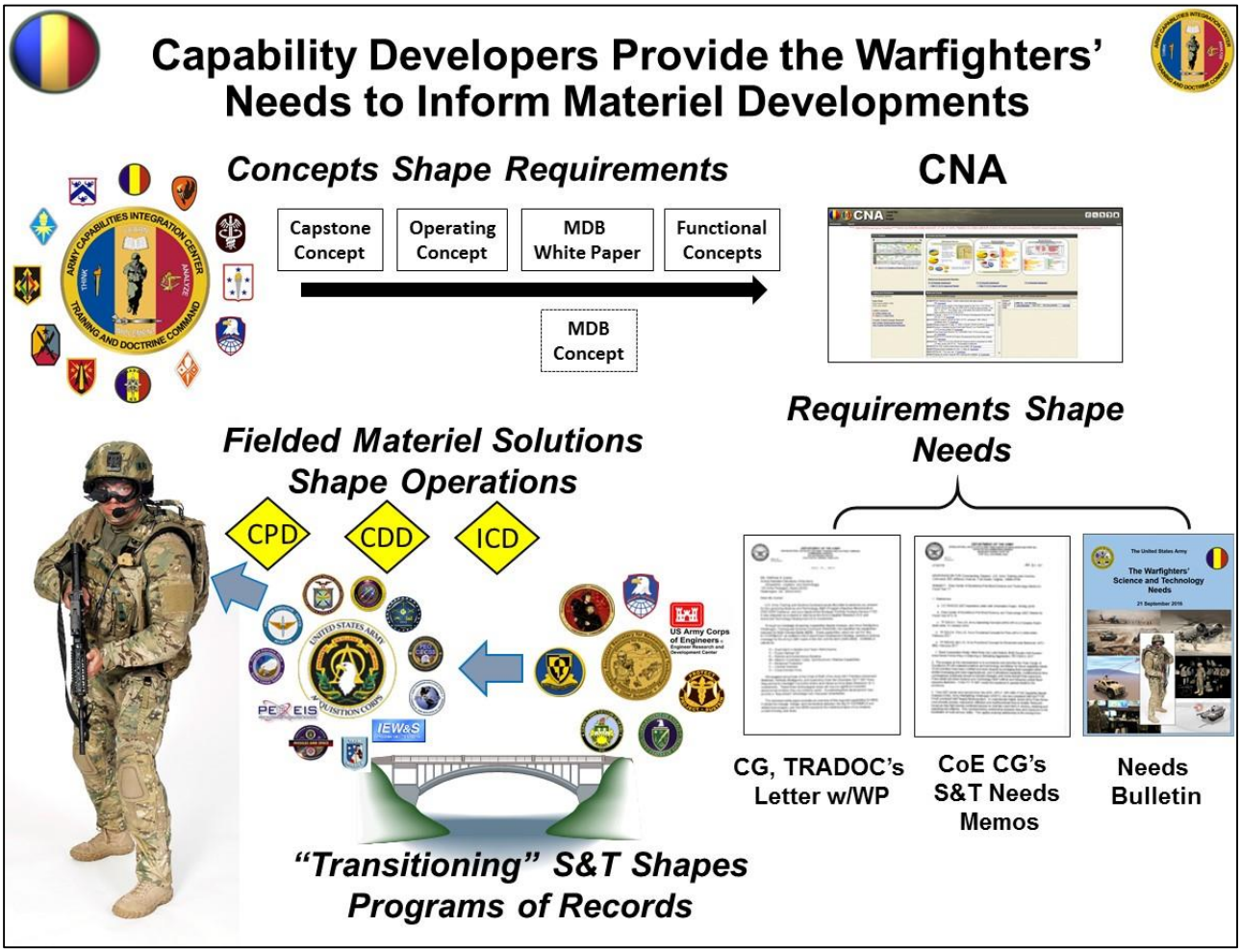
The United States Army

Warfighters' Science and Technology Needs

22 September 2017



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Foreword

From the Acting Director, United States Army Capabilities Integration Center (ARCIC)

Today's Army faces diverse, complex, and dangerous threats to our national security. After years of our Army holding competitive advantages, adversaries are closing the gaps while becoming increasingly more belligerent. Their enhanced capabilities, coupled with the complexity of potential future operations, suggest we could lose our qualitative overmatch for future conflicts without concerted efforts to develop necessary capabilities.

Over the past year, the Army Capabilities Integration Center held multiple learning events focused on mid- and far-term armed conflict. We examined warfighting in the 2030-2050 timeframe and identified both opportunities and capability gaps for Army forces. We are at the leading edge of changes to the fundamental conduct of war. The two most significant insights identified were the increasing urbanization of societies and the increasing lethality of weapon systems as technology proliferation has enabled potential adversaries to take advantage of off-the-shelf technologies with limited investment. These and other anticipated changes in the conduct of war require deliberate sustained action.

Our enemies are becoming more and more capable based on the ubiquitous nature of technology. They are operating in restrictive and urban terrain to evade our long-range detection capabilities. They are developing tiered air defense systems giving them the capability to gain air supremacy from the ground. They are coupling their cyber electromagnetic capabilities targeting social media with their growing unmanned aerial systems to improve general target identification and then massing long range fires to neutralize threats. All of these efforts highlight the ever increasing difficulty of land-domain problems that cannot be solved solely from standoff ranges.

To mitigate the mounting risk to the force and risk to accomplishing the mission, our Army needs to develop the capabilities required to win in complex world, as defined by the Army's Modernizations Priorities: Long Range Precision Fires, Next Generation Combat Vehicle, Future Vertical Lift, Network/C3I, SHORAD/Air and Missile Defense, and Soldier Lethality. As we develop the emerging Multi-Domain Battle Concept and identify subsequent required capabilities over the next several months, we will continue to refine and update the Warfighters' Science and Technology Needs for use in FY18.

Robert M. Dyess Jr.

Robert M. Dyess Jr.
Major General, U.S. Army
Acting Director, Army Capabilities
Integration Center

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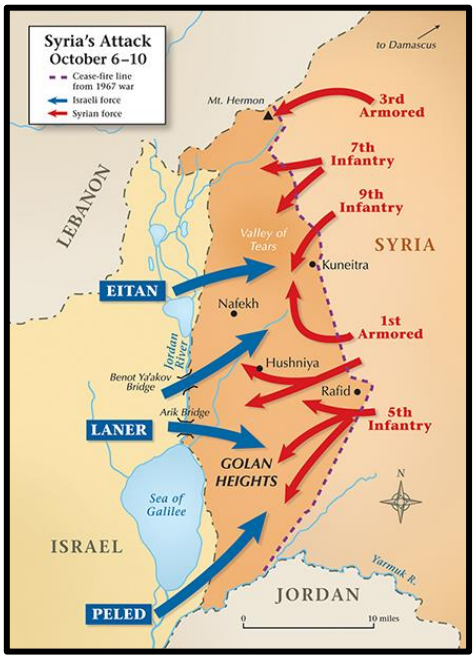
This document is the result of an integrated effort between the Army Capabilities Integration Center, TRADOC Staff, and TRADOC Centers of Excellence (CoEs).

Chapter 1 Needs Bulletin Overview

Over the last 15+ years of combat operations, and still today the U.S. Army focused on winning against irregular adversaries and challenges in both Iraq and Afghanistan that has limited the Army's capability to focus on modernizing our major weapons systems for the future force. Meanwhile, threats, enemies, and adversaries continued to modernize rapidly and became increasingly capable. These conditions point to an emerging future security environment in which U.S. ground forces are increasingly likely to face tactical overmatch in some operations. In addition, decreases to the Army's overall budget over past years compound the challenges of modernization. Compared to the last two drawdowns of the Army (Post Vietnam, post-Cold War) not only has the Army taken a larger percentage cut than previously, but those two previous drawdowns came after the Army had already modernized much of the force. As a result of increasing enemy capabilities and the reduction in resources available for modernization, Soldiers and mission are at unacceptable risk that will continue to increase if not addressed and mitigated.

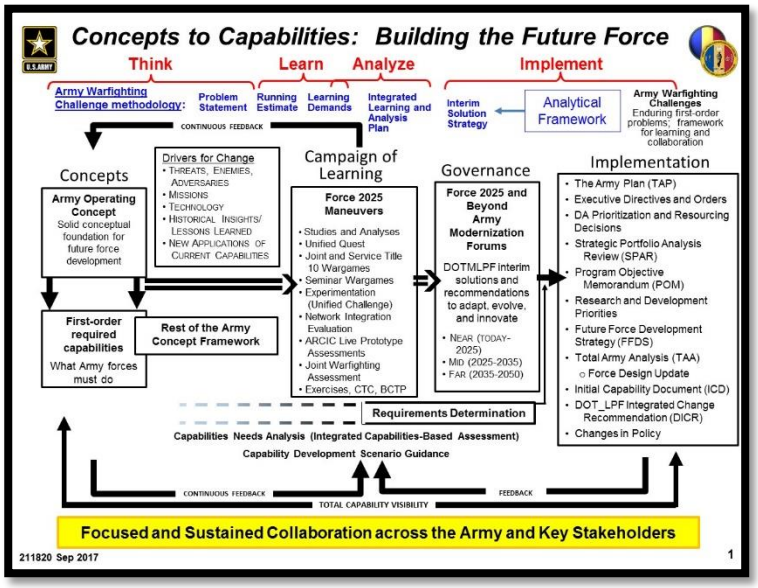
"After the United States emerged from Vietnam, it witnessed the events of the 1973 Yom Kippur War, which underscored how far potential enemies had advanced in terms of weapons and tactics. This war vividly illustrated the lethality of modern weapons, the high value of crew proficiency, and the skill of tactical commanders. The Army responded with a renewed focus on major combat operations and modernized the force to meet the requirements of the new (flexible) response doctrine."[1] In the 1980s, the Army was able to respond to the military problem of winning outnumbered against the Soviet Union by developing a new operating concept - Air Land Battle and produced the "Big 5": M1 Abrams, M2 Bradley, Apache AH-64 Helicopter, UH-60 Black Hawk Helicopter, and the Patriot Missile System. The 2000s however constituted a largely "lost decade" for Army modernization, as billions of dollars were spent on Major Defense Acquisition Programs, which were ultimately cancelled before they ever reached the war fighter. Notable canceled programs included, but were not limited to: Future Combat Systems (FCS), the RAH-66 Comanche Armed



[1] Johnson, David. The Challenges of the "Now" and Their Implications for the U.S. Army, 2016.

Reconnaissance and Attack Helicopter, and the Crusader Self-Propelled Howitzer.[2] Operation Iraqi Freedom (OIF) and Operation Enduring Freedom (OEF) mostly constituted Commercial off the Shelf (COTS) items.

TRADOC as the Army's architect will provide the structure for the governance process and strategic communications strategy that enables the Army to focus future force development and prioritize its Research Development and Acquisition (RDA) strategy. The intent of this initiative is to identify key capabilities and systems which require senior leader oversight to increase the chances of successful delivery of capabilities. The capabilities identified herein *do not* represent all of the capabilities required for our Army, but focus on those that allow the Army to close critical capability gaps and fight in the context of the Army Operating Concept (AOC). In addition, give additional clarity to the Army Modernization Priorities that act as our strategic communication vehicle for Army leadership to galvanize senior leader attention and garner resources in support of future force development. TRADOC uses the Concept to Capabilities methodology to stay ahead of determined enemies in an ever-changing environment; the Army will adapt, evolve, and innovate over time through the ***Think – Learn – Analyze – Implement (TLAI)*** paradigm. Army leaders *think* clearly about future armed conflict then *learn* about the future through the Army's campaign of learning which consists of the physical and intellectual activities to develop interim solutions to warfighting challenges. The Army then *analyzes* these solutions to establish risk based priorities and identify opportunities to ensure Army formations have the capability and capacity to accomplish assigned missions. The Army uses this analysis to *implement* interim solutions to improve the combat effectiveness of the current and future force. Army Modernization Priorities reflects the findings of the *analyze* portion and the ways and means to execute the *implementation* portion of the TLAI paradigm.



As part of *Analyze*, the Fiscal Year 2015 (FY15) Capabilities Needs Analysis (CNA) results identified numerous capability gaps. In FY16 CNA results the Army

[2] CSIS Defense 360, The Army Modernization Challenge A Historical Perspective

discovered even more capability gaps. While modernization has extended the useful life of the Army's combat vehicles, they are losing overmatch.[3] Results from FY16 CNA along with the New Generation Warfare (NGW) study further emphasized, and reinforce the need for Department of Defense (DOD) senior leader attention.

Capability, defined as: "The ability to achieve a desired effect under specified standards and conditions through combination of means and ways to perform a set of tasks." Two conditions will emerge that require the Army to develop and resource major combat systems for implementation: 1) the loss of overmatch (aforementioned) as aging equipment reaches maximum useful life; 2) the potential to face near-peer/peer or competing threats (e.g. China and Russia) while simultaneously facing smaller regional powers and transnational terrorist organizations.

The Army recognizes there are no magical (technological) solutions. The Army retains overmatch through combining technologies and integrating them into changes in organizations, doctrine, leader development, training, and personnel policies. Overmatch in Soldier and small unit performance requires focus placed on fundamental capabilities that empower the Soldier, increase lethality, increase human performance and reduce Soldier loads. The Army must *fit machines to Soldiers rather than the other way around*. The Army will pursue advances in human sciences for cognitive, social, and physical development and emphasize engineering psychology and human factors engineering in the design of modern weapons and equipment. This is key to ground forces success.

To ensure the delivery of these capabilities to support the Army's future force, the systems designed to support these capabilities require intense Army senior leader visibility and oversight. TRADOC will work with HQDA in developing the specific management practices for the Army Modernization Priorities systems. Management practices may include:

a. Chief of Staff of the Army (CSA) approving and directing changes to Capabilities system requirements, resources, and acquisition strategies.

b. Prioritizing funding, manpower and senior leader decision to support implementation of these programs.

c. Reprioritizing funding across the Army's Total Obligation Authority (TOA) to accelerate Capabilities while seeking opportunities to increase Army TOA.

d. Continually assessing Capabilities through *Think-Learn-Analyze-Implement* paradigm.

1 Application of capabilities or use of tactics in a way that renders an adversary unable to respond effectively. Army Operating Concept, 31 Oct 2014, page 19

e. Assigning the best leaders as Program Managers (PM) and TRADOC Capability Managers (TCM) and ensuring consistency and continuity by extending duty assignments (similar to that of Acquisition Category I (ACAT I) and II programs).

f. Leveraging the Army Requirements Oversight Council (AROC) review process as a key decision forum.

g. Assess the health of the Capabilities systems through the Strategic Portfolio Analysis Review and report the status during Program Objective Memorandum (POM) development in the appropriate Senior Review Group.

h. Developing a communications strategy that includes simple, clear, consistent and compelling messages in conjunction with Army Public Affairs, the Office of the Chief Legislative Liaison and Army Congressional Budget Liaison Office.

i. Developing Doctrine, Organization, Training, Materiel, Leadership & Education, Personnel, Facilities, and Policy (DOTLMPF-P) changes to fully implement identified capabilities.

TRADOC will continue to Think, Learn, Analyze, and Implement to identify and refine key systems to provide each of the Army Modernization Priorities capabilities. In addition to the AOC's technology first principles[4], other key considerations for choosing systems that meet the Army Modernization Priorities Capabilities criteria are:

a. Systems essential to winning in a complex world against determined, and increasingly capable enemies are considered.

b. Assure fielding of essential systems in a timely manner through their management by Senior Army leadership.

c. Systems that by their nature will drive the requirements of other systems (e.g. the future tank will drive requirements for the future bridging, recovery and evacuation vehicles).

[4] According to the Army Operating Concept the technology first principles are:
(1) Emphasize integration of technology with Soldiers and teams.
(2) Simplify systems and integrate Soldier training into design.
(3) Maximize reliability and reduce life cycle costs.
(4) Design redundant systems that improve effectiveness under conditions of uncertainty.
(5) Develop systems that degrade gracefully.
(6) Maintain foundational knowledge to reduce the opportunity for surprise.
(7) Reduce logistical demands.
(8) Anticipate enemy countermeasures.
(9) Ensure interoperability.
(10) Consider scale and organizational implications.

d. Systems that have the potential to mitigate critical capability gaps to a large extent and are feasible (affordable and technologically possible).

e. Systems that maximize demand reduction, improve reliability, simplify the network, maintain overmatch, and enable the conduct of expeditionary maneuver.

f. The CSA will provide close oversight and over watch.

"We live in a challenging, increasingly dangerous world. Threats, enemies, and adversaries are becoming increasingly capable and elusive. Threats may emanate from nation states or non-state actors such as transnational terrorists, insurgents, and criminal organizations. Some are approaching near peer status. The Army must be ready to confront revisionist powers and regional competitors while simultaneously opposing transnational terrorist organizations".[5] Unlike the past decades where the Army's' faced a known adversary, the current AOC: Win in a Complex World dated 2014, describes the future operational environment as complex, meaning "it is not only unknown, but unknowable, and constantly changing." Additionally, "the Army cannot predict who it will fight, where it will fight, and with what coalition it will fight." Therefore, to shape security environments by assuring friends, influencing neutrals and deterring enemies and adversaries, the Army engages regionally and must be able to respond globally by conducting expeditionary maneuver[6], developing the situational understanding, conducting [joint] combined arms maneuver[7] and consolidating gains.

To convey the *urgency* of ground future force modernization and instill *confidence* that the Army is poised to effectively use whatever level of resources it is given, TRADOC developed the Army's Future Force Development Strategy (FFDS) The FFDS is designed to focus on urgently needed modernization, ensure fundamentally sound organizations, restore capacity required by the National Military Strategy, address policies which have created serious vulnerabilities, and deliver next generation systems which sustain qualitative advantages. Army Modernization Priorities construct is an evolution from the HQDA G8's Future Force Development Strategy (May 2017 unsigned) to deliver the joint force the Army it needs to achieve and maintain tactical overmatch, now and well into the future.

[5] Testimony at Subcommittee on Airland, Committee on Armed Services, U.S. Senate, April 5, 2016, LTG Herbert R. McMaster, Jr. Director, Army Capabilities Integration Center U.S. Army Training and Doctrine Command (ARCIC)

[6] Expeditionary maneuver is the current concept that guides how the Army organizes, deploys and employs its forces.

Chapter 2 - The Operational Environment (OE)

The future OE will be complex, dynamic, and shaped by the convergence of myriad global trends driven by social dynamics, nature, and technology. Pervasive characteristics of the OE include: increased velocity of human interaction and momentum of events; exponential growth of computing power, speed, and artificial intelligence; potential for overmatch; proliferation of weapons of mass destruction; spread of advanced cyberspace and counter-space capabilities; ease of technology transfer to state, non-state, and hybrid actors; transparency and ubiquitous media; demographics, and operations among populations in megacities, dense urban areas, and in complex terrain.[8]

Land is the most contested domain of warfare, it is where coercion or military force can bend an entity to the will of another, and will remain so throughout the 2025-2050 time frame. However, the Joint Force challenges are increasing in all other domains: air, maritime, space, and cyberspace. Many contests in other domains will ultimately be resolved on land, making it vital for Army forces to be able to respond to a plethora of threats to the Joint Force.[9] For the Army to maintain overmatch in the land domain, proficiency in Joint Combined Arms Operations and cross-domain operations is essential to ensure freedom of action in other domains by supporting the Joint Force's actions to maintain overmatch in all domains.

Major technological investments and advances by adversaries coupled with increasing varied threats present challenges to the ability of Army forces to retain overmatch through the far future. Dominance in all domains will be hard-fought and fleeting. Anticipating the demands of future armed conflict requires an understanding of continuities in the nature of war as well as an appreciation for changes in the character of armed conflict. Technological advances and changes in strategic guidance, joint operating concepts, and security challenges require the U.S. Army to innovate and adapt to ensure that forces are prepared to accomplish future missions. Shifts in the geopolitical landscape caused by technological advances and competition for power and resources influence the character of armed conflict. These

[8] Department of the Army 2014. *The U.S. Army Operating Concept: Win in a Complex World 2020-2040.* TRADOC Pamphlet 525-3-1. 31 October, pages 1-12.

[9] Ibid, page i.

shifts, and violence associated with them, occur more rapidly than in the past due to advances and convergence in technology, and the proliferation of, or access to information.[10]

Adversaries will continue to target U.S. vulnerabilities and try to negate technological areas where the U.S. has the advantage. For the foreseeable future, access to progressively more advanced technology will give adversaries increased advantages in range, inventory, precision of rockets & missiles, space capabilities; counter-precision capabilities, and an increase in the lethality within small units.[11] Where they cannot achieve a technical advantage, the adversary will rely upon the challenges posed by operations in complex terrain, like urban areas and will use innovative solutions to match or supplant historical U.S. technological advantages. The adversary may achieve this through using old technologies in new ways, converging old technologies with new to achieve a new capability, adapting commercial-off-the-shelf (COTS) technologies, or applying an emphasis on research and development to create new technologies to gain an advantage.

To maintain its competitive edge, the Army will have to invest in research and development opportunities and quickly adapt to and integrate new technologies into the operational force. The use of emerging technologies will lead to an entirely new arsenal of low cost, easily employed weapons, and lethal capabilities. However, we expect near-peer competitors to invest the same way, and will likely use, combine, modify, harness, or adapt technologies in creative ways. This creative use of technology will also give the regional actors, radical ideologues, or associated groups an asymmetric advantage through adapting or modifying advanced or readily available commercial technologies.

To effectively meet the operational challenges and emerging threats in 2025, the Army must develop future capabilities, to include the ability to operate freely in the electromagnetic spectrum, maintaining secure, reliable communications and accurate position navigation and timing (PNT) capabilities. The Army must develop advanced protection systems to protect and defend ground platforms. Conversely, to defeat progressively more technologically advanced threat protective systems, the Army must be prepared to advance the capabilities and employment of directed energy weapons along with enhanced conventional capabilities. Future Army forces will project power by applying cross-domain capabilities from land to create synergy across all domains, ensuring Joint Force freedom of movement and action. In addition to working throughout multiple domains, the Army will have to develop effective capabilities to: protect friendly forces, information, and systems; detect adversary threats; react to indications and warnings, and restore capabilities when challenged by adversary systems or tactics.

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[10]ibid, pages 1-12.

[11] Portions of this paragraph were extracted from: Joel Lawton and Phillip Serpico. 2015 “Net Assessment: Threats to Future Army Acquisitions.” Small Wars Journal. (10 October). http://smallwarsjournal.com/jrnl/art/net-assessment-threats-to-future-army-acquisitions

Chapter 3 Multi-Domain Battle

Multi-Domain Battle (MDB)[12] is a rapidly maturing concept to deal with the problems posed in the OE, and captures how the Army could operate and fight in the future against a peer adversary. The MDB concept is threat-based and provides both a framework and an approach for meeting the demands of a lethal, competitive, and contested environment. MDB anticipates new technologies and methods to apply them, available to both capable adversaries and friendly forces. The concept proposes ways to leverage those emerging technological opportunities to defeat aggressive actions short of armed conflict, deter armed conflict, and sustain a favorable security environment.

Employing combined arms principles to create and exploit temporary windows of advantage across all domains is a prerequisite for effective maneuver on the modern battlefield. Decisive combined arms action requires convergence of capabilities to counteract adversaries' strengths while creating and/or exploiting adversary vulnerabilities in one or more domains. MDB evolves current Joint and Service doctrine, placing greater emphasis on space, cyberspace, electromagnetic spectrum, the information environment, and the cognitive dimension of warfare. MDB allows U.S. forces to outmaneuver adversaries physically, virtually, and cognitively. It provides a flexible means to present multiple dilemmas to an enemy by converging capabilities from multiple domains to create windows of advantage enabling friendly forces to seize, retain, and exploit the initiative to defeat enemies and achieve campaign objectives. The key ideas are: Force Posture, Resilient Formations, and Convergence.

Force Posture. MDB requires the calibration of forward presence, expeditionary forces, and integration of partner capabilities to deter an adversary and if required, to defeat it within days and not months. Forward presence is essential to thwarting an adversary's unconventional warfare and information warfare efforts, deterring in the competition phase and when required defeating a threat's conventional campaign thus preventing the fait accompli. Forward stationed or deployed forces must be capable of immediately turning spaces the threat intends to deny friendly freedom of action in and make them into contested spaces by attacking critical vulnerabilities in the enemy's

[12] Multi-Domain Battle: Combined Arms for the 21st Century White Paper (draft)

forces across all domains. Expeditionary forces (to include strategic strike capabilities) that can respond rapidly to reinforce forward presence and partner forces are essential. They must have the expeditionary capacity to maneuver directly from home station into battle because (lethal and non-lethal enemy fires will contest strategic and operational maneuver and prevent reception, staging, and onward movement activities.

Resilient Formations. Sophisticated adversaries will attempt to isolate and defeat friendly forces through their ability to contest the Joint Force in all domains. MDB requires resilient formations capable of conducting semi-independent maneuver throughout the depth of the battlefield from any location in the world to the point of conflict. Resilient formations avoid detection and survive contact with the enemy; train intellectually and are equipped technically to execute mission command in degraded conditions; and maneuver and fight for periods without continuous supply lines or secured flanks. Army forces contribute to solving operational problems outside of the close fight by accessing and contributing capabilities which enable and exploit friendly capability convergence across all domains.

Convergence. Converging capabilities to create windows of advantage across multiple domains enable the Joint Force to maneuver. This requires a sophisticated understanding and coordination of actions across time for a wide variety of capabilities originating from all areas of the battlefield. Commanders must have the ability to identify enemy vulnerabilities, understand, and converge employment of organic and partner capabilities, and verify when windows of advantage exist.

The key to achieving the goals of MDB requires the execution of the Army Modernization Priorities, which are:

Long Range Precision Fires. In order to provide mobile, operational-level kinetic and non-kinetic strike options to restore overmatch, improve deterrence, and disrupt A2AD on a contested and expanded battlefield.

Current fires capabilities reflect obsolete assumptions of guaranteed air and maritime supremacy. Compared to potential adversaries, the U.S. Army is at a disadvantage in the range, quantity, and effects of fires. Ground forces require an increased capability to support maneuver that previously was targeted by the other Services.[13]

[13] Mark Gunzinger and Bryan Clark, Winning the Salvo Competition: Rebalancing America's Air and Missile Defenses (Washington, DC: Center for Strategic and Budgetary Assessments, 2016).

Long Range Precision Fires encompass both lethal and non-lethal effects against targets in all domains (air, land, sea, cyber, and space) from the land domain at increased range, with greater effect, and in spite of attempts to disrupt cyber, electro-magnetic spectrum, or space systems. With improved missiles and munitions, launchers already in use are capable of increased range and effect against multi-domain targets. To shape terrain and deny enemy access to mobility corridors, the Army should continue to develop future munitions capable of delivery in deep, mid and close ranges to maximize the effects of joint fires.

Development of multi-purpose sensors for Long-Range Precision Fires and air-delivered electronic warfare to include anti-ship capabilities will create temporary windows of domain superiority to enable freedom of maneuver.

Next Generation Combat Vehicles. In order to develop replacements for current tanks and infantry fighting vehicles and develop purpose-built unmanned vehicles that realize weight, sustainment, and cost-per-unit savings. This will increase the capability of our existing formations and improving our ability to survive and win on an intensely lethal and distributed battlefield where all domains are continually contested.

Combat vehicles are critical to mission success across the range of military operations and require improvements in lethality, mobility, and protection of combat units. The Army must develop solutions for combat vehicle modernization. Future platforms must incorporate new weapons with greater range and utility in urban environments, smaller size to allow better maneuver in restricted areas, reduced fuel and bulk ammunition consumption rates, and integrated active protection combined with advanced material armor. The active protection systems required to survive on today's battlefield are most effective when integrated into the basic vehicle design.

The Army needs to invest in S&T for advanced materials and to investigate the basic design characteristics for the next generation of combat vehicles to yield improvements in size, weight, power, and maintainability. A new design must be optimized for operations in urban areas and provide 360-degree protection from shaped-charge weapons. New vehicles should incorporate emerging technologies such as networked targeting systems, directed energy weapons, semi-autonomous wingman teaming, and increased-range munitions. Determining which capabilities should be included without incurring undue technical risk requires careful analysis. The Army will

apply the lessons from the Future Combat System program, particularly the need for periodic reevaluation of key assumptions and the reappraisal of performance, cost, and risk.[14]

The employment of Robotic and Autonomous Systems (RAS). Just as RAS are transforming the private sector, these fields have the potential to transform many aspects of military operations. The Army must keep pace with developments in this area to maintain tactical overmatch as potential adversaries are aggressively conducting research into potential military uses of RAS. The use robotics for reconnaissance, obstacle breaching/reduction, Counter-Improvised Explosive Devices (CIED), and transportation. In fields such as explosive ordnance disposal or Chemical, Biological, Radiological, and Nuclear (CBRN) operations, RAS can protect the force by increasing stand-off in high threat scenarios.

Artificial intelligence will reduce the cognitive load on Soldiers through the collection, organization, and prioritization of data. Future armed ground and air combat vehicles with reduced signatures and significantly greater endurance than manned platforms will provide commanders with more options by conducting reconnaissance into the most lethal areas of enemy combined arms defenses.

Autonomous transport vehicles and aircraft will lighten the Soldiers' load and increase the throughput and efficiency of supply distribution. Sustainment forces will conduct convoy operations employing manned-unmanned teaming (MUM-T) techniques with ground transport vehicles. Additive manufacturing capabilities will allow units to make repair parts in forward areas.

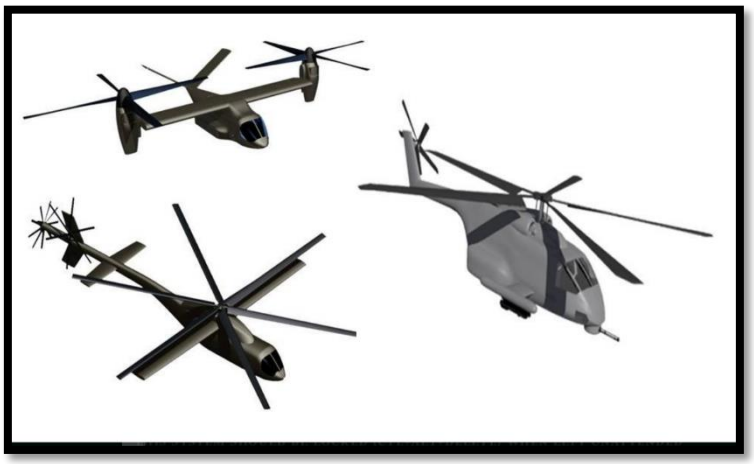
In the far term, the Advanced Threat Detection System (ATDS) improves upon current systems to rapidly develop countermeasures for each type of threat missile. ATDS is a universal detection capability that can detect, track, and cue defeat countermeasures against any incoming threat regardless of seeker type or guidance algorithm. The Modular Active Protection System (MAPS) initiative will provide a standardized architecture to allow the rapid integration of multiple types of sensors and kill systems as technologies and funding become available.

Future Vertical Lift (FVL). In order to develop replacement aviation platforms that includes unmanned/autonomous attack, reconnaissance, and utility/MEDEVAC

[14] Christopher G. Pernin, et al, Lessons from the Army's Future Combat Systems Program (Santa Monica, Calif.: RAND Corporation, 2012).

capabilities with extended range and station time to operate on an intensely lethal, distributed and expanded battlefield and continually contested air domain.

FVL family of systems (lift, attack, and tilt rotor) will apply emerging technologies across several variants to improve operational performance in every aviation mission: reconnaissance units can cover a greater area; attack units can take advantage of fleeting opportunities and respond more quickly to friendly units in need; transport units can move larger forces further and faster to more rapidly build combat power on the objective area; medical units can move casualties over greater distances within the "golden hour" of life-saving treatment. FVL will also incorporate the characteristics and design features necessary for operations in a contested environment.



Developments in helicopter design expect to offer vast improvements in every aspect of performance. Advanced materials will allow increased strength and reduced weight. Computing capability will allow more efficient and effective designs, while improving flight performance. New manufacturing processes combined with better materials yield engines with significantly better performance at the same or reduced weight. Sensors will enable improved threat detection, operation in degraded visual environments, and monitoring the wear of parts. Additionally aircraft need to be equipped with similar advanced protection as addressed in Combat Vehicles.

Network / Command, Control, Communications and intelligence. In order to effectively wage the ISR, Joint, fires, and sustainment fights to retain and exploit the initiative against a peer military adversary in an inherently contested cyber and electromagnetic environment.

The Army must have uninterrupted mission command to support expeditionary maneuver. Adversaries have observed that the key to their success is to disrupt the integration and synchronization of our Joint force and they have invested heavily in their own space, cyberspace, and electronic warfare capabilities. The Army requires advanced capabilities across all of these functions to prevail in the future operational environment.

The Army's Mission Command Modernization Strategy consists of three lines of effort. The first line of effort creates the single, end-to-end network framework described in the Mission Command Network Vision. The second is the Common Operating Environment and Interoperability that creates highly interoperable mission command applications for the full range of unified action partners, sharing information both horizontally and vertically. The third line of effort is Command Post and Knowledge Management capabilities that enable the operations process and provide command post capabilities across home station, while enroute to objective areas on strategic deployment platforms, and while employed in joint combined arms maneuvers.

Similar to combat on physical battlefields, friendly and enemy forces engage in space, cyberspace, and the electromagnetic spectrum to seize, retain, and exploit an advantage.[15] The Army requires assured communications within degraded environments to enable expeditionary mission command. Sensors and precision munitions all require assured PNT within contested environments.

Improving the Army's ability to "fight in space" is vital to maintaining situational awareness on the battlefield, communications between widely dispersed units, and the ability to navigate and strike the enemy with precision. With adversaries possessing the ability to degrade U.S. space-based capabilities, the Army needs to mitigate vulnerabilities in current systems, while designing more resiliency into future systems.

In contrast to some adversaries, the Army's ground forces have limited organic capability in cyberspace and the electromagnetic spectrum. To fight and win across the electromagnetic spectrum, the Army requires advanced signals intelligence and multifunctional electronic warfare systems and electronic warfare planning and management tools. These systems will provide a common understanding of the "electronic battlefield" to enable commanders and staffs the ability to plan, detect, defend, and attack. In cyberspace, Army forces need access to critical data and information networks, while enabling successful defensive and offensive cyber operations.

[15] John Stillion and Bryan Clark, What It Takes to Win: Succeeding in 21st Century Battle Network Competitions (Washington, DC: Center for Strategic and Budgetary Assessment, 2015).

Short Range Air Defense (SHORAD) / Air and Missile Defense: In order to Restore overmatch and survive and operate within sophisticated A2AD where all domains are continually contested.

In air defense capability, emerging technologies are required to improve protection for the Joint Force and friendly populations and infrastructure against manned and unmanned aircraft, cruise missiles, rockets, conventional artillery, and mortars. The same capabilities would be able to assist the Air Force and Navy in unlocking the web of anti-access /area denial systems with less risk to their platforms.

Long-term solutions need to regain superiority in fires. Combat units need mobile tactical air defense systems. Improved propellants, munitions, and launchers are required to achieve greater effects and longer ranges with indirect fire assets. Critical fixed sites must have cost-effective protection against enemy missiles through emerging technologies such as high-energy lasers.

Soldier Lethality. In order to improve Soldier and small unit performance, survivability, and lethality in close combat on an intensely lethal and distributed battlefield.

Soldiers and squads are the foundation of the decisive force. They must be organized, equipped, and trained with superior lethality, situational awareness, mobility, and protection that provides the overmatch required to defeat capable and determined adversaries in complex operational environments. New capabilities must enable freedom of action, permitting ground forces to seize positions of relative advantage and control key terrain to consolidate gains.

For Soldiers, squads, and teams to succeed in the current Operational Environment, modernization efforts must enable four key tasks: Conduct tactical fire and maneuver during combined arms dismounted and mounted operations; Move to decisively close with and destroy the enemy under restrictive terrain; Connect small unit leaders to the Army's Mission Command network; and Tactical transport and maneuver of dismounted and mounted elements over widely dispersed areas.

Squad lethality must improve, particularly from close range through 1,200 meters. Fire control systems that compensate for individual aiming error, improved weapons sights, and enhanced night vision goggles will greatly improve the lethality of the individual Soldier and provide overmatch in close combat. Improved counter-defilade and target acquisition technologies will reduce engagement times and Soldiers' exposure to enemy direct fires.

Excessive physical burdens imposed by organic materiel systems impact Soldiers' ability in movement as well as tactical fire and maneuver. Modernization must enhance small unit mobility by reducing Soldier loads.

Mission Command network capabilities must provide simple and integrated Mission Command, a comprehensive common operational picture, and support for mission planning and rapid execution within the commander's intent.

Human performance, leader development, and training capabilities are also critical components in achieving Soldier and Team Overmatch. S&T efforts need to understand performance requirements at the individual and small team level, the complex sets of knowledge, skills, abilities, and other attributes necessary to enable that performance, and the most effective ways and means to develop those characteristics. Soldiers and squads require a training environment that replicates the complexities and ambiguity of the OE. Future training capabilities must be readily available anytime, anywhere and provide the required repetition and rigor to build mastery of both fundamental and advanced warfighting skills. Adaptive training systems need to personalize the learning experience with tailored feedback and instruction while reducing overhead.

Chapter 4 - Aviation Center of Excellence (ACoE) S&T Needs

The Aviation S&T strategy seeks to achieve and sustain an Army Aviation force, underpinned by fully trained, agile, and adaptive leaders and Soldiers, that possesses the reach, protection, and lethality to achieve overmatch and consolidate gains regardless of conditions. As a foundational component of the AOC and asymmetric capability for the Nation, Army Aviation is fundamental to enabling how the Army operates as part of a joint, inter-organizational, and multi-national team. In order for Army Aviation formations to achieve overmatch in warfighting skills, they must be fully trained and proficient in the use of their equipment. To achieve this goal, there must be innovative training solutions in the institution, combat training centers, and at home station that maximize every training opportunity to ensure we are able to train the way we fight.

a. The following list reflects the ACoE's prioritized capability needs and a list of identified technologies.

1). Range, speed, payload, and capacity consistent with maneuver force lift demands, mission needs over an expanding area of operation (AO) and minimal reliance on: forward arming and refueling points that are logistically intensive, reduce Aviation responsiveness, and create force vulnerabilities.

2). Pilotage systems that improve safety and capability to launch and operate effectively in degraded visual environments. Critical technology development efforts coupled with

technologies to defeat advanced man portable air defense system (MANPADS) threats.

3). Multi-purpose weapons capable of lethal and non-lethal options with reduced weight and increased lethality that are compatible with the needs of both manned and unmanned platforms.

b. The following overarching technology thrusts provide guidance to S&T efforts intended to support fielding capabilities for the far-term (beyond 2025):

1) Develop technologies that enable FVL mission systems architecture technologies and assured communications.

2) Develop technologies that enhance Aviation Armament Architecture technology to support two-way on-board communication with “smart” munitions and integration of future weapons.

3) Develop technologies that significantly reduce cognitive loading and ease of human/machine interface, improving crew efficiency and effectiveness and reducing the training burden.

4) Develop technologies that support highly-reliable designs, optimize selection of maintenance approaches, and reduce overall operating and support costs; and technologies that move beyond traditional turbo-shaft engine and power transmission architecture to reduce dependencies on fossil fuels.

5) Develop improved capabilities to operate in degraded and denied GPS, EW and cyber threat environments.

6) Develop technologies to allow UAS to launch and recover from confined areas during sea basing for future UAS.

Chapter 5 - Training / Combined Arms Center – Training S&T Needs

The Future Force requires a robust, realistic, and adaptable training capability to rapidly develop or adapt Army Training and Education (T&E) to meet the needs of a complex and ambiguous future operational environment. Training and education are not mutually exclusive. Virtually all military schools and professional development programs include elements of education and training in academic programs. Achieving success across the learning continuum relies on close coordination of training and education to develop synergies as personnel develop individually over time, acquiring and performing progressively higher order skills and responsibilities. In order to meet the training demands for Future Force, the Army requires a training environment that is adaptive, supports increased repetition, is low overhead, and available at the point of training need. Soldiers and units require a training environment that replicates the complexities and ambiguity of the OE that are readily available based on an ever changing mission set. The Synthetic Training Environment (STE) is the Army's future collective training environment that supports Multi-Domain Battle training needs. It will provide Soldiers and units with enhanced, realistic training in a challenging and dynamic simulation of the OE that is accessible anytime, anywhere.

a. In the mid-term (2030), the Army will develop a complex training environment to build cohesive teams who improve and thrive in the conditions of ambiguity and chaos. This training capability will enhance home station training and improve Soldier and unit performance by developing the following capabilities:

1) Common Synthetic Environment (CSE). The Army needs the capability to converge legacy, standalone, and simulation systems into a common, service-based, synthetic environment that trains individual Soldiers, unit and staff collective tasks and supports real-time, entity-level, low-latency simulations. This capability must support

multiple simultaneous, distributed training exercises that are scalable across the Army at home stations, reserve training locations, Combat Training Centers, and while units are deployed. It must be able to support live and synthetic exercises with the capacity to support over two million entities across multiple simultaneous running exercises. The Common Synthetic Environment must be scalable and include the simulation capability to realistically represent a complex, multi-domain battlespace of Dense Urban Terrain (DUT) that includes synthetic dynamic terrain.

2) Global Terrain. The capability to rapidly, and accurately collect, develop, digitize, store, and access detailed terrain information from a single correlated terrain database that is easily scalable from soldier level to global level views of the world. Global Terrain comprises land, littoral, and sea features; includes Dense Urban Terrain; subterranean aspects; and their associated human terrain information (i.e., Political, Military, Economic, Social, Information, and Infrastructure - Physical Environment and Time data). Research supporting future synthetic and live training systems is needed to allow these future systems to easily ingest existing military, commercial and sensor data to collect, correlate and update terrain information.

3) Training Point of Need. Future Army training requires a robust and scalable training infrastructure that can provide sufficient bandwidth and cybersecurity to transmit simulation(s) data and to provide learning services to Soldiers and units at home stations, other training locations, or while deployed. This training infrastructure must be able to provide uninterrupted training capabilities to areas with limited network availability.

4) Adaptive Learning. The Army requires that future learning be able to adapt to the learner's states and needs by adjusting the challenge level of scenarios and the amount/type of tutor support in near real time to maximize training effectiveness (e.g. performance, learning, retention, and transfer). Adaptive systems must interpret each learner's data (behaviors and physiology) to determine the learner's states (e.g. engagement, emotions, performance) and to identify individually tailored learning to meet the learner's needs.

5) Mixed Reality. The Army requires the capability of real and virtual worlds to produce new environments and visualizations where physical and digital objects co-exist and interact in real time. Mixed Reality is the umbrella term to describe the

spectrum of immersive graphic presentation technologies spanning Virtual Reality, Augmented Virtually, and Augmented Reality. Through the use of mixed reality technologies the Army intends to develop training environments that are adaptive and can represent the complexities and ambiguities of the operational environment.

6) Realistic Live Simulations. The Army requires the capability to provide live simulations that accurately replicate and realistically represent all the effects of current and future weapons systems during force-on-force and force-on-target training. This includes the capability to replicate direct, indirect, lethal and non-lethal weapons effects, at brigade and below, during live training maneuver exercises. Live training simulations must embed into future weapons systems design in order to reduce costs and overhead.

b. Beyond 2030, future Army training systems will need to accurately represent a complex, multi-domain battlespace that includes terrain, weather, urban, populations, military forces, and equipment with the following capabilities:

1) Intelligent Agents and Tutors using Artificial Intelligence. In order to reduce overhead costs in future simulations, training development, and instructions, the Army will need highly intelligent, cognitive agents, tools, tutors and intuitive processes that can rapidly develop, produce and update training content, program of instruction, and training exercise planning and execution. These agents and tutors must have human-like cognition and behaviors with the ability to reason, learn, and adjust to their human counterparts. Future training simulations will also require intelligent, simulated actors, agents and tools that provide increasing sophisticated simulated combat capabilities, techniques and strategies that can adjust the training complexity to meet the user's training needs.

2) Virtual humans must be capable of supporting natural language processing to enable interactions (verbal and non-verbal) between humans and computer generated forces in the STE and distributed learning environments. A virtual human must be able to reason and make assumptions in order to provide realistic human interactions with the training audience. Virtual humans must be able to replicate human behaviors (ethnicity, language, religion) and mirror the demographics found in dense urban terrain.

3) Training Effectiveness. The Army requires the capability for continuous assessment of the effectiveness of simulation-based training by developing metrics for evaluating unit and team performance in collective training exercises.

4) Holographic Imagery. Future Army training will require the capability for standalone holographic imagery for targets that can be used indoors and outdoors, in various environmental conditions (e.g. weather, daylight/night, etc.), and that stimulate operational systems' sensors.

Chapter 6 - Cyber Center of Excellence (CCoE) S&T Needs

The following represents the priorities of the U.S. Army Cyber Center of Excellence (CCoE) for adaptive capabilities that ensure the security of Department of Defense Information Network – Army (DODIN-A) while increasing the capabilities for cyberspace operations. The Cyber and Electronic Warfare (EW) systems used by the Army to conduct Mission Command, Maneuver, Maneuver Support, Medical Support, Intelligence, Sustainment, Fires, and National-Strategic operations require investments in both basic and applied research in cyberspace and electronic warfare capabilities to better enable Soldiers, Commanders, and National Agencies in the execution of their Cybersecurity missions. Cybersecurity, "the Network", and providing information to the point of need are recurring themes throughout many of the Army's first order analytical problems codified as an Army Warfighting Challenge (AWFC). The focus on these technology investment areas will position the Army for the future and are crucial to the successful execution of efforts within Multi-Domain Battle concept. Based on the AOC Science and Technology objectives outlined in Appendix C "Science and Technology".

a. The following reflect the CCoE prioritized capability needs for the mid-term (2025):

1). Integrated Electronic Warfare. With the rapid pace at which wired and wireless technologies evolve and the Army's dependence on these technologies, it is essential to establish common development baseline for operational EW capabilities. Fully integrated EW capabilities will provide an offset as potential adversaries' transition towards advanced EW threat techniques.

2). Enhanced Spectrum Management Operations (SMO). SMO are the interrelated functions of managing electromagnetic spectrum resources, frequency assignment, host nation coordination, and monitoring of spectrum management policy that together enable the planning, management, and execution of operations within the electromagnetic operational environment during all phases of military operations. Technologies supporting SMO will enhance convergence and network

management activities.

3). Cyber Situational Understanding (Cyber SU). Cyber SU is development occurs through a family of interactive, interoperable, and critical technologies that facilitate maneuver planning, collaboration, and synchronization through integration with commander's user-defined Operational Picture. The fielding of Cyber SU comes within the Army's Command Post Computing Environment, establishing a framework to integrate fielded and emerging cyberspace capabilities into combat operations.

4). Future Waveforms. To bring cyberspace operations to the tactical edge, the Army must develop and implement upgrades to tactical networking waveforms in order to increase capacity, flexibility, robustness, and simplicity of operations. The waveform(s) must provide high throughput (data rates that support tactical requirements) to users within a tactical area of operations and utilize advanced Low Probability of intercept \ Detect \ Exploit technologies.

5). Hardware Software (HW/SW) Convergence. Develop and implement HW/SW standards that enable collapsing multiple Mission Command, Intelligence, and Electronic Warfare systems and functions into a common chassis with synchronized and concurrent operation. This capability allows synchronized multiple use of antennas, reduce the amount of cabling and connections required, and generally reduce the size, weight, and power required for mounted and dismounted Cyberspace Operations.

b. The following reflect the CCoE's prioritized capability needs and potential technology candidates for the far-term (beyond 2025):

1). Autonomous Active Cyber Defense. Develop systems which provide the ability for autonomous network defense through a collection of synchronized, real-time capabilities to discover, define, analyze, and mitigate cyber threats and vulnerabilities without direct human intervention. This capability includes sensor-based artificial intelligence that learns and manages all network topologies.

2). Defensive Cyber Operations (DCO). This group of technologies provides the ability for the network to absorb the shock of a cyber-attack, identify adversary actions, respond with pre-determined actions, and ensure mission continuity. The Department of Defense Information Network Army (DODIN-A) will assess, compose, and deploy cyber elements with known and predictable confidence in their identity, functionality, and content. The Army leverages an integrated joint and holistic industry approach to develop secure systems that can adapt and maneuver

automatically to reduce, counter, and evade cyber-attacks. Capabilities associated with DCO support and enhance Cyber Situational Understanding efforts.

3). Autonomous Cognitive Radio Frequency (RF). A capability that provides a fully adaptive and reconfigurable RF architecture that is agnostic to waveforms and standards. Radios will have a cognitive capability to operate in any frequency band with any modulation using multiple access specifications, depending on the restrictions of the environment and overall EM operating conditions.

4). Assured PNT. Assured PNT is a cross cutting capability that provides access and integrity to PNT information in Global Positioning System denied environments. Assured PNT focuses on providing resilient, robust PNT in a scalable architecture that can span various levels of protection, or PNT assurance levels. As technological threats increase, Assured PNT will focus on developing a resilient PNT capability the Army can confidently rely on.

5). Communications under Extreme RF Conditions. Provide technologies and techniques that address communications in severe jamming and adapt to various jamming and interference sources. The technical objective is to innovate and integrate capabilities through all domains for adaptive interference suppression. This technology development phase will establish relevant technologies appropriate for the constraints and typical missions of various platforms

Chapter 7 - Fires Center of Excellence (FCoE) S&T Needs

Fires S&T needs derive from the AOC, both the Fires and Movement and Maneuver Functional Concepts, the Capability Needs Analysis, Army Warfighting Challenges, and are consistent with the FY16 FCoE prioritized S&T Needs Memorandum. In multi-domain battle, future Army Fires forces must provide precise, responsive, effective, and multifunctional fires to enable maneuver forces as they fight across contested spaces to maintain overmatch in seizing, retaining and exploiting the initiative. This complementary relationship between fires and maneuver is the foundation of multi-domain battle. This rapidly evolving relationship is the driving force behind Fires S&T needs priorities of Cross Domain Fires, Future Combat Vehicles, Expeditionary Mission Command, Cyber Electromagnetic Activities, Directed Energy Weapons, Counter Unmanned Aerial Systems, Robotics/Manned-Unmanned Teaming, and autonomous Fires formations. Fires superiority and overmatch will depend upon the timely delivery of effects against targets across all domains. Current Fires forces focuses are on the ground and air domains. Fires S&T Needs shall expand this aperture to include maritime, space, cyberspace, and the electromagnetic spectrum. Future Fires systems, shooters, and mission command must support target identification, discrimination, de- confliction, and airspace control across all domains and quickly deliver precise capabilities with scalable effects on targets the first time.

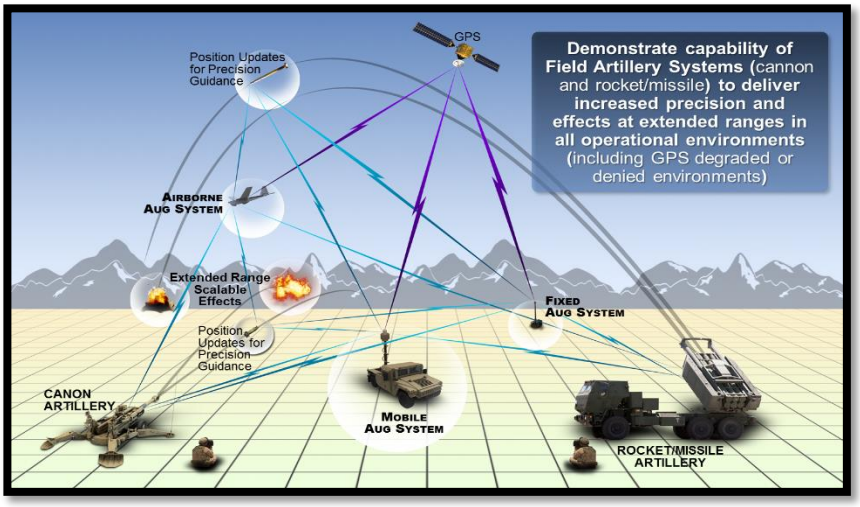
a. The following reflect FCoE's prioritized capability needs and potential technology candidates for the mid-term (2025):

1). The Army's CNA identifies a gap in the Army's ability to defend critical assets against Theater Ballistic Missiles (TBM), Rocket, Artillery and Mortar (RAM), Unmanned Aerial Systems (UAS), Cruise Missiles (CM) and aerial threats. Due to this identified gap, efforts are underway to introduce improved 360° capability to the current Air and Missile Defense (AMD) portfolio.

2). Enemy indirect fire systems out-range U.S. artillery; which limits our ability to

engage targets at extended ranges. Current DOD Cluster Munition Policy (dated 18 Jun 08) eliminates the use of existing cluster munitions after 31 Dec18; degrading the Army's ability to provide area effects against imprecisely located and armored targets. New and innovative S&T efforts must lead to fielding systems and munitions in sufficient quantities to underpin the risk area of fires munition cost equations against inexpensive highly proliferated adversarial threats. In addition, future fires systems must deliver sufficient lethality and massed area effects, resulting in fires forces overmatching threat fires capabilities. The Army needs to attack enemy high value targets protected by air defense systems, electronic guidance jamming and manipulation systems, directed energy systems and nonlethal countermeasures.

3). Fires Sensors (both Field Artillery and Air Defense Artillery) require the ability to conduct both air surveillance and counter fire roles to provide flexibility to the commander and must provide persistent, integrated, all-weather, ubiquitous support in multi-domain battle. Fires organizations will move to five radars in the mid-term and fires strategy envisions further consolidation of air defense artillery and field artillery radars to increase operational flexibility, efficiency, and expeditionary capabilities. This includes operating on the ground or elevated and conducting operations in the land, air, maritime, space, and cyberspace domains. The Army envisions future sensors fusing data from all joint, national, multinational, and commercial sensors from space to subterranean.



The Army's goal is real time integration and targeting data optimization with category 1 coordinates for a range of field artillery applications and fire control quality data for AMD applications. Additionally, Fires Sensors require electronic protection to ensure our ability to integrate and deliver fires as adversaries develop electronic attack capabilities.

b. The following reflect the FCoE's prioritized capability needs and potential candidate technologies for the far-term (beyond 2025).

1). Next Generation Sensors. The Army's vision is to achieve real time integration and optimization of targeting data for a range of fires applications while minimizing the numbers of sensors required on the battlefield. The Army envisions future sensors fusing data from all joint, national, multinational and commercial sensors from space to subterranean to achieve real time integration and optimization of targeting data with category 1 coordinates for a wide range of Field Artillery applications and fire control quality data for AMD applications.

2). Next Generation Shooters. Mid-term investment strategy leans towards consolidating platforms to support joint combined arms operations. In the far-term, the Army sees developments in multifunctional platforms and common missiles and rockets across fire support and Air and Missile Defense (AMD) applications. The Army will leverage and support emerging advanced technologies such as directed energy, electro-dynamic kinetic energy weapons, and hypervelocity projectiles to achieve scalable effects. The Army will leverage robotics to support manned and unmanned platforms enabling the return of additional artillery pieces to the force structure mitigating unfavorable threat indirect platform ratios and improving our expeditionary capability.

3). Next Generation Mission Command. The Army envisions one information system that enables Fires Forces to plan, prepare, and execute fires in real time and in all domains. The future Army information network must provide decentralized network structure, automated battle management aids, fused sensor data, targeting assistance, and fire control quality of service. Ultimately, the goal in the far-term is to achieve a single fires mission command system with the capability to support future multifunctional Joint Inter-organizational / Multi-national (JIM) weapon systems.

Chapter 8 - Human Dimension Division (HDD) S&T Needs

Human Dimension (HD) science and technology (S&T) priorities are intended to Inform S&T efforts and to influence resource decisions. In addition, the Army Human Dimension Strategy incorporates three research and analysis supporting objectives to achieve the vision of optimizing the human performance of every Soldier and Civilian in the Total Force and building cohesive teams of trusted professionals. These priorities are outcome-based and descriptive in nature to allow for maximum flexibility in meeting the requirements. Faced with a complex future operational environment, changing fiscal realities, and continuous engagement as part of unified land operations, the Army will require enhanced capabilities in the cognitive, physical, and social components of the Human Dimension. These capabilities are necessary to shape the environment, prevent conflict, and when required, win the Nation's wars in the strategic environment of 2025 and beyond. There is a pressing need for progressive scientific research in the biological, social, medical, and behavioral sciences, which has been coordinated with Human Dimension related experimentation, and studies designed to determine the kind of human capabilities the future Soldier will need to win in a complex environment. Listed below are prioritized S&T needs that can make a significant contribution.

a. The following reflect HDD's prioritized capability needs and potential technology candidates for the mid-term (2025):

1). Talent Management-Accession. The capability to match Army Professionals to the correct MOS/Branch/Career Program much of the time to meet mission

requirements and promote individual and team success through their identification and accession based on proper evaluation of innate and learned skills, knowledge, personality attributes, cognitive, physical, and social (CPS) abilities and potential.

2). Talent Management-Identify Leaders. The capability to measure and track cognitive, physical and social (CPS) potential, and performance indicators through the Soldier and Civilian career life cycle to identify high potential leaders to promote individual and team success.

3). Talent Management. The capability to manage individual talent throughout the life cycle where expectations, job satisfaction, and success are unclear much of the time, through an integrated approach of recruiting, accessions, retention, professional development, and assignment strategies to ensure optimal performance of all members of the Army profession.

4). High Risk Soldiers and Predict Destructive Behavior. The capability to identify high risk Army professionals and predict self-destructive behavior much of the time to enable leaders to manage these high risk personnel using available human resource and other mitigating support resources.

5). Character and Army Ethic. The capability to identify attributes of character and to assess the success of efforts to develop character so that Army professionals consistently demonstrate their commitment and resilience to live by and uphold the Army ethic throughout a career life cycle.

6). Holistic Health & Fitness. The capability to improve and maintain holistic health and functional fitness to optimize individual and team performance. The goal is to reduce the rates of Soldiers non-deployable for medical reasons and reduce the rate of attrition of first term Soldiers.

7). Team Building. The capability to quickly form, enrich and sustain cohesive teams of modular Army forces and Joint Inter-organizational / Multi-national (JIM) partners

that trust in each other and encourage the exercise of initiative consistent with the philosophy of mission command.

8). Enhance Readiness/Resilience. The capability to enhance individual and unit readiness/resilience in order to resist the negative effects of prolonged exposure to stress so that 80 percent of personnel demonstrate interpersonal adaptive thinking, interpersonal problem solving, and coping skills in order to maintain individual and unit effectiveness.

9). Transition Science and Technology. The capability to field 80 percent of required cognitive, physical, and social enhancements to improve Soldier/team performance within seven years of requirement endorsement.

10). Communications. The capability for Army professionals to communicate clearly and concisely using written communications, oral communications, and social networking skills that effectively meet their job requirements.

11). Develop Subordinates. The capabilities for Army Leaders to coach, counsel, mentor, and advise their subordinates as part of their required supervisory responsibilities.

12). Human Dimension Concepts and Requirements Development. The capability to develop a commonly understood detailed concept and requirements for Human Dimension that addresses its broad scope, the wide range of stakeholder interests, the difficulty in Human Dimension experimentation and complexity of the Human Dimension of Army operations.

13). Human Dimension Capabilities Development. The capability to effectively and efficiently develop and field integrated Human Dimension DOTMLPF-P capabilities using an institutionalized management process that can address the broad scope and complexity of human dimension Army functions, and synchronize the wide range of stakeholder interests.

Chapter 9 - Health Readiness Center of Excellence (HRCoE) S&T Needs

This represents the Medical Functional lane's prioritized capability needs for the future, and technology candidates that may deliver those capabilities. The purpose is to codify the Medical priorities to inform science and technology efforts, and to influence resource decisions. The following capabilities reflect the HRCoE prioritized needs and potential technology candidates for Force 2025B:

a. Enhanced Combat Casualty Care. This suite of advanced medical technologies improves combat casualty survival from the point of injury through enroute care to definitive care and rehabilitation, while reducing the size of the in-theater medical/trauma care footprint.

1). Mid-term technology candidates include endovascular stabilizing capabilities, blood products used for resuscitation, hemorrhage control, burn wound repair / scar mitigation, and a portfolio for future vertical lift platforms with medical equipment that will provide life support to casualties during air medical evacuation. Armored Multi-Purpose Vehicles will provide ground evacuation and medical treatment capabilities far forward on the battlefield.

2). Far-term technology candidates include in vitro-derived (artificial) blood, development of metabolic depressant drugs to stabilize and protect vital organs and tissues during periods of prolonged holding and/or transport. During periods of prolonged field care, virtual health will support medical personnel through mentoring and robotic surgery. Additive printing will create tissues and surgical instruments.

b. Infectious Disease Countermeasures. Infectious disease represents a significant threat to military forces with the potential for significant operational impacts. As new infectious diseases emerge and their identification occurs by the scientific community, medical countermeasures need development to enhance unit readiness and Soldier performance. Prevention of disease through vaccination will substantially reduce the prevalence of disease non-battle injury.

1) Mid-term technology candidates include vector control measures, chemotherapeutic drugs, and vaccines for dengue, leishmaniasis, diarrheal diseases and drug resistant malaria. Developing biologics that act synergistically and/or complimentary to antibiotics.

2) Far-term technology candidates include hyperactive stimulation of an individual's immune system to improve resistance to diseases and drugs that overcome and counter antibiotic resistance mechanisms.

c. Optimize Health and Performance. Incorporate new technologies pushed forward on the battlefield to small units, battalion aid stations, Forward Surgical Teams/Forward Resuscitative and Surgery Teams, and Combat Support Hospitals/Field Hospitals to increase treatment capabilities. This capability enables more accurate decisions about whether a Soldier with mild traumatic brain injuries (TBI) or post-traumatic stress disorder (PTSD) are returned to duty or requires evacuation.

Included in this capability is the development of therapies and resilience strategies to improve recovery from TBI and PTSD. There is an ongoing development for the use of biomarkers to provide rapid diagnosis of PTSD in austere environments. Also included is optimizing mental acuity during continuous and sustained military operations and optimizing Soldier performance in harsh environmental conditions such as high altitude and extreme heat and cold.

1). Mid-term technology capabilities include concussion dosimetry, nutritional supplements that speed recovery, human performance optimization to develop physical, social and cognitive overmatch, physiologic status monitoring, leader tools far forward brain function assessment, and diagnostics.

2). Far-term technology candidates include identification of biomarkers of nano-materiel exposure health effects. Use of neurotransmitters such as dopamine, serotonin, and norepinephrine to improve alertness, energy, cognitive ability, and emotional states.

Chapter 10 - Intelligence Center of Excellence (ICoE) S&T Needs

To support future Army missions in a complex threat environment, the Army must modernize its intelligence collection, analysis, and collection management capabilities. These priorities reflect the intelligence warfighting function's (IWfF) modernization requirements to support an agile, expeditionary force able to influence events in near real-time (NRT) to achieve strategic objectives.

a. The following are the United States Army Intelligence Center of Excellence's (USAICoE) prioritized near-term requirements:

1). Artificial Intelligence (AI) Capabilities to Support Analysis. AI and machine learning capabilities are required to support modern intelligence analysis. The overwhelming amount of data generated by sensors, open source data mining, the Internet of Things (IoT), and support to cyber operations requires AI and data fusion capabilities to free the analyst from performing repetitive functions and allow them to focus on the art of analysis. Areas of particular potential for AI applications include full motion video (FMV) analysis, automated target recognition (ATR) and tracking, and social network trends analysis.

2). Sensor Packages to Support Deep Fires. A system of sensors and sensor platforms capable of providing targeting support to deep fires in a highly contested A2/AD environment where current platforms cannot operate. This requirement includes, but is not limited to, quick-reaction space-based capabilities, low-cost, swarm, disposable sensors, high-altitude lighter-than-air platforms, and non-traditional unmanned aerial vehicles operating in system-of-systems approach.

3). Automation for Real-Time Characterization and Response to a Contested Electro-Magnetic Spectrum (EMS). Future adversaries will employ software defined, reprogrammable radios, radars, and wireless capabilities that will operate in different frequencies and employ agile waveforms based on real-time mission needs and conditions in the EMS. This creates an environment in which future U.S. Cyber/EW/SIGINT formations must be able to be able to sample the EMS and respond in real-time to previously unknown waveforms and enemy RF operating

modes. U.S. collection platforms must leverage computer automation enabled by emerging machine learning and artificial intelligence capabilities to sample, model, and automatically change configurations to deployed systems.

b. The following are USAICoE prioritized near-term requirements:

1). Intelligence Enterprise Architecture. A secure and robust intelligence enterprise architecture is foundational to the future IWfF. The future intelligence enterprise architecture must span sensors, platforms, organizations, Soldiers, and Commanders from maneuver squad to joint task force with appropriate applications for each. This architecture must support scaling and tailoring based on mission to enable timely processing, exploitation, dissemination (PED), shared analytics/distributed analysis, and enterprise collaboration in conditions of limited bandwidth, network outages, and sophisticated, near peer electronic warfare environments. The architecture must also be able to rapidly adopt commercial computing capabilities that exceed government solutions as well as support deployment into Area Access Area Denial (A2AD) and Degraded, Intermittent, and Limited (DIL) environments.

2). Collection Modernization. The IWfF must modernize collection capabilities to counter rapidly evolving technology. Collection modernization includes abilities to collect and process multi-discipline, multi-modal, multi-phenomena data to detect, locate, track, and understand adversary behavior, capabilities, and intentions across the range of military operations and in complex operating environments. Collection modernization extends beyond exploiting traditional data sources to capabilities to exploit new phenomena such as behavioral biometrics, social media, and the internet of things.

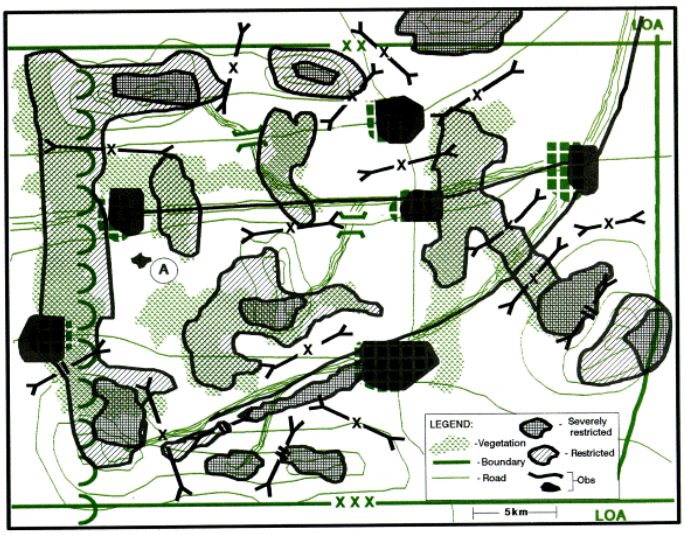


Figure 3-1-4. Mobility corridors.

3). Multi-Function Devices. The IWfF requires a multi-function device to support a wide range of multi-discipline intelligence functions at the tactical edge. This capability should allow Soldiers immediate access to the intelligence enterprise and provide the capability to transform photographs, biometrics, documents, and other sources into immediately actionable intelligence using low run-time applications to access intelligence databases.

4). Sensor Common Operating Picture. Commanders and Collection Managers require the capability to rapidly assess and re-deploy collection systems to maximize capabilities of both organic and other available assets. A Sensor Common

Operating Picture (COP) that displays the location, status, and effectiveness of organic and available systems will allow the Commander/Collection Manager to quickly re-task collection systems to maximize their effectiveness in dynamic environments.

5). Data Fusion at the Point of Collection. Future sensors and platforms must process data on-chip or on-sensor to revolutionize the speed of sensor-to-shooter kill chains, to enable real-time tipping and cueing, and to reduce size, weight, and power (SWAP) considerations.

c. The following are USAICoE prioritized deep future requirements:

1). Modeling, Simulation, and Visualization of Threat Entities and Events. The future IWfF requires the capability to rapidly model, simulate, and visualize threat and non- threat behavior, patterns of life, and potential courses of action in complex operating environments including dense urban areas. This requirement includes the ability to overlay Blue ISR capability for planning and collection management purposes.

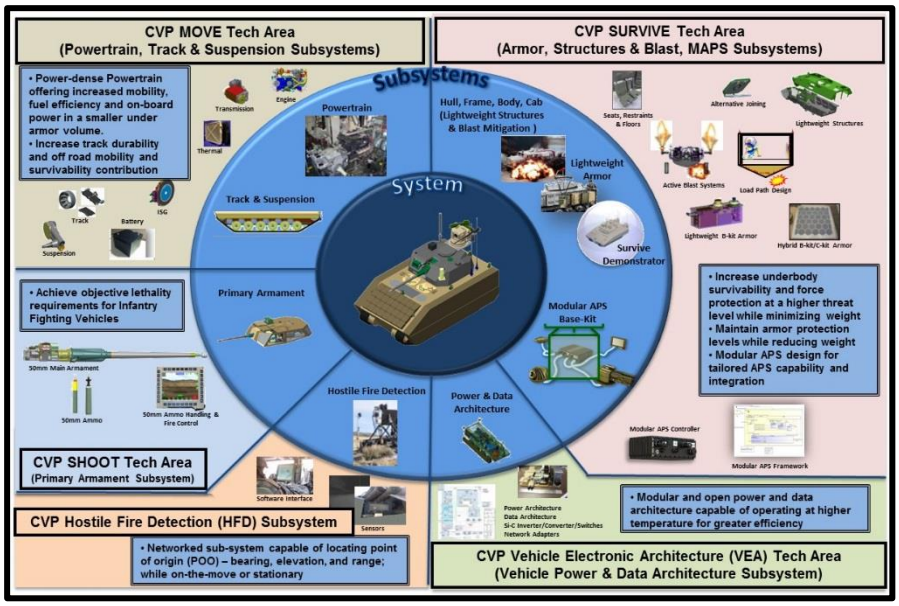
2). Globally-Integrated Knowledge Management (KM). Future KM will allow deep content understanding via ontologies, autonomous intelligent agents, and dynamic Soldier- computer collaboration enabled by heterogeneous multimedia warehouses, cross media analysis and modeling, and multi-lingual natural language queries.

Chapter 11 - Maneuver Center of Excellence (MCoE) S&T Needs

The following are the Maneuver priority recommendations for S&T to inform funding to support the development of capabilities necessary to enable the Brigade Combat Teams (BCT's), and their subordinate formations, to remain dominant.

a. The Maneuver Center's prioritized requirements for S&T for mid and far term are:

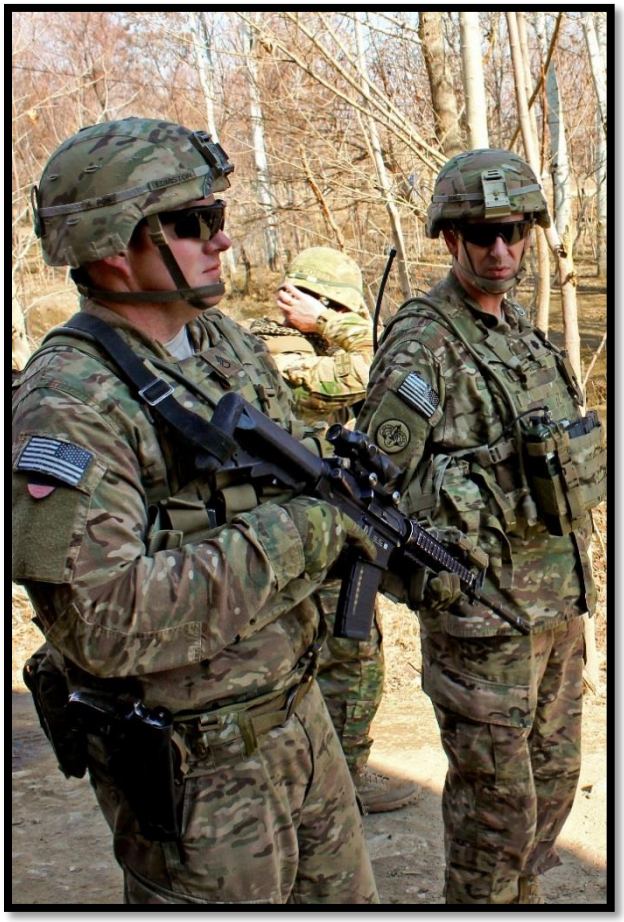
1). Combat Vehicles Modernization. Combat vehicles that enable maneuver formation freedom of movement and action, possess increased precision firepower, and operate with much reduced logistical demand are the first priority. The MCoE supports prototyping in the mid to far term to support development of the Next Generation Combat Vehicle (NGCV). Technology development must nest with the Combat Vehicle Modernization Strategy, and orient on technologies relevant to multiple platforms. The goal is to improve lethality, mobility and protection at much reduced size, weight and power demand by combining new materials such as composites, with advanced armor and active protection systems.



2). Soldier and Squad Modernization. S&T investment in this area should result in reduced cognitive and physical load for Soldiers and leaders. This investment is primarily in the following three areas: First, reduction of the physical load through lighter weight, more capable systems, and offloading through the use of technologies associated with the concept of assured resupply; Second, technologies that improve Soldiers' physical, cognitive, and social abilities. The ability of Soldiers, leaders and units to train more realistically and rehearse more thoroughly in simulated environments with mature artificial intelligence supported by augmented reality and adaptive learning systems; and, Third, technologies that increase detection, identification, and engagement with organic weapons at the Squad/vehicle crew level. Immediate, overwhelming direct and indirect precision fires is critical to win the close fight.

3). Unified Tactical Communication. The ability to access and use multiple forms of communication that provide redundant means to connect tactical formations with adjacent units, unanticipated partners, and joint forces is critical. BCT and subordinate units must have access to real time communications built upon a foundation of resilient and redundant voice, data, and position location. Resilience and trust must be an inherent attribute of the communications architecture that supports leader communications under degraded operations. Communications architecture must support the inclusion of unmanned systems.

4). Advanced Sensors. The ability to rapidly detect and identify in all domains, precisely locate and engage threats at extended ranges with greater accuracy are critical. Advanced sensors coupled with communications networks, are required for effective reconnaissance and security operations, improved situational understanding, sensor to shooter accuracy, and lethality during semi-independent operations and cross-domain maneuver. Reducing the size, weight, and power demand, while improving integration and network linkage of multiple sensors to shooters are imperative.



5). Robotic and Autonomous Systems. Improved unmanned systems with advanced autonomy need to extend the area and time over which small units can effectively operate. Operating semi-independently in potentially degraded environments requires unmanned systems that provide real time full motion video, expeditionary communication networks, extended range and lethality, and the ability to conduct swarming with advanced sensors to achieve overmatch and defeat A2/AD threats.

Chapter 12 – Maneuver Support Center of Excellence (MSCoE) S&T Needs

This chapter represents the improved capability to further enable the Maneuver Support Warfighting Function.

a. Maneuver Support improved capability for the mid-term (2025):

1). Understand the Environment. This is a set of actions applicable in all domains (land, air, maritime, space, and cyberspace). Maneuver Support forces require the ability to employ technical information capabilities leveraging the intelligence enterprise. Included is the ability to conduct terrain and infrastructure assessments, integrated early warning of security, detection at a distance of threats and hazards, understand criminal and security threats, forensics, and the collection of geospatial information to understand the physical and operational environment.

(a) Predictive modeling to assess the extent of CBRN contamination.

(b) Assessment of CBRN contamination post-employment of Weapons of Mass Destruction (WMD) or CBRN munitions.

(c) Production of High Resolution 3-Dimenstional (HR3D) geospatial products.

2). Shape the Operational Environment. Maneuver Support forces require ability to influence the behavior of the local population, the enemy, and the other actions within the operational environment; develop partner nation and friendly military capabilities for self-defense and multinational operations; and support activities to build relationships and/or partner capacity enabling peacetime and contingency access for U.S. forces worldwide. This includes the physical alteration of the terrain, coordinating effects across all domains, construction, repair, and decontamination; road, base camps and physical structure maintenance; and emplacing cross-domain obstacles and barriers.

(a) Assault gap crossings and tactical dry gap crossings to increase military load classification.

(b) Dive operations in support of wet gap crossings.

(c) Terrain shaping operations.

3). Mitigate obstacles and hazards. Maneuver Support forces require the capability to mitigate the effects of obstacles employed to impede freedom of movement. Included is the ability to detect a hazard, preferably prior to being in a blast or contamination radius. Obstacles and hazards include CBRN hazards and WMD; conventional explosive material; homemade explosives; and other forces of explosive hazards.

(a) Detainee control.
(b) Lethality to defeat and/or delay threat attacks.
(c) Combined arms breaching of obstacles.
(d) Clear areas/routes of obstacles, barriers, and explosive hazards, sometimes at maneuver speeds.

4). Enhanced Technical Protection. Maneuver Support forces provide enhanced technical protection capabilities that compliment and reinforce exiting protection capabilities. Actives include, but are not limited to, security force assistance, foreign internal defense, defense support of civil authorities (DSCA) and homeland defense.

(a) Safe engagement and large-scale elimination exploitation of WMD threats and hazards.
(b) Construction of vehicle fighting positions.
(c) Capture and disposal of hazardous waste.
(d) Subsurface detection of CBRN agents and munitions.
(e) Signature management techniques.
(f) Obscuration across the entire electromagnetic spectrum.

b. Maneuver Support improved capability for the far-term (beyond 2025).

1). Capability to conduct Area Denial Operations. While Army Forces in general are concerned with denying enemy advances, maneuver support and protection elements are concerned with denying enemy elements access to critical areas. For example, the enemy can exploit an area around a base camp to gain access to the base camp and/or disrupt base camp operations. Aerial, surface, and sub-surface delivered threats require detection and response.

2). Capability to Facilitate Austere Entry Operations. Future Army Forces will be increasingly more continental United States (CONUS)-based with projection from the perspective of maneuver as well as movement and mobility. The ability to rapidly assess, prepare, and provide multiple entry points for operationally significant forces remains critical to ensure the success of future missions. This capability allows Army forces to control effects of crises, preventing them from becoming irreversible or enduring.

3). Capability to Control/Manage Army Forces/Equipment Signature. Army Forces will continue to require the ability to 'own the day' while decreasing the enemy's probability of hit. By investing in technologies that allow commanders to employ anything from decoys and decades old obscuration to masking the heat signature from thermal viewers, technological advances are required to provide a capability that allows individuals and equipment to blend in with their surroundings like a chameleon. This potentially allows friendly forces to have the freedom to maneuver across the operating environment and increases the protective posture by minimizing the enemy's ability to detect, target and hit our formations.

4). Capability to Conduct Ubiquitous Sensing. As captured in the TRADOC Pam 525-3-4, The AOC, Future Army Forces will still need a means to detect, treat, warn, and avoid threats. The ability to detect obstacles and hazards, maintain visibility of those obstacles and hazards, and propagate the information/images/video stream across the command structure is required to help protect Future Army Forces.

5). Capability to Employ Robotic and Autonomous Systems. Leveraging robotic and autonomous systems will allow greater protection for Soldiers without hindering successful mission accomplishment. Researchers are encouraged to investigate and identify what tasks could be completed by a payload on a robotic or autonomous system and develop the capabilities.

Chapter 13 - Mission Command Center of Excellence (MCCoE) S&T Needs

S&T can be a critical enabler to assist the Army achieve the capabilities required for Force 2025 and fulfill the AOC objective of winning in a complex world. This document establishes MCCoE's priorities and serves to align S&T efforts with future capability needs. This portion highlights key science and technology capabilities to consider in mission command capabilities development. The Army works with joint partners, industry, and key stakeholders to develop future force capabilities consistent with the AOC. The adoption and embracing of the right technologies in the best manner is of the utmost challenge. Key among these is to limit the cognitive burden and prevent overwhelming the individual. With respect to the mission command warfighting function, technologies must help people understand, visualize, describe, lead, direct, and assess.

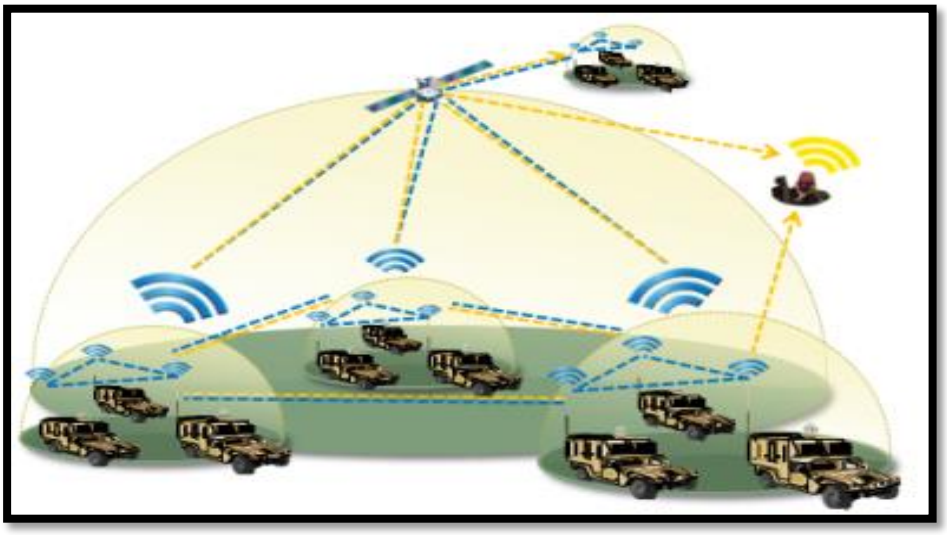
a. Mission Command Center of Excellence prioritized S&T Needs, present through 2025 are:

1). Mission Command Center of Excellence prioritized S&T Needs, present through 2025 Human Dimension. Optimize human performance, build cohesive teams, manage talent effectively, and improve resiliency. Interoperable, simple, and intuitive mission command applications. Applications must aid leaders to better understand, visualize, describe, direct, and assess complex problems in the future operating environment, leveraging Joint Information Environment and Army Common Operating Environment standards and technologies.

2). Interoperable, simple, and intuitive Mission Command applications. These applications will provide a singular Common Operational Picture for leaders to better understand, visualize, describe, direct, lead, and assess complex problems in all domains and in all operating environments. Applications must be standards-based and upgradeable with embedded joint interoperability used by Soldiers and leaders at all echelons; consistent with Joint Information and Army Common Operating Environment standards and technologies. Simple to train and understand by

Soldiers, Mission Command applications must leverage powerful analytic tools producing high quality information to enable leaders and staffs to quickly assess the situation to enhance effective decision making. They must provide the commander and staff voice, data, and video, both at the halt and on the move, to efficiently plan, execute and assess multiple missions, with different types of threats, in multiple contexts in high OPTEMPO environments. These solutions must be intuitive, adaptable, reduce complexity, and provide leaders with a singular common operational picture at all echelons. Applications must be resilient enabling leaders to exercise uninterrupted mission command, capable of functioning in a challenged, denied, intermittent, congested, and low-bandwidth environment. They should support distributed computing, mobility, and use augmented/virtual means to facilitate knowledge generation and develop understanding.

3). Survivable, Agile, and Efficient Command Posts. Future command posts must be agile, able to quickly deploy, emplace, and displace to support high operational tempo mission sets. Command posts must, be redundant, scalable, and facilitate effective Mission Command on the Move. Command Post infrastructure must reduce detectability by reducing signatures, emissions, utilize advanced camouflage, and profile masking technologies. Command post technologies must also optimize resource usage to increase self-sufficiency, and maximize a unit's expeditionary capability.



4). Human dimension. Humans are the central component to achieving the Army's missions. Successful operations in the future environment however will require the Army to focus on two key capabilities. First, the Army must invest to optimize the human performance of every Army professional, both Soldier and Civilian. Second, the Army must train, educate, and assess Army professionals to build, and act as members of cohesive teams that are able to thrive in conditions of ambiguity and chaos. The Army needs technologies that assist leaders in assessing and improving teams as systems; where components (Soldiers and technology) optimize mission accomplishment. Leaders must be able to make such assessments on leader development, situational understanding, cognitive performance and overload, physical performance, mental and physical resiliency, cultural understanding, and human-system interfaces. Additional technologies are needed to enable leaders to conduct better

talent management, self-development, or improve character and ethics, team building, or improve individual and unit resiliency.

5). Integrated Training Environment. Soldiers and Leaders to must be able to leverage the operational force along with the generating force to train the full spectrum of tasks in any operational environment to maintain "training overmatch".

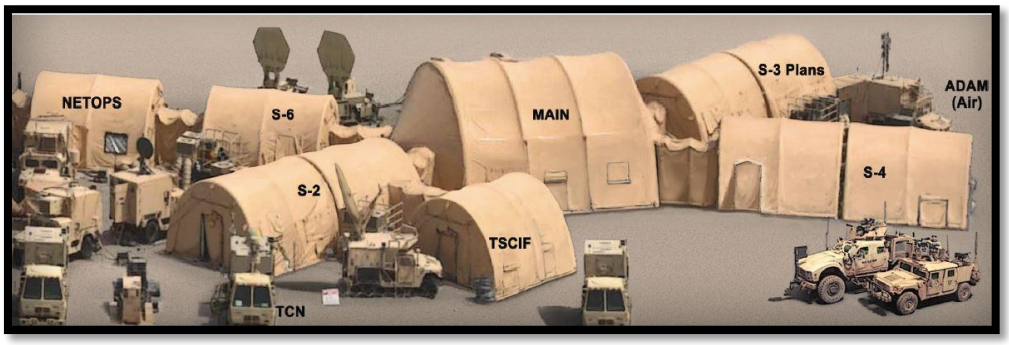
b. Beyond 2025, MCCoE forecasts requirements to fill the following capability needs:

1). General Artificial Intelligence. As Mission Command integrates the various warfighting functions, it requires a complementary technology to leverage and integrate various data sets. A more general artificial intelligence that assumes various forms of machine learning and synthesizes it into an intelligible form is needed to speed data and information ingest enabling leaders develop knowledge and gain understanding.

The artificial intelligence must optimize the relationship among people, resources, tasks, and knowledge for leaders and staff. Solutions must not increase user cognitive load and minimize the need for specialized skill sets to employ. Tools must reduce the time needed to process data to increase the time available for staff actions and organizational decision-making.

2). Robotics and Autonomous Systems (RAS). Future echelons above brigade must enable subordinate units through shaping and support operations. To enable this, robotics must be able to travel, collect, and transmit information across operational level distances. RAS endurance must enable these formations to create periods of overmatch or superiority to empower subordinate operation execution. Able to maneuver in contested areas, sensors must provide high fidelity data to enable the operations process of plan, prepare, execute, and assess. Commanders at echelons above brigade must employ capable formations of robotic and autonomous systems for a variety of mission sets to serve as force multipliers across all echelons to enable the Army accomplishment of a variety of roles and missions envisioned in the AOC.

3). Optimize Human Performance. The most important and dynamic component of the Army echelon is the quality, talent, and cognitive ability of its people. Leader development, organizational training, and professionally challenging military and civilian education programs must remain an enduring capital investment area. Advanced technology also has a role to play in optimizing human performance with the goal of optimizing total group performance as a competitive advantage now and in the future. Advanced simulation systems, simulated environments, tests, and assessments which improve cultural understanding, communication skills, and creative and critical thinking are an important future capability. The Army should also prepare to establish measures and metrics for successful Soldiers and then recruit and manage Soldiers according to their inherent capabilities and trainable competencies.



4). Quantum Technologies. Mission Command can leverage emerging future technologies associated with this area of science. They fall broadly into the categories of: metrology (measurement science), enabling sensing beyond classical limitations; computing/information processing, enabling hard computational/logic problem solving; materials, functional materials with novel properties/capabilities; and communications/quantum networks, enabling novel security protocols. Advances in making these technologies applicable to military operations can assist in solving some of the Army's most pressing challenges such as underground structure and tunnel detection; PNT in a GPS denied environment; early warning of the presence of nuclear WMD material; sensing of magnetic anomalies associated with vehicles and machinery; and detection of biological and neural markers of PTSD and brain trauma.

Chapter 14 - Sustainment Center of Excellence (SCOE) S&T Needs

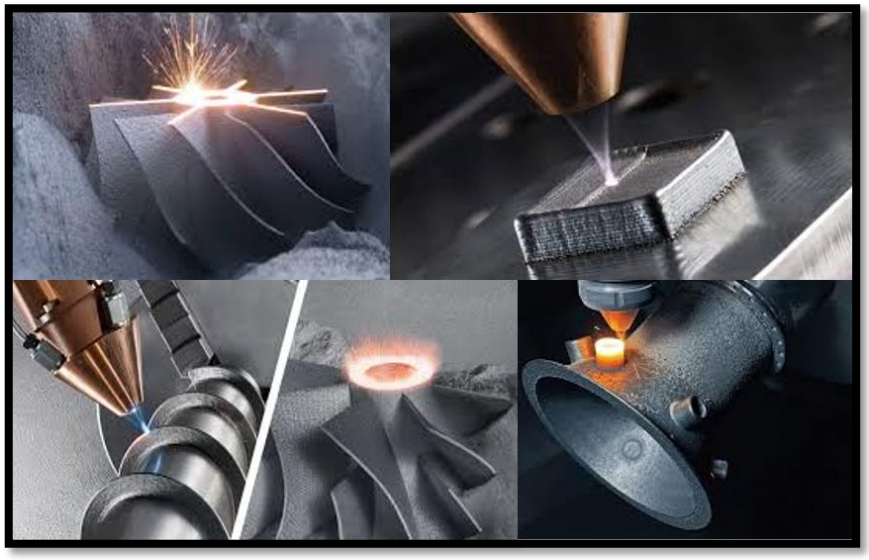
This represents Sustainment's prioritized capability needs for the future and recommendations for future Science and Technology (S&T) investment for the development of capabilities necessary to win in a complex world. The potential technology candidates summarized below have the potential to offer greater flexibility in resource utilization; reductions in total Army demand; increased endurance; and enhanced sustainment capabilities.

a. Sustainment S&T needs for the Mid-Term (2025):

1). Autonomous Resupply. Autonomous ground, aerial, and Army watercraft capabilities need to provide responsive sustainment to widely dispersed units when weather, terrain, and enemy threats pose unsuitable risk to manned air, ground, and surface distribution assets. Autonomous technology incorporated into existing wheeled vehicles or Army watercraft and emerging aerial platforms provides multiple options to commanders and creates multiple dilemmas for our adversaries. Potential benefits include reduced Soldier exposure to risk; extended operational reach to widely dispersed forces; increased throughput capability; reduced human endurance constraints; improved redundancy within transportation network; decreased customer wait time; and increased operational readiness.

2). Alternative Sources of Water. Alternative Sources of Water reduce total Army demand through point-of-need water production, reuse, and efficiencies. Water from air technologies and man-portable water purification systems can increase unit endurance. Potential benefits include improved ability to meet demand at the point of need; reduced convoy requirements and logistics footprint associated with centralized water production and distribution; and extended operational reach to widely dispersed forces.

3). Additive Manufacturing. Additive Manufacturing is a critical enabler to provide responsive sustainment to widely dispersed units and has military application at the strategic, operational, and tactical levels. Potential benefits include enhanced ability to exploit innovation; improved systems design and reliability; ability to meet demand at the point of need; reduced Class IX storage requirements; improved supply metrics; increased operational readiness; decreased manufacturing lead times; and reduced life cycle cost.



4). Improved Tactical Power Management and Distribution. Improved tactical power generation or micro-grid technologies combining hardware and software technology to optimize electrical power production, distribution, storage, and control of power to assure access and build resiliency. Potential benefits include increased efficiency at the point of need; reduced fuel requirements and logistics footprint associated with fuel distribution; and improved endurance for widely dispersed forces.

b. Sustainment S&T Needs for the Far-Term (beyond 2025):

1). Alternative Fuels and Advanced Power Generation. Alternative fuels and advanced power generation can decrease demand for fossil fuels and provide the future force with improved endurance and greater, self-sustaining capability. Alternative sources of energy like hydrogen powered vehicles or greater use of hybrid-electric technology can increase endurance and lessen reliance on contested or extended supply lines. Potential benefits include increased reliability and access to power; increased redundancy within the power distribution network; reduced logistics footprint associated with fuel distribution; and extended operational reach.

2). Enabled Mission Command. A networked, cyber-protected, integrated mission command and sustainment information system that provides a comprehensive common operating picture for decision support from the strategic to the tactical level and empowers leaders, teams, and Soldiers at the lowest levels with relevant operational and sustainment information and situational understanding. Potential benefits include improved access to information; increased agility, reliability, and availability to support expeditionary maneuver; enhanced responsiveness to sustain high tempo operations; and increased integration and redundancy of mission command systems.

Chapter 15 - Space and Missile Defense Command (SMDC) S&T Needs

This chapter codifies the USASMDC's priorities to inform current and future S&T efforts and influence resource decisions. These capabilities derive from a continuous update of current and projected CNA gaps, AOC, Army Warfighting Challenges, Multi-Domain Battle concept, SMDC's Future Warfare Center, and Technical Center assessments.

a. The following reflects USASMDC's prioritized capability needs in support of Army's Force 2025 to mid-Term (now to 2030) and Future Force Design (Far-term 2030 and beyond) efforts.

1). Space and high altitude support to the warfighter. Space and high altitude S&T efforts (near to mid-term) will focus on continuous development and providing superior space and high altitude capabilities by exploiting the work being done by DARPA, staying abreast of commercial developments that can be leveraged on behalf of DoD, and through improvements in space technology. The joint force requires regionally focused capabilities that provide communication, PNT, Intelligence, Surveillance, and Reconnaissance (ISR), and Navigation Warfare (NAVWAR). Small satellites and high altitude solutions will provide this robust and persistent coverage. As the Army becomes more regionally engaged and globally responsive in the conduct of multi-domain battle, it requires assured access to these space support capabilities and the ability to selectively deny these same space support functions to future adversaries.

2). Global Ballistic Missile Defense support to the warfighter. We will continue to synchronize our defense efforts toward rapidly evolving enemy air and missile threats, while pursuing the development of an integrated, "layered," and growing architecture of networked ground, sea, and space sensors. The joint warfighter requires enhanced interceptors and a command, control, battle management, and communications network that will provide a robust, layered capability to defend against a hostile air and

missile attack. The growing complexity of the strategic environment (technological advances of the threat and fiscal realities), the increased threat from radical institutions, and the regional peer threats requires cost efficient and effective methods of integrating current and future capabilities.

3). Directed Energy. We must continue to synchronize our S&T efforts on flexible capabilities such as high power lasers and microwaves to support Integrated Air and Missile Defense (IAMD). Directed energy capabilities complement IAMD kinetic energy capabilities. Directed energy weapons can address a broad variety of threats: long-range rockets, artillery, mortars, unmanned aerial systems (UAS), UAS-borne intelligence, surveillance, and reconnaissance payloads, and cruise missiles. Directed-energy weapons provide quick employment and response to enable multi-domain battle and support current and future force concepts.

b. USASMDC/ARSTRAT's capability needs for the far-term (2030 and beyond) are derived from the AOC, the Army Functional Concepts, analysis of the Army Warfighting Challenges and our assessments. The paragraphs below summarize the recommendations supporting the far-term.

1). Space and high altitude operations. Far-term space and high altitude operations must better integrate, synchronize, and closely align with the

commercial sector to support joint operations of the future warfighter. Next generation SATCOM, PNT augmentation, Intelligence, Surveillance and Reconnaissance, NAVWAR, environmental monitoring and threat warning services will provide the enhanced information superiority and situational awareness capabilities needed to support multi-domain battle and movement to maneuver operations. Persistent high altitude capabilities will augment both the terrestrial and space layers. Blending advancements from the commercial sector high altitude capabilities will provide long duration capabilities for surveillance and communication platforms. Similarly, our S&T efforts will continue to support the training and development of space aware soldiers across the force, building future Army space forces, and the research, development, and testing required to integrate future Army space capabilities to be globally responsive to the joint warfighter.

2). Global Ballistic Missile Defense. All indications are that in the far term, regional peer threats will continue to improve both the quantity and quality of the air and missile threats to the Army and joint force. We need to continue to expand our capabilities due to the continuing development and fielding of advanced threats such as hypersonic missiles, advanced electronic warfare and counter-measures, cyber-attack, stealthy missiles and UAVs, and attack aviation. Our S&T needs to focus on less expensive but more effective interceptors, directed energy to lower the cost per engagement, jam proof sensors to include passive sensors, multiple kill vehicles, and improved target discrimination.

3). Directed Energy. Our far-term S&T efforts must be concentrated on next generation high power lasers, microwaves, solid state lasers, high energy laser beam control, and hypersonic technology systems to counter maturing threats posed by fast missiles such as ballistic missiles, hypersonic cruise missiles, and hypersonic glide vehicles. Developed renewable directed energy capabilities with limitless munition availability, and shorter recharge times to complement our IAMD kinetic energy capabilities. Directed energy weapons have the potential to provide game changing capability to support all forms of warfare.

Chapter 16 - ARCIC Live Prototype Assessment (ALPA)
The Mechanism to Conduct Operational Assessments

ARCIC Live Prototype Assessment (ALPA) is a centralized management process that prioritizes Center of Excellence (CoE) prototype assessments under ARCIC's governance structure. Additionally, the ALPA Process determines venues to address Army Warfighting Challenges (AWFC) learning demands, Capability Needs Analysis (CNA) gaps, and Training and Doctrine Command (TRADOC) focus areas in support of Force 2025 and Beyond (F2025B) and the Campaign of Learning (CoL). ALPA includes four kinds of events: Army Live Experiments (ALE), Focused Assessments (FA), Limited Objective Assessments (LOA), and Innovative Idea Assessments (IIA). ALPA aligns these events with AWFC learning demand running estimates to enhance assessment of new concepts, capabilities, organizations, doctrines, and materiel while identifying DOTMLPF solutions and refining requirements. After planning and executing events, ALPA conducts a follow-up process to trace conclusions and recommendations. Data generated from conclusions and recommendations assists with identifying the best strategy for specific capabilities. Thus, through planning, executing, and following up on Live Prototype Assessments, the ALPA Process informs interim solutions to capability gaps, AWFC running estimates, Operational and Organizational (O&O) plan development, and evolving Force 2025 Maneuver (F2025M) strategic guidance efforts.

ARCIC Live Experimentation (ALE): Provides capability developers, the science and technology community, and industry, with repeatable, credible, rigorous, and validated operational experiment venue(s) to assess possible solutions/technology in support of all Army Warfighting Challenges (AWFC). Currently, four ALE assessments occur each fiscal year. ARCIC sponsored ALE specific events include:

a. Army Expeditionary Warrior Experiments (AEWE) held at Fort Benning, Georgia. The purpose of AEWE is the Army's primary venue for small unit modernization, providing capability developers, Science and Technology (S&T) community, and industry a repeatable, credible, rigorous, and validated operational experiment supporting both concept and materiel development.

b. Maneuver and Fires Integration Experiments (MFIX), held at Fort Sill, Oklahoma. The purpose is to develop, evaluate and expand integrated concepts and material capabilities in order to inform how fires enhances tactical operations at Brigade and below, retain current advantages over adversaries and accelerate investments on contested future capabilities in support of F2025M and beyond.

c. Cyber Network & Electromagnetic Integration Experiments (Cyber Quest), held at Fort Gordon, Georgia. Cyber Quest is a prototype assessment conducted in an operationally relevant environment with Joint, Government, S&T, Industry, and Academia partners to identify innovative and emerging Intelligence, Signal, Cyberspace, and Electronic Warfare capabilities, concepts, and their DOTMLPF-P impacts.

d. Maneuver Support, Sustainment, Protection Integration Experiments (MSSPIX), held at Fort Leonard Wood, Missouri. MSSPIX serves as a venue to provide capability developers, the S&T community, and industry a repeatable, credible, rigorous, and validated operational experiment venue to support both concept and materiel development.

Focused Assessment (FA): More narrowly focused than an ALE, one-time only assessment, conducted anywhere, anytime, or any place. Assesses identified enabling concept shortfalls and modifies concepts. Uses prototype and surrogate systems to represent concept capabilities. FAs address CoE priorities and gap analysis outlined in the CNA process, and aligns with Army priorities supporting the Operating Force. FA's integrate new Tactics, Techniques, and Procedures (TTPs) and combines them with innovative technologies to give Soldiers an advantage across the spectrum of Army Warfighting Functions while informing requirements.

Limited Objective Assessment (LOA): Collaborative assessment efforts with other Army or Joint capability development agencies to develop or refine specific capabilities. This assessment evaluates the progress toward achieving system requirements and resolution of issues. The scope of issues addressed by the system or system of system evaluation is flexible in that it may or may not cover all aspects of operational effectiveness, suitability, and survivability. Typically, the assessment produces input to non-milestone decisions or inquiries and to support system evaluation.

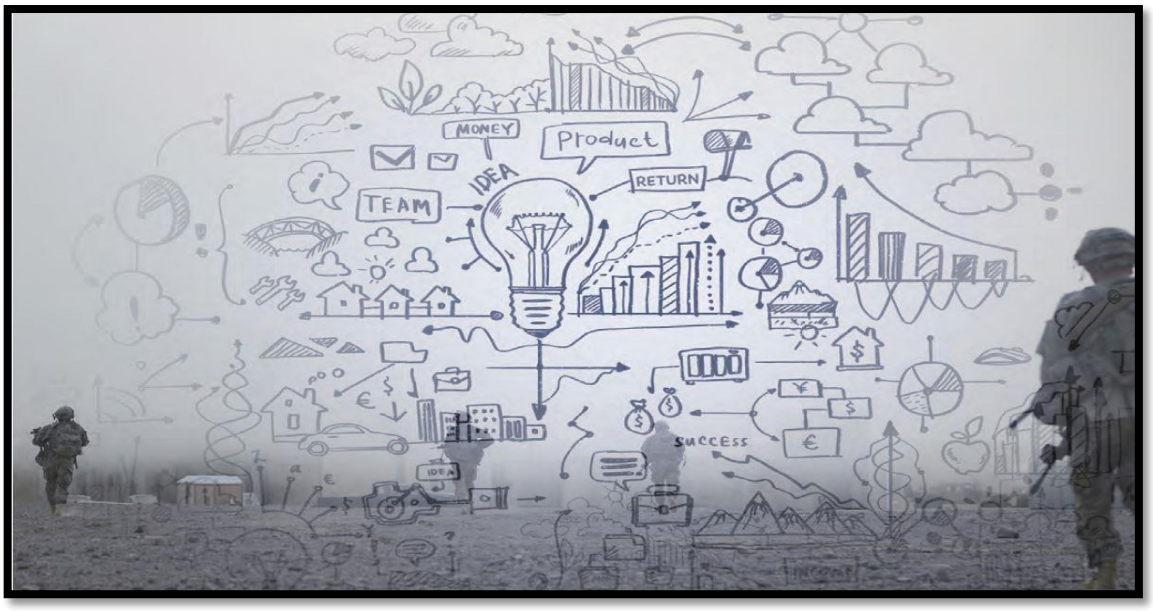
Innovative Idea Assessment (IIA): Collaborative assessment efforts with other Army or Joint capability development agencies to assess high-risk, high-return game-changing emerging capabilities, some vetted through Vulnerability Discovery Experimentation. Individual or small organizations conduct the IIA on a single concept or capability. These are low cost assessments where probability of success is low with a high risk of failure. The results of successful IIAs cross numerous domains with significant impact and providing a high return that potentially impact

Functional Concepts. The second element of IIA is the Innovative Idea Initiative (I3) that focuses on harnessing innovations to create a cadre of forward-thinking, creatively confident Soldiers for F2025B. The I3 creates a platform for Soldiers to pitch innovative ideas to improve their command or the Army in an open forum to fellow Soldier as well as leaders of ARCIC, United States Army Research, Development and Engineering Command, United States Army Test and Evaluation Command, and their own senior leadership.

Chapter 17 – Conclusion

This bulletin by no means is an all-encompassing articulation of Warfighters' S&T Needs. In addition to the capabilities mentioned in previous chapters there are essential cross cutting Technological First Principles[16] that the Army uses to develop future force capabilities with partners and fellow stakeholders:

- Emphasize integration of technology with Soldiers and teams.
- Simplify systems and integrate Soldier training into design.
- Maximize reliability and reduce life cycle costs.
- Design redundant systems that improve effectiveness under conditions of uncertainty.
- Develop systems that degrade gracefully.
- Maintain foundational knowledge to reduce the opportunity for surprise.
- Reduce logistical demands.
- Anticipate enemy countermeasures.
- Ensure interoperability.
- Consider scale and organizational implications.



In the mid-term, absent next generation combat vehicles, the Army must modernize its remaining fleet while integrating leading edge capabilities. Exploitation of these opportunities begins to increase mobility, lethality, survivability and to develop training, doctrine and organizations to best employ these new capabilities in complex, urban terrain within contested operating environments. During this period the Army will establish transition conditions to stop modernizing legacy systems and begin integrating

[16] US Army Operating Concept "Win in a Complex World" pg. 40-41

future combat platforms to create blended formations. Mid-term priorities to restore land power dominance include:

- Advanced long-range fires, including Survive and Project Indirect fires and treaty compliant munitions and missiles.
- Manned-unmanned teaming for air and ground, including purpose-built unmanned vehicles that realize weight, sustainment, and cost-per-unit savings over manned variants while increasing the capability of our existing formations.
- Asymmetric Vision and Decide Faster technology to improve soldier performance by increasing situational awareness at the small unit level, allowing our small units to operate at a tempo that is faster than the adversary can operate.
- Resilient C4ISR networks.
- Next Generation Combat Vehicles (NGCV) of all variants, including armor, ICV, engineer, mortar, and SHORAD.
- Future Vertical Lift that includes unmanned/autonomous Attack, Reconnaissance, and Utility/MEDEVAC capabilities.
- Reduced energy demand for extended range and reduced logistics.
- Close combat capabilities to include squad and platoon organic UAS, virtual trainers and optimized human performance.

In the far term, the Army will complete its transition to the future, fully fielding its future combat platforms and divesting its legacy systems. This new family of combat vehicles and vertical lift must be capable of operating on a sensor-filled, highly lethal, dispersed battlefield and should be fielded across Army formations by the mid-2030s to retain land power dominance over peer adversaries. As the Army fully integrates robotics, autonomous systems, and manned-unmanned teaming, it will explore new ways of organizing to maximize its combat unit potential and reduce logistics tethers to enable dispersed, decentralized operations. The Army's far-term priorities include:

- Artificial intelligence and autonomous systems to expand and improve increased capabilities realized by MUM-T.
- Defeat of adversary artificial intelligence to ensure Army forces operate at faster operational tempo while increasing the friction inherent in adversary operations.
- Synthetic Biology to further enable Soldiers to cope with a highly lethal, violent, fast, and ambiguous future battlefield.
- Directed Energy and advanced energetics to reduce sustainment associated with traditional ammunition and harness the improved lethality promised by lasers and other directed energy weapons.
- Reduced energy demand to minimize logistics and maintenance.
- Beyond novel materials to improve the survivability and decrease the weight associated with our combat vehicles.
- NGCV upgrades to integrate material, energy, AI, autonomy and weapons improvements.
- Future vertical lift upgrades to integrate material, energy, AI, autonomy and weapons improvements.
- Resilient C4ISR networks.

- Human Performance to improve upon advances in the mid-term, allowing Soldiers to cope with a highly lethal, violent, fast, and ambiguous future battlefield.
- Close combat capabilities to include optimized human and unit performance and integration of AI, robotics and sensor support.

The following agencies provided pictures and graphics used within this publication

Army Capabilities Integration Center (ARCIC) Products pages: 1, 2, 8
Army AL&T Magazine (ASA ALT): 11, 12, 13, 14, 15, 16, 17, 21, 23, 32, 37, 38, 40
Army.mil Article: 10, 22, 30, 46, 47, 48
Army Sustainment Magazine: 44, 45
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Fires Bulletin: 24, 25, 26
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