Training for Operations in a Contested Space Domain

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ABSTRACT

The Army depends on hundreds of space-reliant munitions and devices to conduct combat operations. This technology gives our forces a strategic advantage over the enemy in any scenario, whether it is through the use of precision-guided munitions (PGM) or battlefield situational awareness tools. Unfortunately, the adversary is well aware of our dependence upon these capabilities and has been developing the aptitude to challenge our unimpeded use of space-reliant assets by creating a denied, degraded, and disrupted space operational environment (D3SOE). The Army is currently under-trained to fight through a D3SOE, and particularly, higher echelons lack the ability to replicate a contested electromagnetic operational environment in training exercises at Mission Command Training Program **(**MCTP**)** and joint training events. To address this capability gap, the USASMDC/ARSTRAT along with Training and Doctrine Command (TRADOC)-NSC, Program Executive Office Simulation, Training, and Instrumentation (PEO STRI), and the greater Modeling and Simulation (M&S) Community of Interest are developing a simulation solution to train soldiers how to fight through a contested space environment. Sponsored by the Army Modeling and Simulation Office, this effort addresses replicating Global Positioning System (GPS) jamming effects on PGMs. The effort degrades the accuracy of PGMs and affects the Common Operational Picture with respect to unit positions and movements. At the core of this effort is the United States Air Force (USAF) Distributed Mission Operations Center-Space (DMOC-S) developed GPS Environment Generator (GEG) that applies jamming effects to PGMs. The GEG provides precision degradation for various Army PGMs and space-reliant equipment, such as Excalibur, the Army Tactical Missile System, the Guided Multiple-Launch Rocket System, and the Defense Advanced GPS Receivers. The GEG would then provide this information to the Army Joint Land Component Constructive Training Capability (JLCCTC) that uses the information to determine the impacts on units. The resulting training capability will enhance our military's proficiency in detecting, attributing, and mitigating electronic warfare (EW) effects, greatly enhancing survivability and mission success.

ABOUT THE AUTHORS

Christopher Dupre is a USASMDC/ARSTRAT G37 Training, Readiness, and Exercise (TREX) Division military analyst. Chris is responsible for exploring and fielding simulation solutions for the Army space training initiatives in a contested space operational environment. Chris has 23-year as a USAF Intelligence professional where he was a space system acquisition and threat support analyst. Chris also has an extensive Program Manager (PM) background fielding and sustaining USAF exercise simulation tools.

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ARMY SPACE TRAINING STRATEGY GUIDANCE

Soon after September 11, 2001, the Army found itself engaged in counter-insurgency operations in Afghanistan and Iraq. The enemy was primitive with almost no access to highly technological capabilities to use in battle, particularly with regards to electronic warfare. These were the first wars where the U.S. military seamlessly employed space-enabled weapons and devices as a part of everyday operations, largely 'invisible' to operators on the ground. The enemy had no means to challenge our use of space on a large scale and our military conducted operations using space-based assets and capabilities with a significant degree of impunity. The U.S could not, however, always rely on operating with this level of freedom on the battle field. On September 1, 2010, President Barack Obama wrapped up combat operations in Iraq, and on December 28, 2014, he took similar steps to end the war in Afghanistan. These declarations precipitated a shift in defense policy toward East Asia—a region characterized by much more technologically advanced and capable rivals who could present a serious and persistent challenge to our space reliant combat capabilities. This change in focus continues with the Trump administration.

The change of theater focus naturally led to a shift in strategy. In the future, opposition to U.S. forces throughout East Asia will entail the advent of a D3SOE, a threat U.S. military forces have not had to grapple with in a significant way to date. Army leadership realized what was once assured with space security is no longer assured. In light of this threat, they found it necessary to concentrate substantial efforts to enable and protect free operations at all echelons. In order to accomplish that goal, the Secretary of the Army and the Army Chief of Staff signed the Army Strategic Space Plan directing the USASMDC/ARSTRAT to be "the Army proponent for space to analyze, design, develop, implement, and evaluate a training and leader development strategy to improve space knowledge across the Army." This directive led to the Army Space Training Strategy (ASTS) that:

"…addresses key components of space training and education for soldiers at every grade level and echelon, with the objective of improving our understanding and utilization of space capabilities, products, force enhancements, and protection that enable unified land operations, especially in contested operational environments. The strategy addresses institutional and operational domain space training for all soldiers and the continued training and education of our Army's space professionals."

ARMY SPACE TRAINING IMPLEMENTATION

This strategy gave rise to the Army Space Training Integration (ASTI) Branch within USASMDC/ARSTRAT/G37 Training, Readiness and Exercise (TREX) Division. ASTI leads the implementation and integration of the Army Space Training Strategy (ASTS), signed November 2013 (under revision for 2018 release). The ASTS directs soldiers and leaders be properly educated and trained to understand the capabilities, limitations, products, enhancements, and protection space systems provide in the execution of Unified Land Operations, especially in a D3SOE. The ASTS focus is education, training, and placement of soldiers with space knowledge and training (space enablers) at brigade and below. The ASTI Branch focuses on the Operational Line of Effort (LOE) by providing operational training in a D3SOE during multi-echelon Home Station Training (HST), and at both maneuver and mission command CTC, ensuring the ability to initiate and maintain access to space capabilities and mitigate attempts to deny, degrade, and disrupt that access.

ASTI champions three goals and lines of effort with regard to space training:

- Improve the Army's understanding and utilization of space capabilities. ASTI's HST and CTC teams encourage units to identify weapons and equipment they use that are reliant on space-based assets, such as Precision-Guided Munitions (PGMs), navigation, and communication devices.
- Improve operations in contested space operational environments. This goal is achieved through home-station, field, and warfighter training exercises.
- Create an integrated, seamless continuum of integrated, seamless continuum of operational space education and training. Through train-the-trainer programs, USASMDC/ARSTRAT can leverage Division-level Space Support Elements to provide a consistent space training regimen to ensure units at all levels maintain the knowledge to ensure space reliant assets are always available.

LOEs within the ASTS supporting ASTS goals:

- Institutional: Increase space knowledge across the force by incorporating it into institutional training.
- Operational: Train units at home station, and at the maneuver and mission command CTCs, how to exploit space capabilities and respond in a contested space operational environment.
- Personnel Development: Continue to assess and improve Space Cadre training and distribution throughout the Army.

ASTI employs a number of educational initiatives to ensure soldiers are equipped with the knowledge and expertise to fully leverage space-reliant weapons and systems and to work through a D3SOE.

HST focuses on tactical-level, classroom training. The HST Team executes a "Crawl, Walk, Run" training process that was conceptual in FY15. The three-phase training process included an eight-hour program of instruction (Crawl), a live D3SOE range demonstration (Walk), and a field training exercise integration (Run) phase where open-air EW effects are integrated into exercise scenarios.

The CTC Team provides rotational training unit personnel with both classroom and hands-on D3SOE mitigation instruction. Training is conducted at the Joint Readiness Training Center and the National Training Center to audiences mostly comprised of EW personnel. The training events consist of a two-hour block of instruction, including a classified threat brief, a Defense Advanced GPS Receiver operation refresher, and electromagnetic interference mitigation and reporting.

These essential training events combine to prepare soldiers to fight through a D3SOE by prompting them to establish tactics, techniques, and procedures by way of building primary, alternate, contingency, and emergency plans when weapon systems and navigation and communication equipment are degraded or denied due to jamming events.

ARMY SPACE TRAINING D3SOE PRIORITIES

The first priority is to provide D3SOE effects in a simulation training environment that replicate effects on maneuver forces' navigation and positioning, battle tracking systems, fires and aviation assets, and GPS-aided Intelligence, Surveillance and Reconnaissance systems. These effects would ideally affect de-aggregated units down to platoon-level. This capability should also account for the effect of terrain on both friendly and adversary assets

The second priority is timing should be disrupted. One often overlooked GPS vulnerability is to consider the timing capability that Positioning, Navigation and Timing (PNT) assets provide. Loss of timing synchronization can degrade a multitude of military capabilities, to include Intelligence, Surveillance and Reconnaissance feeds, radars, cell phones, and Satellite Communication (SATCOM) radios (SINCGARS and HAVE QUICK, etc.).

The third priority is to replicate SATCOM jamming effects on friendly forces. This capability should incorporate effects for both uplink and downlink jamming across both military and civilian communication platforms and incorporate jamming effects on Intelligence, Surveillance and Reconnaissance capabilities that rely on SATCOM.

The fourth priority is to incorporate space weather/environmental effects into the simulations for land-based components focusing on mobile communication assets such as Friendly Force Tracker.

Finally, D3SOE simulations should be thoroughly networked and robust enough to stimulate surveillance and reconnaissance systems (such as GUARDRAIL/CHAALS, RIVET JOINT, or other systems when employed in the exercise scenario) and provide feeds to analysis systems such as All-Source Analysis System-Light, space operations systems, and DCGS-A intelligence applications to enable Intelligence, Space, and EW staffs to gather, process, and analyze the threat. This would, then drive operations processes to respond to the either for further collection or possible targeting.

ARMY SPACE TRAINING APPLICATION

The MCTP supports the collective training of Army units as directed by the Army Chief of Staff and scheduled by Forces Command (FORSCOM) at worldwide locations in order to train commanders and staffs on mission command in Unified Land Operations.

The MCTP designs and executes multi-echelon, multi-tiered warfighter exercises (WFX) that provide expeditionary-focused, realistic demanding training and leader development opportunities in decisive action scenarios, to commanders and staffs on the unit's approved training objectives. The WFX program is the Army Chief of Staff's exercise program and a culminating training event for Army Division, Corps, and select Brigade echelon units.

The ASTI Branch Mission Command Training Program (MCTP) Team conducts D3SOE-focused academic instruction during a units MCT and at home station for Army Division, Corps, and Army Service Component Command commanders and staffs. ASTI provides D3SOE-focused observer, coach, trainer (OC/T) augmentation and assessment during Division and Corps WFXs and Army Service Component Command exercises. MCT academic training provides a basic understanding and appreciation for D3SOE planning considerations and educates commanders and staffs on the integration of space into their Military Decision Making Process. MCT OC/T support to WFXs and Army Service Component Command exercises assists MCTP Operations Groups with observing, coaching, and training commanders and staffs on the integration of D3SOE into planning and operations across the Current Operations, Future Operations, and Plans planning horizons and the warfighting functions, and captures observations and trends across the force. The MCTP Team continues to foster excellent working relationships with MCTP Operations Groups A, D, and X and SMDC/ARSTRAT G37 Exercise Branch.

During FY17, the MCT Team supported MCTP Operations Groups A and D by providing D3SOE academic training to 75 leaders and soldiers of the 82nd ID (Airborne (ABN)) staff during a MCT. MCT provided reach back support to three divisions in preparation for their FY17 WFXs. The team also provided OC/T support to MCTP Operations Groups, observing, coaching, and training over 500 staff personnel and leaders across five division staffs from 3d ID, 28th ID, 1st AD, 25th ID, 82nd ID (ABN), and III Corps during WFXs. The team also observed, coached, and trained 175 personnel from the U.S. Army Europe staff during Exercise AUSTERE CHALLENGE 17. Target audiences among the staffs included the G-2, G-2 Collections, G-3, Fires, and G-6 as well as the MCTP Operations Groups Senior Mentors and OC/Ts.

The MCT Team creates D3SOE staff planning lessons, incorporating observations and techniques involving the ASTS and applicable guidance, real-world and training threats, and integration of D3SOE concerns into planning and operations across staff and warfighting functions.

ARMY SPACE TRAINING SIMULATION NEED

Despite the broad range of training capabilities the MCTP Team provides, training gaps still exist during WFXs. Currently, exercises primarily use "Work-arounds" or "white card" injects to drive D3SOE situations that require a response from exercise participants. These "man-in-the-loop" drivers are effective in meeting the commander's training objectives by prompting exercise players to work through a problem set using predetermined action plans, but they are somewhat limiting. First, multiple personnel are needed to plan, coordinate, and execute these scenarios. These actions take a large amount of time, reducing the number of opportunities to present them. Furthermore, they do not replicate EW effects in a simulation environment to which exercise players can recognize, react, report, and respond. They may even serve to tip off players that something needs their attention, rather than helping them learn to identify typical visual cues and other indications of a contested space environment. D3SOE effects should also automatically stimulate surveillance and reconnaissance systems and provide realistic data that would drive analysis

and intelligence production and in-turn, lead to defensive and offensive planning and operations. These limitations curb the realism soldiers need to be exposed to in training.

While effective for what they are intended, the Army currently lacks the ability to provide realistic replication of EW effects in a simulation environment for both friendly and enemy forces. This type of training is vital for commanders at and above Division-level to learn how to operate effectively in a D3SOE. The Army requires a simulation capability that can replicate GPS jamming effects in a training environment. Such a simulation should apply a circle error probable (CEP)[1] to GPS-dependent PGM due to GPS jamming effects and disrupt the Common Operational Picture for the Commander and his staff with respect to unit positions and movements. Satellite Communications (SATCOM) should also be affected in training, as it relies on the timing aspect of PNT. If an enemy has the capability to affect the timing of these signals, they can disrupt all associated communications, whether voice, video feed, or text messages.

Simulations are being assessed to incorporate these effects across the services during joint exercises in addition to Army-specific training. This approach would ensure broader exposure to simulated contested space environments and it could eliminate redundancies across the services while fielding these capabilities.

THE GPS ENVIRONMENT GENERATOR: START OF THE SOLUTION

An EW simulation could greatly reduce or eliminate lengthy coordination processes to incorporate jamming effects during WFX exercises, having greater impact and training transfer. USASMDC/ARSTRAT, TCM Constructive, and PEO-STRI are assessing the USAF GPS Environment Generator as a starting point for the Army to simulate a degraded CEP in training exercises. The GEG is a simulation tool that replicates EW effects on PGM in a simulation environment. This government-owned application developed by the USAF DMOC-S, runs on Windows-based systems. The GEG is a machine-to-machine interface that leverages the GPS Interference and Navigation Tool (GIANT) and provides automated real-time GPS accuracy data to simulation systems during advanced operational and tactical Live, Virtual, and Constructive exercises. The realistic navigational accuracies or disruptions to accuracy GEG provides to exercise players simulates the electronic environment they may encounter in a contested, degraded, and operationally-limited wartime scenario.

Figure 1 shows the potential degradation of the CEP during a weapons simulation event in a simulated contested space environment.

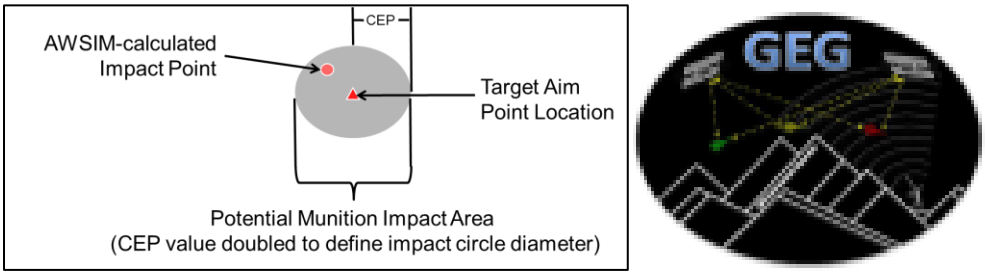

Figure 1. Potential degraded CEP function

The GEG is currently used in the Air Force's Blue Flag training exercises. In these USAF's Blue Flag exercises, the GEG aligns the CEP with the munition and repackages the CEP in a Distributed Interactive Simulation (DIS) protocol data units. These data units are then passed to Air Warfare Simulation (AWSIM) that determines the detonation offset. The detonation offset is subsequently forwarded to the Air, Space, and Cyberspace Environment - Information Operations Suite that determines the battle damage that is fed to the Mission Report.

[1] CEP is a measure of a munition's precision. CEP is defined as the radius of a circle, centered on the target, whose boundary is expected to include the landing point of the munition 50% of the time. For example, if a munition has a CEP of 10 meters, it can be expected to land within ten meters of its target 50% of the time, and more than ten meters from its target 50% of the time.

This adds GPS Jamming functionality for the Air Force in the Multi-Resolution Federation/Joint Training Transformation Initiative federations. If OPFOR GPS jammers are active in the vicinity of an OPFOR fixed site target, it will degrade the accuracy of a Blue Force (BLUFOR) GPS guided weapon launched against that target, thereby reducing the amount of damage inflicted on the target.

The Army is evaluating adapting the Air Force GPS jamming functionality developed for Blue Flag Exercises. (See data flow below.)

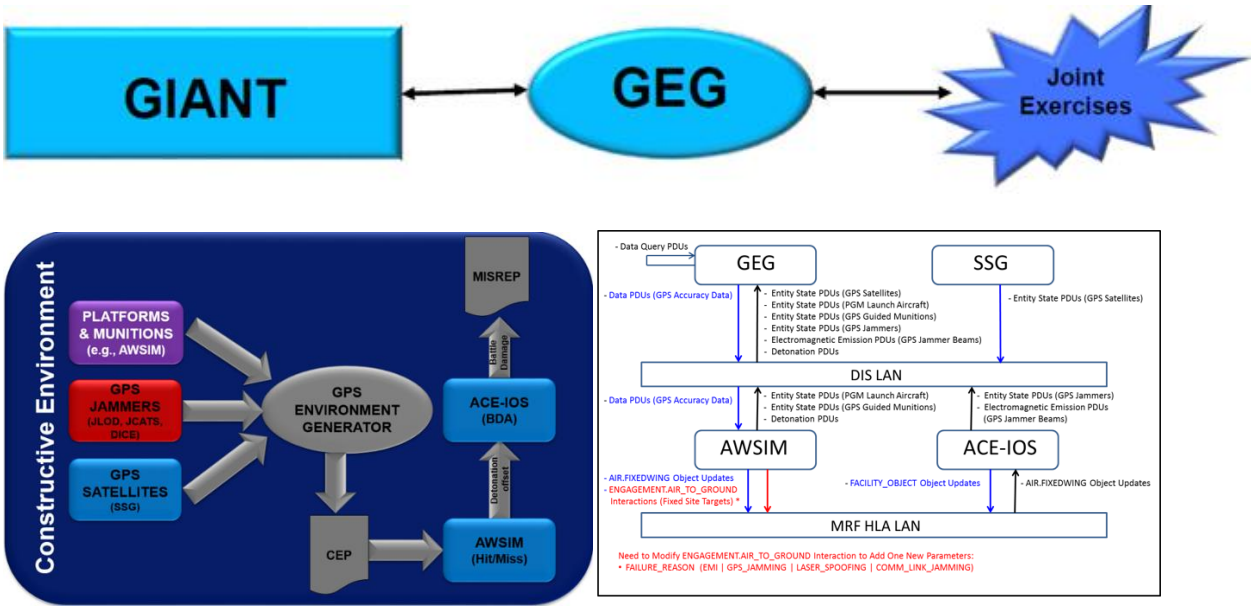

Figure 2. GEG function in Joint Blue Flags Exercises

ARMY SPACE TRAINING APPLICATION: JLCCTC

The Army is evaluating simulation approaches to provide a single, authoritative source for the navigational precision of GPS-guided munitions and weapon system platforms in a simulated degraded GPS environment. This simulation would also replicate precision weapons' CEP degradation due to PNT signal disruption in a constructive signals environment.

The Army's JLCCTC is a High Level Architecture supported simulation tool that supports battalion to Theater MCT. JLCCTC provides Army commanders and their battle staffs the capability to train in an operationally relevant, simulation environment that exercises critical mission command function in a multi-domain battle for all units connected to the simulation federation.

Incorporating an EW Layer in JLCCTC/WARSIM allows GPS-guided/aided systems, jammer to signal ratio on GPS frequencies L1 and L2, position velocity errors/uncertainty, and weapon handoff GPS receiver state[2]. This simulated contested space environment would be based on GPS satellite geometry relative to the affected munition, as well as jammer locations and antenna characteristics, munition guidance and GPS receiver characteristics, and body and terrain masking of each, respectively. CEP is expressed as a horizontal and vertical error/uncertainty in meters. WARSIM would calculate the impact point via stochastic variable determination, using the target coordinates and CEP as input. JLCCTC could use a WARSIM impact point to calculate battle-damage

[2] GPS receiver states 1-7 are: Normal Acquisition, Direct Acquisition, Code Lock, Carrier Lock, Carrier Track/Data Demodulation, Sequential Resynchronization, and Signal Reacquisition.

assessment using the Joint Munitions Effectiveness Manual or equivalent algorithms. WARSIM would then automatically issue a Mission Report to feed Course of Action Analysis.

ARMY SPACE TRAINING DEVELOPMENT: WARSIM

GPS effects within the WARSIM federation affect many functions/systems. These effects would have the purpose of creating an environment that will compel commanders, operators, and crews to recognize when they are conducting operations in a D3SOE, react to the threat by developing tactics, techniques, and procedures that would enable them to operate with minimal impact on the mission, and to report EW occurrences to feed trend analysis. These effects include:

1. FIRES
- GPS guided munitions (Army Tactical Missile System, Excalibur) should demonstrate a reduction in precision and/or dud rate.

2. MISSION COMMAND SYSTEMS/MANEUVER
- Many times, maneuver forces and systems are affected before other Warfighting Functions because they are more apt to be in proximity to GPS jammers before other weapons systems are within their "effects bubble."
- Friendly force tracking (FFT) systems: Icons of units or weapons system that are jammed should show effects commensurate with an EW scenario.
- GPS-reliant Communications Systems: SATCOM and GPS-timing should be disrupted and effects replicated on affected systems.
- Systems: Specifically, manned maneuver systems such as M1 Abrams Tanks, M2/M3 Bradley Fighting Vehicles, M1126 Strykers (and variants), High Mobility Multipurpose Wheeled Vehicles (all variants), AH-64, UH-60, and CH-47 aircraft should be affected by GPS outage.
- These effects should register on FFT systems
- The operator should see effects on FFT icons; effects should replicate GPS outage and switchover/reliance on manual systems. This would train the commander/operator (or crew) to recognize when they are operating in a D3SOE, which will shorten reporting time of the degradation to the tactical operations center. It would also train battle staff to initiate mitigating TTPs, based on the assessed EW threat, and to react to a D3SOE.

3. SATCOM
- Effects on SATCOM is a function of disrupting the timing aspect of PNT. Voice, text, classified and unclassified government internet systems, and other communication systems reliant on the timing function of GPS should be affected. Some of these effects should include loss of communication between tactical radios (e.g. SINCGARS) due to significant loss of timing (more than 15 seconds in SINCGARS). Does not necessarily need to rely on SATCOM to be affected by PNT loss.

4. INTELLIGENCE SYSTEMS (reliant upon GPS such as unmanned aerial vehicle - Shadow, Grey Eagle/Reaper/Predator, Raven)
- These are often the first systems to be affected by GPS jamming because of how and where they operate. These have the most robust existing work-arounds "white card", but a constructive training effect (simulation) would be much more effective.
- Like maneuver systems, the effects should be automatic and be recognizable by the system operator (i.e.; the "pucker" or the "unmanned aerial vehicle operator") as well as on FFT systems to enable recognition, reaction, and reporting.
- Emissions of GPS jammers should be able to be collected and reported. This should be replicated as well to support space analysis capabilities and tasks.

5. PROTECTION SYSTEMS
- Personnel recovery/search and rescue and air defense artillery systems dependent on GPS for PNT and communications should be affected.

6. SUSTAINMENT SYSTEMS

- If within range of the jammer, Combat Service Support-Combat Support/Very Small Aperture Terminal users should be affected, especially if on the move or the system(s) must be set up in a contested environment.

A GEG-like simulation capability will affect more than just fires systems. Additional effects against Mission Command and FFT are a critical training piece. With such a capability, the WFXs will see more effects against maneuver and intelligence systems due to the scenarios and schemes of maneuver.

To accomplish these effects in WARSIM, an EW layer should be developed that will open the gates to enable incorporating numerous EW effects. The layer would take the GPS CEP and apply to all the impacted functions, adjudicating the function with the intended impact. This would eliminate "white carding" or direct instructor inputs to scenarios in training exercises and instead, allow for timely and realistic inputs for meaningful training that would directly affect commanders' situational awareness tools and communications systems commanders and their staffs use in the battlefield. Efforts are currently underway to investigate this potential implementation either by enterprising with the GPS GEG or by using other emerging technical solutions.

CONCLUSION

Together, these simulation capabilities could create a realistic D3SOE environment that will prepare division and above commanders and their staffs to conduct combat operations, performing all warfighting functions uninterrupted to ensure mission success and survivability. An ideal future scenario would be to create a plug-and-play EW simulation that is universal enough to integrate with most aggregate-level simulation tools. Simulations could potentially be developed with the capability to receive simulated EW effects with little or no modifications. Such a capability may require a top-level paradigm shift, and a coordinated effort across military services and industry experts.

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