SDA TAP Lab Using Commercial Technology to Avoid Operational Surprise

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Abstract

In May 2023, Gen Guetlein directed the stand-up of the Space Domain Awareness (SDA) Tools, Applications, and Procedures (TAP) Lab, under Space Systems Command SSC/SZG, the program office for space domain awareness and combat power. The Lab's purpose is to ensure space superiority, recognizing that formidable threats to our space systems exist both in orbit and on the ground. The Lab leverages developing space technologies in industry, academia, and government to fill capability and process gaps and seams in our space defense architecture. General Saltzman provided a Theory of Success to safeguard our systems against attacks, with the primary tenet being to Avoid Operational Surprise. The National Space Defense Center (NSDC) at Schriever, SFB coordinates space defense actions leveraging sensors, intelligence and data from a variety of sources including Space Delta 2. Detecting the initiation of kill chains is imperative to avoiding operational surprise. The SDA TAP Lab's approach involves collaboration with technical staff and operators to decompose kill chains into manageable problem statements. These problem statements drive our Apollo Accelerator, inviting commercial space companies, universities, and Federally Funded Research and Development Centers (FFRDCs) to develop, collaborate, and demonstrate solutions over three-month cycles. Each cycle culminates in a Demo Day, where capabilities are showcased to promote government investment. The first cohort collaborated from October 2023 to January 2024, focused on understanding the nature of operational surprise and developing mitigation strategies. Twelve organizations across industry, academia, and government worked together and developed the following thesis: Surprise comes via camouflage, concealment, deception, and maneuver, therefore we must interrogate targets for evidence of CCDM in order to avoid surprise. This research will show our ability to use existing technology and unclassified data sources to rapidly mature applications, processes, and deploy SDA capabilities into operations within 100 days to close gaps in our kill chains in order to mitigate operational surprise.

1. Introduction

In January 2023, Ms Barb Golf, Strategic Advisor for Space Domain Awareness (SDA), assigned Maj Sean P. Allen the task of planning the stand-up of a new SDA lab. As a visionary and strategic advisor, she understood that SDA is a prerequisite for space superiority. Her objective was to provide the SDA community with unifying vision around protection and defense from adversary kill chains.

In March 2023, General Saltzman published a theory of success called "Competitive Endurance" to guide the Space Force in achieving space superiority [2]. According to General

Saltzman, the theory of success "provides Guardians with shared purpose, and common understanding of our overall strategy towards this objective." Then, in May 2023, Lt Gen Guetlein, in his role as the Space Systems Command (SSC) Commander, officially directed the stand-up of the SDA Tools, Applications, and Procedures (TAP) Lab, with the mission to accelerate the delivery of space battle management software to defense centers. Maj Sean P. Allen was assigned as the inaugural Chief, SDA TAP Lab. During initial planning meetings, Lt Gen Guetlein emphasized the need to collaborate with industry, academia, government, allies, and partners and that sharing data must be a cornerstone of the Lab.

The SDA TAP Lab is modeled around a few key processes: Kill Chain Decomposition, The Apollo Accelerator, and Rapid Technology Onboarding

2. Kill Chain Decomposition (KCD)

The SDA TAP Lab addresses five primary adversary kill chains: GEO Direct Ascent Anti-Satellites, GEO Coorbital Anti-Satellites, LEO Direct Ascent Anti-Satellites, LEO Coorbital Anti-Satellites, and Cyber. Five major steps are performed when decomposing each kill chain: Gather Data, Stakeholder Engagement, Synthesis, Prioritization, and Update Artifacts.

When gathering data, the Lab references existing threat analysis, historical and declassified requirement documents (e.g., JMS and Space C2 programs), and performs interviews with domain experts. All the data used is not classified, unclassified (not CUI), and much originates from the public domain. This is a powerful method for guiding development since it enables broad collaboration, as directed by the Vice Chief of Space Operations (VCSO). It is worth noting that a vibrant public record exists of battle management concepts in every military domain. The lab makes full use of this information which is helpful and necessary for the Space Force to advance a warfighting culture.

During stakeholder engagement, the Lab hosts both formal and informal sessions with SDA operating units, Technical Director Staff (TDS), Combat Development Teams (CDTs), and leadership. Feedback is recorded for the next step, synthesis.

During synthesis, all gathered data and stakeholder feedback is evaluated for categorical similarities and recurring themes. The goal of synthesis is to reduce the total number of needs or requirements without losing information. Examples include needs related to timing and tempo, or battle management concepts such as target identification. Needs are nested into a 3-tier hierarchy Major Functions, Minor Functions, and Problem Statements. The most detailed tier, Problem Statements, is named for two reasons: these are not requirements, and they should be constrained enough that a small team of engineers could address "the problem" in a few short months.

Next, the lab engages stakeholders in the SDA operational community to prioritize the problem statements. The SDA TAP Lab uses a simple "high, medium, low" priority scheme. This makes it simple to coordinate the time and attention of the many Lab participants, especially inside the Apollo Accelerator (described below).

Finally, the outcome of the process is to generate two primary artifacts: 1) The KCD graphic (similar to an Operational View-1), and 2) Problem Statement Table. The KCD graphic is seen below. For ease of understanding, functions and problem statements are aligned in a roughly chronological order. While the actual actions taken during an engagement are certainly not linear, one can generally describe some functions as being performed earlier or later. This becomes helpful during the Apollo Accelerator when large cohorts must be broken into teams based on the function or problem they are addressing. Then, the Problem Statement Table is an internal, dynamic document, which contains various details to aid in performance benchmarking, technology onboarding, and capturing notes from stakeholders.

3. The Apollo Accelerator

The Apollo Accelerator is a collaborative tech accelerator for industry, academia, government, allies and partners to address the problem statements posted to www.sdataplab.org. Joining an Apollo Accelerator is non-competitive process, but applicants must meet minimum criteria. First, intended participants must apply through the website. They must clearly state which problem they intend to address and give a brief description of their intended solution. Additionally, applicants must acknowledge in writing that they understand participation is voluntary and at their own expense and be willing to collaborate with other lab members. Prior to starting a cohort, a degree of security vetting is performed. Then an Apollo Accelerator begins which runs in 3-month cycles, up to 4 times a year.

During each cohort, the Lab coordinates Expert Talks on technical topics, operator engagement sessions, VIP tours, and gives ongoing SDA mission guidance. Additionally, the Lab assists companies in refining their use cases, and differentiating the software being developed. This maximizes the potential value of each product and minimizes direct competition.

Each cohort ends with a Demo Day to showcase prototypes and encourage investment. There is no promise or guarantee of funding. Instead, Demo Days create potential opportunities for companies. If a company has met minimum expectations, there are no security concerns, they have successfully demonstrated a prototype solution to an operational problem, then pending availability of funds and feedback from key stakeholders, the SDA TAP Lab either buys a subscription to the prototype software through the Global Data Marketplace or advocates for investment from other parts of the government. These Apollo Accelerator subscriptions are 12 months in length and are intended to provide a window of time to integrate the capability where needed and plan for transition.

4. Technology Onboarding

Once a prototype has been successfully demonstrated, we begin the technology onboarding process. The SDA TAP Lab seeks to minimize interruption or impact on current operations while delivering capabilities as quickly as possible. Integration of prototypes into existing operational workflows is both an administrative as well as technical challenge. Battle management responsibilities are geographically distributed around the globe. Within a given operating location, functions may also be spread across classification levels and networks. Some functions are more tactical in nature and are performed close to sensors or where data are generated. Other functions are more focused on coordination of effects and happen at a defense center. In summary, there is no single answer for where or how to integrate – the answer depends on community engagement to enhance current operations without interruption or degradation.

When making these decisions the SDA TAP Lab 1) aligns each prototype with the mission of specific organizations, 2) determines what networking or IT infrastructure is available to those operators, 3) identifies code deployment pipelines to safely move the prototype to the target environment, 4) and pre-negotiates those pipeline owners so the lab is ready to move quickly when awards are made. Examples of existing pipelines the SDA TAP Lab leverages include Gravity, managed by SpaceCAMP, an Air Force Research Lab (AFRL) organization and Platform One which both have existing Authority to Operate (ATO) or are making good progress toward an ATO. The Lab benefits as a user of these pipelines. Several other pipelines are also in coordination. We refer to making these deployment decisions as defining The Golden Path.

We then have until the end of the Apollo Accelerator subscription to either sustain or sunset the prototype. The SDA TAP Lab coordinates with operational and acquisition stakeholders to plan those next steps which may include: 1) Extend the decision window through additional research and development funding new government customers, 2) Sustain the capability within an existing program office, 3) Offboard the capability. This is a community decision based on many factors which must be carefully considered.

5. The First Year

A total of three Apollo Accelerator cohorts have completed since 26 October 2023. We are currently in cohort 4 at the time of this writing. Each cohort has grown in size and scope. Currently, cohort 4 consists of 218 individuals from 59 companies from 3 countries, includes undergraduate and graduate students from multiple universities, and sponsorship from four government organizations. The Lab has issued a total of 28 subscriptions to 19 companies and has deployed two applications to classified environments where they run automatically.

The SDA TAP Lab has established multiple partnerships such as with Maui Economic Development Board (MEDB), The Catalyst Campus for Technology and Innovation (CCTI), Defense Innovation Unit (DIU), National Security Innovation Network (NSIN), and DARPA among others. The demand from industry and government has been significant. Senior leaders have honored the lab with personal visits such as General Guetlein, Lt Gen Garrant, Congressman (R-VA) Rob Wittman, Congressman (D-NJ) Donald Norcross, and Professional Staff Member (PSM) Mr. Bill Adkins. Finally, on 28 August 2024, General Guetlein requested a personal office call with Maj Allen to reinforce the value of the SDA TAP Lab mission and commend the work of the Lab.

6. Avoiding Operational Surprise

The SDA TAP Lab's mission (accelerate the delivery of space battle management software to defense centers) has a broad scope. While there are many actions we must take to protect and defend space systems, we prioritize taking action to avoid operational surprise (Theory of Success) and to detect the start of a kill chain (Delta 2 Commander, Col. Raj Agrawal). This is the lens through which we guide companies in the Apollo Accelerator.

Apollo Accelerator Cohort 1 laid conceptual and technical foundations that future cohorts have built upon. Cohort 1 companies included: Intrack Radar Technologies (IRT), Katalyst Space Systems, HEO Robotics, True Anomaly, Lockheed Martin, Digital Arsenal, Blue Halo, and students from CU Boulder, and Yale. Together, they developed a hypothesis to translate the Theory of Success into software. Through a series of design thinking sessions, operator engagements, and subject matter expert interviews, Cohort 1 penned this hypothesis: Surprise comes through camouflage, concealment, deception, and maneuver (CCDM). To avoid surprise, we must interrogate targets for evidence of CCDM.

Cohort 1 then also defined four ways in which CCDM might theoretically be employed on orbit. These include deploying a threat system that 1) mimics a benign satellite, 2) mimics an inactive satellite (playing dead), 3) mimics debris or natural objects, 4) attempts to not be tracked (covert or clandestine operations). From here, Cohort 1 then began imaging what indicators might expose these CCDM techniques. For example, if an object is supposedly debris, detecting a maneuver or controlled change in attitude indicates the contrary. Each indicator builds evidence about the identity of the object. The novelty of these approach is that these indicators can be automated and scaled quite easily. Currently Apollo Accelerator companies have identified 25 unique indicators of CCDM. This is what we mean by interrogating targets for evidence of CCDM.

While these concepts are common in other warfighting domains, to the best of our knowledge, this may be the first formalized description of such concepts for the space domain. Cohort 1 systematically decomposed a complex problem through collaboration between industry and academia using only historical, public domain, declassified and theoretical stimulus.

7. The Surprise Window

These concepts have continued to mature in cohorts 2 and 3. We propose that opportunities for surprise are finite. That is, we expect surprise to be exercised when and where an adversary perceives a weakness or limitation in our own systems (regardless of the accuracy of their belief). We describe this as the surprise window. Understanding when the surprise window opens and closes may allow us to pre-posture forces and human attention to better protect and defend.

Cohort 3 identified a specific case where a possible surprise window may exist: the first two days following a launch. Anecdotally, it is common for the U.S. Space Force to make orbits available to the public within hours to days following a new launch. This can be measured using public data made available by the government. It is common for publishing the first orbit after launch to take longer when there are many satellites deployed from the same launch vehicle (e.g., ride share launches). Hypothetically, if an adversary perceived this data publishing delay as a limitation or weakness, they may choose to implement CCDM in this 2 day window.

Several real-world, public, events during Cohort 3 inspired this belief. On 4 July 2024, China launched TIANHUI 5C and TIANHUI 5D satellites from Taiyuan Space Center aboard a Long March 6A. Both satellites appear to have been successfully deployed [3]. Then on 5 July 2024, a Swiss company s2a detected and tracked a large debris cloud around the upper stage [5]. This event has not been confirmed yet by U.S. Space Command (USSPACECOM). Then again on 6 August 2024, China launched 18 “G60” satellites from Taiyuan Space

Center aboard also a Long March 6A [4]. All 18 of the G60 satellites appear to have been successfully deployed. Then, on 7 August 2024, the upper stage experienced a catastrophic fragmentation event producing hundreds of pieces of debris. USSPACECOM confirmed this event on 8 Augist 2024 [1].

We make no comment about the cause or intent of these events. However, we presume it takes time, human attention, and computational resources to analyze and report these events. If automation fails, human attention suffers, or time runs short, what opportunities might exist for an adversary to employ CCDM? We ought to remain vigilant about the potential for operational surprise and develop capabilities to avoid it. The Apollo Accelerator is a key initiative to improve automation and avoid operational surprise.

As we decompose kill chains into progressively smaller problems, we eventually arrive at "micro-service" sized functions with simple interfaces. The Lab helps companies orchestrate micro-services into automated workflows to achieve higher level battle management objectives. We identify real world events, such as domestic launches, to test and evaluate both the micro-services and the workflows together. On 6 June 2024 cohort 3 successfully demonstrated enhanced automation by processing the Starship-IFT 4 launch from Boca Chica, Texas. Using fully commercial and public domain algorithms and data, the team performed these following almost completely autonomous actions. The test was an early success of the model of the Lab to rapidly decompose a complex problem, assemble a large team, develop, integrate and test new capabilities.

1. Kayhan Space evaluated that launch commit weather criteria were satisfied
2. Using public seismic data, GTC Analytics detected the launch event
3. Using GOES-16 infrared imagery, CU Boulder detected the launch event
4. Intrack Radar Technologies automatically generated a predicted initial orbit (called a launch "nominal")
5. Leidos calculated which SDA sensors would have opportunity to track the target and then sent collection requests to a telescope in South America to perform tracking
6. Total elapsed time from launch detection to sending a collection request to track the target was approximately 1.1 seconds

8. Next Steps and Conclusion

The SDA TAP Lab will achieve stable funding, refine business processes, and scale. We are planning to establish SDA TAP Lab campuses in key locations to facilitate better interaction with allies and partners. While these plans are preliminary, this may include an SDA TAP Lab on Maui in the coming year. In parallel with growth, we plan to leverage the momentum from the Apollo Accelerator alumni who have climbed a steep learning curve and are ready to tackle increasingly complex problems on the road to full automation. We anticipate showcasing a fully automated space battle management prototype system within 18 months. As we demonstrate measurable improvements in space defense, we will also be maturing our partnerships with programs of record. We are here to accelerate the delivery of their requirements and assist them in being successful in achieving national security objectives.

Time is of the essence – Tempus Est Essentiae. The mission of the SDA TAP Lab is to accelerate delivery of space battle management software to defense centers. We do this by decomposing adversary kill chains, and identifying the major steps required to defend our systems from attack. We post our problem statements on our website (www.sdataplab.org) and invite industry, academia, government, allies and partners to address these through our Apollo Accelerator 3-month cycles. We will either buy a subscription or advocate for investment in successfully demonstrated solutions. We are here to support the operational community with grit and focus and are going to build, integrate, test, and demo needed capabilities to avoid operational surprise and detect the start of a kill chain until we are out time. We have enjoyed the support of senior leaders like General Guetlein, Lt Gen Garrant, and Ms Barb Golf. We look forward to making them proud of the work we are doing.

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