Air Land Sea Application Center

Joint Base Langley-Eustis, Virginia

https://www.alsa.mil

Suppression of Enemy Air Defenses (SEAD) Battle Tracking Challenges in Contested Environments

By Maj Evan G. Fillman, USAF

Introduction

The offensive counterair-SEAD campaign is central to joint air forces achieving effects in the contested and degraded operations (CDO) environment.[1] (For brevity, offensive counterair-SEAD will be referred to as SEAD hereafter.)

SEAD efforts create localized air superiority through avoiding, suppressing, or destroying the enemy's integrated air defense system (IADS). The ability to achieve effective SEAD grows in complexity with the advancement of enemy systems and countertactics. The next evolution of automated battle tracking systems offers an opportunity to aid warfighters in tackling these evolving SEAD tactical problems.

This article aims to identify tactical challenges in SEAD and suggests potential remedies for inclusion in next-generation, battle-tracking software suites.

There is a groundswell in ideation and development of automated battle-tracking systems backing the move to Joint All-Domain Command and Control (JADC2) and acquiring the Advanced Battle Management System.[2] Some use artificial intelligence and machine learning as panaceas for complicated data fusion problems. However, current paradigms require humans to design automation software solutions based on concrete problem sets. Hence, the warfighter must continue to deliver concrete requirements to defense contractors to produce software that aids warfighters in achieving desired effects by optimizing decision quality.

This article focuses mainly on SEAD against surface-to-air threats in a CDO environment. This focus is not meant to ignore other aspects of SEAD (such as air-to-air engagements) but to provide anecdotes in a familiar context. The theory backing many of these concepts applies across various mission sets, throughout the all-domain spectrum, including the primary mission SEAD may be supporting. This article begins by reviewing the SEAD battle tracking process and identifying SEAD battle tracking challenges. Then, it distills each challenge into an area where automation could aid the warfighter. Finally, it suggests solutions that may assist in rethinking SEAD battle tracking with automated human-machine teaming.

A United States (US) Air Force B-2A Spirit assigned to the 509th Bomb Wing at Whiteman Air Force Base, Missouri (bottom), and a Royal Netherlands Air Force F-35A Lightning II conduct aerial operations in support of Bomber Task Force Europe 20-2 over the North Sea, March 18, 2020. Low Observable aircraft like the B-2A and F-35A are critical in suppression of enemy air defenses operations. (Photo by MSgt Matthew Plew)

The SEAD Tactical Problem

The core tactical problem in SEAD is opposing observe, orient, decide, and act (OODA) loops described in joint doctrine and multi-service tactics, techniques, and procedures.[3] Opposing forces compete to identify, locate, intercept, and relegate the opponent forces as quickly as possible.[4] The friendly SEAD forces attempt to render the enemy IADS ineffective to enable a reduced-risk environment for friendly operations. The dynamic targeting loop of find, fix, track, target, engage, and assess (F2T2EA) drives this process.[5]

Each entity in the IADS receives an instance of the F2T2EA process. The sum of all entities, in an IADS, results in the battle tracking, common operating picture (COP) of the enemy's IADS.[6] SEAD battle tracking, in this context, tracks target entity progression throughout the F2T2EA process. Then, effective SEAD battle tracking enables forces to make decisions to avoid, suppress, or destroy the enemy IADS in concert with multiple F2T2EA loops.

The enemy acts to complicate the friendly SEAD solution by using countertactics. The enemy learned to employ countertactics (such as limiting radiation, or employing mobile or passive shot doctrine, or using camouflage and deception) to increase their effectiveness. This implies, these tactics aim to reduce the effectiveness of friendly SEAD efforts.[7] Each of these countertactics increases the complexity of effective battle tracking thereby increasing the risk to mission objectives.

The complex nature of SEAD battle tracking leads joint forces to create a COP of the enemy IADS to share across the force. The central problem becomes keeping the COP as accurate as possible to enable friendly operations and effective follow-on SEAD. Friendly forces will attempt to use all available sensors to maintain accuracy of the enemy IADS threat picture from mission planning through engagement and assessment. Many tactical challenges associated with IADS updates arise from the concurrent dynamic targeting and battle tracking processes.

The battle tracking COP is, simultaneously, a powerful and a dangerous tool for SEAD operations. Any COP, inherently, contains errors associated with limitations on how data is presented for interpretation. An air COP creates the potential illusion of truth data and, inevitably, leads to a confirmation bias from its users. Virtually all COPs contain issues associated with data concurrency, including false positives, false negatives, and inaccurate or missing data. A false positive, showing a threat is present that is not, forces resource allocation and incorrectly raises the risk to force for friendly forces. A false negative, not showing a threat that is present, incorrectly lowers the risk to force and, possibly, allows the enemy an asymmetric advantage. Any threat COP is probabilistically correct. There is a chance that the data displayed on the COP is correct, or the real world has changed, the COP has not been updated, and the COP is incorrect. The seams between COP (battle tracking) truth and reality truth are the places to identify the root causes of many of the tactical challenges for SEAD battle tracking.

The IADS battle tracking COP begins with an intelligence estimate of the enemy IADS. The intelligence estimate products are known as the electronic order of battle (EOB), the defensive missile order of battle (DMOB), and the air order of battle.[8] These orders of battle are used for mission planning and as starting points from which informed updates can occur. Friendly forces also use intelligence estimates to assess the pre-mission risk to force.

A proactive approach to battle tracking and managing the F2T2EA process for each entity on the orders of battle can address many of the following tactical challenges and lead to more effective SEAD. The enemy will act to complicate the friendly SEAD solution using countertactics, which manifests as tactical challenges to friendly SEAD forces. These challenges may occur at any point in the F2T2EA process. Additionally, these challenges point to prospective functional areas for automation and human-machine teaming.

False Negatives

Tactical Challenge 1: A lack of emissions does not equal “killed” or “off”.

The core challenge is the enemy has learned radar emissions can give away their position. SEAD forces must ensure they do not translate a lack of emissions into being killed or powered off (for a threat system). A system that is off, but not dead, still presents a potential threat because it can turn on at any moment. However, for systems requiring active radiation to function, being off achieves partial SEAD success. Furthermore, friendly sensors may not be in an adequate position or have the capability to collect a particular type of emission even if the system is emitting. Therefore, time since last emissions may be misleading. Removing a threat based on a lack of emissions may lead to a false negative.

TSgt Skyler McCloyn (left) loads a miniature air-launched decoy (MALD), ADM 160X, onto a B-52 Stratofortress July 13, 2020 at Barksdale Air Force Base, Louisiana. MALD’s electronic warfare capabilities are useful in suppression of enemy air defenses operations. (Photo by A1C Celeste Zuniga)

Tactical Challenge 2: IADS stimulation does not equal 100% stimulation.

There is a danger in assuming efforts to stimulate an IADS (get the enemy to turn on their radars) will be 100% effective. This means, when threatened, enemy air defense operators will want to radiate in self-defense. SEAD forces must not rely on an assumption that their efforts to stimulate the IADSs have succeeded to a certain threshold. Tactics used to encourage stimulation may not succeed. Assuming a threat is not present based on a lack of emission, may lead to a false negative.

Tactical Challenge 3: The engagement does not equal killed (yet, may appear so, temporarily).

If a threat is engaged, how does the SEAD package know it had a successful engagement? A weapon's timeout does not equal a kill. Forces must be cautious to ensure they do not translate an engagement into a kill until the assessment process is sufficiently complete and meets the commander's risk threshold. Using standoff weapons in situations where the employer is unable to observe impact is an example of the need for a deliberate assessment step on employment effectiveness. A bomb hit assessment (BHA) by tactical units may provide initial indicators of effects, but a further battle damage assessment by intelligence personnel takes time.[9] Further complicating matters is whether forces employ a temporary effect. Removing a threat that has only been engaged but not assessed, or temporarily engaged, may lead to a false negative. An inaccurate assessment can lead to a false positive if BHA assessed a miss but effects were achieved.

False Positives

Tactical Challenge 4: Is there a new (surprise) threat?

Once operations commence, it is difficult to decide if there is a new threat that was not previously known or forecasted. A certain threshold of data must be met to add a new threat to battle tracking. Not adding a threat or adding a threat too quickly can negatively affect friendly planning and execution accuracy. Adding a threat without sufficient confirmation can lead to a false positive.

Tactical Challenge 5: Has a threat moved?

Extending from the last challenge is determining if a threat is new or has moved. Data precision must correlate to some change-reporting threshold. If a threat has moved a small distance, the battle tracking may correlate the data to a previously estimated position when, in reality, the threat has moved. A threat that moved but was correlated to its forecasted position would lead to invalid precision targeting information. Correlating a threat too quickly may lead to a false positive.

Tactical Challenge 6: Is the threat a deception?

Increasingly, the enemy may be able to deploy deception during the SEAD fight, which increases the complexity of any of the aforementioned complex scenarios.[10] Knowledge of potential deception should drive an appropriate adjustment in collection tactics and awareness during analyses. Warfighters should also keep in mind the enemy may deploy previously unknown or unexpected IADS deception techniques.

Section Conclusion

Given these challenges, the Services should aim to create the next generation of battle tracking software that can aid in mitigating these challenges. Asking for software that helps with SEAD or connects the force is too vague. Just as the Services aim to create a specific missile for a specific purpose, they should be specific in outlining the capabilities complex software should achieve for purposes of battle management and command and control.

Theoretical Methods to Address SEAD Tactical Challenges

There are several avenues for addressing battle tracking tactical challenges. To provide design requirements for automation, consider the optimal solution algorithm. These recommendations, at their root, are improvements addressing the tricky business of tracking and data fusion that need to occur for modern SEAD battle tracking. Many of the following solutions are overly cumbersome to humans, so the Services should use automation to implement the algorithm and provide actionable data to operators. The advantage lies in compressing the OODA loop for decisions using an emerging data fusion technology enabled by JADC2.[11]

None of the following ideas entirely solve the problem but, instead, attempt to represent the battle tracking situation more thoroughly. Each solution has far-reaching implications in terms of obtaining the solution (from data science, computer science, and interconnectivity aspects) but are not beyond feasibility. Together, these improvement ideas set the stage for possible SEAD innovations, including those in JADC2 systems.

F2T2EA State Cycle Tracking and Cueing

The first area for improvement is to aid forces in tracking the F2T2EA process per emitter. Several of the challenges result from skipping a step in the F2T2EA process or accidentally assuming a step was completed. Automation solutions should track where each IADS entity is in the dynamic targeting process. Furthermore, this data is then shared throughout the forces and used to cue and queue the next platform as required and available. Additionally, tracking the state enables the battle tracking system to prompt for human in/on the loop decision making when needed.

US Marines assigned to 1st Air Naval Gunfire Liaison Company, I Marine Expeditionary Force Information Group, fire a M142 High Mobility Artillery Rocket System (HIMARS) during an exercise on May 1, 2020 at San Clemente Island, California. The HIMARS long-range strike capabilities are valuable in suppression of enemy air defenses operations. (Photo by Sgt. Manuel A. Serrano

Also, state cycle tracking IADS entities represent the temporary aspects of the SEAD fight. Applied effects may be temporary (such as electronic attack jamming) or kinetic. In each case, the assess step provides information that may quickly cycle the target entity to a different step in the F2T2EA process. The depth of required data quickly approaches a limit where automation is needed to aid operators. Extending from this solution is how to discern IADS battle tracking in a probabilistic fashion.

Probabilistic Thinking

The second technique is thinking in a probabilistic fashion about the emitter state. Essentially, warfighters will associate a probability of correctness with an emitter tracking state. This probability represents the certainty or uncertainty of truth relating to the tracked entity. Suppose a known, forecasted emitter is on, which might equal one (100% chance for on and located/0% chance for dead). A known, forecasted emitter that has been verified killed is zero (0% chance on/100% chance for dead). There exists many states between one and zero as a decimal state between the two bounding end-states.

For instance, an emitter status might be .7 or (70% on and located/30% killed), upon which the final vote would make it (0% on/100% killed) or 0. Additionally, if a threat is emitting at a known site, there may be less than 100% chance the emitter is where the operator thinks it is located. Therefore, a threat may be on 80%, or accurate. If operators begin to associate probabilities with tracked entity threat systems, it will allow more accurate risk-to-force calculations.

Probabilistic thinking may seem cumbersome, but it mirrors closely what a friendly battle tracking expert believes is the truth about the enemy's IADS. As Nate Silver wrote in his best-selling work, *The Signal and The Noise*, probabilistic thinking "represents the most honest expression of the uncertainty in the real world."[12] Applying probabilistic thinking and processes in battle tracking lowers the chance for a false positive or negative and limits confirmation bias in the presentation to the warfighter. Furthermore, it enables efficiencies (such as the ability to switch from a precision effect to an area effect) if the certainty of coordinates is low.

Fusion Vote System

The two preceding recommendations lead to creating a confidence-based vote system on threat emitter tracking modifications. The probabilistic vision of the enemy IADS battle tracking enables a voting system to adjust probabilities. For example, after mission planning is complete, the likelihood of accuracy for each emitter location and state might be around 50%. The confidence of the emitter may move up and down during the battle using various data and correlations. The data fusion automation may need additional inputs from operators based on the tactical environment as well, not solely machine-to-machine inputs.

Increasing Tracking Fidelity of Threat Emitters

Determining whether a threat is on or off is insufficient fidelity in SEAD battle tracking. From a friendly-force perspective, a threat's battle tracking state cycles through over the duration of the air battle and as the F2T2EA process iterates. The nature of intelligence forecasting EOB and DMOB combined with mission planning often leads operators to limit the fidelity of emitter states to on or off. However, there is an opportunity to increase the fidelity of information beyond just on or off. There are at least three significant determinants of emitter state: emissions state, physical state, and whether the threat was forecast in the given location. Each combination of these determiners creates a different state, where logically possible. Moving between the tracking states occurs due to new intelligence or a sub-F2T2EA process completing.

Table 1 represents the range of potential end states for a given emitter. Additionally, actions that may transition between states are the portions of the F2T2EA process. By increasing threat tracking fidelity, the warfighter can glean important insights into enemy intent and also adjust risks to friendly forces. A surprise threat is more serious than a known threat, and warfighters need a methodology to annotate that information.

Table 1. Proposed Emitter State Chart

State	Emissions State	Physical State	Forecast	Plain English	Delta Planned Risk	Confidence/ Probability in Data
1	On	Present	No	Surprise emitter, actively emitting, surprise location	Increase	(0.0 to 1.0)
2	On	Present	Yes	Known emitter, actively emitting, forecast location	No change	(0.0 to 1.0)
3	Off	Present	Yes	Known emitter, not emitting, forecast location	No change	(0.0 to 1.0)
4	Off	Present	No	Surprise emitter, not emitting, surprise location	Increase	(0.0 to 1.0)
5	Off	Not Present	Yes	Known emitter, not emitting, missing from location	Decrease	(0.0 to 1.0)
6	Off	Killed (F/K/M)	Yes	Known emitter, not emitting, killed in forecast location	Decrease	(0.0 to 1.0)
7	Off	Killed (F/K/M)	No	Surprise emitter, not emitting, killed in surprise location	Negates prior increase	(0.0 to 1.0)

Legend:
F—Firepower Kill
K—Catastrophic Kill
M—Mobility Kill

Together, individual entity state tracking, probabilistic thinking, implementing a fusion vote system, and increasing tracking fidelity of threat emitters would improve battle tracking capabilities for warfighters. The process of achieving many of these effects requires far-reaching modifications to equipment, networks, and protocols in the joint force. Leaders must, however, provide concrete goals to work toward and not just settle for robust interconnectivity.

The Promise of JADC2 for Contested Battle Tracking

The goal of JADC2 is to "connect every sensor to every shooter."[13] Inevitably, this leads to JADC2 solutions containing a massive amount of incoming data from players on the battlefield, in all domains. With the help of advanced automation algorithms and, possibly, artificial intelligence, the stage is set for massive data fusion to occur. JADC2 systems can, and should, specifically address the previously discussed battle tracking challenges.

Unidentified Airmen from the 605th Test Evaluation Squadron, Detachment 3 operate the Common Mission Control Center (CMCC) on March 5, 2021 at Beale Air Force Base, California. The CMCC directly supported the "on ramp" during two nights of find, fix, track, target, engage, and assess events. (Photo by Shelton Keel)

In the interconnected vision of JADC2, data move between players so quickly that the battle tracking COP is the actual battle, and the battle is the COP.[14] If every sensor is linked to every shooter, the limit of effectiveness is the battle tracking fusion that happens in between the two endpoints. The battle tracking solution generated by JADC2 will never be 100% correct, but its software must, at least, account for these known challenges. It would be a terrible loss of capability and opportunity to acquire the JADC2 systems only to address legacy SEAD challenges.

The JADC2 acquisitions enterprise and engineers must consider specific SEAD challenges in designing JADC2 battle tracking systems and algorithms. Each false positive and negative scenario represents a difficult challenge for data engineers. Each tactical challenge presents a subprocess with many iterations for JADC2 to address. The acquisitions process should address these inherent SEAD challenges, specifically, in the requirements document for JADC2 subprocesses. During the JADC2 acquisition processes, leaders must require defense contractors to win the base scenario and not hide from the most challenging scenario.

Additional challenges for the JADC2 enterprise are accurate developmental and operational tests during the JADC2 system fielding process.[15] The test architecture, real or simulated, must demonstrate and test the tactical challenges discussed in this article. Warfighters must have confidence in their systems when they go to war, and operational test and evaluation is critical to establish this trust.[16] Test personnel should not limit test orchestration and experiment design on these important SEAD issues.

Conclusion

Tactical challenges in SEAD battle tracking are prime areas to focus on for improving tactics and technology for any SEAD fight. Many of the challenges in SEAD battle tracking are simple to understand, yet complex to address. Any new SEAD battle tracking system should provide the capability to track entities throughout the F2T2EA process. Additionally, these systems should think in a probabilistic fashion about threat emitters that is enabled by a confidence vote system on their status. Furthermore, systems should increase the fidelity to SEAD battle tracking by considering more states per emitter than just on or off. Many of the challenges presented herein are known and logical challenges of the modern SEAD fight. JADC2 systems personnel must account for these tactical challenges during acquisitions, engineering, and testing. Improving SEAD battle tracking is one step on the way to winning the SEAD fight.

Maj Evan Fillman is a Joint Air Land Sea action officer for the Air Land Sea Application Center (ALSA) at Joint Base Langley Eustis, Virginia.

End Notes

---

[1] I would like to thank Col Andrew Beitz for his valuable input on this article.

[2] Nishawn S. Smagh, "Defense Capabilities: Joint All Domain Command and Control," *Congressional Research Service In Focus*, April 6, 2020, 3.

[3] Joint Chiefs of Staff, Joint Publication 3-60, *Joint Targeting*, September 28, 2018, https://jdeis.js.mil/jdeis/new_pubs_jp3_60.pdf; Air Land Sea Application Center, ATP 3-01.4/MCRP 3-22.2A/NTTP 3-01.42/AFTTP 3-2.28, *Multi-Service Tactics, Techniques, and Procedures for the Joint Suppression of Enemy Air Defenses*, December 2015, https://intelshare.intelink.gov/sites/alsacenter/SiteCollectionDocuments/jsead_2015.pdf.

[4] David Deptula et al., "Restoring America's Military Competitiveness: Mosaic Warfare" (The Mitchell Institute for Aerospace Studies, September 2019), 29, http://www.mitchellaerospacepower.org/mosaic.

[5] Joint Chiefs of Staff, JP 3-60, II–23.

[6] Joint Chiefs of Staff, Joint Publication 3-09, *Joint Fire Support*, April 10, 2019, IV–07, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_09.pdf?ver=2019-05-14-081632-887.

[7] Benjamin S. Lambeth, "NATO's Air War for Kosovo - A Strategic and Operational Assessment", Online Rand Research Documents (RAND Corporation, 2001), 111, https://www.rand.org/pubs/monograph_reports/MR1365.html.

[8] Joint Chiefs of Staff, Joint Publication 3-01, *Countering Air and Missile Threats*, May 2, 2018, III–3, https://www.jcs.mil/Portals/36/Documents/Doctrine/pubs/jp3_09.pdf?ver=2019-05-14-081632-887.

[9] Joint Chiefs of Staff, Chairman of the Joint Chiefs of Staff Instruction 3162.02: "Methodology for Combat Assessment", March 8, 2019, B-4, https://www.jcs.mil/Portals/36/Documents/Library/Instructions/CJCSI%203162.02.pdf?ver=2019-03-18-121700-237.

[10] Elliot Bucki, "Flexible, Smart, and Lethal: Adapting US SEAD Doctrine to Changing Threats," *Air and Space Power Journal* 30, no. 2 (Summer 2016): 67.

[11] Deptula et al., "Restoring America's Military Competitiveness: Mosaic Warfare".

[12] N. Silver, *The Signal and the Noise* (Turtleback, 2015), 61.

[13] Smagh, "Defense Capabilities: Joint All Domain Command and Control," 1.

[14] Greg Zacharias, *Autonomous Horizons: The Way Forward* (Maxwell Air Force Base, Alabama: Air University Press ; Curtis E. LeMay Center for Doctrine Development and Education, 2019), 38.

[15] "Large Force Test Event Focused on SEAD, LO and EA Complete at Nellis AFB," Air Combat Command, accessed September 12, 2020, https://www.acc.af.mil/News/Article-Display/Article/2302826/large-force-test-event-focused-on-sead-lo-and-ea-complete-at-nellis-afb/.

[16] Deptula et al., "Restoring America's Military Competitiveness: Mosaic Warfare," 46.

Originally released 1 April 2021 at https://www.alsa.mil/News/Article/2543194/suppression-of-enemy-air-defenses-sead-battle-tracking-challenges-in-contested/

Habilis – Credibilis - Celeritas