The Smart Targeting Environment for Lower Level Assets program (*concept shown here*) will enable soldiers to operationalize robotics to rapidly employ, build, and share target data in multi-domain operations. (Graphic illustration by Jamie Lear, U.S. Army Combat Capabilities Development Command C5ISR Center)

Hunting the Adversary

Sensors in the 2035 Battlespace

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A few things we've learned over the last year of study … about future high-end war between nation-states or great powers, and the first, not surprisingly, is that it will be highly lethal … with sensors everywhere, the probability of being seen is very high. And as always, if you can be seen, you will be hit. And you'll be hit fast, with precision or dumb munitions, but either way you'll be dead.

—Gen. Mark A. Milley

Sensors across intelligence disciplines help military forces find and ultimately destroy their adversaries. According to futurist Michael O'Hanlon, "Sensors are the military technologies that provide information about … targets, terrain and weather, civilian populations, key infrastructure, and friendly forces."[1]

By the year 2035, changes in sensor technology and military affairs will make the battlespace exponentially

more lethal in terms of how quickly combatants can locate and destroy adversaries. Writing in the year 2000, O'Hanlon similarly envisioned a future battlespace where "an information grid with real-time data processing and dissemination can synergistically integrate sensors, vehicles, and weapons to produce impressive new military performance."[2]

Consequently, based on projected changes in sensor technology and military affairs out to 2035, the U.S. Army should adapt its sensor approach to find adversaries. By 2035, the Army should adapt across the doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy (DOTMLPF-P) transformation framework to find adversaries while avoiding detection. This adaptation will ensure the Army optimally exploits developments in sensor technology and military affairs out to 2035.

The Evolution of Sensors Out to 2035

The ensuing analysis, written in the context of conventional conflict with peer or near-peer adversaries, explores ways in which sensors could evolve out to 2035. Insights into ways the Army should transform aspects of the DOTMLPF-P to fully exploit sensors follow the analysis.

In the 2035 battlespace, sensors in the imagery intelligence (IMINT) discipline will be severely constrained, compelling increased reliance on sensors in other intelligence disciplines to help Army forces locate adversaries while avoiding detection. These other intelligence disciplines include signals intelligence (SIGINT, encompassing electronic intelligence [ELINT] and communications intelligence [COMINT]), measurement and signature intelligence (MASINT), human intelligence (HUMINT), and open-source intelligence (OSINT).

Imagery Intelligence

Using technological advances in missiles, radars, and directed energy out to 2035, rival U.S. peers (China and Russia) will contest U.S. imagery intelligence collection efforts in the air and space domains in future conflict. American leaders already anticipate that space will be a contested environment in future high-end conflicts with peer adversaries like Russia and China, which is why the United States created the U.S. Space Force.

The following examples underscore the likelihood that by the year 2035, a peer adversary like China will have significantly enhanced its contemporary capability to challenge the United States in the air and space domains, and consequently deprive the Army of the IMINT it needs to find adversaries. China already demonstrates the capability to constrain America's airborne and space-based IMINT sensors. Regarding constraining U.S. airborne IMINT sensors, in 2016, RAND assessed that China's "modern strategic Surface to Air Missiles (with ranges of at least 100 kilometers) make up approximately 30 percent of the total PLAAF [People's Liberation Army Air Force] inventory; however, with the advent of the indigenously produced HQ-9 and the pending acquisition of the most advanced Russian Surface-to-Air Missile (the SA-21), this percentage is expected to rise."[3]

As far as constraining space-based IMINT sensors, in September 2019, Gen. John Raymond, head of U.S. Space Command and Air Force Space Command, was reported to have asserted (in his remarks at the Mitchell Institute for Aerospace Studies) that China is developing directed energy weapons—probably building lasers to blind U.S. satellites.[4] Additionally, China has already demonstrated anti-satellite missile capability based on its widely publicized, successful January 2007 test.[5] China is also developing optical telescopes and radars that, in addition to tracking objects in space, can provide missile warning. In a 2020 report, the Secure World Foundation wrote that "China is developing a sophisticated network of ground-based optical telescopes and radars for detecting, tracking, and characterizing space objects as part of its space situational awareness (SSA) capabilities."[6]

The above projected challenges to acquiring IMINT by 2035 will be further compounded by advances in distance and accuracy of long-range fires. Advances like these will increasingly normalize beyond line-of-sight

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engagements in ground combat. This confluence of projected advancements in counter-IMINT sensing and long-range fires will complicate the Army's effort to find and engage the enemy first; evolving the "*see* first, shoot first" theory into "*sense* first, shoot first." In other words, the Army will be compelled to exploit sensors in other intelligence disciplines to rapidly find adversaries in the 2035 battlespace. This warrants some exploration of how sensors in other intelligence disciplines will be featured.

networked with other sensors, will enable the Army to find adversaries and maintain general situational awareness in the 2035 battlespace by increasing the force's ability to collect information or data from an adversary's electronic signals and emissions.

Though it is likely that engagements in outer space will degrade space-based ELINT sensors by 2035, the Army will still be able to rapidly find adversaries and maintain situational awareness by using advanced

> The rapid evolution of military weapons, technology, concealment methods, and proliferation out to 2035 will create the need to definitively detect, locate, identify, and destroy some enemy capabilities before they are ever employed against U.S. forces.

Signals Intelligence

By 2035, the Army's IMINT collection capabilities will be severely challenged by peer adversaries, compelling the institution to rely primarily on sensors in the signals intelligence discipline to find adversaries. SIGINT sensors will help the Army locate adversaries through electronic signals generated by devices such as radars and weapon systems, and communication signals such as radios, phones, etc. Two categories of signals intelligence sensors will be critical to finding adversaries in 2035.

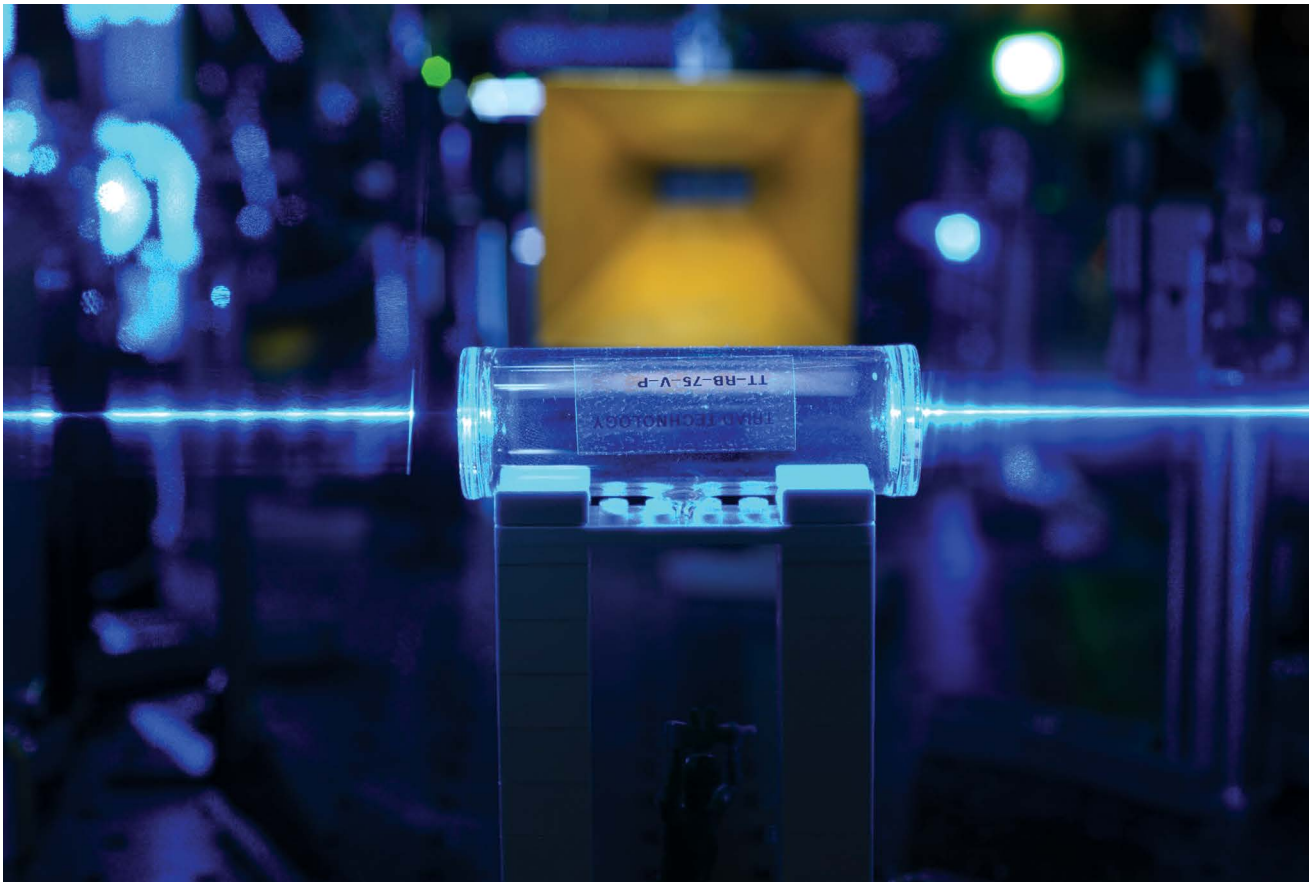
Electronic intelligence. ELINT is a type of signals intelligence. According to ELINT researcher Richard L. Bernard, "ELINT is information derived primarily from electronic signals that do not contain speech or text."[7] Per this definition, it follows that electronic intelligence sensors enable the detection, identification, and analysis of an adversary's signals structure, emission characteristics, modes of operation, emitter functions, and weapons system associations for those emitters. Associations include radars, beacons, jammers, and navigational signals.[8]

By 2035, peer adversaries' contest and denial of U.S. IMINT acquisition will compel the Army to extensively employ electronic signals intelligence sensors to find adversaries while ensuring the troops evade similar sensors that adversaries will deploy. ELINT sensors, (far-ranging) terrestrial sensors like those envisaged for their Tactical Intelligence Targeting Access Node (TITAN). TITAN is the Army's planned modular, expeditionary intelligence ground station that will link an array of space, aerial, and terrestrial sensors to provide targeting data directly to Army fires networks.[9]

Communications intelligence. Drawing from the above definition of ELINT, COMINT can be defined as information obtained primarily from electronic signals that contain speech or text. In this sense, COMINT includes information gathered from radio transmissions, broadcasts, telephone conversations, text messages, and online communications.

Contemporary advances in signals intelligence sensors indicate that the Army's future SIGINT sensors will be far more advanced and capable of rapidly locating adversaries. This is particularly true in the case of COMINT sensors. For example, in 2018, Army scientists developed a quantum receiver that employed the highly excited, sensitive Rydberg atoms to detect communication signals. Building on this accomplishment, Army research labs announced in March 2020 that its researchers had created a quantum sensor. According to Army research labs,

> A quantum sensor could give Soldiers a way to detect communication signals over the entire radio frequency spectrum, from 0 to 100 GHz. Such wide spectral coverage by a



Atoms in a glass vapor cell are excited with laser beams to Rydberg states. They detect the electric fields coming from the gold antenna in the background and imprint the information back onto the laser beams. This technology could be used to detect communication signals over the entire radio-frequency spectrum. (Photo courtesy of the U.S. Army)

single antenna is impossible with a traditional receiver system, and would require multiple systems of individual antennas, amplifiers and other components.[10]

Measurement and signature intelligence. The rapid evolution of military weapons, technology, concealment methods, and proliferation out to 2035 will create the need to definitively detect, locate, identify, and destroy some enemy capabilities before they are ever employed against U.S. forces. MASINT as an intelligence discipline will prove useful in this regard. MASINT is information derived from analyzing various types of data collected by sensors that help identify distinct features characteristic of the fixed or mobile target capability that is the source, emitter, or sender. MASINT sensors are able to collect information on radars; acoustics emanating from equipment and human activity; electromagnetic pulses; lasers and directed energy; and chemical, biological, radiological, nuclear, and explosive materials.[11]

By 2035, advances in computing power and sensor technology will result in MASINT sensors that provide real-time information that identifies the signatures of existing and emergent threat capabilities and forces.[12] This development will help the Army pierce through the fog of adversary deception and denial with real-time situational awareness supportive of rapid targeting and destruction of adversaries.

Human intelligence. HUMINT is information collected from human sources overtly and covertly.[13] Improvements in sensor technology coupled with enhanced capabilities to quickly employ lethal, accurate fires will result in a greater unit dispersal in the 2035 battlespace. This increased dispersal will see greater dependence on and exploitation of human intelligence as a means of finding adversaries while avoiding detection. In other words, unit dispersal in battle will foment an unprecedented need for the Army to

creatively employ individual soldiers as sensors in an integrated battlespace network.

Conflict in and around megacities will increase the Army's use of personnel as human intelligence sensors to identify adversary forces concealed in and around civilian population centers. It is likely that conflicts in 2035 will be fought in and around megacities given the steadily growing population in many of the world's urban areas. According to the U.S. Army's 2014 study of megacities (cities with a population of over ten million), "It is highly likely that megacities will be the strategic key terrain in any future crisis that requires U.S. military intervention."[14] The number of megacities worldwide will increase by 2035. According to the Army, "There are currently over twenty megacities in the world, and by 2025 there will be close to forty."[15]

Open source intelligence. OSINT is information that is publicly accessible through various forms of media (television, radio, newspapers, open-access websites, webpages, etc.). According to the U.S. Naval War College, "OSINT refers to a broad array of information and sources that are generally available, including information obtained from the media (newspapers, radio, television, etc.), professional and academic records (papers, conferences, etc.), and public data (government reports, demographics, hearings, etc.)."[16]

OSINT is highly accessible, but there is an exorbitant amount of data that intelligence personnel need to sort through. Compounding this problem in 2035 will be the all-encompassing existence of cyberspace as a domain of conflict with concerns like misinformation and different forms of cyberattacks to hinder or manipulate sensors, military operations, and everyday life. Pete Singer and Allan Friedman assert that "while cyberspace was once just a realm of communication and then e-commerce … it has expanded to include … the underlying sectors that run our civilization" such as food distribution, banking, water, power, etc.[17] These concerns will help spur the evolution of OSINT sensors out to 2035, resulting in sensors that are not only better able to quickly scan large amounts of data to collect useful actionable information but also detect nefarious activities in cyberspace.

Transformation Implications for the Army Out to 2035

The evolution of military affairs and sensors across intelligence disciplines out to 2035 carries considerable transformation implications for the Army. To optimize its ability to find adversaries given the anticipated changes in military affairs and sensors out to 2035,

the Army will have to adapt across the DOTMLPF-P transformation framework.

Doctrine. To optimize its ability to find adversaries and evade detection in the battlespace of 2035, the Army will have to adapt doctrine to ensure it can locate the enemy and engage first. To this end, the Army must assume it will have to fight blind (limited IMINT) most of the time. It will need to develop concepts and doctrine to support sensors in SIGINT and in other intelligence disciplines that locate targets rapidly and accurately. In other words, the Army must evolve concepts and doctrine to optimize its ability to locate and engage enemy forces without seeing them.

Army forces will have to contend with fighting blind in scenarios with situational awareness challenges worse than the 25–28 March 2003 sandstorms encountered during Operation Iraqi Freedom. According to Greg Fontenot and his coauthors, this sandstorm severely hindered operations by obscuring visibility and grounding Army aviation capabilities. Consequently, Army forces had to rely heavily on sensors in the form of ground surveillance radar (GSR), specifically the AN/PPS-5D, a sensor capable of detecting targets aurally when weather conditions limit visibility. The authors wrote that during this epic sandstorm,

> While all other reconnaissance assets were severely degraded, GSR consistently reported enemy targets. GSR's greatest accomplishment during the war was on 26 March when Sergeant Perez's team, consisting of Specialist Apostolou and Private Vasquez, detected 40 enemy targets during a sandstorm. The targets were … subsequently destroyed by indirect fire and Close Air Support assets.[18]

Organization. Anticipated technological advances and the prevalent use of sensors in the 2035 battlespace will make it easy for large formations to be detected and attacked. Gen. Mark Milley, former Army chief of staff, and current chairman of the Joint Chiefs of Staff, anticipates that sensors will proliferate the future battlespace, greatly increasing the probability of being detected and destroyed.[19]

Consequently, the Army should develop and experiment with concepts that optimize its organizational structure (order of battle) to fight dispersed while preserving the ability to mass lethal effects. Retired Gen. William Wallace asserts that in future war against a peer or near-peer adversary, given the ongoing advances in military capabilities, "physical mass will be a recipe for disaster. Formations will learn to routinely mass effects while remaining widely dispersed in time and space."[20] Army artillery is already capable of massing fires from widely dispersed units, so the concept is familiar.

Training. Increased dispersal and decentralization in the battlespace of 2035 will require the Army to train competent, adaptive personnel capable of making timely and effective decisions that expedite operations. This can be accomplished in part by shaping training to promote the philosophy and culture of mission command, or trust tactics, while discouraging institutional proclivities for conformity of thought and uncritical compliance.[21] According to Donald E. Vandergriff, mission command "is rooted in the German idea of Auftragstaktik, which implies that once one understands the commander's intent, he or she is responsible for using creativity and initiative to adapt to changing circumstances and accomplish the mission."[22]

The Army can promote a culture of mission command by ensuring soldiers cultivate a greater repertoire of knowledge, skills, and experiences during training. This emphasis on professionalization will build the competence and trust necessary for a culture of mission command.

Materiel. The projected evolution of sensors out to 2035 carries implications for Army innovation and capability development during relative peacetime conditions. Interestingly, there are also implications for Army adaptation in wartime.

Considering it is already anticipating fighting in a sensor-laden battlespace in 2035, during relative peacetime, the Army should heavily invest in the development of advanced SIGINT, MASINT, HUMINT, and OSINT sensors, as well as sensor-defeat capabilities to counter those of its adversaries. Subsequently, the Army should invest in effective, easily employable sensors

Previous page: A Ghost Robotics Vision 60 prototype walks with a security forces airman at a simulated austere base 3 September 2020 during the Advanced Battle Management System exercise at Nellis Air Force Base, Nevada. The prototype uses artificial intelligence and rapid data analytics to detect and counter threats to U.S. military assets in space and possible attacks on the U.S. homeland by missiles or other means. (Photo by Airman 1st Class Zachary Rufus, U.S. Air Force [background edited])

that it can produce relatively quickly and affordably. This acquisition approach will foster widespread sensor employment by reducing the cost per unit and operator workload, while optimizing combat utility.

Weapons and engines that rely on renewable sources of energy as opposed to expendable ammunition and fossil fuel respectively will help the Army fight dispersed by reducing unit reliance on logistics support. So, the Army should invest in directed energy weapon systems and renewable energy-powered systems.

Unlike the slower pace of innovation in peacetime, the Army will have to adapt quite quickly in war, especially against industrialized peer adversaries in the 2035 time frame where manufacturing speeds will likely be much faster. According to military change expert Williamson Murray, wartime adaptation sees less time for transformation due to "the terrible pressures of war as well as an interactive, adaptive opponent who is trying to kill us."[23] So the Army will have to adapt faster in a conflict in 2035 than it has ever adapted before.

Consequently, to aid its sensors and defeat adversary sensors, the Army should invest in telemetric learning capabilities in some combat systems. These capabilities will help the Army acquire performance data of adversary capabilities in ongoing operations and use it to rapidly manufacture overmatch capabilities to gain an edge. Investing in rapid manufacturing approaches like three-dimensional printing will aid in this regard.

Additionally, adopting modular designs and open architectures in the combat systems built out to 2035 will help the Army rapidly adapt in wartime. Writing about rapid innovation, Dan Ward asserts that "modular designs, open architectures, well-defined interfaces … help a system respond well to future changes."[24]

Leadership and education. Fighting dispersed in the battlespace of 2035 will require the Army to educate and groom professional, competent leaders with a strong capacity for creativity and decisiveness. Competence, creativity, and decisiveness are crucial to building a culture of mission command, or Auftragstaktik, which according to Jörg Muth means that "there is direction by the superior but no tight control."[25]

Competence is made up of the knowledge, skills, and experiences that will enable timely and effective decision-making. Creativity and decisiveness will enable leaders to develop innovative effective solutions and quickly implement them to fulfill their commander's intent in the absence of persistent oversight and guidance. In his analysis of Auftragstaktik and creativity in Army officer/leader education in the U.S. and German interwar era, Muth writes that in the German military academy, creativity was viewed as a principle of problem solving, which ensured "the whole German professional military educational system paved the way for … Auftragstaktik."[26]

Personnel. Fighting dispersed will decentralize unit formations in 2035, necessitating a healthy culture of mission command in the Army. Mission command requires competence-based trust between commanders throughout the chain of command. By 2035, data from contemporary talent alignment and management efforts will enhance the Army's ability to screen and put the right (competent) people in command, which will inspire the competence-based trust vital to a healthy culture of mission command.

Facilities. Relative to the sensor-laden battlespace of 2035, the concern in this aspect of the DOTMLPF-P framework centers on avoiding an adversary's detection and attack of the Army's mobile field facilities such as forward command posts, logistics supply points, etc. Wallace acknowledges this concern in future conflict. He writes about "the threat to any massed logistics formations," and argues that "in fact, any significant signature, be it visual, thermal, acoustic or electronic, will invite a response."[27] As part of its electronic warfare capability development efforts, the Army must consider developing and fielding mobile shelter systems that evade detection by enemy SIGINT sensors by 2035.

Policy. In the 2035 time frame, based on contemporary trends, innovative policies will be needed to address the information and operational security concerns posed by military personnel's use of social media, wearable Bluetooth, and possibly biologically embedded, nanotechnological personal use devices. Adaptive Army policy governance will help reduce the vulnerabilities of personal use technologies to adversary sensors and intelligence collection efforts.

Conclusion

By 2035, military affairs, sensor technology, and employment methods will evolve considerably due to ongoing strategic competition between nation states. This exploratory analysis has shown that within this

time frame, the U.S. Army will have to adapt holistically to effectively exploit sensors.

Subsequently, the Army must continue to aggressively monitor and explore the evolutionary possibilities of sensors across intelligence disciplines and pay close attention to the ever-expanding cyber domain of war. This will enable the Army to "sense first and shoot first" in future conflict with peer adversaries. ■

Notes

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