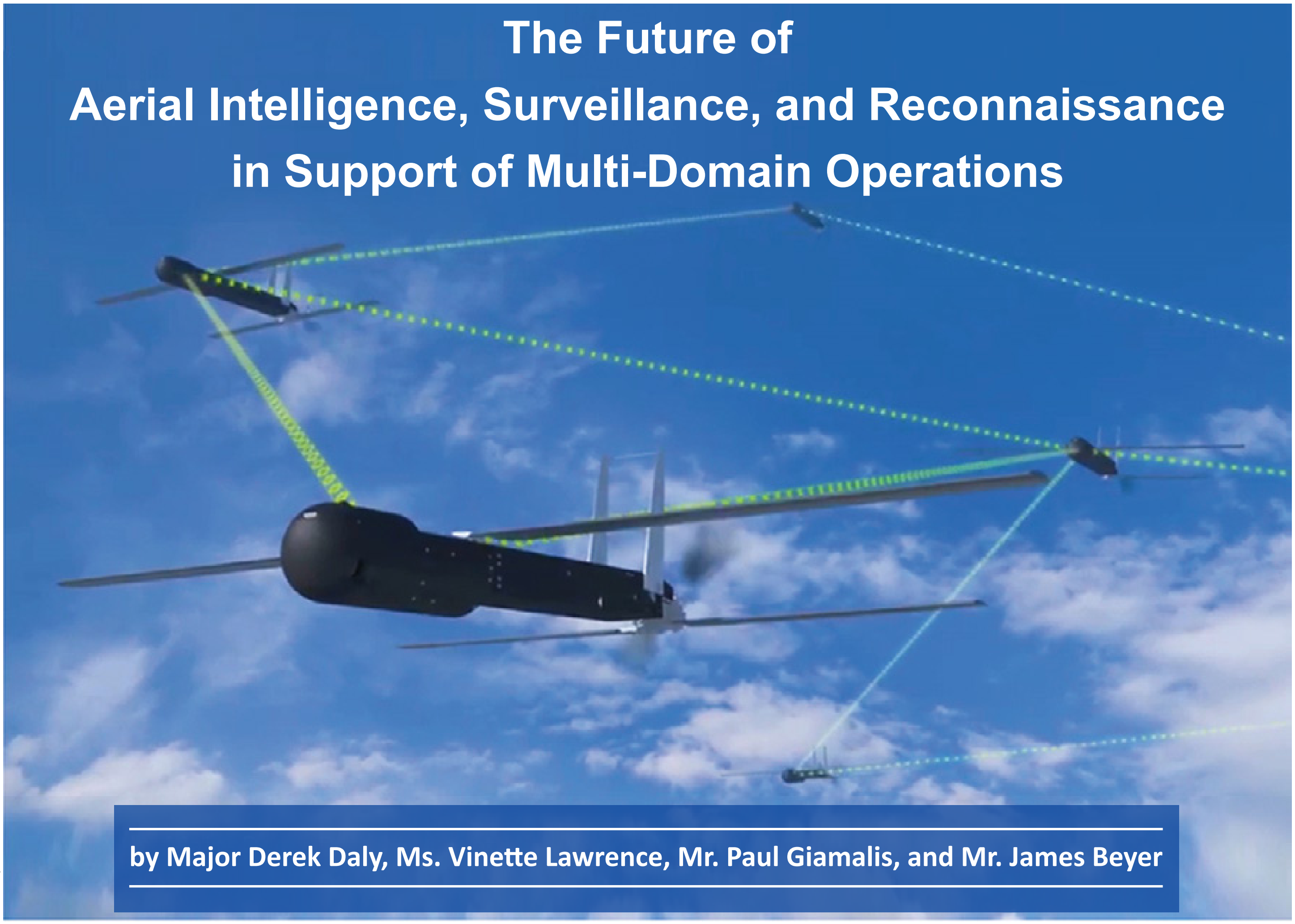
The Future of Aerial Intelligence, Surveillance, and Reconnaissance in Support of Multi-Domain Operations



Courtesy of the U.S. Air Force

by Major Derek Daly, Ms. Vinette Lawrence, Mr. Paul Giamalis, and Mr. James Beyer

Introduction

This article describes efforts to transform the way the U.S. Army conducts aerial intelligence, surveillance, and reconnaissance (AISR) in support of multi-domain operations (MDO) and sets the stage for future force requirements to address AISR modernization. It outlines a paradigm shift in AISR capabilities and examines DOTMLPF–P[1] implications for the capabilities proposed in the following documents:

- *U.S. Army Intelligence Center of Excellence (USAICoE) Aerial Intelligence, Surveillance and Reconnaissance (AISR) in Multi-Domain Operations (MDO) White Paper.*
- *Initial Capabilities Document (ICD) for Multi-Domain Sensing Systems (MDSS).*
- *United States Army Intelligence Center of Excellence (USAICoE), Next Generation Aerial Intelligence, Surveillance, and Reconnaissance (NGAISR) FY18 DOTmLPF-P Assessment.*

The Emerging Operational Environment

Over the past 17 years, the U.S. Army intelligence community focused on counterterrorism and counterinsurgency operations in Iraq and Afghanistan. However, studies of the emerging operational environment describe a future of contested norms and persistent disorder. Adversary nations are developing the means of creating political and military standoff to degrade key capabilities (for example, disrupting access to land, space, cyberspace, and the electromagnetic spectrum). The methods employed in the emerging operational environment will turn long-presumed strengths into potential weaknesses. As a result, the comparative U.S. military advantage and the ability to conduct uncontested operations against a sophisticated adversary have diminished, and the current AISR fleet is ill equipped to operate against peer competitors. The Army, as an element of the joint force, solves this problem by conducting MDO to prevail in competition and dis-integrate enemy antiaccess and area denial (A2AD) systems.

The Operational Problem

Successful operations in such an environment will require AISR to undergo a significant transformation. The current AISR fleet is optimized for counterterrorism and counterinsurgency but has significant survivability challenges against a peer threat. The adversary's A2AD capabilities present a challenge to the joint/multinational ability to achieve air dominance and control and to project power onto land from the air and maritime domains. In many instances, standoff distances would force current AISR platforms beyond the collection range of named and targeted areas of interest. Army intelligence faces challenges in balancing today's readiness requirements against the requirements of the future fight.

Current AISR Capabilities and Shortfalls

The current AISR fleet is a collection of commercially adapted manned platforms and purpose-built unmanned aircraft systems (UAS). The fleet provides a suite of advanced sensors and technologies enabling cross-cueing, onboard processing, and fusion of geospatial intelligence and signals intelligence (SIGINT) collection in support of tactical maneuver commanders. These capabilities are task organized to provide actionable intelligence to tactical commanders and intelligence products to enable planning and execution at higher echelons. The fleet has several challenges and shortfalls:

- ✦ Current capability to develop targets out to the range of emerging fires systems is limited.
- ✦ Platforms optimized for aerially permissive environments operate at vulnerable altitudes from vulnerable runways.
- ✦ Size, weight, power, and cooling concerns limit the Army's ability to add aircraft survivability equipment.
- ✦ Platforms are vulnerable in a peer fight with very few options to improve the survivability of current platforms or sense deep enough to be relevant.
- ✦ Platforms are expensive, slow to produce, low density, and difficult to replace.
- ✦ Current aerial sensor processing, exploitation, and dissemination (PED) timelines do not support dynamic targeting timelines in large-scale ground combat operations.

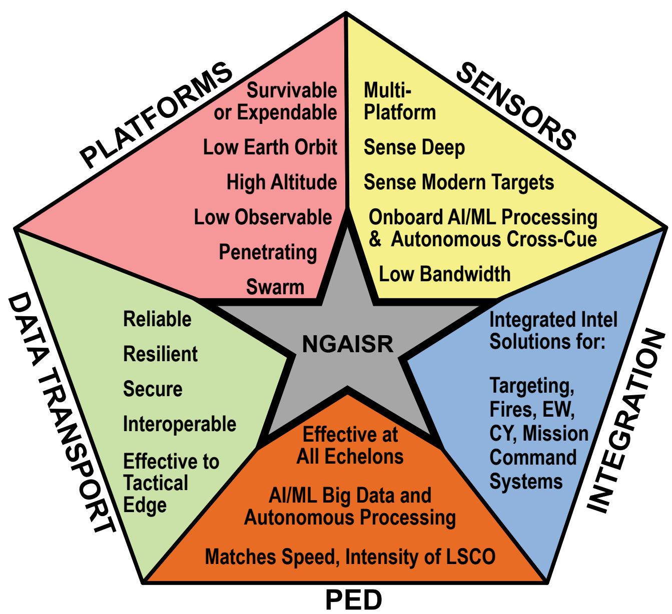
The development of TRADOC Pamphlet 525-3-1, *The U.S. Army in Multi-Domain Operations 2028,* fundamentally changed the vision of AISR operations. With the subsequent incorporation into FM 2-0, *Intelligence*, and FM 3-0, *Operations,* MDO consequently exposed critical shortfalls in AISR capabilities. Furthermore, a plethora of studies, white papers, concepts, and strategies belied the imperative of updating all aspects of AISR in order to align with the modernization efforts of other warfighting functions in the collective pursuit of a third offset strategy.

Central Idea/Solution

The next generation AISR DOTMLPF–P study focuses on future AISR challenges and requirements to examine the readiness of Army aerial intelligence to conduct information collection through 2035. The study provides a solution strategy for the MDO-capable force (by 2028) and the MDO-enabled force (by 2035) and focuses on five major categories, shown in Figure 1, scoped to address appropriate elements of modernization:

- ✦ Platforms.
- ✦ Sensors.
- ✦ PED.
- ✦ Data transport/network architecture.
- ✦ SIGINT/electronic warfare (EW)/cyberspace integration.

The end state is a force capable of supporting Army and joint warfighting functions in MDO.



AI	artificial intelligence	LSCO	large-scale combat operations
CY	cyberspace	ML	machine learning
EW	electronic warfare	NGAISR	next generation aerial ISR
ISR	intelligence, surveillance, and reconnaissance	PED	processing, exploitation, and dissemination

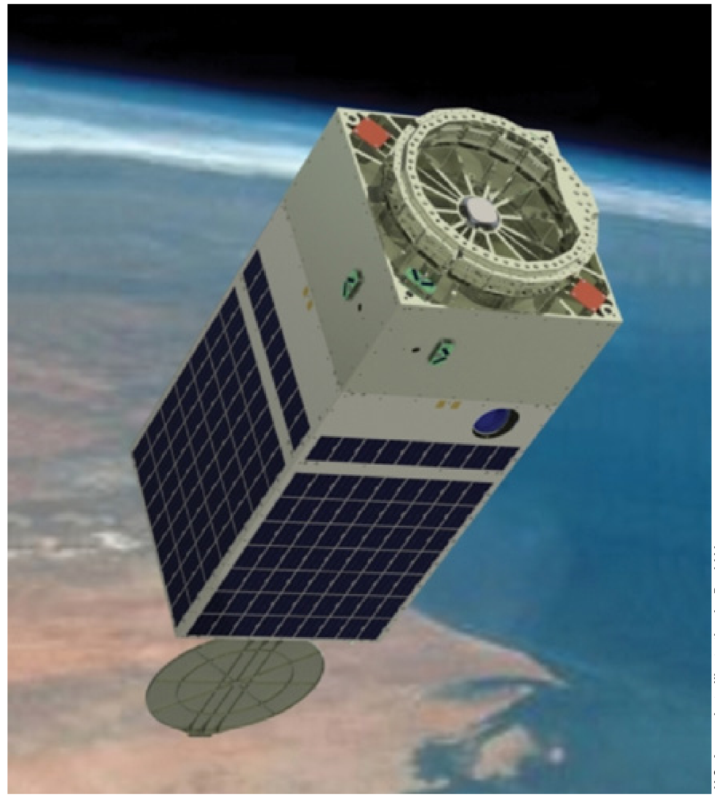
Figure 1. Multi-Domain Sensor Systems Required Capabilities

To achieve this, the Army must provide agile, adaptable, interoperable, multimodal, and multifunctional AISR capabilities to operate in a highly contested and complex environment in multiple domains. Multimodal is based on principles of sensor diversity meant to simultaneously detect multiple characteristics and signatures emitted by targets of interest. The objective of multimodal sensing is to increase detection accuracy and reduce false alarm rates while operating in a complex, cluttered environment. Multifunctional refers to the ability to employ a variety of capabilities to perform multiple Army warfighting functions simultaneously, or in combination, to achieve a certain effect or outcome. The future AISR fleet must provide commanders with shared situational understanding in all phases and operational environments, across the range of military operations, including against peer threat competitors posing complex A2AD and overmatch dilemmas in depth. Desired outcomes include—

- The right mix of capabilities to fulfill requirements of commanders in competition and armed conflict.
- AISR operations beyond mid-altitude constraints in large-scale ground combat operations.
- A complementary family of airborne multi-intelligence, multimodal, multifunctional technical sensors with improved operational flexibility, joint interoperability, tactical responsiveness, and the ability to service sophisticated targets.
- Improved integration initiatives with standards-based interoperability to support agility, partnering, and cross-domain synergy in support of penetrating ISR and long-range precision fires.
- Artificial intelligence and machine learning as critical enablers throughout the tasking, collection, processing, exploitation, and dissemination and analysis process.
- Reconfigurable platform architectures with multilevel security communications and data transport capability.
- The ability to survive and operate in A2AD environments and in congested, contested cyberspace and electromagnetic spectrum environments.
- Shortening of the sensor-to-shooter link to account for the threat's mobility and the tempo of MDO. This includes addressing PED and integration with mission command systems.
- Organization of the AISR force to support commanders at echelon, specifically at echelons above brigade.

Near-Term Solution Strategy (Present to 2025)

The next generation AISR DOTMLPF–P study advocates a capability development and deliberate modernization strategy predicated on an agile and adaptive approach that reflects careful stewardship of allocated resources and accounts for risk, fiscal reality, and state of technology. In order to do so, future AISR systems must develop and leverage foundational and interrelated capabilities. The near-term solution strategy includes platforms, sensors, PED, network/architecture, and SIGINT/EW/cyberspace integration.



U.S. Army photo illustration by David Vergun

Kestrel Eye is an electro-optical nanosatellite developed by the U.S. Army Space and Missile Defense Command/Army Forces Strategic Command. It will improve mission command on the move for brigade combat teams, allowing tactical leaders to synchronize action, seize the initiative, and maintain near real time situational awareness.

Platforms: Platforms associated with AISR exist to position sensors for the collection of threat signatures. Army intelligence requires platforms that can survive, suffer attrition at an acceptable rate, or exist for one-time use (expendable). Survivability characteristics include reduced signatures, cyberspace/EW resilience, and a multilayered approach (very low altitude, very high altitude, low Earth orbit, and national technical means of verification).

Sensors: Modernization strategies in the near term must focus on continued improvements in sensor range and resolution to enable intelligence collection in large-scale ground combat operations. Army intelligence should pursue miniaturized sensors capable of pairing with small, attritable, or expendable platforms to gain access to threat signatures. Fielding of advancements in several areas will inform sensor development for future aerial platforms: high-definition electro-optical/infrared, precision geolocation, wideband SIGINT, hyperspectral imagery, light detection and ranging, foliage penetrating, and advanced synthetic aperture radar/moving target indicator radar sensors on airborne platforms. Given the pace of MDO, sensors must operate autonomously using distributed, self-healing mesh networks to aggregate data. Sensors must contribute to shortening the sensor-to-shooter link and support automatic target recognition, battle damage assessment, and situational understanding.

PED: AISR platforms must leverage Distributed Common Ground System-Army based data refinement and exploitation through semi and fully autonomous information fusion capable of alerting analysts and collection managers of key indicators and warning intelligence. Processing and automated decision-making improvements at the sensor will reduce the cognitive load on sensor operators and PED analysts. Continuous refinement of automation of data analysis and machine learning will drive development of artificial intelligence.

U.S Army Graphic

A collaborative effort between Army researchers has resulted in a tool that will enable the Army to model, characterize, and predict the performance of current and future machine learning-based applications on mobile devices. The soon-ending Network Science Collaborative Technology Alliance made this effort possible.

Network/Architecture: The Army built and fielded its mission command network in an unopposed environment. The result was a network vulnerable to cyberspace, electronic, and physical attack when facing a peer threat in large-scale ground combat operations. Future investments need to provide redundant, resilient communications capabilities and computing hardware configured to synchronize data when the network is available. Ongoing development of open-architecture, software-defined SIGINT and multi-intelligence sensors compliant with established standards to support cooperative mission applications (for example, theater net-centric geolocation) will facilitate interoperability and flexibility through expeditious responsiveness to threat tactics, techniques, and procedures. Upgrades to the existing fleet and enduring capabilities must include technologies to provide assured position, navigation, and timing through the incorporation of precise alternatives to the Global Positioning System.

SIGINT/EW/Cyberspace Integration: Cyberspace and EW capabilities will continue to provide low cost alternatives to mitigating traditional U.S. advantages. Incorporation of cyberspace/EW effects delivery capabilities into SIGINT sensors will encourage synchronized operations to capitalize on windows of opportunity in positions of advantage. AISR collection data must propagate throughout national to tactical intelligence in standardized data models discoverable by multiple echelons.

Mid-Term Solution Strategy (2026 to 2035)

The following is the mid-term solution strategy.

Platforms: The manned AISR fleet will transition from vulnerable platforms to survivable ones, in part through incorporating a full suite of advanced, effective aircraft survivability equipment. Future aircraft operating in large-scale ground combat operations will need to specialize in one of two ways: (1) runway-independent, close-area deployable or (2) long-endurance, heavy payload.

Improved and alternative propulsion methods will incorporate runway-independent capabilities to permit Army AISR to operate at the speed of maneuver in an environment where forward arming and refueling points and main command posts are increasingly mobile. Dispersed, forward operation of aerial assets would capitalize on positions of relative advantage to launch and collect with minimal travel to target and limited distance from refuel.

Networked, groups 1 and 2 UAS will develop greater endurance, autonomy, and interoperability, enabling maneuver element employment in support of all warfighting functions. Historically limited to "over-the-hill" reconnaissance missions, future UAS will possess miniaturized sensors with sufficient resolution to support situational understanding. A swarm of terrain-sensing, autonomous, small UAS launched by disparate maneuver elements will optically, aurally, and electronically sense and define the battlefield. Individual swarm elements will carry varied sensors, each providing a portion of the data necessary to reveal enemy position and intent. Autonomous communications UAS will provide a robust, composite self-healing network to feed collection to tactical analysts.

Advancements refined and fielded in the mid-term will transition Army AISR into an expedient, versatile fleet prepared to integrate runway-independent aircraft and automation into formations. This future force will execute comprehensive joint operations to provide real-time situational understanding to every echelon of Army forces.

Sensors: Adaptation and standardization of sensor payloads and mitigation of size, weight, power, and cooling constraints will enable maximum versatility from a single or pair of airframes. This would be better than developing unique aircraft for a specific discipline or capability. Interchangeable, interoperable, networked sensor packages will permit a single airframe to fulfill the full spectrum of intelligence collection possibilities. These universal sensors will include or interface with onboard, automated intelligence processing capabilities to reduce data transmission requirements and perform autonomous tipping and cueing. Advances in quantum imaging/sensing and quantum computing have the potential to significantly improve imaging sensitivity and data processing.

PED: At the command post, network-enabled automated PED will parse and format data while simultaneously conducting autonomous fusion and feeding the common operational picture. Artificial intelligence assistance to intelligence analysts will permit prompt determination of threat courses of action and hasten targeting cycle iterations. Data output will adhere to established inter-Service, multi-organizational, multinational common data models permitting immediate data discovery and enhanced collection utility. This refined information will expeditiously feed into mission command and fires networks to facilitate operations and planning.

Network/Architecture: The family of systems associated with the Multi-Domain Sensing Systems (MDSS) will include functions beyond offloading of collected information. Incorporation of command and control network functions and sensor-to-shooter linkages will elevate the aerial layer into a central role facilitating data exfiltration and availability at all echelons. Expansion of capability in this category will include improved accessibility to and interoperability with joint, interagency, and multinational partner data networks and unit communications. In addition to data and network standardization, this is accomplished through an expeditionary constellation of aerial-based information relay nodes capable of deep fires area penetration in support of multi-echelon and multinational operations.

SIGINT/EW/Cyberspace Integration: Sensors will support integrated SIGINT, EW, and cyberspace in order to sense and exploit a larger array of threat signatures. Sensors will capitalize on modernization and miniaturization of antenna along with supplementary technologies to collect on a major portion of the electromagnetic spectrum. Advancements will enable collection on unintentional radiations of electromagnetic energies and allow simultaneous collection and contribution to network operations. Integrated sensors will perform automated high-speed scanning, detection, and geolocation augmented by data fusion at the point of collection capable of leveraging joint or Army sensor data to provide near real time situational understanding and targeting information to shorten the kill chain. MDSS capabilities provide intelligence support to offensive and defensive electronic attack to achieve deny, degrade, disrupt, deceive, destroy effects against communication and noncommunication targets in accordance with cross-domain fire engagements. Incorporation of cyberspace capabilities into SIGINT/EW sensors allows for the mapping of adversary cyberspace (physical network, logical network, and cyber-persona layers) and identification of capabilities and vulnerabilities of the adversary's cyberspace infrastructure.

DOTMLPF–P Findings

The summarized DOTMLPF–P recommendations listed on the next page are dependent on implementation of the aforementioned materiel solutions captured within the MDSS initial capabilities document.

U.S. Army photo illustration by Peggy Frierson

Cyber-Electromagnetic Activities, or CEMA, teams are now routinely operating with brigade combat teams at combat training centers and during home station training.

Doctrine.

- Doctrine must adapt to account for the expanded range of AISR systems and missions, and incorporate operational lessons learned.
- Incorporating MDSS capabilities will require descriptions of the roles and responsibilities associated with information collection outside of the medium altitude.
- New or improved platforms and sensors will require development of fundamental principles and tactics, techniques, and procedures for Soldiers and leaders to understand how systems within MDSS collect, maneuver, and survive.
- Doctrine must also outline the conduct of AISR-associated PED and the processes associated with integrated capabilities.

Organization.

- Force design updates may be necessary to ensure optimal organization of future force AISR equipment, maintenance, and personnel. These updates may also provide for expanded, organic ISR capability at the division level.
- Force design updates should address the number and type of personnel required to support AISR. The right leaders to plan and execute missions in the complex low Earth orbit, high-altitude, and low-altitude environments are essential.
- The organizations involved require adaptability and self-sufficiency to capitalize on windows of opportunity in expeditionary operations while operating in a joint environment. Central to this idea is the assignment of sufficient equipment and maintenance to provide organic ISR capabilities to the MDO unit of action—the division.

Training.

- Capability and materiel developers must design effective training tools as critical components of MDSS. New equipment training, technical inserts, and materiel upgrades must occur at institutional, home station, and combat training center venues.
- Training will require the replication of MDO environments and must accommodate a sustainable progression of individual skills and collective tasks. MDSS will dramatically increase the necessary level of Soldier proficiency at all levels.
- Analysts and operators must understand academically challenging scientific, technological, engineering, and mathematical principles to pilot, direct, and maintain the platforms, sensors, and networks associated. All training domains will need to incorporate advanced concepts into training at all levels.
- Integration of SIGINT, EW, and cyberspace affects the institutional training of all personnel. Increased emphasis on the electromagnetic spectrum and the cyberspace domain, including the development of Army aerial EW programs of record, levies a force-wide training requirement. The global rise of cyberspace-enabled sensors and systems increases the need for integration of friendly and adversary cyberspace considerations into training.

U.S. Army photo illustration

By 2025, airspace over future battlefields will be extremely congested and potentially dangerous.

Materiel.

- Among the solutions are upgrades to the survivability and performance characteristics of the existing manned and unmanned platforms.
- Advancements in the security of aerial transmissions are required to prevent enemy disruption or interception of information collection.
- Existing aerial sensors also require upgrades to improve attributes of interoperability, range, resolution, onboard processing, and reduced bandwidth transmission.

- ✦ The subsequent increase in information collected will require additional processing power and bandwidth for PED elements at all echelons.

Leadership and Education.

- ✦ Professional military education will require updating to ensure leaders understand MDSS capabilities and employment.
- ✦ Leaders associated with AISR collection and command and control need a sound foundational understanding of AISR capabilities and aerial information collection. This should include an understanding of the strengths and weaknesses of platforms, sensors, and networks in varied environments, including disrupted, intermittent, and limited.
- ✦ Leaders will also require an understanding of the personnel, equipment, and organizational implications of integrated SIGINT, EW, and cyberspace.

Personnel.

- ✦ As Army AISR transitions to a more MDO-capable fleet, expect updates to intelligence military occupational specialty (MOS) requirements to ensure personnel have the relevant skillsets and professional competencies.
- ✦ Some capabilities described in the MDSS initial capabilities document, such as high-altitude platforms and low Earth orbit satellites, may need an entirely new MOS to operate. Others demand specific skills underdeveloped or absent in the force, such as PED of advanced spectral imagery or operation of a quantum illumination detection and ranging sensor.
- ✦ MOS 353T (Intelligence Systems Integration and Maintenance Technician)/35T (Military Intelligence Systems Maintainer/Integrator) assignments and skills must expand to integrate new technologies into the network and the AISR fleet. These personnel need the expertise to troubleshoot and maintain sensors and platforms relying on highly advanced technologies and materials in expeditionary environments.

Facilities.

- ✦ Fielding of new systems may require updates to home station training and PED reach facilities to support MDO AISR capabilities.
- ✦ Launching and recovering low Earth orbit satellites and high-altitude platforms, such as lighter-than-air, will require facilities with the appropriate area and equipment. Other platforms, such as high-altitude UAS, could operate from existing facilities.
- ✦ To use artificial intelligence and machine learning to enable global PED, the Army must construct data centers capable of processing and storing the speed and amount of data expected by MDSS capabilities. This will require at least one data center to support the PED of aerial information collection.
- ✦ Army training ranges need the ability to manipulate the electromagnetic spectrum to accurately replicate contested, congested large-scale ground combat operations.
- ✦ Soldiers and systems need realism in training to gain proficiency and verify the operability of integrated SIGINT/EW/cyberspace aerial capabilities.

Policy.

- ✦ MDSS has significant potential to expand Army ISR into traditional Air Force domains such as space. This may require policy adjustments regarding the de-confliction of airspace and command and control processes. As the Army considers alternative operational altitudes for AISR, it must ensure the platforms adhere to inter-Service policy. The fiscal investment in nontraditional platforms associated with MDSS should not culminate in a concept or system that the Army will not operate.
- ✦ MDSS will require interoperability to enable multidomain command and control in joint environments. Whether data is direct from the aircraft or disseminated by the intelligence community, AISR data needs to reach the appropriate organic and joint echelon. The information collected must transfer in near real time to data sources available to as many intelligence and warfighter consumers as possible, including unified action partners.

Conclusion

Major findings from the next generation AISR DOTMLPF–P study and other supporting studies and analyses conclude that AISR requires platforms that can survive, suffer attrition at an acceptable rate, or exist for one-time use (expendable). Survivability characteristics include reduced signatures, cyberspace EW resilience, and a multilayered approach (low-altitude, high-altitude, low Earth orbit, and national technical means of verification). Army intelligence must also field sensors that can collect modern signals, sense deep, integrate with cyberspace/EW, and offer flexible platform options.

AISR modernization and the transition to MDSS will require some sustainment of the current AISR fleet in the near term, to service ongoing operations and provide a developmental bridge. To achieve the goal of the modernization of AISR through the MDSS model, a number of efforts incorporating every warfighting function must occur.

Several interdependency implications to the next generation AISR operating concept are outlined in the DOTMLPF–P study. Many include working in conjunction with partner capability developers in order to leverage their platforms and capabilities. The traditional Joint Capabilities Integration and Development System process for the development of an initial capabilities document must lead a successive series of capability production documents to address the vast number of complex issues and unique capabilities. Where applicable, the rapid prototyping and fielding outlined by the Army Futures Command should accelerate the implementation of more mature technologies.

Endnote

1. DOTMLPF–P: doctrine, organization, training, materiel, leadership and education, personnel, facilities, and policy.

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