the needs of the cities of tomorrow.

Beginning at the End

The path to smartness begins at its end, according to the National League of Cities: “[Before buying smart cities technology] cities should consider the outcomes they want to achieve. The most successful Smart City initiatives will be those with clear objectives that solve public problems unique to each city.”[8]

More succinctly, said Deloitte CEO Cathy Engelbert, “Cities … have to think big but start small.”[9]

This approach has taken time to develop. When smart cities took root in the 1990s, their champions were IBM, Cisco, and other companies that developed products sold as solutions. Smart cities scientist Boyd Cohen calls this technology-driven period “Smart Cities 1.0.”[10] What followed was a generation of mayors and city officials who identified future issues and how technology addressed them in Smart Cities 2.0. Citizen involvement created a Smart Cities 3.0 model that is ongoing, according to Cohen.

The art of the possible became reality in the minds of an educated public eager for and demanding change. Quality of life became the product of an ecosystem built to generate solutions to questions such as:

- Does the city want more effective public safety?
- More efficient transit?
- Better access to health services?
- More reliable disaster response?
- More efficient utilities?
- Better schools?
- More greenspace? Recreational facilities? An arena? A ballpark? All of the above?

With input from citizens, city administrators and urban planners learned that answers were in data that was available—at a price. Smart cities technology can be expensive, and cost often drives the scope of its implementation, making it incremental.

At their core, smart cities use a data-gathering network of IoT sensors, nodes, and software to generate data for research, and analytics to interpret the story the data tells. That data includes citizen input that often drives decision-making and implementation. Smart cities are built on government-citizen dialogue, fostered by ease of public access to the process. That dialogue runs the gamut of inputs, ranging from digital access to smart cities websites, to town halls and open council meetings, to committees that work hand-in-hand with officials.

“The way forward today is a community-driven, bottom-up approach where citizens are an integral part of designing and developing smart cities, and not a top-down policy with city leaders focusing on technology platforms alone,” said Bettina Tratz-Ryan, Research Vice President at Gartner, at a 2018 “Development of Smart Cities” symposium in Dubai.[11]

Smart cities data is foundationally geospatial. Both providers and consumers can foster smart growth based on geographic characteristics as part of the value of smart city investments.

For example, the citizens of Vancouver and Surrey, British Columbia, answered the call for input on the region’s application for part of a $300 million Canadian Smart Cities Challenge award for innovation. They came up with a corridor for autonomous vehicles that would eliminate crashes with cars driven by humans. The bid received $250,000 from the Canadian government for

7. Corrine Reichert. ZDnet. “Cisco Live 2018: CEO Chuck Robbins Pushes Tighter Datacenter Security.” https://www.zdnet.com/article/cisco-live-2018-ceo-chuck-robbins-pushes-tighter-datacentre-security/.
8. National League of Cities. “New Report on Smart Cities Released by National League of Cities.” https://www.nlc.org/article/new-report-on-smart-cities-released-by-national-league-of-cities.
9. 2017 World Economic Forum. “Smart Cities/Smart Nations” (video). https://www.google.com/search?ei=1-R1W97mGpCV5wKd0rj4Aw&q=Cathy+Engelbert+Deloitte+Smart+Cities&oq=Cathy+Engelbert+Deloitte+Smart+Cities&gs_l=psy-ab.3..33i299k1.2127.14690.0.15419.75.44.0.0.0.0.307.5926.0j23j6j2.32.0..3..0...1.1.64.psy-ab..47.28.5619.6..0j35i39k1j0i131k1j0i67k1j0i131i67k1j0i20i264k1j0i22i30k1j33i160k1j33i22i29i30k1.334.aEiBHxhil4E.
10. Boyd Cohen. “The 3 Generations of Smart Cities.” https://www.fastcompany.com/3047795/the-3-generations-of-smart-cities.
11. Smart Cities World. https://www.smartcitiesworld.net/news/news/citizen-engagement-is-key-to-smart-city-success-2685.

research and was short-listed for a $50 million award.

Other dialogue is fostered, for example, when a city official tells a town-hall-style audience that smart cities data will be used to bring commerce and industry to a community, then assures questioners that personally identifiable information won't be used to create customer mailing lists.

Turning On (and Off) the Smart City Lights

Because of costs, some cities made purchases in piecemeal, believing smart cities technology to be a solution to an existing problem rather than part of a whole.

For example, New York was one of several cities to buy acoustic sensors, which detect and track gunshots. Other cities used parking technology to help drivers find available spaces. Still others used technology to plan public transit. But most technologies weren't integrated with each other to offer a broader picture. Now cities are turning to streetlights as a step toward broader adoption of smart cities technology. Lighting is ubiquitous and generates high energy costs, and savings from smart cities technology significantly improve the bottom line.

Cities are deploying light-emitting diode (LED) bulbs and fixtures to replace more expensive sodium and mercury vapor bulbs. Even greater savings and possibilities come from networking lights for advanced controls. Using GEOINT principles, the system can be mapped to determine where maintenance is needed and to plan for future smart cities technology expansion and security. The map also becomes part of the foundation for dialogue with the public.

The lights themselves can be manipulated to be dimmer in safer neighborhoods, brighter in commercial and high-crime areas, and can be controlled seasonally to adjust to weather conditions.

Cities have saved money and lowered CO2 emissions with smart streetlight programs. Chicago, for example, expects to save $10 million annually in energy costs with a 270,000-light, four-year retrofit and the addition of intelligent controls.[1]

Using a smaller example, the town of Richmond Hill, part of Greater Toronto, expects to save nearly $1 million annually from its implementation of 13,000 networked streetlights using Itron's SLV smart city management platform.[2] Kansas City, Washington, D.C., Pittsburgh, and other cities are making comparable investments.

Lighting fixtures can also host acoustic and air quality sensor nodes, and those that monitor pedestrian sidewalk use, traffic congestion, parking availability, school zone activity, weather, and other public safety and quality-of-life issues. Cities are also considering streetlight infrastructure for adding cameras, emergency response aids, smart traffic lights that can adjust timing to align with demand, and public Wi-Fi.

Autonomous Vehicles

While surveys show public opinion of autonomous vehicles (AVs) remains mixed, investment in research accelerates. In an October 2017 report, the Brookings Institution determined 160 projects spent $80 billion on AVs from 2014 to 2017, and that as much would be spent in 2018 alone.[3] Still, a 2018 report from Deloitte showed only a small percentage of U.S. respondents consider driverless vehicles safe, though the report also indicated a trend toward more trust when compared to earlier surveys.[4]

In March 2018, a pedestrian was killed in a crosswalk by an Uber Volvo driving in automatic mode, and five days later the safety driver of a Tesla operating in automatic mode died when the car struck a barricade in Silicon Valley. In each case, the safety drivers were determined to be at least partly at fault.

Though many manufacturers are aiming at AV or driver-assisted AV rollouts in the next decade, there are more than 270 million manned automobiles on the road in the U.S. and weaning drivers off them is going to take time. It's also going to mean that the human element continues to be part of traffic and autonomous vehicle research.

As AVs grow in scope and capability, smart cities can contribute to AI that can drive vehicle development. Driverless cars with sensors and algorithms that interact with smart city IoT sensors, as well as with sensors and geo-fencing, can help with autonomous navigation, updating dynamic maps that are downloaded into the vehicles. Traffic light sensors, sensors in school and construction zones, traffic flow sensors, parking availability sensors, and weather and road condition monitors offer the potential to build a "halo of safety" around autonomous vehicles.

Threat Risk Grows with Networked Devices

Even when the IoT was considered a personal amalgamation of baby monitors, garage-door openers, light switches, television remote controls, and other conveniences, there was concern about hacking. That concern has been heightened by smart city technology in which every sensor and step along the data value chain is considered a potential portal for cyberattack.

To name just a few concerns—Could a hacker take over electronic traffic control boards and light systems to create chaos? How would that that impact AVs?

Could someone override sensors monitoring the water level in a reservoir to create a flood? Could a hacker-created snarl impede first responders in an emergency? Alter the power grid? Exacerbate the impact of a weather emergency or other natural disaster?

1. *Forbes*. "From Connected Street Lights to Smart Cities." https://www.forbes.com/sites/pikeresearch/2018/04/06/smart-cities/#32ac69a113c8.
2. *LEDs Magazine*. https://www.ledsmagazine.com/articles/2018/04/toronto-town-settles-on-smart-lights-for-now.html.
3. Brookings Institute. "Gauging investment in self-driving cars." https://www.brookings.edu/research/gauging-investment-in-self-driving-cars/.
4. Deloitte. "2018 Global Automotive Consumer Study." https://www2.deloitte.com/us/en/pages/manufacturing/articles/automotive-trends-millennials-consumer-study.html.

An accidental missile alert in Hawaii on January 13, 2018, and hackers setting off 156 outdoor tornado sirens in Dallas on April 7, 2017, highlighted potential security issues. So too did the Intelligence Community's finding that Russian-sponsored actors invaded U.S. election infrastructure in 2016, in addition to reports of foreign attempts to impact the nation's power grid.

Those questions and actions drove researchers from IBM Security, dubbed IBM X-Force Red, and Threatcare, along with others, to probe smart cities infrastructure for vulnerabilities. Many were found, and companies that built data-gathering and processing platforms responded with patches for existing vulnerabilities and more security-conscious software development.[5]

The result is more secure—and costly—smart cities technology and, likely, a budding related security industry to address future fears. And need for more and better geospatial technology and applications—and GIS-trained people to run them.

How Maritime Geospatial Analysis Helps Identify Asymmetric Threats

By CAPT. Jatin S. Bains, Merchant Mariner; CDR (US Navy Intelligence Retired) Dennis Pendergist; and CDR (Indian Navy Intelligence Retired) Shishir Upadhyaya, Ph.D.

The Challenges

Earth observation and remote sensing in the maritime domain cover 70 percent of the Earth's surface, where almost every conceivable illegal and legal activity occurs. The maritime domain is also home to the movement of more than 90 percent of world trade. National exclusive economic zone boundaries are widely recognized by the United Nations. Furthermore, low Earth orbit (LEO) satellites are widely used for remote sensing with automated identification system (AIS), optical, radar, and signals intelligence (SIGINT) payloads. The maritime domain hosts approximately 250,000 compliant surface craft and approximately 250,000 quasi-compliant surface craft. In other words, up to half and maybe more of the vessels on the sea who should follow specific rules and regulations dealing with identification and intent on the water do not do so continuously.

In reality, a non-state nefarious actor can proceed undetected since mandatory platform AIS transmissions rely on self-governance and can be spoofed, hacked, or even turned off. According to a November 11, 2015 article by *marineelectronicsjournal.com*, one study conducted in 2013 suggests that nearly one quarter of all AIS-equipped vessels have AIS turned off at least 10 percent of the time, hiding the vessel's true location. Other sensors such as optical, radar, and SIGINT can mainly validate geo-location, which also depends on data latency. The concept of Identification Friend or Foe on surface combatants is a well-designed process with suitable sensors. This article highlights that nefarious actors are readily capable of launching asymmetric attacks since the platforms used are mainly unregistered, non-compliant, and typically fail to follow International Maritime Organization regulations.

Numerous entities continue using efforts such as manual sightings to signal triangulation to create an extensive database of ship movements. Likewise, numerous efforts have been undertaken to build a database of crafts used in illegal fishing. In today's world, non-state actors are challenging nation states, institutions, and private enterprise through a wide range of overt and covert activities. These are referred to as "asymmetric" or "hybrid" threats/warfare, and the maritime domain has proven especially vulnerable. As we continue to see in the South China Sea, a hybrid approach lowers the chance of criminal or militant actors being interdicted because of the miniscule chance of being identified or tracked in the vast maritime domain. This phenomenon requires a whole of government approach to access the necessary means and authorities to address these types of threats. Thus, asymmetric or hybrid threats are best understood when framed as an attack on governance.

Transnational, non-state actors such as ISIS use subtle, far-reaching, and opportunistic methods including legal trade. In other cases, they can be more brazen, but operate in a gray zone where the affected state has few response options without escalating the situation into an armed conflict. In general, governments and institutions with weak governance are more susceptible. Corruption, low levels of public trust, ineffective law enforcement, poor border and port security, weak security protocols for critical infrastructure, and a lack of cooperation between the government and the private sector increase vulnerability.

Threats to maritime security have always existed but modern communication, online banking, supply chain visibility, and other factors have allowed asymmetric and hybrid threats to be weaponized against globalization. It is important to understand that more than 75 percent of global critical infrastructure (offshore oil wells, drilling rigs, floating liquefied natural gas platforms, seaports, offshore pipeline loading arms, etc.) are owned by the private sector. Geospatial analytics help identify asymmetric threats by leveraging artificial intelligence (AI) and near real-time data analysis.

Databases and Sensors

Numerous databases and sensor systems are available with various methods to cross-reference and identify surface craft. The emerging source of data is

5. *Wired*. "The Sensors That Power Smart Cities Are a Hacker's Dream." https://www.wired.com/story/sensor-hubs-smart-cities-vulnerabilities-hacks/.

open-source intelligence (OSINT), which is often derived from unstructured data available on the internet or via other reporting mechanisms. The large swath of geospatial data has often existed in silos due to classified sensor data being handled differently than unclassified data in an effort to protect sources and methods of data collection. It is widely acknowledged that a significantly lower percentage of data is now classified than compared with the pre-internet era as a result of today's pervasive and fungible nature of data and access. The recent emergence of LEO payloads and the geospatial data they deliver are providing multiple opportunities to integrate and merge sensor with non-sensor data.

Efforts such as the Department of Justice-led SeaHawk Task Force in Charleston, S.C., the Joint Interagency Task Force South (JIATF South) in Florida, JIATF West in Hawaii, the Maritime Security Task Force in Singapore, and the Naval Coordination and Guidance for Shipping in Bahrain are all examples of fusion or data integration entities intent on identifying threats. These entities have mostly been successful and led to improvements in the ability to mitigate a number of asymmetric and other potential maritime-related threats.

Data collection has become a pervasive and a substantial part of OSINT. For example, piracy data can be obtained via nefarious maritime events reported in local news or bulletins. Or there is the emergence of social media postings and other data streams generated around illegal fishing, hijackings at sea, United Nation sanctions, etc. Other subject matter experts have said that the substantive amount of volunteered geographic information available leads to a host of AI rules facilitating geospatial intelligence (GEOINT), which leads to improved maritime domain awareness for stakeholders.

The Rise of Non-State Actors

In the new era of global finance, big data, and mass migration, the principle of territorial sovereignty agreed to at the Treaty of Westphalia in 1648 is under threat. The early 20th century brought western nations to establish a set of national values—defense, taxation, and law, among others—that gave governments substantial control of national identity. The world has now evolved to the point which big data companies such as Google, Amazon, and Facebook have assumed many functions previously associated with the state, from cartography to tracking.

In the past few decades, more countries are going the way of Yemen, South Sudan, Syria, and Somalia, and are flush with opportunities for nefarious non-state actors. The political technology is charismatic religion, and the future they seek is inspired by the ancient golden empires that existed before the invention of nations. It is in the world's most dangerous regions that today's new political possibilities are imagined. Recognizing that the non-state actor has substantial tools available to them and that global data is ubiquitous and fragmented, it is reasonable to assume that stakeholders such as navies, coast guards, and marine police units do not have near real-time actionable intelligence to understand intent, mitigate asymmetric threats, and react. This discipline is operationally called maritime domain awareness or maritime security, and is guided by AI and big data analytics.

Ascertaining Intent

Ascertaining intent is possible by deciphering the quantum of reliable, real-time, and single source data using AI, machine, and deep learning in a cloud-based environment where data from multiple sources can be correlated and analyzed. This enables the capability to establish change detection conditions for a defined area of responsibility or interest. Movement of regular trade is historically captured and object detection algorithms on synthetic aperture radar (SAR) data reveal where non-compliant targets that do not transmit, spoof, or hack identification signals are located.

A good example is the unusual movements of small craft in the Sulu Sea between Sabah, Malaysia, and Mindanao, Philippines, where the terrorist group Abu Sayyaf is known to be active. When change detection algorithms observe an increase or decrease in the non-compliant cluster, they can reliably predict that nefarious activity is imminent. Utilizing these methods, the entity is then able to establish, in near real-time, maritime domain awareness including the monitoring of intelligence triggers such as governance, proliferation, etc., that alert us to the prospect of nefarious activities by non-state actors.

To reach a conclusive state of reasoning, we must first be able to corroborate and validate conditions when such clusters appear, for example, when an oil tanker (candidate for piracy) passes, when a slow-moving tug and barge unit (candidate for commodity theft) passes, when a cruise ship passes, or when the U.S. Navy undertakes a scope of Freedom of Navigation Operations. We will then be able to query a library of optical and SAR imagery, each with metadata outlining the state of the area of responsibility and interest. The resultant spatiotemporal heat maps are able to position valuable insight when a commander is evaluating near real-time situational awareness from single-source data based on the commander's concept of operations. Ascertaining intent is further validated with numerous other data attributes from satellite sensors such as speed, course, length, and track. We believe spatiotemporal threat reasoning will become the primary model for ascertaining levels and types of asymmetric threats.

Operational Benefits

It must be acknowledged that the blockchain revolution has just begun. Blockchain is a type of distributed database that allows untrusted parties to reach consensus on a shared digital history without a middleman. It is considered to be incorruptible. A distributed database eliminates a single point of attack and makes blockchain a highly secure and reliable source of truth. This is an important point for stakeholders such as navies, coast guards, and marine police who need to validate the security risk of unknown entities.

The value of the discussed blockchain methodology in theater is multifold:

- Largely eliminates data latency.
- Provides near real-time management of compliant and non-compliant targets in theater.
- Provides a model for creating a library of non-compliant "dark objects."
- Provides an extensive library of maritime (non-naval) threats in theater.
- Generates intelligence on demand for any designated area of responsibility and/or interest.
- Empowers in-theater GEOINT analysts with near real-time and more comprehensive tipping and cueing.
- Allows the commander to create mission-based rules on demand using near real-time, single-source data.

Conclusion

The emergence and integration of mature commercial geospatial and non-spatial capabilities allows us to address asymmetric threats in theater and in near real-time. A sizeable advantage of commercially available capabilities helps improve GEOINT collaboration with coalition partners. Those valuable data nuggets come from diverse sources and collectively define, corroborate, and validate the mosaic. The art of ascertaining context and intent is not opaque but a rigorous process of defining spatiotemporal threat modeling. The emerging space-based Earth observation marketplace is unprecedented in size, scale, and vision, with the expressed intent to provide timely geospatial information and analytics to the world.

Discussion is taking place among government geospatial analysts to determine how commercial remote sensing imagery, analysis, and services can be best applied to support U.S. government missions. What is needed to achieve an optimal mix of OSINT and GEOINT data for all U.S. government users? What regulatory impediments remain for the commercial Earth observation community to fully support U.S. government needs? Likewise, it is reasonable to expect the intelligence, surveillance, and reconnaissance enterprise to work hand-in-hand with the broader Intelligence Community, embrace commercial space capabilities, and integrate them with decision support systems across all echelons.

It is undisputed that the demand for timely, relevant, accurate, and customized geospatial products has exploded. The growth in demand has coincided with the emergence of global architectures such as Amazon Web Services, which is poised to move data to customers with almost no time delay. The customer base, now composed of both government and coalition government entities around the globe, has pushed commercial, space-based GEOINT providers to develop machine-to-machine algorithms to almost instantly process and analyze data streams, then produce customized contextual results based on stakeholder needs. This has been coined Actionable Information as-a Service (IaaS), available on demand anytime and anywhere via an internet browser.

Unlocking the Cultural Digital Footprint from Natural Language at Scale

By H. Andrew Schwartz, Ph.D., Stony Brook University; Brenda Curtis, Ph.D., University of Pennsylvania; Christine DeLorenzo, Ph.D., Stony Brook University; Salvatore Giorgi, M.S., University of Pennsylvania; and Peter Small, M.D., Rockefeller Foundation

The growth of social media yields an unprecedented ability for a populous to passively report cultural data such as:

- Behavior (e.g., exercise, smoking, drinking, and food consumption).
- Psychological characteristics (e.g., mental health, sense of community, beliefs, and engagement in life).
- Socioeconomic markers (e.g., education, commerce, real estate, and work).

Historically, creating an understanding of the "cultural digital footprint" from limited datasets has been conducted using qualitative research techniques such as manually reading and summarizing cultural data. However, new data science techniques emerging from the intersection of natural language processing, machine learning, and computational social science allow the conversion of unstructured information from social media into quantitative spatial and temporal data, automating the understanding of the cultural footprint of communities.

Recently, we have been exploring the advantage of the cultural digital footprint

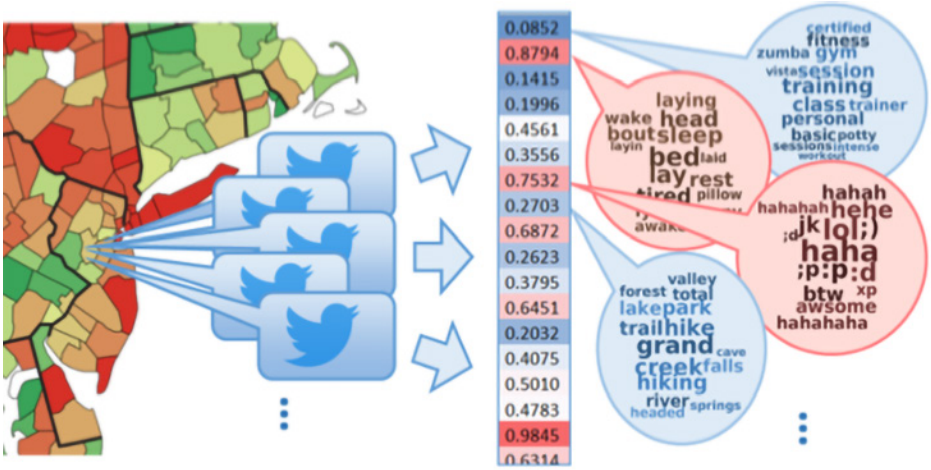

Figure 1. Social media and web content are mapped to U.S. counties whereby patterns of language can be encoded as a representation of each geographic area. Colors indicate greater (red) or less (blue) frequency of mention.

by evaluating its predictive analytic power as compared to typical structured geospatial data, and what we are finding is quite striking. Cultural characteristics derived from Tweets on Twitter often provide more predictive power for rates of health, psychological, and economic outcomes as compared to standard socioeconomic and demographic variables.

The general idea, as depicted in Figure 1 on the previous page, is that unstructured language data is mapped to its geographic origin and then natural language processing routines can be run to turn the unstructured text into a structured, quantitative representation of the geographic area. For example, the structured representation could contain the frequency with which particular words are mentioned. Because words are our primary form of communication, often the contents of these representations are also interpretable. For example, Figure 1 depicts a representation of a county in New Jersey by the frequency with which specific topics are mentioned. Talking about sleep may be frequent, while talking about the training class at the gym is less so. In this way, digital footprints in language can unlock geographically structured insights into cultural and psychological factors that were previously accessible only through expensive surveying techniques. Early work with such data looked directly at linguistic differences by region.[1] In this article, we discuss more recent work that takes the next step of relating geographic difference to health, psychological, and economic outcomes.

Current Research on Geographic Language

Prior to the growth of web and social media data, relating health outcomes across a large number of communities to cultural factors typically relied on expensive and limited surveys (a notable exception being crude behavioral proxies such as number of fast food restaurants, bike trails, etc.). The digital footprint of culture offers a novel and potentially more powerful perspective. Using geographic language representations along with machine learning techniques, one can often predict county mortality rates in the U.S.

For example, when predicting atherosclerotic heart disease mortality, geographic language from Twitter contained more predictive power by itself than 10 standard variables including demographics, socioeconomics, and standard risk factors such as smoking, diabetes, and obesity.[2] More recently, we found encodings from Twitter show predictive power beyond 15 standard structural variables (covering demographic, socioeconomic, geographic, and surveyed behavioral and psychological information) for seven out of America's top 10 causes of death. Figure 2 shows prediction results for cancer mortality rates.

One might find these results particularly striking when considering, for the most part, the people Tweeting are not those dying of cancer. Rather, the Tweeters are more like canaries that together provide a powerful characterization of a community. In fact, the users on Twitter are not even perfectly representative of their community, specifically they skew young among a number of other minor deviations.[3]

Still, the outcomes evaluated against are in fact representative, demonstrating that a biased sample of community language can be mapped to unbiased outcomes.

To better understand how geographic language can represent a community, researchers have also considered psychological outcomes and economic metrics. Using the same data as the mortality study (using counties covering more than 90 percent of the U.S. population), we attempted to predict the life satisfaction scores of those communities derived from surveys.[4] Compared to standard demographic and socioeconomic data previously available, current methods (involving techniques for integrating heterogenous variable type:

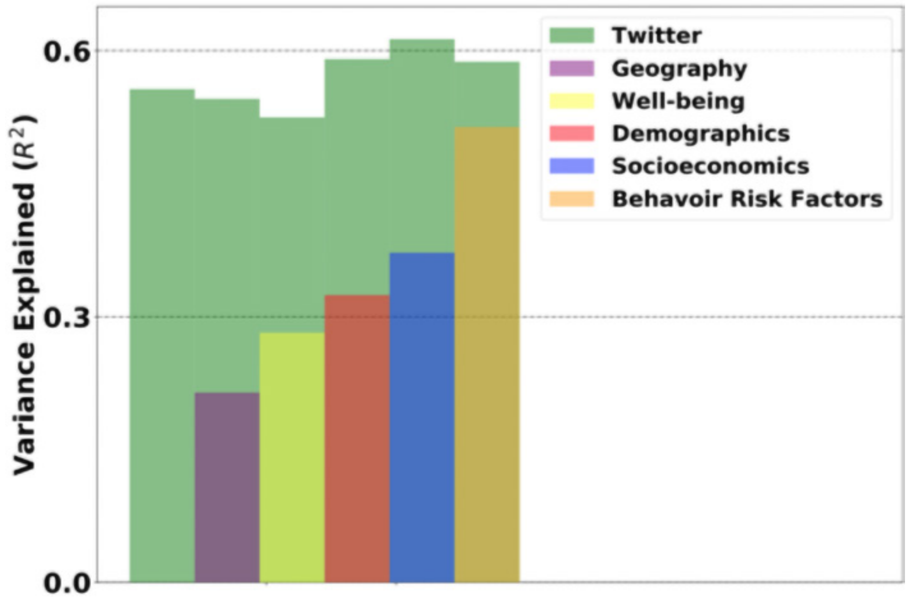

Figure 2. Prediction of U.S. county cancer mortality in 2013-2015 using digital footprints derived from 30 billion Tweets. Green indicates Twitter performance above and beyond standard geographic predictors.

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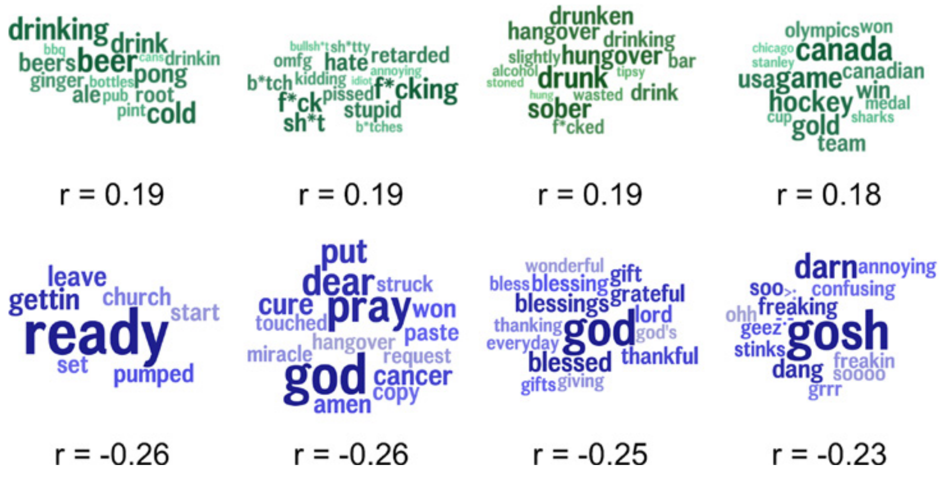

language and census demographics) are able to increase the variance explained by 22 percent in predicting surveyed life satisfaction.[5]

Social media can also provide a window into economic outcomes. When looking at change in the median sale price of homes across a community, geographic language once again provided a significant improvement over demographic, social, and economic variables.[6] Together, this suggests the breadth of social media to represent a community spans information about health, psychological, and even economic factors.

Prediction often isn't the end game when it comes to geographic language. Instead, researchers often seek insights—potentially novel relationships between community attributes and outcomes. This is often done by looking at the language patterns that are most correlated with outcomes. For example, tied in with the psychological literature, words relating to outdoor activities, spiritual meaning, exercise, and good jobs correlate with increased life satisfaction, while words signifying disengagement such as "bored" and "tired" show a negative association. We looked at community alcohol consumption data along with language patterns in Twitter as compared to demographic and socioeconomic information. Through open-vocabulary analyses—those unrestricted to specific linguistic categories—nearly unbounded numbers of predictive patterns emerge.

As another example, Figure 3 shows the topics (clusters of semantically related words) that are most predictive of geographic areas with high (top) and low (bottom) rates of excessive drinking.[7] Mediation analysis resulted in topics that explained much of the relationship associated with socioeconomics and excessive alcohol consumption. Social media language contains key pieces of information public health officials can use to monitor behavior and identify people and communities most in need of intervention.

For all the contrasting we have done between the value of surveys and geographic language, it is worth noting much of the approach to geographic language is inspired by survey techniques. Delving deeper into methods and data, we found it is helpful to statistically model each community as a collection of people whose digital footprint can be measured over multiple Tweets rather than simply counting the words within a community. This mirrors aggregating individual survey takers into a community. Words are aggregated from Tweets to users and then from users to U.S. counties, giving accurate measures of the people in the community as opposed to the Tweets in the community. This method has been shown to achieve state-of-the-art prediction accuracies on four different U.S. county-level tasks spanning demographic, health, and psychological outcomes.

Researchers, including some of the authors of this article, have recently been working to make aggregate geographic language data more accessible. While the social media data typically used for geographic studies is technically publicly accessible, it is often impractical or violates terms of service to share the raw data separately. However, aggregate community data is much smaller in size than raw text, and it is typically individually anonymized. To that end, we recently released on GitHub[8] a large community level aggregate dataset, the County Tweet Lexical Bank, derived from 37 billion Tweets—more than one billion of which were mapped to 2,041 U.S. counties.[9] This dataset spans 2009-2015 and includes multiple language features aggregated over various time spans.

The Future of Geographic Language

"A therapist, the joke goes, knows in great detail how a patient is doing every Thursday at 3 o'clock." – David Dobbs, The Atlantic

The power in geographic language patterns lies in their ability to capture everyday concerns. They are not a one-time snapshot of a community, but rather an ongoing (perhaps biased) window into culture. Measures obtained in snapshots and set intervals can introduce many biases, such as recall bias (e.g., bias in recalling a recent state due to current subjective feeling) or variability in mood

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across hours/days. These measures often require assessment outside of naturalistic circumstances that can introduce biases.[1]

Much of the work thus far with such data has largely neglected the temporal dimension (and for good reason—simply establishing a connection between the data and real-world outcomes was needed and the time dimension can overcomplicate analyses), but we believe the future of such data and its grandest utility involve utilization of space and time.

One promising avenue for bringing in the time dimension to language-based geographic studies is the application to mental health epidemics. Dr. Thomas Insel, former director of the National Institute of Mental Health, described digital behavior measures as providing "a more objective, textured picture of people's lives."[2] Daily behaviors assessed through technology such as social media offer unique insight into mental health status. Developing new platforms to understand mental health is critical because the traditional U.S. mental health care infrastructure is drastically overburdened, leaving many without care.

Approximately one-third of Americans with serious mental illness receive no treatment, and those that are treated often receive inadequate care, with increasing gaps in service.[3] This unmet need is greatest in traditionally underserved groups, including those with limited incomes, without insurance, and living in rural areas.[4] Even with economic setbacks, such folks and their communities are often well represented online.[5] Numerous studies have now shown self-reported conditions related to mental health, including depression, anxiety, PTSD, and suicidality are strong evidence for the use of social media for psychiatric assessment.[6,7] Practical utilization is still on the horizon with prediction of mental illness rates by community being an obvious potential application.

Let's consider one of the current mental health epidemics, drug overdose deaths, which are now the leading cause of injury related death in the U.S. In 2016, drug overdoses accounted for more than 63,000 deaths annually with nearly two-thirds of these deaths involving a prescription or illicit opioid.[8] Geographic language can capture and quantify the types of dialogue on social media associated with time of drug use relapse, opioid overdoses, and addiction treatment dropout. In addition, one can examine the amount and patterns of dialogue on social media with respect to opioid addiction treatment need, emerging synthetic opioids, and risk and protective factors for drug use. These results would demonstrate the robustness of social media language analysis and enable public health practitioners to craft adaptive algorithms to the characteristics of each population.

The future of geographic language also appears propitious for socioeconomic applications. Social media has a long history of use for tracking opinions and sentiment. Applications for tracking sentiment[9] often relate to products reviews,[10,11] and political concerns such as links between sentiment and public opinion polls.[12,13] However, unlike the previous applications of social media that neglected time, these applications have mostly neglected geography. Researchers are beginning to use these same methods to track beliefs in climate change and other environmental issues,[14,15] but the integration of geography is largely unexplored. One can easily imagine these beliefs being tracked at the community level in the same way various corporate and government agencies use standard polling and surveys, but with more frequent updates at a fraction of the cost.

At first, it may seem like using social media data for geospatial intelligence is jumping on the Twitter bandwagon. However, it's hard to imagine a resource that can capture such a large variety of cultural phenomena—public digital footprints from millions of individuals across thousands of communities. Of course, unlocking the information can be non-trivial. Like many forms of data science, studying geographic language is often a multidisciplinary endeavor involving trial and error.

Experts such as computer scientists are needed to design and implement the data analyses while social scientists or domain experts help drive the beneficial questions and interpret the results. Still, more and more experts are beginning to leverage

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such data across a variety of fields. As a result, more tools are becoming available along with aggregate processed datasets, such as our County Tweet Lexical Bank,[16] reducing the barrier to entry and enabling new applications. We have seen predictive power and insights emerge from health to psychological and economic outcomes. However, one insight that alludes us is just how geographic intelligence from social media will be used next.

Building a GEOINT Cluster in the Greater St. Louis Region

By Steven R. Thomas, Ball Aerospace; Patricia Hagen, Ph.D., T-REX Innovation Center; Aine O'Connor, Cortex Innovation Community; Blake Mills, LaunchCode; Sekhar Prabhakar, CEdge Software Consultants; Stephen H. Tupper, Missouri University of Science and Technology; Mark Brickhouse, Ph.D., Saint Louis University; Roberta Lenczowski, Roberta E. Lenczowski Consulting; and Steve Wallach, Steven P. Wallach Consulting, LLC

The greater St. Louis region has come to be known for its excellence and robust ecosystem around health care and life sciences. The region has been growing as an innovation hub for other sectors including cybersecurity and information technology. Now there is a focus on making St. Louis a go-to destination for the geospatial industry and a center of excellence for geospatial intelligence (GEOINT) innovation, tradecraft and education. The greater St. Louis region has long hosted a number of companies, organizations, and government agencies that play a pivotal role in advancing the impact of GEOINT. The geospatial work occurring in the greater St. Louis area ranges from national security issues to urban planning decisions and includes a plethora of efforts like geospatial research in biosecurity, monitoring the environment for threats to human health, water supply, and agriculture, promotion of economic development, support to urban safety and distribution-of-services programs, and preparation of earth science education. The National Geospatial-Intelligence Agency's (NGA) decision to build its $1.75 billion western campus in North St. Louis affords massive potential for economic development by anchoring the development and growth of the commercial geospatial and location-based technology industry within the region. St. Louis must support the growth of a cutting-edge geospatial cluster with tools, resources, and networks to encourage and incentivize innovation and entrepreneurship; attract and retain geospatial and locational expertise and research; and develop long-term strategies to leverage opportunities for sustainable, inclusive economic growth.

Economic trend experts expect the geospatial industry to grow from an estimated $299.2 Billion in 2017 to $439.2 Billion in 2020, with a rapid growth rate of 13.6%—even faster than a growth rate of 11.5% between 2013 and 2017.[17] Technological advancements and the democratization of geospatial information have accelerated industry growth. The rapid expansion of the industry is being experienced across the world, with double-digit growth in emerging markets such as Asia Pacific, the Middle East, and Africa. However, North America remains the dominant economic engine of geospatial industry growth due to an innovation-centric model. The resulting exponential demand and delivery of geospatial data characterizes the "Big Data" mandate to manage and analyze the volumes of raw and processed data that are now available or can be developed.

Although the defense sector (represented primarily by NGA) is an anchor for the geospatial cluster in the St. Louis region, GEOINT and analysis is a tool for all industries including precision agriculture, oil and gas exploration, high-velocity logistics, marketing and retail, smart cities, the Internet of Things, and autonomous vehicles. The region's geospatial cluster will make possible the GEOINT center of excellence, supported by three fundamental factors:

1. A thriving educational eco-system focused on training all aspects of the U.S. Department of Labor's Geospatial Competency Model (see Figure 1. Below) providing a continuous, highly trained, highly qualified workforce.
2. A prosperous incubator environment supporting the creation and growth of start-up companies, small businesses, and the research and development (R&D) community.
3. A robust R&D community that continually tackles complex geospatial issues and strives to provide meaningful innovations that drive progress across the full spectrum of the geospatial industry.

To ensure the advancement of the GEOINT tradecraft in the greater St. Louis region, from which the impact extends to the state and country, a focus on growing and training internal talent pipelines is paramount. In the 2018 State and Future of GEOINT report article titled "Strengthening the St. Louis Workforce," the authors discuss the challenges presented by the constantly growing need for talent. Rethinking traditional talent curation processes and replacing them with innovative training models breaks down these barriers and produces a stronger geospatial workforce.

Focusing GEOINT Training

Civilian education systems, public and private, play the role of attracting and winnowing talent into the GI&S sector and transitioning talent into the workforce pipeline. Universities expand that civilian education function in graduate schooling to deepen intellectual bases in study, to explore new potentialities in research, to distill new thought leaders for the science and application of why, where, and when, and to prepare the future academic leaders. Co-operating academic institutions throughout the St.

16. github.com/wwbp/county_tweet_lexical_bank
17. GeoBuiz 2018 Report GEOSPATIAL MEDIA AND COMMUNICATIONS COPYRIGHT 2018

Louis region are striving to integrate all these functions from often-disconnected, competitively pre-existing, and scattered programs. These institutions receive encouraging support from industry and community partners that come together with academia, using guidance from USGIF to form the St. Louis Area Working Group (SLAWG). Much of that guidance can be found within USGIF's GEOINT Essential Body of Knowledge (EBK), which identifies four competency areas: *GIS & Analysis Tools, Remote Sensing & Imagery Analysis, Geospatial Data Management*, and *Data Visualization*. Those areas coincide with the "Industry Sector Technical Competencies" layer of the DOL GTCM in Figure 1. The Geospatial Technology Competency Model framework was developed through a collaborative effort involving the Employment and Training Administration (ETA), the GeoTech Center, and industry experts.

Over the course of 2013-2014 and again in 2017-2018, the GeoTech Center and industry subject matter experts updated the model with guidance from ETA to reflect the knowledge and skills needed by today's geospatial technology professionals.

Each EBK competency is defined with a group of topic areas and within each of those a set of skills or knowledge points. The EBK framework is based upon capturing each phase of a GEOINT task to ensure accurate reflection of GEOINT most current practices. As an example, one might track the GIS analysis task to some specific degree or certification that requires understanding the geospatial data fusion topic, as provided by some course work—like Data Fusion 101—and which includes as a study area knowledge of metadata standards.

The SLAWG was essentially established to bring together community, government, industry and academic partners in the region to form a self-reinforcing market of programs, degrees and certifications that "fill in" the educational and training aspects of each block in the competency model. Academic institutions throughout the region are using the EBK to form a common aim point in terms of student learning somewhat akin to the current concept of "a common core." This relatively simple approach makes a consistent guide for the academic design. In parallel with teaching programs aligned to the EBK, regional institutions are incorporating more of the GTCM—blending the tools with aspects of "Industry-Wide Technical Competencies," "Management Competencies," "Workplace," "Academic" and "Personal" competencies. Increasingly, both improvisers and practitioners are diving more deeply into the human-machine system interfaces, which can profoundly affect the efficacy of the geospatial industry. Institutions through the greater St. Louis region are creating a portfolio of training and education programs for needed competencies. Multiple institutions support a diverse array of pathways, with some foundation criteria, for students to secure the talents and skills to support the GEOINT market throughout the region, state, and nation.

Geospatial education and training programs (some explicitly certified by USGIF) are used by defense, intelligence, and civil federal agencies, like NGA and the U.S. Geological Survey—both in Missouri. These programs are designed for competency in specific job tasks and are dynamically adaptive over time as technology advances and requirements are refined. Companies like Esri and ERDAS, among others, award geospatial certificates for technical competency using their tools and applications. For professional certifications, the American Society for Photogrammetry and Remote Sensing, the GIS Certification Institute, and USGIF have established field-specific eligibility criteria and specialized testing for professionals. All these efforts help standardize expectations for recognized proficiencies.

Innovative Training Opportunities

Traditional education pathways have proven successful in producing quality GIS talent. Solidifying the St. Louis region as a GEOINT hub will require embedding some unconventional solutions. One of the nonprofits successfully providing new, non-traditional training in St. Louis is LaunchCode, which began working with NGA at the end of 2017.

LaunchCode provides instruction and courses supporting two types of developer pipelines. LaunchCode's free, intensive, six-month long "zero-

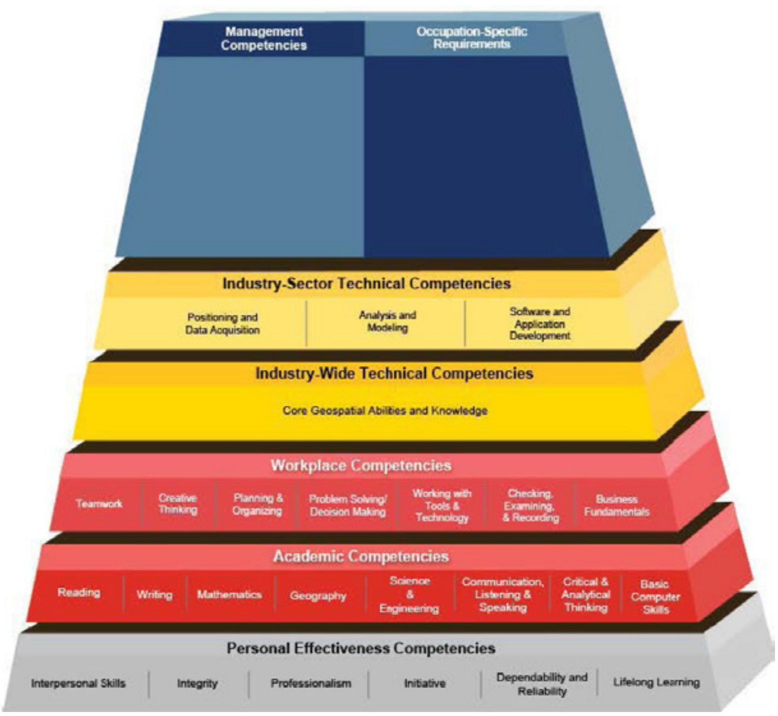

Figure 1. U.S. Department of Labor Geospatial Technology Competency Model.

to-developer" courses, LC101 and female-focused CoderGirl, cultivate a diverse, job-ready pool of junior web developers. Graduates typically have unconventional resumes but demonstrate the drive and aptitude that make great GEOINT professionals. LaunchCode's GIS DevOps course produces a second, more advanced pipeline of individuals equipped specifically with the specialized skills in high-demand by the GEOINT Community. The innovative curriculum, created by LaunchCode in partnership with NGA, Boundless, and Pivotal, blends classroom instruction and mentorship with self-guided, project-based learning. During the 10-week instruction portion of the course, students have the benefit of support and camaraderie while the five weeks spent on their projects provide valuable, real-world experience. The project focuses on using geospatial technology to create geographic and time-based trends (such as Zika virus outbreaks). Applying open-source technology in a hands-on, project-based learning environment not only promotes exploration and critical thinking by nature, it prepares students to excel in the GEOINT field by encouraging them to find the right tool for the problem at hand. Many of the emerging research trends and needs in GEOINT require innovative and cross-disciplinary tools, which proliferate in the open-source world. Students emerge as more flexible and stronger spatial thinkers, and therefore, better prepared to excel in solving real-world GEOINT challenges.

Growing Opportunities for Geospatial Startups

The St. Louis GEOINT community is collaborative and multifaceted. About 25 possible "homes" for startups exist in the metro area, including incubators, accelerators, and co-working spaces. By May 2018, nearly 80 entrepreneur support organizations were providing funding, community support, resource networks, and advice. As the GEOINT Community grows in the St. Louis region, new organizations, programs, and events have created a community of practice around geospatial research and technologies. Two key sites characterize the eagerness of the St. Louis region to support a geospatial center of excellence. Just four miles from Downtown St. Louis, the Cortex Innovation Community is a 200-acre urban innovation district in midtown St. Louis focused on the generation and growth of tech-based businesses and jobs. Cortex is home to 350 jobs and about 4,500 employees. A significant number of companies in Cortex use and/or develop geospatial technologies, including Esri, Boeing, Aerial Insights, Microsoft, and aisle411, among others. Cortex also hosts several innovation centers and activities that support startups and entrepreneurs with space, mentoring, funding, networking opportunities, and other resources. The Cambridge Innovation Center (CIC-St. Louis), for example, continues to expand a community of entrepreneurs by offering low-cost space and memberships for startup companies and corporate project teams. Venture Café, St. Louis' flagship event, is the Thursday gathering that regularly attracts more than 500 attendees to informally reinforce creativity and entrepreneurship. Accelerators such as Capital Innovators fund cohorts of companies from all over the world. These Cortex-sited initiatives encourage the St. Louis Region cluster concept.

T-REX is a 501(c)3 non-profit innovation center in downtown St. Louis that provides incubator, co-working, meeting, and event space to entrepreneurs; programming to support technology entrepreneurs; and a community and network of support to assist tech-focused startups. T-REX is home to several startup accelerators as well as non-profit funding and support organizations focused on technology entrepreneurship. But the organization offers more than just office space. It is a rare combination of an extraordinarily diverse community, valuable programming, and entrepreneurial culture. T-REX has developed special relationships with NGA and the GEOINT Community, including important R&D initiatives the community can most productively conduct in unclassified spaces. A Memorandum of Agreement between USGIF and T-REX also brings significant activity with NGA and the geospatial industry to the T-REX facility. T-REX's momentum in advanced information and intelligence technology innovation provides an excellent foundation for the R&D of a geospatial innovation hub. The organization is completing a $10 million capital campaign to renovate its historic downtown facility and is in the process of upgrading space its 160,000 square-foot building. As part of its renovation plan, T-REX will build and outfit a Geospatial Resource and Innovation Center to support the growing geospatial cluster.

Another Dimension to Innovation

Throughout the St. Louis region and across the state, various entities, including but not limited to, large companies, small businesses, NGA and academic institutions are conducting numerous R&D efforts that are pushing the limits of geospatial science. The R&D footprints of Cortex and T-Rex warrant attention for the cluster concept mentioned earlier but notable R&D advances in other locations. As another example, Saint Louis University's (SLU) sponsors a number of initiatives to grow geospatial research, and innovation, while also educating the future entrepreneurs and workforce. GeoSLU is an internally-funded initiative, recognizing the interdisciplinary scope of remote sensing and GIS, that coordinates and expands the geospatial capabilities across the university in Earth & atmospheric sciences, biology, computer science, civil engineering, epidemiology & biostatistics, aerospace and mechanical engineering, political science, chemistry, and the school for public health and social justice. GeoSLU is also developing the business model for a planned Geospatial Institute at SLU that will coordinate geospatial research efforts across the university, provide data analysis and mapping support, coordinate community outreach and geospatial workforce development, and grow training, degree, and certificate offerings in geospatial and allied domains. SLU is pioneering research on drone technology, remote sensing, open-source indicator and predictive tools, and educational research. The university is coordinating with the St. Louis community to integrate the emerging SLU Geospatial Institute with the growing St. Louis area geospatial enterprise through a new Cooperative Research and Development Agreement with NGA, participation with Arch-to-Park, presence at T-Rex and Cortex, and the GeoSLU Advisory Board of local business leaders. NGA and SLU are co-sponsoring a new geospatial conference in Saint Louis to bring together government, academic, and industry partners who can grow the region's geospatial enterprise.

Conclusion

The greater St. Louis region and state of Missouri are steadfast in their intent to serve as a center of excellence for the geospatial industry, where leading companies look for geospatial expertise, talent stability, idea stimulation, business magnetism, and information protection. When NGA chose St. Louis for its future state-of-the-art facility, the city, region and state along with numerous companies, academic institutions, and non-profit organizations made a commitment to succeed on many social, educational, economic, environmental, security, and political levels. This success will reap merits globally as the St. Louis region takes its deserved position as an acknowledged center of geospatial excellence.

Aging Infrastructure, Aging Workflows, and The M3 Solution

By Patrick C. Suermann, Ph.D., P.E., LEED AP, Texas A&M University; Dean Wilt, Booz Allen Hamilton; and Pete Kelsey, Carahsoft

The U.S. Department of Defense (DoD), the largest real estate property owner in the world, is struggling to maintain its enormous infrastructure portfolio in support of both current and anticipated mission requirements. Though the department spends about $20 billion annually on facilities sustainment, restoration, and modernization, a recent DoD report rated 32 percent of its facilities worldwide in "poor" or "failing" condition.[1] Compounding these issues, the methods DoD uses to collect and analyze infrastructure data to make portfolio management decisions are labor-intensive and costly.

DoD manages more than 24.9 million acres of land worldwide, occupying 276,770 buildings comprising more than 2.2 billion square feet.[2] These locations also contain 178,113 structures (e.g., towers, storage tanks, piers, and wharfs), and another 107,092 linear structures (e.g., runways, roads, pavement, fences, and electrical distribution lines). To inspect and determine what infrastructure is in need of repair, upgrade, or replacement, DoD currently sends out inspection teams to physically observe and evaluate each building, tower, road, pipeline, etc. The team manually gathers assessment data and often stores it in disconnected systems, thus preventing the sharing of information for advanced analytics or enterprise-wide analysis. Errors creep into the data through manual input or the subjective assessments of individual inspectors. Time-consuming methods of physical inspection also mean that years—and sometimes decades—may pass between inspections.

Most problematic is that current practices for inspection and data collection do not generate the insight necessary to guide effective decision-making for infrastructure investments. With much of the data stored in silos, it is difficult to meet the demands for timely, accurate, and integrated perspectives that drive well-informed investment decisions. As a result, decision-makers often focus narrowly and inefficiently on their most immediate needs, because they do not have the tools or information that can provide a strategic view of how best to optimize infrastructure in support of current and future missions.

DoD's challenges should resonate with anyone who operates and maintains facilities and infrastructure. This kind of "business as usual" approach is not sustainable. The challenge is this: How can leaders make informed and effective infrastructure investment decisions—decisions consistent with an enterprise-wide infrastructure management strategy—in today's budget-constrained environment?

Any physical structure—be it a building, runway, or large facility with design and construction predating the digital age—can be digitized. The vast majority of DoD facilities and infrastructure predate CAD/BIM as such no digital data exists. Owner/operators can gain the insight they need for objective, data-driven investment decisions by incorporating commercially available technologies and solutions into their infrastructure inspection, analysis, and decision-making processes. Many organizations are already familiar with technologies such as unmanned vehicles and sensors, which they use to support other mission areas. The key is understanding how to apply the technologies to address modern infrastructure challenges and needs.

Many commercial companies have already begun using some of these tools to inform their infrastructure investment decisions. The digitization process and the technology involved is quickly revolutionizing the operation, maintenance, security, and safety workflows and protocols of these assets.

The M3 Solution

Consider the M3 approach: measure, model, and manage. The measure phase calls for the digitization, or capture, of the asset. Numerous sensor types are available for this phase including LiDAR, SONAR, Ground Penetrating RADAR (GPR), Mechanical Resonance Imaging (MRI), and photogrammetry. All of these

1. Statement of Mr. Pete Potochney, Performing the Duties of Assistant Secretary Of Defense (Energy, Installations and Environment) Before the House Appropriations Committee Subcommittee on Military Construction, March 3, 2016, p. 5.
2. "Base Structure Report – Fiscal Year 2015 Baseline: A Summary of the Real Property Inventory," pp. 7-8.

sensors can be ground-based, drone-based, manned, or unmanned.

The data provides a lot of value, but the creation of a solid model, the model phase, can provide even more value in terms of visualization, simulation, and analysis.

Once the measurement data are captured and a model exists, stakeholders have a digital twin of the asset that can be repurposed for any number of scenarios including safety, security, outreach, and education. This is the management phase: managing assets virtually. Later, virtual 4D and 5D analysis can be run to determine the time and cost required to make improvements and repairs. “What if?” scenarios of many types then become possible to evaluate.

Use Case No. 1: The USAFA Cadet Chapel

Designed in the late 1950s and dedicated in September 1963, the U.S. Air Force Academy (USAFA) Cadet Chapel in Colorado Springs, Colo., is a stunning structure featuring 17 identical spires that soar 150 feet into the air and a 99-foot clearance inside the iconic chapel. Able to hold five simultaneous services for a variety of faiths, it is a modernist architectural gem and Colorado’s most visited manmade structure.

Unfortunately, 55 years of exposure to the elements will take its toll on any building. The chapel’s concrete foundation, for example, has been damaged by annual freeze-thaw cycles, and the building is experiencing water infiltration. Additionally, the original gaskets and seals system were value engineered in the original construction and the building has subsequently leaked since its commissioning.

To determine what other repairs might be needed and how best to communicate the need for renovation to key stakeholders, USAFA decided to assess the existing state of the chapel by documenting the structure in an entirely new way.

To tackle this task, the academy partnered with Autodesk, whose ReCap

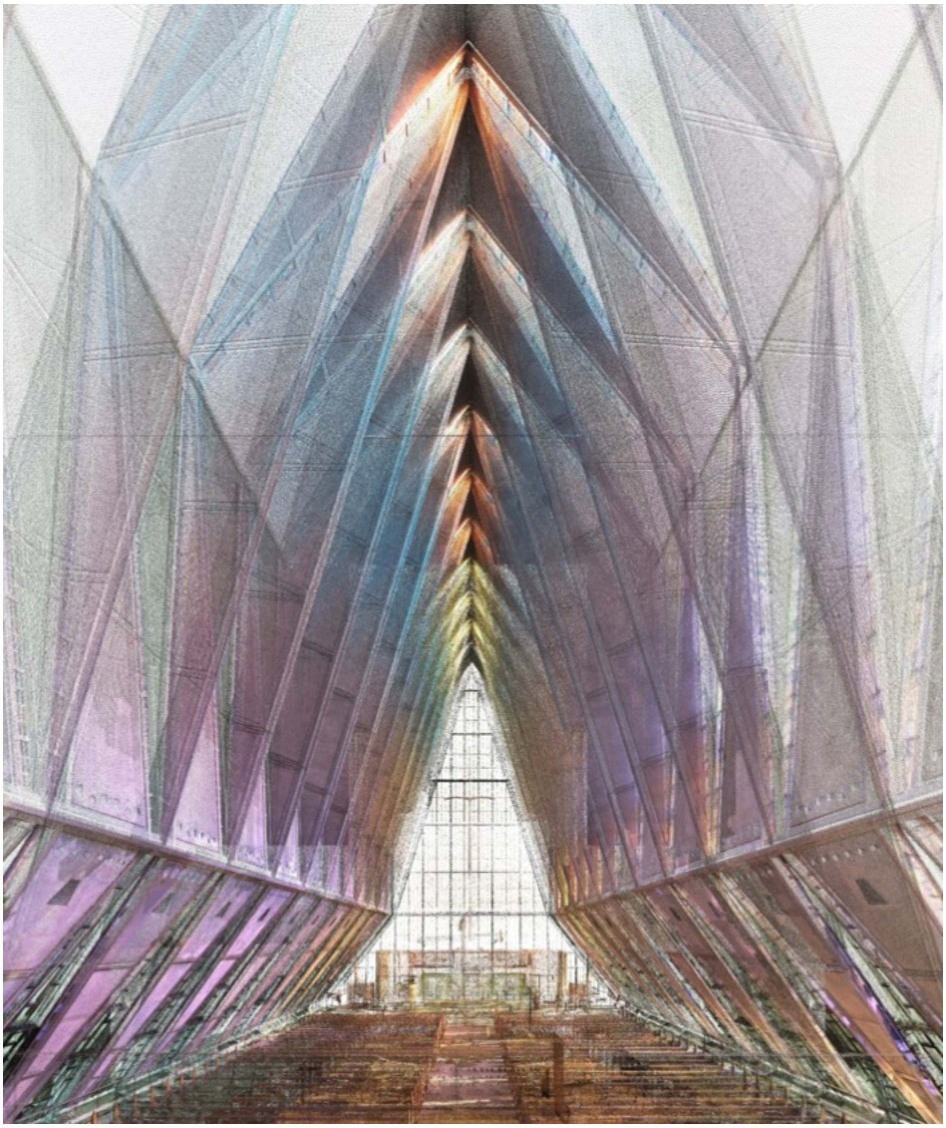

Figure 1. USAFA Cadet Chapel point cloud data from the measurement phase. Image Credit: Autodesk.

reality capture software is able to digest data from multiple sources and generate a single, photorealistic 3D model capturing every detail of a structure. Working with the 36 Civil Engineer Squadron from nearby Peterson Air Force Base, the measurement phase was completed using ground- and UAV-based LiDAR and photogrammetric technology.

The modeling phase involved the creation of a Building Information Model (BIM) using Autodesk Revit software.

Now that the chapel is modeled in Revit, the possibilities in the management phase are nearly limitless. Whole-building envelope energy and lighting analysis may be performed. Exterior wind studies can be conducted. Computational Fluid Dynamics analysis can perform more advanced studies to inform the best HVAC design to save energy and ensure the comfort of chapel occupants. A wide range of structural analyses are possible, including a new wind load simulation feature that would be useful in studying the unique geometry of the chapel. Direct links from the model to visualization programs enable unmatched visualization and animation possibilities. The ultimate result is a digital twin of the chapel that is being used to effect repairs, and that will serve indefinitely as a baseline dataset to measure change, as well as a successful proof of concept to show the greater Air Force new ways to manage assets.

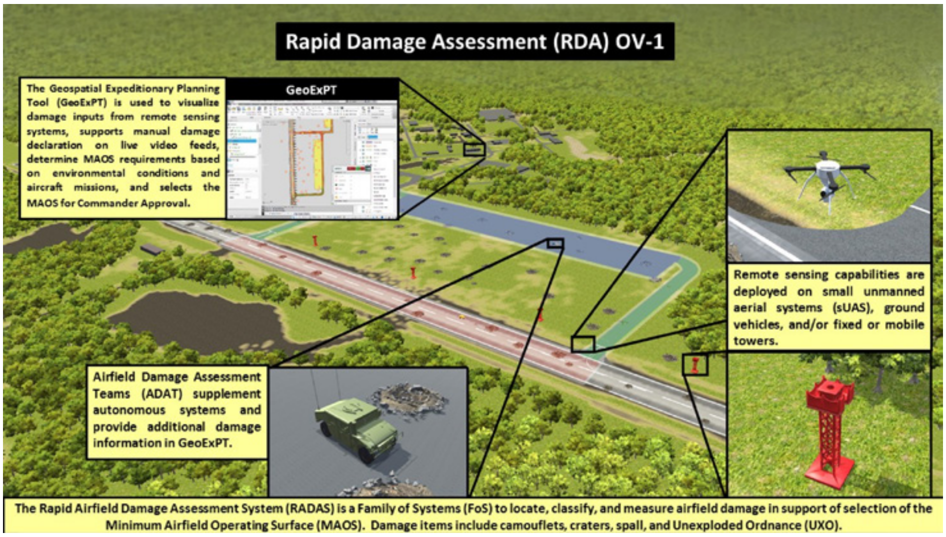

Figure 2. Image Credit: Air Force Civil Engineer Center.

Use Case No. 2: The Rapid Airfield Damage Assessment System

DoD is well aware of the vulnerability of its airfields. Operating and maintaining airfields in combat situations is mission-critical in terms of maintaining air supremacy. As such, the ongoing Rapid Airfield Damage Assessment System program is all about assessing damage, identifying and mitigating any unexploded ordnance (UXOs), and accomplishing repairs as quickly as possible. Performing these tasks remotely and robotically is paramount for the safety of the technicians. Finally, time is the critical element. All of this must happen within hours so the airfield can resume operations.

As different as this scenario may appear to the USAFA Cadet Chapel, the M3 workflow still applies. Establishing a baseline dataset of the intact airfield, assessing damage, and identifying UXOs is the measurement phase. Determining the most efficient path to a repaired and operational airfield can be done from both measurement and model data. Updating and maintaining the existing airfield model, which includes the repairs, is the management phase. The Air Force has heavily invested in technology that helps eliminate human physical inspection and replaces it with reality capture and artificial intelligence-based change detection. The future of airfield repair will be safer and more rapid due to this technology.

Use Case No. 3: Glen Canyon Dam

Glen Canyon Dam (GCD) in Page, Ariz., is operated and maintained by the U.S. Bureau of Reclamation (USBR). Designated national critical infrastructure by the Department of Homeland Security, it is a secure facility that operates 24/7/365. As GCD is a hydroelectric dam it not only manages the water supply to much of the Southwest, it also provides electricity to the region.

Designed and built in the ’50s and ’60s, little to no digital data existed of the facility. Operations, maintenance (O&M), and security were conducted as efficiently as possible using the analog data of the period. In 2016, USBR decided to embark on a proof of concept project to create a digital twin of the facility. Confidence was high that the resulting model would provide value well beyond the original project scope focused on O&M. The measurement phase used LiDAR, SONAR, and photogrammetry to create the digital twin. A solid CAD/BIM-based model was then created.

The data provided value almost immediately. Moving large, heavy pieces of equipment in and out of the facility safely and efficiently could be modeled virtually. Would the equipment fit? How long would it take? How much would the upgrade/repair cost? What was the state of silt buildup on the upstream side of the dam related to the intakes? Insight into these important questions could all be better determined and planned for virtually. The final phase of the project will be to create a virtual facility that can be used to run security-based scenarios such as evacuations, terrorist events, and even outreach and educational efforts as the facility has high tourist traffic.

Diving Deeper into the M3 Process

The main elements underlying the M3 process for improving infrastructure assessments and decision-making include:

Innovative Autonomous Data Collection Platforms:

DoD and commercial organizations can accelerate data collection by using UAVs, ground vehicles, submersibles, and other autonomous platforms equipped with sensors. In addition to gaining easier access to remote or hazardous locations, these platforms can also fill gaps in current data collection. DoD could also repurpose existing platforms such as satellites to enhance data collection.

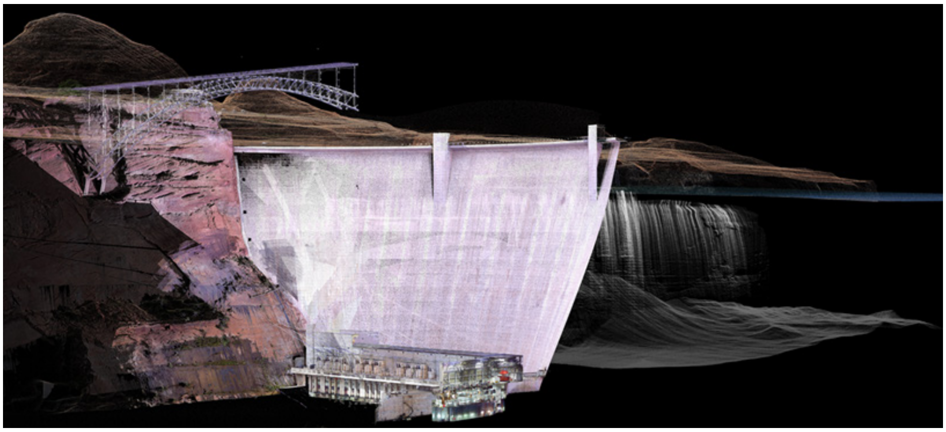

Figure 3. Cross section view of the LiDAR and SONAR measurement data of Glen Canyon Dam. Image Credit: USBR.

Multi-spectral Sensors:
Deploying video and photographic imaging as well as infrared, topographical, and LIDAR sensors on fixed assets or autonomous platforms to collect real-time imaging and infrastructure data has proven effective. Advances in storage and computing power have enhanced the ability of small, sensor-carrying platforms to collect and deliver valuable data.

Powerful Cloud Computing:
Organizations already collect large stores of data that can inform infrastructure management. They can also take advantage of public or open-source datasets as well as enhance existing data with new sensor data from unmanned systems and other sources. The maturation of cloud computing enables organizations to store, access, share, and manage massive amounts of data mined from these varied sources.

Advanced Analytical Solutions:
Modern analytic tools can apply sophisticated algorithms and models to parse through large amounts of data to detect anomalies and trends and conduct multi-dimensional analysis of potential problems, solutions, and costs.

Visualization:
Modern decision-making tools can integrate and present complex analytic findings in dashboards and other displays, providing decision-makers with a realistic picture of the infrastructure situation in a 3D/4D virtual or alternative visual reality (e.g., simulations, holograms, and multidimensional analysis). This enables them to clearly analyze and compare investment trade-offs across their entire infrastructure portfolio.

Applied together, these advanced technologies offer many opportunities to accelerate the data collection process, generate added value or return on investment for existing data, and create new efficiencies and solutions that go far beyond the 1950's-style inspection methods currently in place. For example, UAVs and other data collection platforms, combined with next-generation analytics and data visualization, can anchor a more efficient, accurate, and timely assessment approach—and at a substantially lower cost than physical inspection teams. Infrared UAV sensors enable surveys of an entire infrastructure portfolio, efficiently pinpointing areas of concern.

Equipped with LiDAR to establish a building's 3D structure and GPS to supply coordinates of a particular building, UAVs can leverage infrared capabilities for surveillance of larger groups of buildings in a single flight. Thus, as opposed to inspecting buildings individually, airborne infrared sensors allow for an expedited analysis of potential structural issues in a multiple-structure or base-wide facility portfolio.

The advantages of using unmanned vehicles to inspect buildings also hold for inspections of other types of structures, such as nuclear facilities, airports, ports, pipelines, towers, and bridges. This allows teams to conduct surveys more rapidly and on a more regular basis. The inspection processes are repeatable, and the sensor data are reliable, measurable, and shareable, while the automated inspection reporting offers decision-makers on-demand access to an objective, enterprise-wide view of their infrastructure portfolios, significantly shortening the inspection cycle. It should be noted that physical teams are still necessary—for example, to inspect infrastructure where sensor data have indicated a problem, such as a steam pipe leak, excessive corrosion, or unwanted moisture. But the overall reduction in the need for physical inspections to discover these issues will reduce costs while increasing worker safety, particularly when inspections cover large expanses or include rugged, difficult-to-reach locations and confined spaces.

Implementing M3 for Better Decisions

Capitalizing on M3 will require a new approach to inspecting infrastructure, analyzing the data, and presenting the results to decision-makers. The goal isn't simply to collect more data, but more importantly, to replace outdated practices with more powerful, cost-efficient methods, while also leveraging existing data sources. To extract maximum value from the collected data, the new approach will integrate the diverse datasets to facilitate rigorous analytics and present a comprehensive, enterprise-wide view of the infrastructure portfolio.

The first step involves developing a diagnostic of existing data and client needs: What data does the organization already collect? What additional data do decision-makers need to effectively assess their infrastructure and plan investments? Data collection and analysis represent a complex and challenging undertaking due to a number of factors such as lack of relevant data, an abundance of data, the high cost to collect data, data anomalies, multiple data systems, and gaps that limit the ability to conduct integrated analysis.

With this insight, the next set of activities focuses on filling gaps and accelerating data collection using innovative platforms and sensors, open-source and untapped data sources (e.g., weather), and techniques such as geo-tagging to enhance data.

We then establish the processes and controls for connecting accurate, timely data. Accurate data provide the foundation for high-end analytics and the development of alternatives. It is essential for identifying efficiencies, tracking trends, and making process, facility, and equipment adjustments, as well as for demonstrating and quantifying actual cost savings, efficiencies, and schedule improvements.

Identifying the right datasets and knowing what to analyze requires staff with expertise and knowledge in facilities, public-private partnerships, resource management, and the organization's mission. This expertise, when combined with strong communications skills, an ability to work across functional boundaries, and an understanding of the links and synergies of data help to achieving operational, cost, and schedule goals.

The final set of activities focuses on providing results by strengthening decision-making through modeling, simulation, and machine learning.

Organizations can see a significant return from their expanded data collection by applying advanced decision-making tools and techniques, which allow for complex sets of data to be analyzed faster and more cost effectively. These tools can analyze enormous datasets to highlight the anomalies and trends that vary from the rest of the set. In addition, the tool's capacity for multi-dimensional analysis enables it to study more factors at one time, allowing the analyst to understand how each variable relates to the others.

M3 workflows help organizations pinpoint and resolve problems within a large infrastructure portfolio with limited time and resources. Moreover, this activity creates an integrated analysis of alternatives that generates clear recommendations and enhanced decision-making consistent with the infrastructure management strategy.

GEOINT Transformation and Driving the Future of Information Dominance

By Damon Brady, Sr. Director, Product Development and Programs, BAE Systems; John Steed, Director, Geospatial Services, Tesla Government; and Anthony Sanchez, Technical Director, Veritone

The exponential growth of sensors, geospatially relevant data, and advanced analytics has created increased opportunities for geospatial analysis and is quickly leveling the asymmetric GEOINT leadership advantages previously owned by few. Not since the transition from film to digital imagery has the geospatial analysis profession experienced such a rapid transformation, and the new "digital universe" of geospatially relevant data continues to expand, incorporating and inspiring new technologies.

The statistics are impressive: According to 2017 market reports from Tauri Group, Earth observation satellite count is growing at a five-year Compound Aggregate Growth Rate of 47 percent and by 2025 we will see more than 750 new "eyes in the sky" providing imagery, videos, and multiple other types of data for analysts to consume. Similarly, the commercial drone population (excluding military and personal drones) is expected to grow at least 50 percent to more than 800,000 in the same timeframe, according to BI Intelligence reports. When combined with the ubiquitous proliferation of Internet of Things sensors, Forbes predicts our digital universe could expand to more than 163 zetabytes by 2025. Already, there is so much information available that significant amounts of data cannot be processed in the traditional processing, exploitation, and dissemination workflows, resulting in potential loss of information dominance and the inability to extract new insights and value.

Charting a Path to Transformation

Mission leaders are challenging the GEOINT Community to lead the way in this complex new environment. It is a logical ask—after all, one of the best ways to correlate and understand the relationships among different datasets is through images. As a result, GEOINT is evolving beyond providing imagery and geospatial awareness to be the epicenter of data fusion, responsible for the interpretation and visualization of highly disparate, differentiated data streams. While accepting this challenge and driving forward with GEOINT transformation is an exciting prospect, we must also recognize that this magnitude of organizational change is neither easy nor immediate. It is an iterative process that will evolve over time, yielding a result that will likely be substantially different from what was initially envisioned.

Transformation begins at the top, with the effective communication of vision and mission objectives needed to align stakeholders in the pursuit of common goals. These objectives are based on a recognition of our increasingly important role across intelligence and data-driven disciplines. They define an underlying value proposition developed with a realistic understanding of the impact transformational change has on the enterprise's people, processes, and tools. In order for the community to succeed in our GEOINT transformation, we must employ a holistic, integrated approach to tackle the main issues related to big data, human capital optimization, and the application of advanced technology tools to meet the needs of both the GEOINT and broader Intelligence Communities.

Implementation of an integrated approach is often easier said than done. The reality is there are many challenges and obstacles in the way of achieving transformative success. Tactically, this includes things such as the likely requirement to modify existing workflows and processes in critical areas where operational disruption is not an option, managing issues around operations security and sharing information between organizational silos, and mitigating concerns related to data integrity and provenance. Strategic challenges may be even greater with fundamental business decisions to be made around evolving technology, funding availability, and an ever-changing political landscape.

These challenges are ever-present, and what remains at the end is the need to understand what can be done to make these goals actionable. There are several ways to chart a path, including leveraging business process transformation or organizational change management methods. Given the importance and relevance of technology in the mission, however, it may be most appropriate to approach the challenge from a systems engineering perspective. Application of a systems engineering methodology provides a requirements-driven framework to decompose large systems into their constituent subsystems and components, apply change, and rebuild as an integrated and holistic system. For the diverse and rapidly evolving GEOINT Community, this approach has the benefit of focusing expertise and creating an environment of iterative, actionable, and measurable steps toward achieving transformation goals.

Unlocking Value from Big Data

One of the key areas that can benefit from this approach is big data. The GEOINT discipline is facing immense challenges in keeping up with the amount of data to process, analyze, and disseminate. This is not only because of the sheer quantity of overhead imagery collected, but also a result of the surge in full-motion video, all-source, and unstructured data. The kind of problems the GEOINT Community will need to solve tomorrow are no longer solely based in geospatial context. The addition of open data, surveillance streams, and vast amounts of unstructured text from news sources, social media, and other communications makes new insights available to the GEOINT Community. The challenge is to incorporate this additional information into valuable, relevant, and timely intelligence.

Today, there is simply too much information to process and analyze using yesterday's systems. As GEOINT has evolved to become a focal point for data fusion, a new demand has emerged for geospatial tools and workflows that creatively solve future unknown problems.

Fortunately, artificial intelligence (AI) and machine learning (ML) can help drive the community toward achieving these objectives. The rapid rise of AI/ML means that capabilities are becoming commoditized and increasingly prevalent in the commercial space. They are currently providing industries such as advertising, law, medicine, and finance the ability to extract meaning from unstructured sources at scale. Inserting AI/ML technology into the GEOINT Community was inevitable since the data processing requirements call for increased data-driven and automated solutions. Near-term AI/ML solutions are focused on solving problems concerning throughput and productivity. That is, automating repetitive tasks analysts use to search and discover intelligence in real time. This type of application is low-hanging fruit for the technology, but it's just the tip of the iceberg as the pace of the market moves faster than the pace of innovation.

The approach in the GEOINT Community thus far has been to invest in point solutions that solve narrow use cases as a proof of concept. This is a typical way for government to add most new technology and software. However, the concern is that the cost and capability of AI/ML technology is changing so rapidly that initial investments made become outdated and decrease in value as each day passes. To solve this problem, organizations must think about incorporating AI infrastructures that flexibly scale with the changing technology. A GEOINT future with AI/ML augmented solutions will provide highly adaptable ecosystems of analytic capabilities that are designed and leveraged to cost-effectively solve real-time, mission-critical tasks.

People are Still Essential

Many changes have occurred throughout the GEOINT industry in the last half century, from heads-up digitizing, satellite improvements, and big data management to AI/ML and the movement from using software interfaces to leveraging scripting and coding languages to perform tasks. The pace of change has increased significantly in recent decades, and while a highly debated topic, some researchers predict that computers will achieve basic human cognitive capability within 20 years. This has the potential to automate many of the basic, repetitive tasks currently performed by human analysts.

In the interim, the question remaining is, "How do GEOINT teams keep up with the fast evolution of technology and data while maintaining institutional knowledge and expertise?" It is paramount that the role of seasoned veteran analysts continues to guide our understanding of what is valuable from GEOINT data, but new data and processes must be leveraged to improve the speed of production and to derive new, valuable insights that may not have been previously accessible or conceivable.

There are several areas of potential focus in human capital optimization that will help realize the benefits of GEOINT transformation quickly while maintaining the mission-critical quality and reliability provided by our highly skilled workforce:

Leverage institutional knowledge:

Strong links should be created between teams that configure technology and the analysts who leverage it. Just like a race car is built with the driver in mind, insights from experience can help guide and ensure that technological advancements and adoption evolve in a symbiotic way.

Train the trainable:

Create new methods to incorporate new learning for seasoned analysts. Not all new technologies need to be adopted and used by technophiles. Building capacity for existing experts will add more value to already valuable assets.

Encourage on-the-job technology research:

Providing time for GEOINT analysts to research changes and trends in the industry can lead to a more educated and industrious workforce. The tools of the trade and new options for improving old tasks should be on the minds of workers, and this should be institutionalized from leadership through mid-level management to ensure the GEOINT Community remains competitive.

Create skills transfer programs:

Some new skills (such as tool automation) can be trained to personnel across departments, enabling improved workflow and collaboration throughout different teams and disciplines. Enabling personnel to train skills to others not only reinforces that skill, but also builds cross-team/department cohesiveness and expands capabilities across the organization.

Achieving GEOINT transformation and moving our field forward requires rethinking how workflows have been developed and managed in the past. As leaders communicate strategic vision and mission goals, we can apply proven methodologies to break down traditional information silos and iterate how we apply limited resources toward developing integrated solutions for the future.

A holistic view and willingness to adapt is important to effectively capitalize upon technology advancements that can address today's big data glut, and advanced technology must be thoughtfully but aggressively applied to achieve better, faster, and more confident operations. Perhaps most importantly, ways in which we acquire, train, and deploy human capital must be re-imagined to focus on speed, assessment, and complex decision-making. The GEOINT transformation will drive new best practices in each of these areas to enable the data fusion needed to maintain our information and intelligence advantage.

The Changing Face of Remote Sensing: Harnessing Innovation to Enable New Applications

By Rakesh Malhotra, Ph.D., North Carolina Central University; Gordana Vlahovic, Ph.D., North Carolina Central University; Karen Schuckman, Pennsylvania State University; Cordula Robinson, Ph.D., Northeastern University; Camelia Kantor, Ph.D., the United States Geospatial Intelligence Foundation; Timothy Walton, Ph.D., James Madison University; Timothy Mulrooney, Ph.D., North Carolina Central University; James Rineer, P.E., RTI International; Chris McGinn, Ph.D., North Carolina Central University; and Craig Gruber, Ph.D., Northeastern University

We live in a more interconnected and information-rich world than at any other period of human history. The advent and pervasiveness of networked computing has changed how we view and share information and how we gather, store, and process it. These changes are spurred by the miniaturization of equipment and gadgets, the ever-shrinking cost of data gathering, automated data analysis, and increased processing power. The amount of digital storage and computing power that used to fit in a room now fits in your palm, and machine learning and artificial intelligence are affecting how we interact with each other and use information every day.

Geospatial intelligence (GEOINT) is no exception to these changes spurring the next revolution in remote sensing and spatial information gathering. While remote sensing and satellite imagery have always been important, newer entrants such as unmanned aerial vehicles (UAVs) and small satellites enable an array of visualization and analyses tools that were hard to imagine just a decade ago.

Spatial Data and GEOINT

Keyhole—an In-Q-Tel-funded company bought by Google in 2004[1]—launched a revolution that made spatial information available to anyone connected to the internet. Google re-launched Keyhole's EarthViewer application as Google Earth in 2005 and almost immediately it was adopted by individuals, companies, non-governmental organizations (NGOs), and governments to access spatial information.[2] Suddenly, "eye in the sky" had a new meaning, as anyone could explore any part of the Earth and GEOINT was in everyone's toolbox.

Google Earth, though revolutionary, had limitations such as scale and temporal lag.[3] The high-resolution spatial information was weighted toward data-rich areas such as the U.S. and Europe, and the underlying satellite data were updated periodically but not frequently nor based on the needs of any particular project or news story. Google Earth is not the first or the last story of a geospatial revolution.

UAVs and small satellites stand to alter data dynamics worldwide, especially in countries and locations with poor data infrastructure. While the UAV revolution will alter data collection on a local, regional, and project scale, small sats will provide almost real-time data at a global scale. The geospatial industry stands to benefit from the miniaturization of hardware and the enhanced processing power of both applications.

Unmanned Aerial Vehicles

Perhaps the most prevalent example of the miniaturization of geospatial information gathering has been the advent of UAVs, also popularly known as drones.[4] In the past few years, UAVs have become mainstream so quickly that policy-makers, geospatial organizations, and software developers are playing catch up. For example, it was only in 2016 that the U.S. Federal Aviation Administration (FAA) put guidelines in place to clarify the use of UAVs for fun (hobby) and work (professional flying). A few important factors including miniaturization have helped popularize UAVs over the past few years and close calls with UAVs at sensitive locations such as airports forced this action. High-performing UAVs with gimbals, video recording at 60 to 80 frames per second, and flight times ranging from 30 to 45 minutes can be purchased for under $1,000. This is a critical price point for recreational purposes, but also has significant global policy implications as UAVs become affordable to NGOs, non-state actors, and individuals. The other crucial element aiding the proliferation of UAVs in fields such as GEOINT, agriculture, disaster management, and human development is the reduced lag time when compared to the availability of existing data. Satellite data with daily periodic frequency are expensive and capturing aerial photography can be cost-prohibitive. Moreover, non-military UAV projects are flown at an altitude of 400 feet or lower, and data acquisition can occur even under cloudy conditions

1. Andrew Foerch. "The Genesis of Google Earth," *Trajectory Magazine*, November 1, 2017, http://trajectorymagazine.com/genesis-google-earth/.
2. Todd C. Patterson. "Google Earth As a (Not Just) Geography Education Tool," *Journal of Geography*, 2007:106(2):145-152.
3. T.B. Lefer, M.R. Anderson, A. Fornari, A. Lambert, J. Fletcher, M. Baquero. "Using Google Earth As an Innovative Tool for Community Mapping," *Public Health Reports*, 2008:123(4):474-480.
4. Reg Austin. *Unmanned Aircraft Systems: UAVS Design, Development and Deployment*. John Wiley & Sons; 2011.

with multiple repeat cycles per day. For these reasons, UAVs will continue to be the tool of choice for missions where data collection is time critical.

The argument for choosing UAVs over satellite or traditional aerial imagery is particularly compelling when the study area is relatively small, the political climate supportive, and the weather cooperative. The top range for UAVs to capture images and return safely is about 500 acres, but that reduces quickly with an increase in payload and flight path variations. Though UAVs are more susceptible to rain and wind, they are less susceptible to cloud cover. The politics of an area are also important to consider. Will the local population look at a UAV suspiciously and what can be done proactively to mitigate this concern? Projects implementing UAVs should address these issues by coordinating and seeking permission from local authorities, sharing information prior to UAV flights, and involving regional stakeholders in data and attribute collection that enriches imagery datasets with information about local landmarks.

Just as the advent of computers did not render paper obsolete, UAVs will augment data gathering rather than replace existing remote sensing technology. This will lead to even more data than can be physically reviewed by individuals, making future projects reliant on automation and machine learning. Still image analyses are well developed due to the long history of photogrammetry and the implementation of structure from motion (SfM) technologies. Though current automated applications have limited appeal, they will continue to expand. The next few years will see rapid development in UAV full-motion video (FMV) and data analysis that include real-time data availability and mobile applications specifically designed to leverage UAV data. Examples of real-time analysis of video data have been appearing in both intelligence and commercial applications and are only set to accelerate.[5]

The most common sensors offered are still or video, but other sensors such as infrared and LiDAR are becoming increasingly popular. The push to create UAV infrastructure-as-a-service has given rise to platforms that leverage cloud services to combine UAV data capture and image analyses.

A lack of data standards will hamper interconnectivity and the seamless transition of UAV data. Just a decade ago, the development of data standards for LiDAR helped catapult the technology from simple terrain analysis to myriad applications. Data standards not only help with inherent standardization but also create opportunities for new applications. The standardization of UAV data, particularly FMV, is the next logical step in the integration of UAVs with geospatial tools. Geospatial organizations such as the Open Geospatial Consortium and the American Society for Photogrammetry and Remote Sensing are starting to establish standards for the capture, sharing, and analysis of UAV datasets. Standards will be essential for multiple stakeholders and partners to seamlessly coordinate data analysis. As more applications are developed and UAVs are used for additional services, visibility will lead to greater acceptance in the civilian world as with previous military technologies that crossed over.

Small Satellites

Just 65 years ago, the then Soviet Union launched Sputnik, sending the U.S. and the USSR into a Space Race. Within a decade, the U.S. Corona program provided proof of concept that imagery gathered from space had vital defense applications.[6,7] This technology is at the core of remote sensing as we use it today. For all of the 20th century, collecting images from satellite data was the purview of governments and included programs such as Landsat (U.S.) and SPOT (France). The key reason for this was that building, launching, and managing satellites was expensive. (Landsat 8 cost USD $850 million).

The shift from public to private enterprise in the space industry has accelerated, and the current revolution is ushered in by the aptly named small satellites (also known as nanosatellites or cube sats) that are comparatively smaller. These satellites provide important advantages compared with traditional Earth observation satellites such as the ability to capture data over the same spot on Earth more frequently and even on demand. Another advantage is that low-cost, low orbiting satellites are usually launched as accessory payloads to larger satellites, further reducing project costs and offering cheaper data acquisition than traditional remote sensing satellites.[8]

These rapid changes in satellite imagery data collection create both opportunities and challenges. An obvious opportunity is that consumers have access to a constant stream of high-resolution imagery with reduced lag times. This opens up remote sensing to a host of applications that focus on spatial monitoring and analyses at various scales. The fact that the entire planet is being mapped on a daily basis provides spatial analysts the ability to easily access imagery of the same location from last week, last year, or even further back.

Natural and man-made disasters occur unexpectedly, and this shift from targeted acquisition to daily global mapping can be beneficial in areas that were not of interest pre-disaster but are now the focus of data collection. For example, having daily imagery prior to an avalanche or flood helps with the development of early detection tools for similar events. Such hindsight will help improve protocols as well as enhance the development of forensic remote sensing and the ability to review potential scenarios applied to a vast array of human, social, and environmental events.

5. Matt Alderton. “Imminent Ubiquity,” *Trajectory Magazine*, June 5, 2015, http://trajectorymagazine.com/imminent-ubiquity/.
6. Paul Dickerson. *Sputnik: The Shock of the Century*. Walker & Co; 2007.
7. Curtis Peebles. *The CORONA Project: America’s First Spy Satellites*. Naval Institute Press; 1997.
8. Kristin Quinn. “The Maturation of SmallSats,” *Trajectory Magazine*, March 7, 2014. http://trajectorymagazine.com/the-maturation-of-smallsats/.

GEOINT Applications

Both UAVs and small satellites are extending current applications and creating new ones in a variety of fields such as homeland security, food security, port security, and beyond. Based on the desired application, UAVs can capture oblique or orthorectified images. Humanitarian applications usually require oblique images so information on sign boards and sides of buildings can be captured and used to identify locations not easily identified in orthophotos. UAVs are altering the global film, music, sports, and real estate landscapes by creating videos and still images that were expensive, impossible, or required specialty flights just a few years ago.

The push to gather infrared and near-infrared data is largely driven by agricultural applications, and these sensors are critical to the development of applications for which information about vegetation and water are used as inputs to predictive models. Increasingly, identification of specific crop types and crop health at multiple times during the season is integrated with traditional satellite data. Thus UAV-collected data can classify crops, monitor crop growth variability and disease, estimate biomass, and support site-specific crop management with daily intervention in some cases. Vendors, particularly in the agricultural segment, offer cloud hosting and automated analysis of UAV data.

Both homeland security and port security have benefited from these GEOINT technologies. However, friends and foes of all stripes have adopted these technologies as well, including terrorist organizations such as Hezbollah and nations such as China. Seaports are large, complex areas that play a significant role in national security and the global economy. A single disruption to port operations can harm a nation's economy and cause worldwide effects on the flow of global trade. Workflows driven by multisource and real-time data can strengthen port security. Real-time data integration, including updates provided by UAVs and small satellites, identify risks and assist with prioritizing and establishing secure evacuation routes. Selected evacuation routes can continue to be surveyed for obstructions, vulnerable infrastructure can be identified and surveyed, and port facility stakeholders can be alerted and updated to deploy necessary courses of action. The overhead, real-time synoptic views afforded by UAVs and small satellites allow for focused monitoring of current situations and the deployment of nimble disaster management strategies.

For humanitarian aid and monitoring, UAVs can conduct an aerial survey of community infrastructure such as schools in and around a study area. Such applications have lower costs than door-to-door surveys. Any study with repeat data collection or in which change detection needs to be recorded can benefit from this technology. In the domain of food security, UAV data can be used in combination with satellite imagery to support communities dependent on agriculture. Other monitoring examples include sprawling slums, crowds at protests or festivals, the ebb and flow of refugee camps, trash accumulation and disposal in urban areas, measuring economic activity at marketplaces.

Conclusion

With spatial information becoming available at various temporal and spatial scales, new tools and applications that integrate and use this information continue to emerge. A similar example of ubiquitous spatial data comes from the early 1990s, when GPS data were made available for civilian use, illustrating how spatial information, when offered in an easily accessible form, creates ubiquitous opportunities.

It is hard to envision that the skies will be filled with UAVs and space congested with small sats. This is unlikely to happen as collision avoidance and platform sharing technologies emerge, and space and the skies are mapped and zoned into lanes and corridors. In the future, visual information will rely on a pyramid directly correlated with the altitude of acquisition. Local and low-altitude UAVs will capture and transmit local information (akin to local broadcasting stations), and satellites will prevail on the regional and national levels.

Most applications on laptops, cellphones, and other devices, including virtual reality wearables, will access and use near-live spatial information. Just like location, vantage viewing will be the norm and expected by users. Such expectations will be pervasive, with users relying on oblique and ortho images to understand and make all kinds of decisions. Visualization from all angles will be as important in the future as communication is today, with input provided regularly from UAVs and small sats.

User expectations will change from "what I see" to "as if I am there" and change how we communicate digitally. Images and videos will be as strong as words and will also have an impact on GEOINT. The "eye in the sky" will become the eyes of everyone interacting on the scene, including warfighters, first responders, rouge actors, and humanitarian agents. The acute irony is the closer everyone is to the action visually, the further most people will be from it actually.

The proliferation of imagery and increased data acquisition will also pose challenges. In the new world of petabytes and zettabytes, imaging and cataloguing the entire planet every day is an enormous task with allied concerns related to ethical use. New algorithms, machine learning, and automated image extraction will continue to define how we use and analyze imagery from various platforms.

Innovation and change are the bedrock of human ingenuity. Whether it was the agricultural, industrial, or medical revolutions, each brought a greater level of prosperity and complexity to our world. Today, we are in the midst of an information revolution for which spatial information plays an integral role. Tomorrow we will be in a "visual revolution" with UAVs and small sats at its forefront. This visual information will be integrated into current and future applications as another piece in the information pie that is continuously ingested and applied for myriad innovations.

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