Conclusion

To understand NATO GEOINT, it is essential to understand two distinct parts. One part is GEOINT conducted in NATO member countries. The second is GEOINT produced in NATO. In studying the NATO member countries of Belgium, Canada, Denmark, France, Germany, Poland, Romania, Norway, Portugal, Turkey, the U.K., and the U.S., we found that "national" and "NATO" GEOINT are fundamentally different phenomena. We found that a country's GEOINT tradecraft belongs to the nation's history, culture, and available resources. This is contrasted with NATO GEOINT tradecraft, which belongs to NATO's history, policies, and the U.S. support of the NIFC. The work illustrates how studies of GEOINT organizations have important value. Above and beyond this, the impact of a mixed group of international researchers was strategic and enlightening. One of the primary outcomes of the course was to break down the boundaries between academic institutions and reveal cultural insights among the international GEOINT community.

Recommendations

There are three primary recommendations that emerge from this work. First, educators need to promote the study of GEOINT organizations to better understand their behaviors, practices, and processes. Second, a mixed group of international learners and researchers should be encouraged. The international mix of students that participated in the course created relationships among academic institutions and developed shared cultural insights. Last, there is a need to improve the means of investigating GEOINT organizations and capabilities. A systems science approach might better capture the set of methods, techniques, and skills that form the tradecraft of producing GEOINT.

The Role of GEOINT in the Integration of Commercial, Small UAS into the National Airspace System

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Geospatial intelligence (GEOINT) is "the exploitation and analysis of imagery and geospatial information to describe, assess, and visually depict physical features and geographically referenced activities on the Earth. GEOINT consists of imagery, imagery intelligence, and geospatial information."[7] Most people understand GEOINT to be the various forms of satellite imagery supporting a geographic information system (GIS) used to understand a variety of activities acting upon the Earth, and that's partly correct.

However, GEOINT comes from far more sources than from satellites alone. Moreover, GIS and GEOINT are not the same thing. GIS is to GEOINT what timber is to a house. Of the many uses for timber, supporting the framework for a house is but one. While some use GIS and GEOINT interchangeably, it is important to remember that GEOINT, like a house, is focused on the human more so than the Earth. A fun way to explore GEOINT is to apply the prefix "geo" to a human activity and review the concepts that come to mind (i.e., geo-political, geo-economic, geo-healthcare, geo-retail, geo-transportation, etc.). This "geo-cognitive" exercise will quickly replace the solid lines between geospatial disciplines with dashed lines, and this is a good method for beginning to understand GEOINT tradecraft. In this article, we explore how the GEOINT tradecraft is evolving within the aviation industry through the introduction of unmanned aerial systems (UAS) into the National Airspace System.

Types of GEOINT

There are two widely recognized arenas for GEOINT. First, the U.S. Intelligence Communities rely on GEOINT to support their national security mission objectives. Second, commercial industries are increasingly using GEOINT to both sharpen their competitive edge and to better know their customers. There are two commercial GEOINT subtypes: *active* and *passive*. Active GEOINT is intentionally created and distributed, while passive GEOINT is inadvertently or unknowingly created and distributed. We focus on commercial GEOINT in this review because it is the enigmatic source of unprecedented volumes of data. Commercial GEOINT is difficult to regulate as it comes from numerous sources having various accuracies, is potentially spoofed, and is most readily available to adversaries.

Commercial GEOINT is created by and for commercial, and often public, use. While it is true that commercially owned satellites contribute invaluable data streams to commercial GEOINT, it is also true that consumer products are contributing as much or more. The smartphone, for example, is the quintessential source of consumer-produced commercial GEOINT. We present smartphones, and mobile devices in general, as a metaphor for understanding unmanned aerial systems (UAS). In fact, there are cases where a smartphone served as the "brain" of a UAS.[8,9]

Mobile devices are capable of producing high-resolution geotagged images. They are also capable of producing geo-referenced social media, interacting with Internet of Things (IoT) automation services, and using artificial intelligence

7. National Geospatial-Intelligence Agency. 2006. "NSG GEOINT Basic Doctrine Pub 1.0."
8. Mateo Borri. 2017. *RobotsEverywhere - Air.* https://robots-everywhere.com/re_site_wp/robots-everywhere/air/
9. David Steitz and Rachel Hoover. 2013. *NASA's Latest Space Technology Small Satellite Phones Home.* December 4, 2019. https://www.nasa.gov/press/2013/december/nasas-latest-space-technology-small-satellite-phones-home.

(AI). Mobile devices are so good at producing and interacting with geospatial content, they have earned a place in the tool kit of professional surveyors. Professional surveyors commonly use mobile devices to supply kinematic corrections from virtual reference stations, making mobile devices tools for improving positional information to subcentimeter accuracy. Another compelling play for mobile devices is how they can turn any consumer into a potential surveyor. In this context, a consumer may actively or passively contribute geo-technical data to a commercial entity.

This type of GEOINT transaction between a business and its consumers typically comes in the form of a consumer convenience. Consider a crowdsourced navigation application that allows individuals to share traffic conditions in real time. The consumer actively exchanges traffic data with other consumers while passively providing detailed knowledge of traffic patterns, consumer route history, and any associated metadata (photos, contacts, etc.) to the application provider. This example involves the transfer of both active and passive GEOINT.

Now consider how the crowdsourced navigation application above scales when consumers, or drivers/pilots, are replaced with AI, and the equipment they control becomes autonomous. This consideration reveals the necessity of traffic management for unmanned systems, and prepares us for understanding the challenges presented during the integration of UAS into the National Airspace System. How are location-enabled mobile devices different from UAS? Both are mobile, potentially interacting with humans, capable of gathering intelligence, making decisions from that intelligence, and disseminating that intelligence. And both have been shown to exhibit machine-to-machine backchanneling at times. This presents significant GEOINT concerns, as well as an added concern in the form of supply-chain security risk.

A GEOINT-UAS Knowledge Gap

Working with GEOINT involves tradecraft, and it is difficult to define GEOINT tradecraft beyond a dynamic interaction with GEOINT. The tradecraft is both multidisciplinary and cross-industry, resulting in competing ideas and applications across industry lines. The lexicon is evolving even within the Intelligence Community. So, it's not surprising that GEOINT sits on the periphery of the commercial UAS industry. Presently, the UAS industry is focused on safely operating in the National Airspace System with increased complexity and autonomy. New standards for pilot certification, airworthiness, and airspace authorization are emerging, quietly and diligently increasing the presence of GEOINT in the commercial UAS industry. Together, the emergence of GEOINT and UAS standards and protocols makes them difficult to discuss despite a growing codependence. To help clarify this codependence, let us first walk through the stages of UAS developments and point out the crucial stage where GEOINT becomes relevant.

sUAS Traffic Management

As you may know, the Federal Aviation Administration (FAA), NASA, and other federal and industry partners have been collaborating to develop a sister traffic management system to the FAA's manned Air Traffic Control. The sister system is designed to serve UAS weighing less than 55 pounds and operating below 400 feet. Specifically, these are small UAS (sUAS). sUAS operations are expected to produce a low-altitude (Class-G) air traffic density that requires a dedicated traffic management system, hence the imminent UAS Traffic Management (UTM) system.

UTM development was planned to include four technical capability levels (TCLs).[1] TCLs are not described with respect to GEOINT, and we put forth the notion here that the presence of GEOINT increases with each TCL as shown in Figure 1. Each TCL introduces improved operational capability in favor of autonomy, and the human pilot is incrementally replaced with AI. The resulting intelligence is aware of its environment through sensors and is intended to operate near people and eventually interact with them.

Technical Capabilities Level 1

TCL 1 was achieved at Integration Pilot Program (IPP) test sites by FAA-approved academic and industry partners in Fall 2015. Reserved airspace was mandatory, and the types of activities focused on demonstrating surveillance and reconnaissance for industrial monitoring. Agriculture, forestry, natural processes (e.g., wildfires), and infrastructure monitoring were all demonstrated in TCL 1. All TCL 1 operations were conducted within visual line of sight and

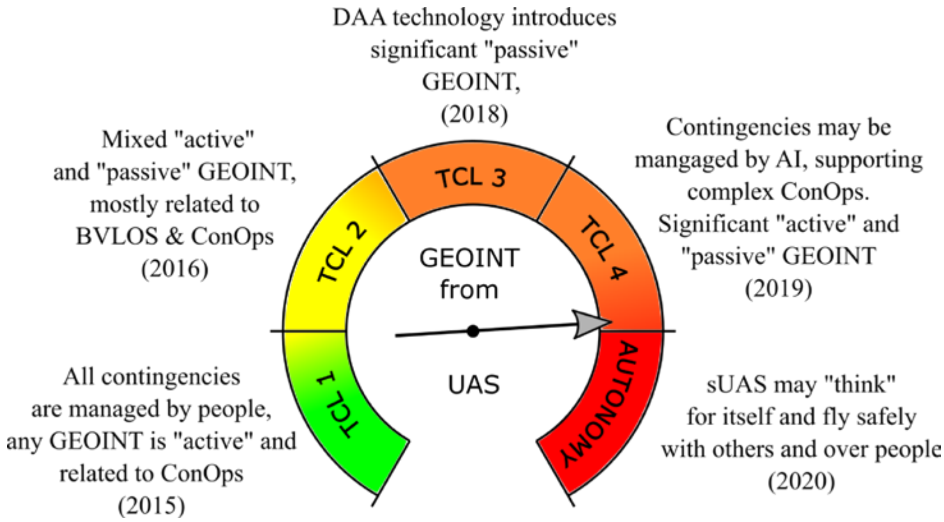

Figure 1. Codependence of UAS technical capabilities levels (TCL) and GEOINT. The presence of GEOINT increases as UAS become more autonomous.

1. NASA-FAA. 2018. "UTM ConOps v1.0." *UTM Concept of Operations Version 1*. https://utm.arc.nasa.gov/docs/2018-UTM-ConOps-v1.0.pdf

remotely piloted by a human pilot. All contingencies were handled by the pilot. Any GEOINT involved at TCL 1 resided with the pilot and was not essential to the sUAS operation.

Technical Capabilities Level 2

In just over a year, TCL 2 was achieved. Operations that demonstrated capabilities for flying beyond visual line of sight were introduced, as well as dynamic airspace reservation. This expanded the TCL 1 operations to include third-party tracking of an sUAS. TCL 1 and 2 were both conducted in sparsely populated areas. Some contingencies were handled by the sUAS with pilot supervision. Minimal GEOINT was present as sensors assisted crew with information in support of flying beyond visual line of sight.

Technical Capabilities Level 3

TCL 3 was achieved in 2018. The extra time required resulted from added complexity of capabilities. In contrast to TCL 1 and 2, TCL 3 allowed for ground observers to include sensors in addition to humans. Both responsive and nonresponsive sUAS tests were conducted to help determine how to manage sUAS that were "noncooperative." TCL 3 allowed for operations to be tested in moderately populated areas. Other tested capabilities included tracking and communication with other sUAS as well as managing cargo. Some contingencies were handled by the sUAS without pilot supervision. Developments in the hardware used for sensing and avoiding were coupled with AI, and this significantly elevated the presence and use of GEOINT through the use of detect-and-avoid (DAA) and sense-and-avoid (SAA) technology.

GEOINT, DAA, and SAA

TCL 3 introduced capabilities for DAA and SAA technology to an sUAS. It is important to note that DAA and SAA technologies are responsible for providing information to an onboard AI system that decides how to manage obstacles. It is also important to note how these technologies afford a greater range of capabilities to an sUAS than their implied purpose. Sensors that support DAA and SAA can include optical, acoustical, and image processing strategies. The combination of onboard sensors and intelligence allows an sUAS to manage UTM goals, as well as operate under conditions in which communications and positioning capabilities have been compromised, such as link loss or denied GPS. Therefore, an sUAS operating near airports, infrastructure, or other sensitive areas is gathering intelligence as part of its safety strategy, and this intelligence undoubtedly includes GEOINT. The acquisition of GEOINT using DAA and SAA technology is a security concern because the intended use for the data may change depending on the context in which it serves a given ConOps.

Technical Capabilities Level 4

TCL 4 advancement has been intensifying since early 2019. TCL 4 milestones include short, autonomous flights using radar-based ground observers and onboard tracking and avoidance systems.[2] The first demonstrated operation beyond visual line of sight without ground-based observers of any kind was completed.[3] Contingencies were handled by the sUAS. Urban operations, operations over people, and operations at night were also demonstrated. Safe operation beyond visual line of site without human oversight further increased the integration of GEOINT into UAS operations.

Both GEOINT subtypes (active and passive) are present in TCL 4. Furthermore, both active and passive GEOINT may be utilized in support of flight operations and/or a ConOps. There are conditions where active and passive are interchangeable, based on context. For example, flying (without surveying) near a pipeline or nuclear power plant reveals structural information to the DAA system. Such intelligence is active GEOINT with respect to safe flight operations but may become passively associated with communication to air traffic control, ground control stations, and third-party service providers.

Beyond TCL 4: Autonomy

The capabilities demonstrated in TCL 4 mark a pivotal role in UTM development where a shift must be made from sUAS safety to sUAS security. The next phase of UTM requires sUAS data to flow through a developing UTM system. This means that intelligence generated onboard an sUAS will begin moving through UAS service suppliers in support of UTM goals, potentially carrying unrelated GEOINT in support of ConOps goals.

Moving Past the GEOINT-UAS Knowledge Gap

The presence of GEOINT in UAS operations grows with each milestone in the developing UTM system. Further, GEOINT is independently and inseparably tied to the safe operating procedures and the ConOps behind each mission. The rapid growth of the sUAS industry carries so much momentum that our GEOINT cards may sometimes be dealt face up. And just like with mobile devices, this may be tolerated for some applications while it is unacceptable for others.

The FAA's mission lies in regulating aviation within the National Airspace System, primarily through traffic management. The FAA will soon be presented with streams of GEOINT coming from UAS. How will the FAA, or any agency affected by GEOINT coming from unmanned systems, handle this? Unmanned systems are also found on land and in water. The answer is that these organizations likely are not equipped to handle these GEOINT streams. Instead, the data must effectively flow across a team of agencies, each one preparing the data stream for the other in such a way that security and safety remain optimum. Intelligence gateways, "GEOINT Gateways," need to be embedded within unmanned systems industries, and the National Geospatial-Intelligence Agency will require a panoptic view of these gateways. The data flowing to and through law enforcement will undoubtedly differ from the data flowing to and through Amazon, Google, UPS, and the like.

2. AUVSI. 2019. "University of Alaska Fairbanks Team Completes First FAA-Approved BVLOS Mission in the U.S." August 5. https://www.auvsi.org/industry-news/university-alaska-fairbanks-team-completes-first-faa-approved-bvlos-mission-us
3. Isabella Lee. 2019. "Iris Automation Detect-and-Avoid System Earns Second BVLOS Waiver and Trust of FAA." *UAV Coach*. August 22. https://uavcoach.com/iris-automation-bvlos/

GEOINT Gateways will be required to move information with improved bandwidth compared to that seen in HTTP-based communication. Edge computing, IoT messaging protocols, and decentralized architectures are all growing in tandem with the need for these GEOINT Gateways, and they will likely combine in the solution. This is less of a big data problem and more of a distributed "Big IoT" problem for unmanned-systems and intelligence industries to collaboratively solve.

Advancing GEOINT Through Clarity in the Employment Market

By Talbot Brooks, Delta State University; Dr. Christopher Anderson, GSX; Dr. Robert Austin, Austin Communications; Dr. David Alexander, U.S. Department of Homeland Security; and Dr. Camelia Kantor, USGIF

Finding high-quality candidates for positions in the greater geospatial intelligence (GEOINT) industry is an ongoing challenge for many employers because of high variability across the educational and training landscape, as well as the extraordinarily varied experiences brought by employees. Likewise, jobseekers have an equally difficult time discovering suitable positions because of the wide variety of titles used and a lack of clarity about the required level of competency needed in position descriptions. Both factors combine to stymie education, business, and government efforts to quantify and substantiate workforce needs and better prepare future candidates.

Anecdotal evidence indicates that confusion in the GEOINT employment marketplace has tangible consequences. Significant salary mismatches across seemingly similar positions, high turnover prompted by employer and employee dissatisfaction, and inconsistency across academic and training curricula are all symptomatic of dysfunction, which ultimately translates into what are widely reported as significant financial and productivity losses for both employer and employee. Peer-reviewed literature strongly supports the idea that improved selection processes, particularly those related to motivational fit, can improve both operations and profit.[1]

Refining the education and training pipeline such that it more closely aligns with position titles and job descriptions is an important first step in minimizing such losses. Three essential actions have begun to address this challenge:

1. Redefining the codification of occupations and academic programs.
2. Segmentation and professionalization of the workforce.
3. The creation of a body of knowledge focused on learning objectives rather than topics.

While these three initiatives represent substantial progress, they fall short due to a lack of comprehensive industry leadership and a clear vision of the future for GEOINT as an industry and an academic discipline. In article, these positive first steps are identified and potential solutions discussed.

Codification of Occupations and Academic Programs

President George W. Bush's administration identified geospatial technologies as a high job-growth area in 2001.[2] A substantial investment commitment was desired for the geospatial arena, but was quickly mired by a lack of definition around the terms related to all things "geospatial," and a debate over whether it constituted an industry. The Association of American Geographers, the Geospatial Information and Technology Association, and the U.S. Department of Labor's Employment and Training Administration (DOLETA) collaborated to form the Geospatial Industry Workforce Information System (GIWIS) in an effort to:

- Develop a constructive definition of the geospatial industry.
- Develop a web-accessible server of industry, job, and educational information called GIWIS.
- Create an industry image and outreach campaign.
- Develop a local pilot program for using GIWIS.
- Take steps to ensure the sustainability of GIWIS and the outreach program.

Numerous roundtable meetings of thought leaders solicited input about these topics from more than 200 representatives from across industry, academia, and government in an attempt to build consensus. The following definition was eventually reached and integrated into a web portal designed to meet the needs of industry, academia, and jobseekers:

> *"The geospatial industry acquires, integrates, manages, analyzes, maps, distributes, and uses geographic, temporal, and spatial information and knowledge. The industry includes basic and applied research, technology development, education, and applications to address the planning, decision-making, and operational needs of people and organizations of all types."*[3]

The work performed in creating the definition and portal represented the first truly large-scope effort at understanding the emerging geospatial industry using a massive, consensus-driven process. At the same time, but independent from the civilian geospatial world, the idea of defense activities that used geospatial technologies and tools was maturing from a map/observe/report

1. Matthew O'Connell and Mei-Chuan King. "The Cost of Employee Turnover." *Industrial Management*. 2007:49:1:14-19.
2. Geospatial World. "GITA Receives $700,000 Grant from U.S. Department of Labor." As reported on July 22, 2005. Retrieved on October 20, 2019 from https://www.geospatialworld.net/news/gita-receives-700000-grant-from-u-s-department-of-labor/.
3. GIWIS portal as was available through 2010 at http://www.giwis.org. A summary presentation, including screen shots, is available at https://www.fgdc.gov/ngac/meetings/december-2010/geospatial-industry-workforce-information-system.ppt.