Advancing the U.S. Army's Counter-UAS Mission Command Systems to Keep Pace with Modern Warfare

Maj. Gen. Joel B. (J. B.) Vowell, U.S. Army
Maj. Anthony R. Padalino, U.S. Army

As of this writing, units in Combined Joint Task Force-Operation Inherent Resolve have been attacked over one hundred times by one-way unmanned aircraft systems and have learned much in the way of establishing defensive and protective measures using various systems and techniques.

"Attention in the BDOC! Four unknown tracks bearing 216 degrees, altitude 250' AGL, range thirteen kilometers, 151 knots, estimated time to impact two minutes forty-seven seconds!" Spc. Jones, an infantryman serving as a base defense operation center (BDOC) C-UAS system operator, stared at his computer screen as his heart began to race. "Attention in the BDOC! Another four tracks just populated ten kilometers to our west, same altitude and speed—less than two minutes to impact."

Jones quickly selected a track on his screen to mark it hostile and then selected through the appropriate software menus to launch an interceptor—this manual process had to be repeated for each individual track. "Sir, I clicked on the wrong drop-down menu on the fourth track, the interceptor failed to launch, and I didn't have enough time to engage tracks seven and eight with interceptors … estimated impact in fifteen seconds." 1st Lt. Kane, the BDOC officer in charge, turned over to his NCO in charge (NCOIC) and said, "Announce brace over the Big Voice!" Seconds later, three Shahed-131 UAS slammed into life-support areas on their outpost—the payloads exploded, instantly killing and wounding multiple soldiers moving from their living quarters to the nearest bunker.

Jones's heart sank as he watched the BDOC raid camera screens display the images of his mortally wounded brothers-in-arms lying on the ground, as the BDOC NCOIC beside him began to coordinate with crisis response units. "There has got to be a faster way to knock these one-way UAS down," thought Jones. Just then his eyes widened as he looked back at his screen—three more tracks had appeared while he was busy attempting to intercept the last eight air tracks, "Sir, three more tracks inbound, thirty seconds to impact."

One of the emerging characteristics of warfare is the proliferation of one-way unmanned aircraft systems (UAS). In both Ukraine and Iraq/Syria,

Two variants of the Coyote 2C drone interceptor are fired during testing at the Yuma Proving Ground, Arizona, in 2021. The kinetic interceptors provide the U.S. Army with a flexible short-range counter-unmanned aircraft system capability. (Photo courtesy of the U.S. Army)

the ongoing fights consist of cheaply produced unmanned aircraft packed with explosives that fly on GPS or Global Navigation Satellite System (GLONASS, the Russian equivalent to GPS) to exact target locations hundreds of kilometers away from a safe launch point. However, existing mission command systems fielded to counter enemy UAS lack necessary technological capabilities to adequately defend combat power on today's battlefield. Mission command systems for counter-UAS (C-UAS) require artificial intelligence (AI), machine learning, and automation to assist operator decision-making and enable simultaneous employment of defeat mechanisms. Furthermore, current fielded systems lack data interoperability with emerging industry detection and defeat systems, resulting in base defense operation centers (BDOC) having multiple "closed" networks to defeat a common threat.[1]

This article identifies the requirement to implement AI, machine learning, and automation into U.S. Army C-UAS mission command systems. Current C-UAS mission command systems rely on operators to complete a manual identification and engagement process that occurs sequentially for each threat and is impractical for scenarios with multiple threats attempting to overwhelm defensive capabilities. By implementing the recommendations in this article, the U.S. Army will have a mission command system with a competitive advantage in countering current and future enemy UAS threats and tactics.

Definition of Terms

Automation. The "use of technology to perform tasks with minimal human input" and reduced or eliminated human intervention. Process automation uses rules-based decision-making based on human system input parameters.[2]

Artificial intelligence. The 2018 *Department of Defense [DOD] Artificial Intelligence Strategy* defines AI to be "the ability of machines to perform tasks that normally require human intelligence—for example, recognizing patterns, learning from experience, drawing conclusions, making predictions, or taking action—whether digitally or as the smart software behind autonomous physical systems."[3]

Machine learning. The machine learns from data using a training algorithm to gain "knowledge" that is not programmed by humans. The system will learn from environmental examples rather than being specifically programmed.[4]

Human in the Loop versus Human on the Loop

In the context of modern warfare, the terms "human on the loop" and "human in the loop" refer to the level of human involvement in decision-making and control over a system that leverages AI or automation. The difference between these two approaches lies in the degree of autonomy granted to the system and the level of human oversight and control.

Maj. Gen. Joel (J. B.) Vowell, U.S. Army, is the commander of Combined Joint Task Force-Operation Inherent Resolve. He received his commission from the University of Alabama in 1991 and is a career infantry officer. He has been stationed in Europe, the Pacific, and many posts across the United States. His last assignment was the commanding general of U.S. Army Japan, Camp Zama, Japan. Vowell has been on three combat tours in Afghanistan and two in Iraq, including both surge campaigns. He commanded the 3rd Brigade Combat Team (Rakkasans) of the 101st Airborne Division at Fort Campbell, Kentucky, and Afghanistan. Vowell was a War College Fellow at Stanford University and was the Army chief of staff's Senior Fellow to the Brookings Institution.

Maj. Anthony Padalino, U.S. Army, is an operations officer in 2nd Battalion, 15th Field Artillery, 2nd Brigade Combat Team, 10th Mountain Division, deployed forward to Al-Asad Airbase, Iraq, in support of Operation Inherent Resolve. He holds a BS from Western Michigan University and an MS from Embry-Riddle Aeronautical University. During his career, he has deployed to the U.S. Central Command area of operations four times, and he has served with the 4th Infantry Division, the 101st Airborne Division, and Human Resources Command.

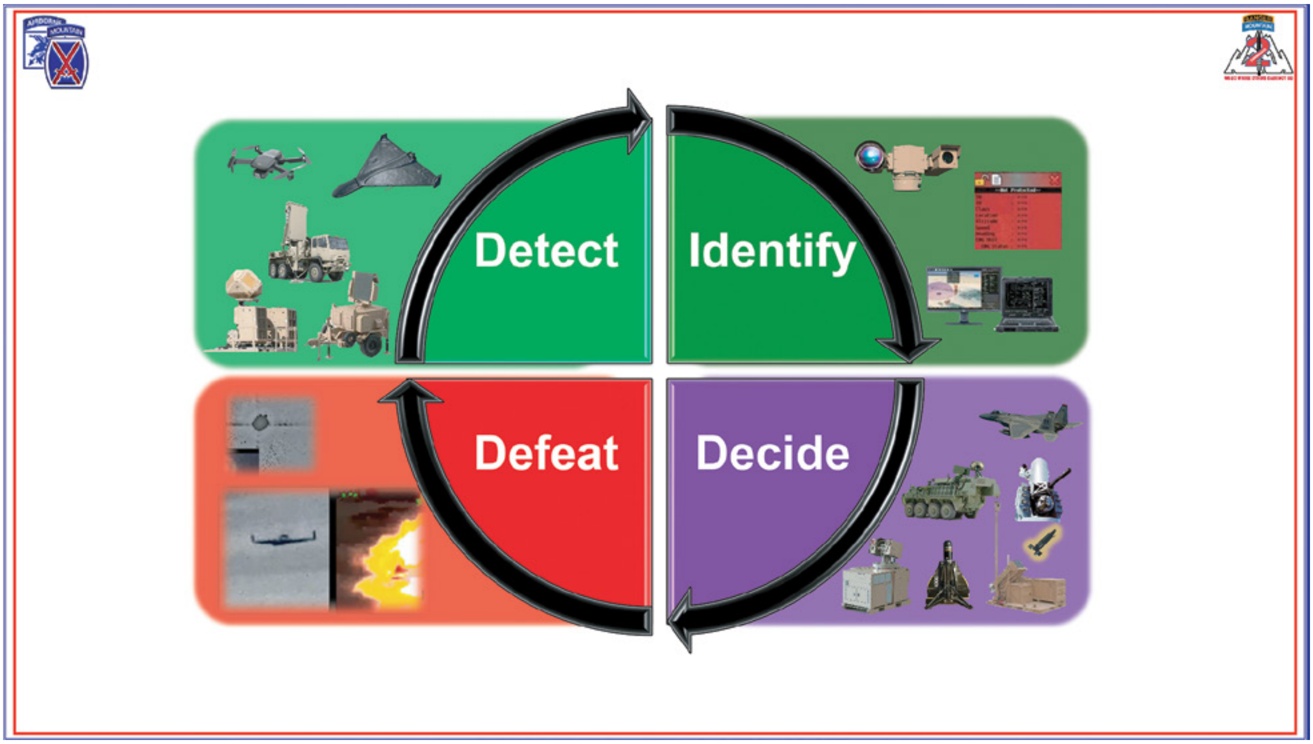
Human in the loop. A human is directly involved in the decision-making process and has "complete control over starting or stopping any action performed" by the system.[5] This approach is often favored for safety, task precision, responsibility, and control. However, there are situations where having a human in the loop may not be practical or effective.[6] The current C-UAS process is an example of human in the loop, where operators must perform every task and parameter input to create an action by the system.

Human on the loop (HOTL). A human provides oversight of an automated system, but the automation can take action without human preapproval. This approach allows for faster decision-making and response times, which will be vital in the future of rapidly evolving threats. In high-stress situations that impact a human's ability to apply micromotor skills and sound judgment, a supervised autonomous mode (HOTL) will be more effective than relying solely on human decision-making.[7] Aegis Combat System and the MK 15 Phalanx Close-In Weapons System used on Navy ships are examples of HOTL defensive weapon systems.[8] Once activated and under supervision by a human, these systems can independently attack missiles, helicopters, and aircraft that pose a threat to the ship or other protected assets.[9]

Counter-Unmanned Aircraft System Process

The C-UAS process employs active defense measures in a process with four distinct elements: detect, identify, decide, defeat. This sequence provides a useful framework for evaluating threats posed by UAS across diverse operational environments and the potential application of automation to enhance operator actions. Within the joint force, this process is actively applied inside BDOCs that serve as the responsible coordination, management, and employment node of C-UAS assets and systems.[10]

Detect. The first step in the C-UAS process is to detect the presence of air tracks in the area of operations. This is done through various radar



(Graphic by Maj. Anthony R. Padalino, U.S. Army)

Counter-Unmanned Aircraft System Process

sensing and tracking methods, including aerial and ground sensors. Raytheon, for example, developed the 360-degree AN/MPQ-64 Sentinel radar that provides detection of UASs, rotary-wing aircraft, and fixed-wing aircraft with identification friend or foe interrogation capabilities. Raytheon also developed the 360-degree Ku-band Radio Frequency System (KuRFS) that can sense and track aircraft, rocket, artillery, and mortars. The KuRFS radar supports multiple kinetic and nonkinetic C-UAS weapon systems such as the Palletized High-Energy Laser, Land-based Phalanx Weapon System, and the Raytheon Coyote interceptor.[11]

Identify. When an air track is detected, the next step is to analyze the track and determine if it is friendly or hostile. This is done through identification friend or foe interrogation of the track using identification friend or foe capable radars (such as the Q-64 mentioned above), airspace controlling agencies (air traffic control, combined air operations command), or hostile characteristics. Distinguishing between friendly and hostile threat tracks is a complex process that uses one of two methods, positive and procedural.[12] Positive identification is the most preferred and does not require visual identification to determine a suspect air track—digital identification (physics-based) using known hostile characteristics can be used to determine if a track is a hostile UAS.[13] Procedural identification uses geography, heading time, and aircraft flight path to determine friend or foe—usually paired with an air tasking order and/or operational graphics.

Decide. Two decisions are made in this phase: first, to determine whether there is a requirement to engage (rules of engagement, geopolitical situation, tactical situation, etc.); and second, to determine what method will be used to intercept the threat. If an operator identifies an air track as hostile, he or she decides to use a kinetic or nonkinetic weapon to intercept the identified threat. The bearing, altitude, range, and speed of each individual threat is evaluated to determine the requirement to engage and employ the appropriate weapon for the most efficient and effective engagement.

Defeat. Operators achieve successful kinetic or nonkinetic effects on identified hostile tracks in this

The Forward Area Air Defense Command and Control user interface provides a common air picture. (Photo courtesy of Northrop Grumman)

phase. Visual confirmation of intercept or digital confirmation are the methods used to determine positive or negative effects in this phase. If a hostile track is not defeated, the operator employs additional assets until he or she defeats the threat or it impacts its intended target.

Manual Engagement Challenges

The Forward Area Air Defense Command and Control (FAADC2) is the U.S. Army's current mission command system that provides the network architecture to detect, identify, and employ kinetic and nonkinetic defeat effects.[14] The FAADC2 has been in use by the Department of Defense since 1989.[15]

The FAADC2 system's current use of manual engagement processes in the identify, decide, and defeat phases significantly inhibits the effective and efficient defeat of enemy threats, especially when given mere seconds to make a decision. The operator must manually interrogate each radar track and manually process each defensive system individually against a hostile target, which is time-consuming and prone to human error.

This manual process prevents simultaneous engagements that will be required in rapidly evolving combat scenarios. The time expended in manual engagements will allow a swarm of UAS to attack and penetrate defensive layers unimpeded. BDOC operators often face task saturation and an increased likelihood of human error when simultaneously contending with multiple UAS attacks, potential friendly air traffic, transitioning between weapon systems, assessing other threats, and managing current engagements.

The FAADC2 system requirement for manual operator engagements distracts operator focus on critical air track identification and further exacerbates human error and inefficiency to defeat UAS. Improvements in threat UAS attack speeds (jet-powered Shahed-238) and use of terrain masking to avoid early radar detection further diminish the effectiveness of manual methods and will lead to a breakdown in C-UAS intercept success.

Recommendations to Advance C-UAS Mission Command Systems Artificial Intelligence–Assisted Identification

AI should be integrated into mission command systems for enhanced operational efficiency in detecting hostile air tracks. This integration assists operators by providing continuous analytical capabilities to interrogate air tracks within a base defense zone. The strength of AI is its ability to analyze and identify patterns from previously recorded data. C-UAS mission command systems should store previously recorded threat data on a secret cloud-based repository to enable theater-wide access by AI identification systems to integrate air track data at a velocity and precision unattainable by human operators.

AI's capability to recognize and identify threat air tracks and promptly alert human operators will reduce task saturation and allow operators to retain final track identification authority. Incorporating AI into track identification will enhance the accuracy of operator identification and will reduce the time taken to identify threats, increasing the time to alert ground forces of imminent threat and resulting in the preservation of combat power.

Machine learning algorithms will play a vital role in the identification phase by enhancing the mission command system's ability to assist operators to discriminate between hostile and nonhostile air tracks over time by analyzing physics-based radar track data, full-motion video, and other forms of detection data. Machine learning algorithms will improve AI's ability to alert operators of threat tracks while also ensuring operators are aware of likely friendly tracks based of recognized data characteristics.

Failing to integrate AI and machine learning algorithms into mission command systems will result in BDOCs that perform only as well as the human operator—which is not at the system's maximum potential. Human operators who lack the benefit of AI and machine learning tools are at a disadvantage. They risk failure to quickly identify tracks and they risk failure to ensure the successful interception of hostile tracks to prevent UAS from striking their intended targets. While humans can perform interrogation and identification manually, they are not able to perform tasks with the same precision, speed, and consistency as AI.

Automated Engagement: Advancing the Decide and Defeat Phases

To address the limitations of the current manual FAADC2 engagement process, the U.S. Army should implement automation processes into the decide and defeat phases once an operator confirms an air track is hostile. By incorporating automation, the FAADC2 system will automatically engage with the appropriate method until the threat is defeated. This automated engagement capability would significantly reduce engagement response times and enable the operator to focus on threat identification and airspace deconfliction while the system selects and monitors defeat options for the most efficient means of intercept—free of human error. Moreover, the C-UAS process retains HOTL to ensure a human remains involved in the decision to launch.

Automated engagement would remove the requirement for a human operator to manually select each individual track and perform the multiple-step sequential process to launch an interceptor and fire a Land-based Phalanx Weapon System or a Palletized High-Energy Laser for each assessed threat. With an automated decide and defeat capability, the operator provides human supervision of engagements of human-confirmed hostile tracks, while the C-UAS decide and defeat system has the ability to conduct simultaneous engagements using multiple weapon systems to mass against multiple threats and achieve a true combined arms defensive fires capability. Automated defeat capability will increase UAS intercepts, decrease engagement times, substantially reduce human error, and significantly increase the probability of defeating a UAS swarm attack.

Critics of automated engagement may cite the need for operators to manually engage identified threats to ensure systems are acting within the laws of armed conflict and the rules of engagement.[16] However, these reservations are mitigated within the identify phase of the C-UAS process, where a human determines the threat as hostile and directs machine intervention. We propose that hostile tracks will not be engaged unless an operator (1) confirms the track as hostile and (2) authorizes the system to engage (human "on the loop" vs. human "in the loop").

C-UAS Future: AI-Assisted Identification, Automation Decides and Defeats

AI will provide human operators the ability to identify multiple tracks in congested airspace within the full potential of radars. The only limitation of threat identification will be the radars' performance in detecting UAS attempting to evade or mask their signature. Human operators still could interrogate tracks manually and will retain the final authority to classify air tracks as friendly or hostile.

Automation in the decide and defeat phases will enhance the C-UAS mission command system's effectiveness by enabling autonomous and simultaneous engagements of UAS after a human confirms an air track as hostile. Real-time data fusion through cloud-based repository storage and advanced machine learning algorithms that evolve with threat tactics, techniques, and procedures will enable automated systems to evaluate the threat level posed by an air track marked hostile by a human operator and determine the appropriate response, such as the employment of a kinetic system like an interceptor or the activation of electronic warfare countermeasures. This automation would not only save valuable engagement time but also reduce the burden on human operators, enabling human focus on threat identification and defeat supervision.

Enhancing Future Warfare Capabilities

The integration of machine learning and automation into the identify, decide, and defeat phases of the FAADC2 mission command system should be immediately implemented by the U.S. Army. By leveraging automation, AI, and machine learning technology available today, mission command systems can adapt and learn from current threats observed in combat and increase UAS intercept success rates. Similar advancements in commercial automotive technology have led to vehicles equipped with AI and machine learning that enable autonomous driving capabilities. Vehicles harnessing AI and machine learning technology are able to learn from the surrounding environment, access data real-time through repositories, improve decision-making, learn object classification, and provide operator alerts.[17] Automation process technology exists within the DOD as well; one just has to look to the U.S. Navy Aegis Combat System ships. We must apply emergent technology to advance our industrial age systems to innovate at the speed of warfare.

Decreased threat identification times, increased intercept capability, and enhanced accuracy achieved through automation will provide a tactical advantage in countering emerging UAS technologies and threats, especially those aimed at strategic assets, troop concentrations, and high priority locations. As adversaries continue to innovate and deploy UAS, to include jet-powered Shahed-238 UAS, operators will have seconds to correctly detect, identify, decide, and defeat hostile air tracks. The U.S. Army must stay ahead of threats versus waiting to adapt.

Conclusion

The FAADC2 mission command system has played a crucial role in countering air threats and managing airspace since 1989. However, the industrial-age manual engagement process utilized by our current system poses challenges in terms of efficiency for current tactics, techniques, and procedures observed on the battlefield in Ukraine, Iraq, and Syria and ultimately threaten the survivability of our personnel. By incorporating AI, machine learning, and automation technologies, the FAADC2 system will advance C-UAS defeat abilities beyond the threat capabilities of our adversaries. Automated engagements placing operators on the loop enables a C-UAS combined arms defense with tactical and technical decision speeds that human operators cannot perform by themselves.

The risk to not advancing C-UAS mission command systems and maintaining manual C-UAS processes will allow malign state and nonstate actors to compete with the United States along the conflict continuum at a relatively low-cost/high-reward trade-off. As seen in recent events in the Middle East, malign state and nonstate actors' ability to conduct precision strikes on U.S. forces with low cost UAS places a risk to force with strategic-level impacts and places our national interests at risk. The risk to mission in large-scale combat operations is the attrition of formations from the port to the front line of troops. Intervention capabilities lacking the speed and precision of the digital age will fail to prevent the mass destruction of logistical nodes and combat power, requiring additional resources for combatant commanders to achieve a desired military end state. Incorporating AI, machine learning, and automation into the C-UAS fight is a high-priority effort requiring immediate attention to stay ahead of adversaries in this rapidly evolving threat environment. ■

Notes

1. Deputy Secretary of Defense, memorandum, "Creating Data Advantage," 5 May 2021, https://media.defense.gov/2021/May/10/2002638551/-1/-1/0/DEPUTY-SECRETARY-OF-DEFENSE-MEMORANDUM.PDF; Department of Defense (DOD), *Department of Defense Data, Analytics, and Artificial Intelligence Adoption Strategy: Accelerating Decision Advantage* (Washington, DC: U.S. DOD, November 2023), https://media.defense.gov/2023/Nov/02/2003333300/-1/-1/1/DOD_DATA_ANALYTICS_AI_ADOPTION_STRATEGY.PDF. The inability to pass data between mission command and defensive systems is in direct contradiction to the deputy secretary of defense's 2021 "Creating Data Advantage" directive to Pentagon senior leaders and combatant commands, and the 2023 *Department of Defense Data, Analytics, and Artificial Intelligence Adoption Strategy*.

2. "What Is Automation?," IBM, accessed 19 March 2024, https://www.ibm.com/topics/automation.

3. DOD, *Summary of the 2018 Department of Defense Artificial Intelligence Strategy* (Washington, DC: U.S. DOD, 2018), 4, https://media.defense.gov/2019/Feb/12/2002088963/-1/-1/1/SUMMARY-OF-DOD-AI-STRATEGY.PDF.

4. Greg Allen and Jack Shanahan, *Understanding AI Technology* (Washington, DC: DOD Joint Artificial Intelligence Center, 2020), 7, https://www.ai.mil/docs/Understanding%20AI%20Technology.pdf.

5. Jackson Barnett, "AI Needs Humans 'On the Loop' Not 'In the Loop' for Nuke Detection, General Says," FedScoop, 14 February 2020, https://fedscoop.com/ai-should-have-human-on-the-loop-not-in-the-loop-when-it-comes-to-nuke-detection-general-says/.

6. Jean-Michel Verney and Thomas Vinçotte, "Human-On-the-Loop," *Joint Air and Space Power Conference 2021 Read Ahead* (May 2021), https://www.japcc.org/essays/human-on-the-loop/.

7. Barnett, "AI Needs Humans 'On the Loop.'"

8. "AEGIS Weapon System," Navy.mil, last updated 20 September 2021, https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2166739/aegis-weapon-system/; "MK 15 - Phalanx Close-In Weapon System (CIWS)," Navy.mil, last updated 20 September 2021, https://www.navy.mil/Resources/Fact-Files/Display-FactFiles/Article/2167831/mk-15-phalanx-close-in-weapon-system-ciws/.

9. Amitai Etzioni and Oren Etzioni, "Pros and Cons of Autonomous Weapons Systems," *Military Review* 97, no. 3 (May-June 2017): 72–81, https://www.armyupress.army.mil/Journals/Military-Review/English-Edition-Archives/May-June-2017/Pros-and-Cons-of-Autonomous-Weapons-Systems/.

10. "Counter-Unmanned Aircraft Systems (C-UAS)," Department of Homeland Security, 2 July 2023, https://www.dhs.gov/science-and-technology/counter-unmanned-aircraft-systems-c-uas; Army Techniques Publication (ATP) 3-01.81, *Counter-Unmanned Aircraft System (C-UAS)* (Washington, DC: U.S. Government Publishing Office, 2023), https://armypubs.army.mil/epubs/DR_pubs/DR_a/ARN38994-ATP_3-01.81-000-WEB-1.pdf.

11. "KuRFS: Ku-band Radio Frequency Sensor," Raytheon, accessed 19 March 2024, https://www.rtx.com/raytheon/what-we-do/integrated-air-and-missile-defense/kurfs.

12. ATP 3-01.81, *Counter-Unmanned Aircraft System (C-UAS)*.

13. Ibid.

14. "Northrop Grumman's FAAD C2 System Enables Integrated Short Range Air Defense in Baltic Region," Northrop Grumman, 5 June 2023, https://news.northropgrumman.com/news/releases/northrop-grummans-faad-c2-system-enables-integrated-short-range-air-defense-in-baltic-region.

15. U.S. General Accounting Office (GAO), *Battlefield Automation: Army's Air Defense Command and Control System Status and Program Issues*, GAO-NSIAD-90-12BR (Washington, DC: U.S. GAO, 20 December 1989), https://apps.dtic.mil/sti/tr/pdf/ADA292160.pdf.

16. Jovana Davidovic, "What's Wrong with Wanting a 'Human in the Loop'?," War on the Rocks, 23 June 2022, https://warontherocks.com/2022/06/whats-wrong-with-wanting-a-human-in-the-loop/.

17. Kaviraj Sankar, "Automotive Radar Advancements with AI—Revolutionizing Safety & Perception (Part 1)," Multicoreware, 5 September 2023, https://multicorewareinc.com/automotive-radar-advancements-with-ai-revolutionizing-safety-perception-part-1/.