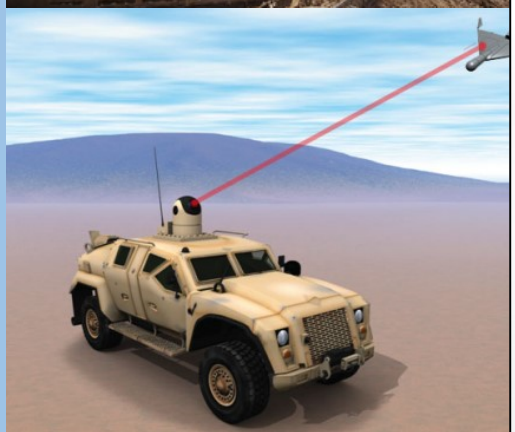
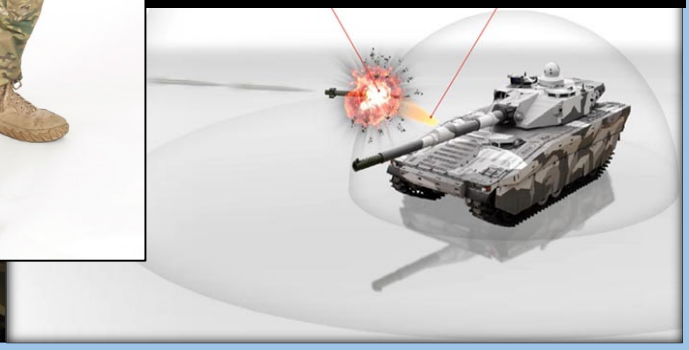
The United States Army

The Warfighters' Science and Technology Needs

21 September 2016



“Our fundamental task is like no other – it is to win in the unforgiving crucible of ground combat”
General Mark A Milley,
39th Chief of Staff of the Army

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

Chapter 1 - Introduction and Background

This document provides an overview of the Warfighters' Science and Technology (S&T) needs to better inform those who develop materiel for the Army.

In June 2016, TRADOC codified the Army Capabilities Areas and initiated work towards the Multi-Domain Battle concept:

a. Future Vertical Lift

b. Combat Vehicles

c. Cross Domain Fires

d. Advanced Protection

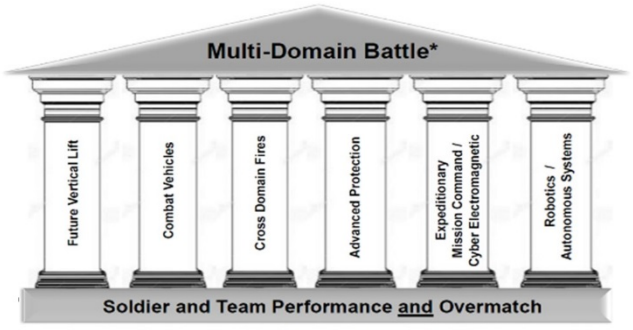
e. Expeditionary Mission Command / Cyber Electromagnetic

f. Robotics and Autonomous Systems

With a cross cutting capability of:

g. Soldier / Team Performance and Overmatch

Simultaneously, the TRADOC CoEs began refining their prioritized functional S&T needs into memoranda of record from their Commanding Generals which were sent to CG, TRADOC. Each memorandum focused on the unique required capabilities identified through the Campaign of Learning (CoL). These capability areas appear in past and draft Functional Concepts developed by the COEs and represent the "bottom-up" element of the Warfighters' S&T needs.



Multi-Domain Battle: In the 1970s, the Army developed the AirLand Battle concept for warfighting. How-ever, the Joint Operating Environment 2035 describes a future environment with contested norms and persistent disorder. Backed by modernized militaries, revi-sionist states seek to revise the post-World War II security order. These states, and their proxies, possess military capabilities to support aggressive policies; and unlike the recent past, these adversary capabilities challenge U.S. dominance in the aero-space, maritime and cyber-electromagnetic domains.

Chapter 2 - The Operational Environment

The future operational environment (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; 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.[1]

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.[2] 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 advances by adversaries and increasing threats present challenges to the ability of Army forces to retain overmatch through the far future. 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 shifts, and violence associated with them, occur more rapidly than in the past due to advances in technology, and the proliferation of, or access to information.[3]

[1] 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.

[2] Ibid, page i.

[3] ibid, pages 1-12.

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, and precision of rockets and missiles; space capabilities; counter-precision capabilities, and an increase in the lethality within small units.[4] Where they cannot achieve a technical advantage, the adversary 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, or applying an emphasis on research and development to create new technologies to gain an advantage.

The pervasiveness of more lethal and technologically advanced weapons throughout the OE increases the importance for the Army to understand the entities that may employ those systems or weapons. The U.S. may face one or a combination of the below threat archetypes:

Near-Peer Competitors: The near-peer competitors represents nuclear-capable nation-states possibly partnered with one or more non-state actors through ideological, religious, political, or other ties. Near-peer competitors have the infrastructure, research and development capabilities, and manufacturing abilities to pursue or advance scientific research or technologies. These enemies can employ advanced information technology, conventional military forces armed with modern equipment, and irregular forces at various levels of organization, training, and equipment. Their forces will likely try to deny the U.S. the ability to fully apply all the elements of national power – but especially the military – in a useful manner.

Regional Actors (Nuclear): Slightly less developed are capable regional powers with well-trained armies that have worldwide reach through the employment of nuclear weapons and strong military modernization efforts. Regional actors will likely steal or reverse engineer technologies, and are more likely to pursue asymmetric technological advantages. This archetype maintains capability in all domains of warfare, has the capability to project military power in some limited fashion beyond adjacent nation-states, and is focused on keeping those it perceives as hostile out of the fight by conducting "political warfare." Their forces place a premium on combining conventional, unconventional, regular and irregular forces, and cooperation with criminal enterprises to create multiple dilemmas for their adversaries.

Regional Actors (Non-nuclear): Mirroring the Regional Actors (Nuclear). They pose substantial equipped armed forces that employ conventional arms and supplement that capability with a well-trained paramilitary or militia force. Like the nuclear regional powers, they also combine conventional, unconventional, regular and irregular forces, and cooperation with criminal enterprises to create multiple dilemmas. Their forces are largely infantry-based with some modest older and often obsolete armored forces.

[4] Portions of this paragraph were extracted from: Lawton, Joel 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

These actors will usually be pursuing the acquisition of strategic capabilities such as nuclear weapons or advanced long range ballistic missiles. They will also have access to niche technologies or capabilities such as advanced chemical or biological weapons. These archetypes primarily pose a threat to adjacent nation-states that have resources to pilfer, or large populations that share ethnicity, religion, or ideology.

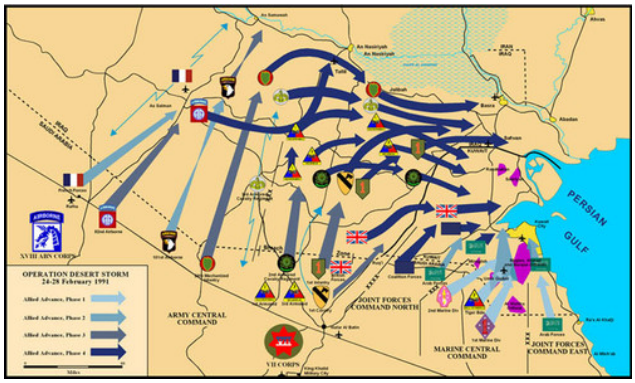
Radical Ideologues: An increasingly large number of organizations with limited conventional capabilities are using violent methods that are intended to create fear (terror) to achieve their political objectives. These threat archetypes will conduct operations for religious, political, or ideological goals. They deliberately target or disregard the safety of non-combatants to further an ideology, gain power, and seize control of populations, infrastructure, or resources. Radical Ideologues range from small lightly armed cells to paramilitary organizations with substantial capabilities. These threats normally have access to advanced technology through commercial markets and can achieve selected overmatch of nation-state combat systems at specific times and places. Advanced technology includes weapons of mass destruction and a formidable computer network attack capability. These forces typically place a premium on operating in urban areas and complex terrain because of the inherent protection that these places provide.

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, near-peer competitors are expected 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.

Chapter 3 - Overview of Needed Army Capabilities

There are two emerging conditions that require the Army to develop and resource major combat systems. First, the upcoming loss of overmatch as the aging Big 5 systems from the 1980's modernization (M1 Abrams Tank, M2 Bradley Fighting Vehicle, Apache AH-64 Helicopter, UH-60 Black Hawk Helicopter, and the Patriot Missile System) begin to reach their maximum useful life. Second, growing potential threats from near-peer or smaller regional powers and transnational terrorist organizations. The needed Army Capabilities address these critical capability gaps in the mid-to-far timeframe.



The Army Capabilities initiative provides a framework to enable the Army to focus future force development and prioritize Research, Development, and Acquisition (RDA) activities. The intent of this initiative is to identify key capabilities which require intense senior leader oversight to increase the chances of successful fielding. The Army Capabilities framework does not represent all of the capabilities required for our Army, but focuses on those that allow the Army to close critical capability gaps and fight in the context of the Army Operating Concept (AOC). In addition, this initiative allows Army leadership to communicate critical needs for Army forces to garner resources in support of future force development.

Backdrop: Over the last 15 years of combat operations, U.S. Army forces rightly focused on winning against irregular adversaries and challenges in Iraq and Afghanistan. This focus limited modernizing for future fights against more technologically advanced enemies. Meanwhile, enemies and adversaries continued to modernize rapidly for the future and became increasingly capable. Taken collectively, these threats point to an emerging future security environment in which U.S. ground forces are more and more likely to face overmatch during tactical operations. In addition, decreases to the Army's overall budget compound the Army's modernization challenges. Compared to the post-Vietnam and post-Cold War drawdowns, the Army has taken a larger percentage cut than during previous reductions in the force that were preceded by more significant future force modernization. As a result of increasing enemy capability and the reduction in resources available for modernization, Soldiers and mission accomplishment are placed at undesirable levels of risk.

"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."[5] 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". The past decade constituted a largely "lost decade" for major Army systems as billions of dollars were spent on Major Defense Acquisition Programs (MDAP) which were ultimately canceled before reaching the Warfighter. Notable canceled programs included, but were not limited to: Future Combat Systems (FCS), the Ground Combat Vehicle, the RAH-66 Comanche Armed Reconnaissance and Attack Helicopter, and the XM 2001 Crusader Self-Propelled Howitzer.[6]

"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".[7] Unlike the past decades when the Army's adversaries were known, the future operational environment as described in the current Army Operating Concept, is 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, developing the situational understanding, conducting joint combined arms maneuver and consolidating gains.

Lastly, the anticipated fiscal environment in the mid-term limits the Army's ability to develop new major combat systems. While the AOC helps decision-makers understand how Army forces must fight and win in the future, the concept is only a starting point in the debate to garner the resources necessary to deliver the needed future capabilities.

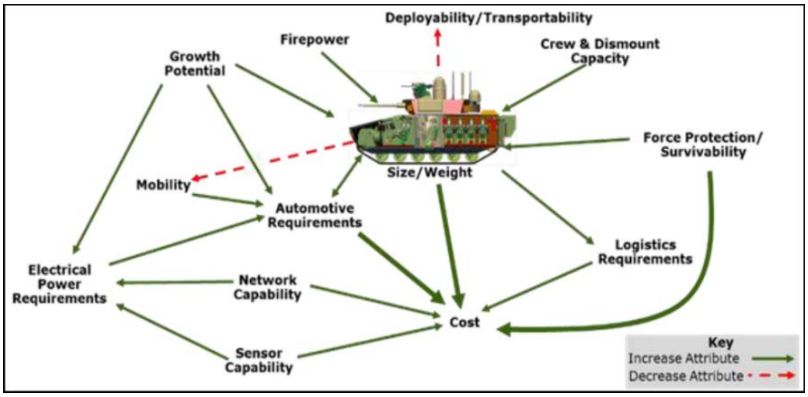
[5] Johnson, David. The Challenges of the "Now" and Their Implications for the U.S. Army, 2016.
[6] CSIS Defense 360, The Army Modernization Challenge A Historical Perspective
[7] Testimony at Subcommittee on Airland, Committee on Armed Services, U.S. Senate, April 5, 2016

Chapter 4 - Description of the Army Capabilities Needed

The following describes the Army Capabilities needed:

a. Future Vertical Lift (FVL). FVL enables Joint Forces Commanders to dictate the terms of operations and take the fight to the enemy at the time and place of our choosing, not just when conditions are favorable, with a greater capability to overcome the constraints of complex terrain, higher altitudes, extreme temperatures, and extended distances while performing operations throughout the Joint Operations Area. Having a FVL Family of Systems will provide the Joint force with a family of platforms capable of conducting all missions currently performed by rotary wing assets including air assault, air movement, command and control, attack, reconnaissance, medical and casualty evacuation, non-combatant evacuations, humanitarian assistance/disaster relief, maritime resupply and interdiction, and combat search and rescue. The FVL family of systems will provide expanded vertical take-off and landing capabilities in the areas of range, speed, payload, reliability, high fuel efficiency, and reduced logistical footprint.

b. Combat Vehicles. Brigade Combat Teams (BCTs) require the lethality, mobility, and protection to achieve overmatch in the conduct of expeditionary maneuver and joint combined arms operations. The Army achieves overmatch by sustaining existing fleets, improving combat vehicle platforms and systems, developing new vehicles and systems, replacing obsolete platforms, and constantly assessing the combinations of mobility, protection, and lethality as balanced against weight and cost to ensure appropriate maneuver capabilities for the force. Implementing the Combat Vehicle Modernization Strategy will help ensure Army maneuver formations overmatch future adversaries across the range of military operations in a complex operational environment.

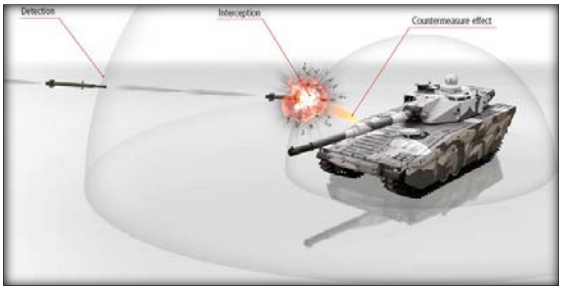


c. Cross Domain Fires. Cross Domain Fires involves employing joint and combined mutually supporting lethal and non-lethal fires across all domains to achieve effects designed to create multiple dilemmas for the adversary, achieve overmatch, and enable Joint Combined Maneuver. Cross-domain capabilities give commanders multiple options and enable presenting multiple simultaneous dilemmas to an adversary. Army operations are inherently cross-domain. Army forces depend on and complement joint efforts in all domains in the conduct of joint operations. Army forces support Joint Force freedom of movement and action by projecting power from land across the air, maritime, space, and cyberspace domains and the electromagnetic spectrum, as well as "influencing" the information environment and human perceptions. Fires must be flexible, able to respond easily to a variety of circumstances and conditions. Fires must be tailorable, able to organize units and systems to meet commanders' intent in a variety of operating environments. Fires must be precise, operating with accuracy, producing desired effects only on desired targets, building confidence in fires units' capabilities. Finally, fires must be responsive, deploying and achieving desired effects rapidly[8]. Changes in technology are making multi-mission sensors and shooters capable of performing both the traditional fires and air defense functions technologically feasible. Fires units must deliver timely effects against targets through all domains to achieve overmatch against enemy fires. Currently, fires focus largely on the ground and air domains. The future operational environment will demand fires that can also effectively operate across the maritime, space, and cyberspace domain and the electromagnetic spectrum. Fires systems must deliver fires; targeting efforts must support target identification, discrimination, de-confliction, and airspace control; and fire control through all domains.

d. Advanced Protection. Advanced protection capabilities are required due to aging ground combat vehicles and aircraft, the need for more capable forces with fewer transport and sustainment needs to meet expeditionary requirements, and the advancement of threat capabilities in lethality. Without advanced protection capabilities, future Army forces lose differential advantages in aviation as well as lose overmatch against near-peer threats within Brigade Combat Teams. The Army requires a Modular Active Protection System (MAPS) initiative with standardized architecture for signal and data processing, plug-and-play sensor integration, hostile fire detection and networking. The intent is to apply vehicle appropriate hostile fire detection with multi-spectral sensor suites, such as hard and soft kill Active Protection Systems (APS), to all Army tactical vehicles. The Army's APS strategy provides a phased survivability set technology

[8] Joint Cross-Domain Fires and Maneuver White Paper 10 May 2016

integration approach to grow and transition capability over time. The APS expedited Non-Developmental Item (NDI) approach in parallel with MAPS provides a "kittable" APS integration package to accelerate APS fielding in FY19, should an urgent need arise. The spectrum of threats encountered by Soldiers in small units is varied and complex -- current equipment, clothing, and other protective measures do not provide adequate protection without adding significant mobility challenges. Force Protection partnerships will formulate S&T programs that increase the level of individual protection for Soldiers at reduced total weight and volume while enabling increased physical and mental agility, particularly over extended periods. The goal for all Soldier protection systems is to reduce the number and severity of injuries and casualties.



e. Expeditionary Mission Command / Cyber Electromagnetic. To win in a complex world, against increasingly capable and elusive enemies, our Army must deploy combined arms, air-ground forces quickly with the right combination of mobility, protection, and firepower. We must be able to maneuver from multiple locations with capabilities delivered from global, theater, and local resources. This requires unmatched Mission Command capabilities to orchestrate these activities. Since American military power is joint power and becoming increasingly more coalition, our Mission Command network is essential for interoperability with mission partners to enable the effective integration of military, inter-organizational, and multinational efforts. The network must enable exercising Mission Command, achieving situational understanding, and executing expeditionary joint combined arms operations. Cyber Electromagnetic Activities (CEMA) are activities leveraged to seize, retain, and exploit an advantage over enemies in both cyberspace and the electromagnetic spectrum, while simultaneously denying and degrading adversaries' use of the same while protecting our Mission Command systems[9]. Current and future adversaries have taken notice of how dependent U.S. forces are on communications capabilities. Trends in cyber security illustrate the urgency for the Army to synchronize CEMA efforts. CEMA capabilities developed by potential adversaries may disrupt communications and deny U.S. land forces freedom of maneuver; e.g., enemy global positioning satellite jamming capabilities could render precision fires inaccurate. Defensive CEMA capabilities will counter enemy threats while offensive capabilities provide Army forces with a global combat advantage using highly technical capabilities to create multiple dilemmas for our adversaries. Integrating CEMA effects is essential to our ability to conduct successful unified land operations.

[9] FM 3-38 Cyber Electromagnetic Activities February 2014, pg. 1-1

f. Robotic and Autonomous Systems (RAS). RAS enhance formations through manned-unmanned teaming to increase combat effectiveness, expand terrain coverage, and reduce risk to Soldiers while conducting hazardous tasks. RAS present multiple dilemmas to adversaries and can help provide overmatch across the range of military operations. RAS must protect the force at increased standoff distances, enhance situational awareness, lighten physical and cognitive workloads, improve sustainment, improve maneuver, and conduct lethal engagements where manned systems are limited. The overarching goal of the Army RAS strategy is to achieve an evolving level of autonomy. Currently, there are basic levels of autonomy in unmanned aircraft systems (UAS) but most systems are still intensively operator managed. For ground vehicles, the initials steps taken to evolve autonomy is the Leader-Follower (L-F) Automated Convoy System and the Squad Multipurpose Equipment Transport (SMET). Ground vehicle autonomy is a gateway technology and once obtained will be available for all ground vehicles to better protect Soldiers and achieve overmatch. Achieving autonomy takes an iterative approach that starts with tele-operation or remote control, followed by semi-autonomy and then full autonomy. The L-F and SMET capabilities are the Army's first steps towards semi-autonomy. The Army has several remotely controlled systems, e.g., small counter-IED robots, unmanned aerial systems and some engineer vehicles for lane clearing. However, remote controlled systems generally require a 1:1 operator-to-robot ratio. Decreasing the Soldier-to-robot ratio provides significant gains in unit effectiveness and labor savings. A semi-autonomous capability, such as the L-F Automated Convoy System, reduces the number of Soldiers required to operate vehicles during convoy operations, thereby reducing the number exposed to risk. In the future, the Army will add autonomous capability to different types of tactical wheeled vehicles and combat vehicles to greatly increase force protection and provide options to commanders for maneuver in combined arms operations. [10]

[10] Robotics and Autonomous Systems (Draft dated 16 July 16)

g. Soldier/Team Performance and Overmatch. The cross cutting capability of Soldier / Team Performance and Overmatch ("+1") focuses on fundamental capabilities that empower the Soldier and increase team performance. 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 weapons and equipment. Decentralized operations in complex environments require competent leaders and cohesive teams that thrive in conditions of uncertainty. Leaders and Soldiers must remain resilient and preserve their moral character while operating in environments of persistent danger. Successfully operating in the future requires the Army to focus on two key concepts. First, the Army must optimize the human performance of every Soldier and Army Civilian in the Total Force. Emerging advances in S&T provide the Army the opportunity to improve training, education, leader development, and talent management in pursuit of optimal performance. Second, the Total Army must build cohesive teams of trusted professionals who thrive in ambiguity and chaos. In the past, Soldiers and Army Civilians trained to excel in known fields of tactical and technical competence. While these competencies remain important, the increasing uncertainty of the future environment requires Soldiers and Army Civilians who are not just comfortable with ambiguity and chaos, but improve and thrive in even the most difficult conditions and achieve mission success.[11]

[11] Army Human Dimension Strategy Info Paper 04 Jan 16

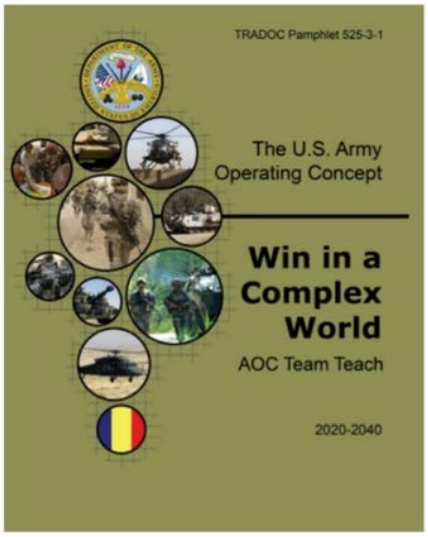
Chapter 5 – Cross Cutting Technological First Principles

The Army recognizes that there are no "silver bullet" technological solutions. The Army retains overmatch through combining technologies and integrating them into changes in doctrine, organizations, training, leader development, and personnel policies. While the Army Capability Areas address the Army's critical capability gaps, they are not all-encompassing. Equally important are cross-cutting technological principles such as reducing logistical demands, maximizing reliability and reducing life-cycle cost, and simplifying systems.

a. Below are the Cross Cutting Technological First Principles[12] that the Army uses to develop future force capabilities with partners and fellow stakeholders:

(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) Assure interoperability.

(10) Consider scale and organizational implications.

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

Chapter 6 - 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 fielding of the next generation of vertical take-off and landing platforms (FVL Family of Systems) capable of operating at significantly increased speed without degradation in hover efficiency.

(2) Develop technologies that enhance safety of flight in degraded and denied environments and at higher operating speeds.

(3) Develop technologies to support the next generation of UAS. Mature and demonstrate autonomous decision-making capabilities and confidence to allow traditionally manned missions to become unmanned, operations in complex, denied GPS, EW, and cyber threat environments, and confined launch and recover areas to include sea basing.

(4) Develop technologies to address the 'chance encounter' threat, to include rocket propelled grenade, MANPADS, and small arms.

(5) Develop network, communications, and architecture technologies to enable assured communications with the supported force.

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

(7) Develop technologies that support ultra-reliable designs, optimize selection of maintenance approaches, and reduce overall operating and support costs.

(8) Develop technologies that move beyond the traditional turbo-shaft engine and power transmission architecture to reduce dependencies on fossil fuels.

(9) Develop technologies to improve transition time from S&T to the field by enabling shorter certification durations and contributing to improvements in the airworthiness certification process.

Chapter 7 - Cyber Center of Excellence (CCoE) S&T Needs

The increased reliance of the global society upon the cyber domain greatly affects military operations. The systems used by the Army to conduct mission command, maneuver, maneuver support, medical support, intelligence, sustainment, fires, and national-strategic operations require cyberspace operations to integrate and provide information to Soldiers, commanders, and national agencies with increasing volume, velocity, and veracity. Cyber is a primary issue in achieving National Security.

a. Cyberspace Operations support all Warfighting Functions and enable national technical operations. Cyberspace operations are based on the AOC, the following reflect CCoE's 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 a 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.

(3) Cyber Situational Understanding (Cyber SU). Development of Cyber SU through a family of interactive, interoperable, and critical technologies will facilitate maneuver planning, collaboration, and synchronization through integration with the commander's user-defined operational picture. Cyber SU fielded within the Army's Command Post Computing Environment, will establish 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 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 would allow 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 dis-mounted cyber 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-Tactical (DCO-T). DCO-T 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 will assess, compose, and deploy cyber elements with known and predictable confidence in their identity, functionality, and content. The Army leverages a joint and holistic industry approach to develop secure systems that can adapt and maneuver automatically to reduce, counter, and evade cyber-attacks. DCO-T supports and enhances Cyber Situational Understanding efforts.

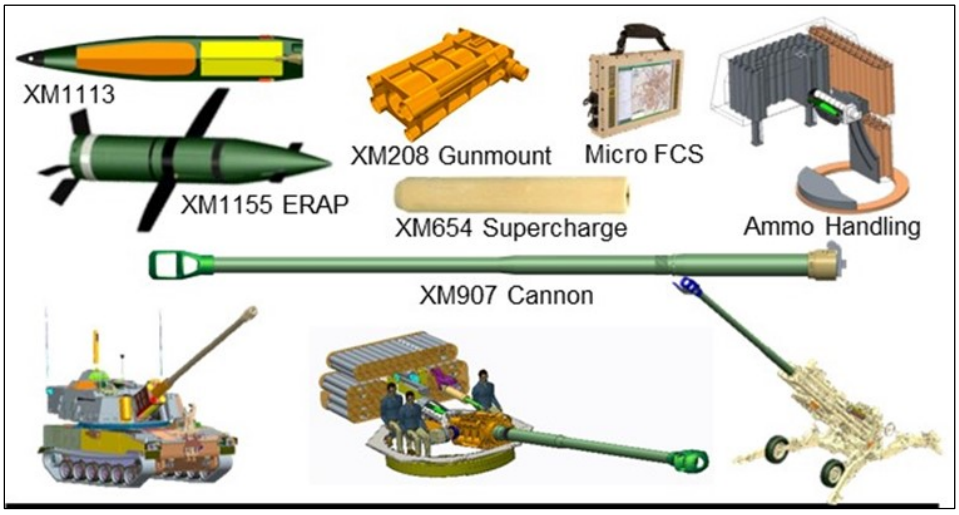
(3) Autonomous Cognitive Radio Frequency (RF). A capability that provides a fully adaptive and reconfigurable RF architecture that is agnostic to waveforms and standards. Radios will have a cognitive capability to operate in any frequency band with any modulation using multiple access specifications,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

(4) Assured Position, Navigation, and Timing (PNT). Assured PNT is a cross cutting capability providing access and integrity to PNT information in Global Positioning System denied Navigation Warfare (NAVWAR) environments. NAVWAR is the deliberate defensive and offensive actions to assure friendly use and prevent adversary use of PNT information through coordinated space, cyberspace, and EW capabilities. The Army must develop the ability to gain and maintain PNT dominance, providing required overmatch in areas enabled by PNT.

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

Fire's S&T Needs derive from the Army Functional Concept for Fires (AFC-F) and Army Warfighting Challenges (AWFC). Fires S&T needs primarily focus on cross domain fires, however, the areas of combat vehicles, expeditionary mission command, cyber electromagnetic activities, and robotics and automation will be key enablers to future Fires systems. Fires forces of the future must be precise, flexible, tailorable, and responsive to maintain overmatch against all threats and in all domains. Fires units must deliver timely effects against targets through all domains to achieve overmatch against enemy fires. Currently, Fires forces focus largely on the ground and air domains. The future operating environment, however, will demand fires that can also effectively operate across maritime, space, cyberspace, as well as the electromagnetic spectrum. Fires systems of the future will support target identification, discrimination, de-confliction, and airspace control through all domains and precisely deliver capabilities with scalable effects to create the desired effects on target with the first engagement.



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

(1) Air and Missile Defense (AMD) Systems. The need to defend critical assets against theater ballistic missiles (TBM), rocket, artillery and mortar (RAM), unmanned aerial systems (UAS), and cruise missile (CM) threats. The need for efforts that improve 360 degree capability to the current air and missile defense (AMD) portfolio.

(2) Long Range Fires/Area Effects (Cluster Munitions). OSD Policy will remove the use of cluster munitions in 2019 due to the inability of existing stockpiles to meet DoD one percent unexploded ordnance (UXO) policy. New and innovative S&T efforts that reduce the UXO to less than one percent will return this capability

(3) Fires Sensors. Fires Sensors (both Field Artillery (FA) and Air Defense Artillery (ADA)) require the ability to conduct both air surveillance and counter fire roles to provide flexibility to the commander. Additionally, fires sensors require

electronic protection to ensure our ability to integrate and deliver fires for the projected future.

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 for a wide range of FA 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 AMD applications. The Army plans to 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, which reduce force structure and improve 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 weapon systems.

Chapter 9 - Human Dimension (HD) 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[13] 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.

a. Listed below are prioritized S&T needs that can make a significant contribution.

(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.

[13]http://usacac.army.mil/sites/default/files/publications/20150524_Human_Dimension_Strategy_vr_Signature_WM_1.pdf

(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) Identify 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, interagency, intergovernmental and multinational (JIIM) 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 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 Intelligence prioritized mid-term future requirements (2025):

(1) Intelligence Enterprise Architecture. A secure and robust intelligence enterprise architecture is foundational to the IWfF. The future intelligence enterprise architecture must span sensors, platforms, and organizations from tactical to national. This provides access to the intelligence enterprise at every echelon – from maneuver squad to joint task force with appropriate analytic applications for each. This architecture must be scalable and enable timely processing, exploitation, and dissemination (PED); shared analytics/distributed analysis; and enterprise collaboration in conditions of limited bandwidth and network outages.

(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, track, and understand adversary behavior, capabilities, and intentions across the range of military operations and in complex operational environments. Collection modernization extends beyond exploiting traditional data sources to capabilities to exploit new phenomenon such as behavioral biometrics, social media, and the internet of things.

(3) Collection Management Modernization. Commanders and collection managers require the capability to rapidly assess and re-deploy collection systems to maximize capabilities of both organic assets and other available resources. A sensor common operating picture displaying the location, status, and effectiveness of organic and available systems will allow the commander/collection manager to maximize collection systems' effectiveness in dynamic environments.

b. The following are the Intelligence prioritized far-term future requirements (beyond 2025):

(1) Deep Learning Support for All-Source Intelligence Analysis. The deep future IWfF requires deep learning systems working in massive volumes and varieties of data to recognize nuanced patterns of life and other not-so-easily observed individual, group, or network behavior. Deep learning systems will team with intelligence analysts to comprehend an unprecedented volume, variety, and velocity of data.

(2) Modeling, Simulation, and Visualization of Threat Entities and Events. The deep future IWfF must support maneuver forces with agent-based simulations or game- theoretic computing to assist planning staffs consider a wider range of enemy courses of action and potential consequences of friendly action through war-gaming capabilities. Future modeling and simulation turns must produce 3D displays of threat courses of action, grounded in real world observations, and must reduce the analyst's burden via user-centric intuitive design.

(3) Real-Time Event Processing and Fusion. The IWfF must modernize to real-time event processing in order to keep pace with deep future operating environments. Real-time event processing, as the follow-on to cloud-based analytics, must provide the architecture and analytics for extremely rapid sense-making and decision support in response to an ever increasing pace of battlefield activity.

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. Efforts to develop a new fighting vehicle and tank are the first priority. Future Army maneuver forces lack the capability to overmatch the enemy in the conduct of expeditionary maneuver, air-ground reconnaissance, joint combined arms maneuver, and wide area security. MCoE supports development of technologies that will enable development of a vehicle for the Infantry BCT that will afford selected elements the protection, mobility, and fire power to support their forcible and early entry tasks.

(2) Tactical Networks. BCTs require the capability to establish and maintain secure communications in sufficient capacity to enable mission essential information exchange throughout the formations. Of particular importance is the small unit (company and below) and dismounted communications and connectivity to higher networks. The ability to establish and maintain situational understanding to the lowest levels is critical.

(3) Advanced Sensors. Improved sensors need to extend the reach and lethality of Army formations. Advanced sensor requirements permeate all the other priority areas and are integral mechanisms of vehicles, unmanned systems, and those carried by individual Soldiers. This, along with tactical networks, is critical to establish and maintain situational understanding especially for the dismounted Soldier.

(4) Lighten the Load. Soldiers are more capable than in any time in history, but their capability has come at the expense of over burdening them with systems which often weigh too much and which, in some cases like body armor, inhibit their performance. Demonstrations are needed of lighter weight weapons and integrated power with significant weight reduction. Efforts to develop lighter Soldier systems, to reduce the power demand, create power management solutions, and to develop manned and unmanned systems that can reduce the load they are required to carry are all underway. The concept of "assured resupply" of small units (company and below) may allow leaders to reduce the amount of equipment and supplies Soldiers carry must be pursued.

(5) Human Dimension and small unit leader leadership. Pursue technology that enables them to train more realistically and to rehearse more thoroughly in simulated environments with augmented reality so that they never have to execute a mission that they have not encountered in training and rehearsal.

(6) Small Unit Lethality. Our units should never be in a fair fight. Their ability to employ firefight ending capabilities immediate, overwhelming precision direct and indirect fire is the goal. Efforts to increase the lethality of small units must also include technology necessary to network and enable employment of Joint fires.

(7) Unmanned Systems. Improved unmanned systems to extend the area and time over which small units can operate effectively are required. Unmanned systems will increasingly be required to not only provide full motion video to leaders, but also to establish expeditionary communication networks, extend lethality, and to employ an advanced compliment of sensor technologies. These capabilities will assist in the increase of small unit mobility, lethality, precision, and situational understanding.

Chapter 12 - Medical / 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 en-route 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 of medical equipment that will provide life support to casualties during ground and air medical evacuation.

(2) Far-term technology candidates include artificial blood, cellular oxygenation capability other than the use of blood, and development of metabolic depressant drugs to stabilize and protect vital organs and tissues during periods of prolonged holding and/or transport.

b. Infectious Disease Countermeasures. Infectious disease represents a significant threat to military forces with the potential for significant operational impacts. Identification of new infectious diseases by the scientific community as they emerge, require medical countermeasures 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, leishmaniosis, diarrheal diseases and drug resistant malaria.

(2) Far-term technology candidates include hyperactive stimulation of an individual's immune system to improve resistance to diseases and medications that act upon antibiotic resistant bacteria.

c. Optimize Health and Performance. Incorporate new technologies pushed forward on the battlefield to small units, battalion aid stations, Forward Surgical Teams/Forward Resuscitation 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, far forward brain function assessment, and diagnostics, nutritional supplements that speed recovery, human performance optimization to develop physical, social and cognitive overmatch, physiologic status monitoring, and leader tools.

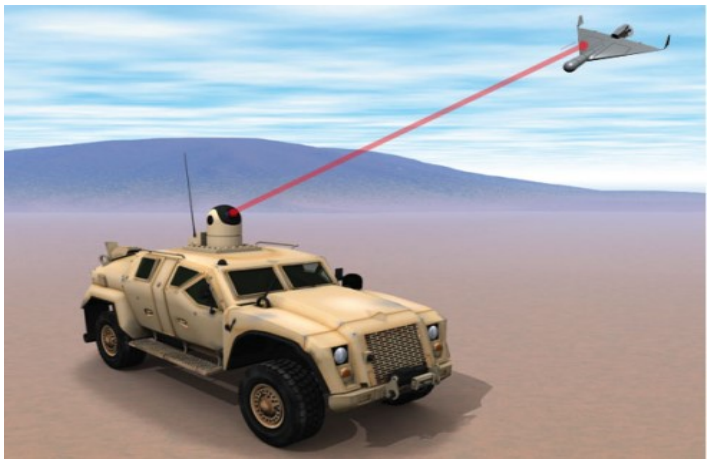
(2) Far-term technology candidates include identification of biomarkers of nanomaterial exposure health effects.

Chapter 13 - Missile Defense (Space and Missile Defense Command (SMDC)) S&T Needs

The purpose is to codify the Missile Defense priorities to inform S&T efforts and influence resource decisions.

a. The following reflects prioritized capability needs and potential technology candidates for the mid-term future (F2025B) for missile defense as written by SMDC.

(1) Space and high - altitude support to the warfighter. Space and high altitude S&T efforts focus on continued development of regionally focused capabilities such as small satellites, or similar high altitude platforms to support and extend tactical communications. Position Navigation and Timing (PNT) capabilities focused on providing assured PNT in degraded environments. Small satellites or similar high altitude platforms to provide tactically responsive intelligence, surveillance, and reconnaissance. S&T efforts focusing on the development of capabilities to support offensive navigation warfare and the control of adversary access to space support. These are critical capabilities to enhance joint and Army force operations. As the Army becomes more regionally engaged and globally responsive in the conduct of high tempo joint combined arms operations, it requires assured access to these space support capabilities and the ability to selectively deny these same support functions to future adversaries.



(2) Global Ballistic Missile Defense support to the Warfighter. Our S&T efforts must continue to focus on enemy air and missile threats and pursue the development of an integrated, “layered” architecture of networked sensors, ground, sea, and space. Similarly, enhanced interceptors and a command, control, battle management and communications network providing the joint warfighter with a robust, layered defense to defend against a hostile air and missile attack is a necessary capability. The evolution of multiple sophisticated capabilities requires a holistic approach that effectively integrates offensive and defensive, kinetic and non-kinetic, and alternative capabilities to defeat air and missile threats. The growing complexity of the strategic environment (technological advances of the threat and fiscal realities) requires cost efficient and effective methods of integrating current and future capabilities.

(3) Directed Energy. We must continue to focus our S&T efforts on 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 provide a potential counter to 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 have the potential to provide cost-effective and flexible engagements for these threats.

b. Missile Defense capability needs for the far-term (beyond 2025) derive from the AOC, the Army Functional Concepts, and analysis of the Army Warfighting Challenges.

(1) Space Operations. Far-term space operations must provide better integration, synchronization, and robustness to support joint operations of the future warfighter. Robust space capabilities that include regionally focused constellations of small satellites will provide next generation satellite communications; PNT augmentation; intelligence, surveillance, & reconnaissance; environmental monitoring and threat warning services directly to the tactical edge. These robust space-based and space enabled capabilities will provide the enhanced information superiority and situational awareness capabilities needed to support high tempo, noncontiguous, and simultaneous distributed operations. 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.

(2) High Altitude operations. Expanding our capabilities in the high altitude layer is essential to establishing the multi-tiered capabilities addressed in our operating concept and many of the communication and ISR capabilities under development. Our future S&T efforts need to support regionally focused, enhanced high altitude systems that are sustainable for extended time periods, and include platforms, ground stations and payloads tailored to support expeditionary maneuver. As the aerial layer matures, persistence high altitude capabilities will augment both the terrestrial and space layers to provide robust and expanded capabilities to the lowest tactical levels. High altitude platforms include both lighter-than-air and heavier-than-air platforms. They integrate improved designs, fabric/composites, launch, and recovery systems. Blending advancements from the commercial sector high altitude capabilities will provide long duration capabilities for surveillance and communication platforms to see over-the-horizon for theater and homeland defense operations. Both lighter-than-air and heavier-than-air capabilities will benefit the Joint Warfighter by providing responsive, long endurance platforms to support globally responsive Combined Arms Maneuver and Wide Area Security.

Chapter 14 - Mission Command Center of Excellence (MCCoE) S&T Needs

This portion highlights key S&T 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 Army Capabilities initiative and the Army Operating Concept. 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. The following represent the mid-term needs that present opportunities to incorporate rapidly into Force 2025 new, yet mature technologies:

(1) 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) Agile, Robust, Resilient Network. A mission command network that enables expeditionary mission command and reach, accessible at the point of need for operations that include unified action partners.

(3) Command Post Survivability and Demand Optimization. Future command posts must be survivable against an array of threats and optimize logistical demand.

(4) Assured Network Access and Security. An easily understood, single mobile, protected network configured, managed, and secured which maximizes connectivity and capacity for operations.

(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) Optimize Human Performance. The Army must effectively assess and manage the quality, talent, and cognitive ability of its people with operationally focused measures, metrics, and medical programs that contribute to an effective and adaptable force.

(2) Mission Command of Robotic and Autonomous Systems. The future Army will employ larger formations of robotic and autonomous systems requiring artificial intelligence and advanced mission command interfaces.

(3) Enhanced Data to Decision. Mission Command systems must have tools to perform automated analysis to enhance a leader's ability to better understand, visualize, describe, direct, and assess operations.

Chapter 15 - Protection / Maneuver Support Center of Excellence (MSCoE) S&T Needs

This chapter represents the prioritized capability needs to further enable the Protection Warfighting Function.

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

(1) Mitigate obstacles and hazards. Chemical, biological, radiological, and nuclear (CBRN) and/or general purpose forces require the ability to engage a weapon of mass destruction (WMD) to prevent their use, stop the transport of WMDs, detect subsurface CBRN use, decontaminate large numbers of contaminated personnel, and assess the extent of CBRN contamination. Engineer Soldiers performing route clearance functions require the ability to detect buried improvised explosive devices (IED).

(a) Theater Army conventional forces need the capability to safely engage (disrupt, neutralize or destroy) a WMD threat to prevent use to protect against loss of life and equipment.

(b) Theater Army conventional forces need to improve the capability to stop the transit of WMDs, its delivery systems, or related materials, technologies, and expertise during decisive action to protect against the loss of life.

(c) CBRN forces need enhanced capabilities to assess the extent of CBRN contamination under post-employment of WMD or CBRN munitions to identify: hazards, exposed populations and proposed mitigation measures in near real time increasing situational understanding to protect against the loss of life.

(2) Shape terrain. Engineer forces require the ability to employ U.S. policy compliant obstacles to influence movement and maneuver or deny terrain.

(a) Engineer brigades, maneuver enhancement brigades, fires units, and BCTs need the capability to employ U.S. policy compliant (man-in-the-loop) obstacles to influence the movement and maneuver of enemy forces or deny enemy forces use or access to key terrain/facilities.

(b) Theater Army conventional forces need enhanced capabilities under decisive operations to interrogate non-line of sight subsurface CBRN threats or hazards (e.g. tunnel complex) very deeply to minimize loss of life and equipment.

(3) Protect the force, populations, and resources. Military Police Soldiers require an improved means to disseminate police information and fused criminal intelligence with unified action partners, host nation, and security personnel.

(a) The CBRN units need enhanced capabilities to quickly conduct decontamination of Soldiers in support of Unified Land Operations (ULO) to prevent loss of life and human suffering.

(b) All operational Army units need improved capabilities to detect IED threats while conducting mounted or dismounted operations and remaining outside the blast effect radius, to maintain freedom of maneuver.

(c) The MP Brigade needs enhanced capabilities to disseminate police information and fused criminal intelligence with Unified Action Partners, host nation and security personnel in ULO to enable targeting and prosecutions.

b. Protection S&T Needs for the far-term (beyond 2025).

(1) The 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. These aerial, surface, and sub-surface threats require detection and response capabilities.

(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. In the U.S. Army operating concept, 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.

Chapter 16 - 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; and increased sustainment capabilities.

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

(1) Autonomous Aerial Resupply. Unmanned aerial distribution platforms support responsive sustainment to widely dispersed units when weather, terrain, and enemy threats pose unsuitable risk to manned air and ground assets. Autonomous aerial resupply capabilities reduce Soldier exposure to risk; decrease demand for ground distribution requirements; extend operational reach to widely dispersed forces; improve redundancy within the transportation network; decrease customer wait time through point-to-point and on-demand delivery; and increase operational readiness.

(2) Autonomous Ground Resupply. Autonomous Ground Resupply incorporates autonomous technology into existing tactical wheeled vehicles (TWVs). Vehicles can operate independently or in a manned-unmanned teaming environment. This capability allows control, as well as mission assignment remotely through an operator control unit. Potential benefits include reduced Soldier exposure to risk; extended operational reach; increased throughput; mitigated human endurance constraints; improved Soldier ability to focus on mission-critical tasks; and enhanced options to shape the future force.

(3) Alternative Sources of Water. Measures to provide alternative sources of water reduce the total Army demand through point-of-need water production, reuse, and

efficiencies. Potential benefits include improved ability meet demand at the point of need; reduced convoy requirements and logistics footprint associated with centralized water production and distribution; and increased endurance for expeditionary forces.

(4) Additive Manufacturing. Additive Manufacturing is the process of making a three-dimensional, solid object from a digital model using an additive process where successive layers of material are laid down to form different shapes. It is a critical enabler for military use and has application at the strategic, operational, and tactical level. Potential benefits include improved ability to meet demand at the point of need; reduced Class IX distribution requirements; decreased manufacturing lead times and Authorized Stockage List (ASL) requirements; improved supply metrics and increased operational readiness; and reduced life cycle cost and enhanced ability to exploit innovation.

(5) Intelligent Power Management and Distribution. Intelligent power management and distribution (IPMD) combine hardware and software to optimize usage and distribution of electrical power. IPMD will enable energy informed operations to inform decisions, optimize use, assure access, and build resiliency. Potential benefits include increased efficiency at the point of need; reduced requirements and logistics footprint associated with fuel distribution; and improved endurance for widely dispersed, expeditionary forces.

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

(1) Alternative Fuels and Advanced Power Generation. Advanced power generation can decrease the total Army demand and provide the future force with improved endurance and greater, self-sustaining capability. Potential benefits include increased reliability and access of power; reduced demand for fossil fuels, increased redundancy within the power distribution network; reduced requirements and logistic footprint associated with fuel distribution; and increased endurance for widely dispersed, expeditionary forces.

(2) Information to Decision. A networked, cyber-protected common operating picture available at the point of need that 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 17 - 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.

a. In the mid-term (2025), 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) Single Synthetic Environment (SSE). S&T research that supports the establishment of a single synthetic simulation-training environment. This environment will provide research and technology that will deliver a scalable, low overhead, integrated synthetic training environment that delivers training to point-of-need, when needed, and realistically replicates a complex and dynamic operational environment.

(2) Augmented Reality. Platform or standalone that provides immersive, full spectrum, training experience for small units at home station or deployed with minimal infrastructure; allows Soldiers to be immersed in local live and complementing Synthetic Training Environments (STE) in real time. Allows for the interaction (haptic, 3D sound, voice and gestures) with synthetic entities and immerses Soldiers and units in an augmented reality enabled environment integrated with the STE.

(3) Live Training Simulations. The Army's future tactical engagement systems require the ability to provide Global Positioning System (GPS) geo-pairing simulation that replicate live fire conditions to enhance force-on-force training. This technology helps to overcome limitations of the current laser-based (e.g. Multiple Integrated Laser Engagement System – MILES) systems and maximizes embedded training or dual use capabilities for mounted and dismounted operational systems and sensors.

(4) Individual and Collective Adaptive Learners. To remain competitive, the learning model will seize opportunities to use technology as an enabler to engage and appeal to digital age learners. Through cognitive research, the Army will develop innovative and effective training methods that expedite training and change the focus on the Soldier's individual learning needs through collaborative learning. The Army will develop scientifically based guidelines, procedures, and methods to improve the small unit's ability to effectively and efficiently train, in order to enhance unit readiness and resilience.

b. Beyond 2025, Army T&E will continue to streamline and improve by aligning the STE with live training and the Training Information Infrastructure (Tll). The STE is a single system that emphasizes the cognitive and social elements of the Human Dimension. It converges current constructive and virtual environments and enhances live training through the integration of augmented reality. The STE will provide 2D and 3D views of the environment, thus delivering a virtual and constructive training capability based upon the needs of the training audience. Built on a One World Terrain database, the single synthetic environment enables training anywhere in the world, in any domain on land, sea, air, space or cyberspace. The STE will be able to represent megacities so that U.S. forces can more efficiently prepare to combat threats arising within the megacities of our world. Future ranges require the capability to use augmented reality or holographic images to create a more realistic training range environment. A single synthetic environment greatly reduces the complexity of today's simulation federation architectures. Required Capabilities beyond 2025 are:

(1) Synchronized Live Training. The Army requires the capability to rapidly develop and conduct synchronized live training, to brigade level, in conditions that fully replicate the physical, social and cognitive complexities of the OE. This requires a comprehensive (individual and collective), embedded, combined-arms training capability that includes mission command and maneuver (mounted and dismounted) tasks. This immersive capability must provide individual and multi-echelon simulation(s) to enable small unit collaborative training using synthetic mission planning and rehearsal capability enablers in the OE.

(2) Stimulate Mission Command Systems and Sensors. These realistically replicate combined arms effects and capabilities, replicate hybrid threat capabilities and joint, interagency, intergovernmental, and multi-national (JIIM) parters, interoperate among air, ground, and other Service training systems, and provide rapid and realistic feedback to the individual, vehicle or equipment. It will provide network capacity and infrastructure to support worldwide, secure, wireless delivery of T&E products on platforms that range from fixed computers and simulation centers to mobile platforms across all training environments and domains.

(3) Adaptive Learning/Learner Centric Enterprise. This is an accessible, responsive, and adaptive capability to access on-demand, mobile learning content worldwide at the point of need. Its design requires clearly defined protocols and standards allowing interoperability to support multiple T&E products, agnostic architecture that plays products on multiple types of devices and systems, and facilitates validation and assessment of content and effectiveness. Soldiers, Army Civilians, and their leaders will be able to conduct accurate self-assessments to determine future T&E requirements to improve knowledge, skills, behaviors, and abilities. Mobile delivered instruction will mimic a one-on-one tutor by adapting and tailoring individualized learning to the learner's prior knowledge and learning style preferences.

(4) Virtual Human. Future training, leader development and education require artificially intelligent virtual human capabilities to represent combatant and non-combatant forces, indigenous populations, and JIIM players to replicate the complex OE. The virtual humans must have a cognitive architecture capable of supporting natural language processing to enable autonomous interaction (verbal and non-verbal) with humans and computer generated forces in the various applications in the STE and distributed learning environments. A virtual human can understand, reason, and make assumptions about the environment and distributed learning training applications. Virtual humans will populate large-scale simulations to expand the range of on-demand, interactive training opportunities and reduce human overhead support.

(5) Augmented Reality. Develop augmented reality capability to project virtual entities of aircraft, vehicles, people, and battlefield effects in the live environment. Augmented reality enables most home station training to become a dynamic, cost-effective training environment.

Chapter 18 – Conclusion

To accomplish its future mission, the Army must leverage technology advancements. Below is a list and description of S&T areas relevant to Army concepts and future operations. This is not intended to be an all-inclusive list of S&T areas and technologies, but should provide a starting point from which developers across DoD, academia and commercial organizations can focus their efforts. The list highlights some of the linkages and benefits of such technologies to enable effective unified land operations.

a. Internet of Things.[14] This technology area will continue to revolutionize how the world humans and machines function. Over the next 30 years, embedded sensors, actuators, and data communications technology will change how we think about information networks. The Army and the Department of Defense will not be immune to the movement, as new requirements are placed on command node items and structures. The Army will have sensors similar to the commercial sector to enable near-real-time information and control throughout the area of operations. What do future command nodes need to look like to enable the realization or actualization of the internet of things? The potential exists to find new efficiencies in communications, energy, logistics, and intelligence, among many fields.

b. User Interfaces. Innovations in human-computer interaction are poised to reshape the way we interact with the digital world. Speech interfaces are already in digital assistants like Apple's Siri and Microsoft's Cortana. Augmented reality and other emerging technologies such as gestural interfaces, virtual reality, and brain-computer interfaces could connect us more directly with computational devices. These technologies will have far-reaching implications for interaction design and collaboration between the human and the machines, as well as between humans (individuals and teams). The speed at which correct information can be found and information transferred to enable decision making will significantly increase. The technologies associated with human-machine interfaces will play a key role in achieving a number of Mission Command and command post design characteristics.

[14] The Internet of things is the interconnection via the Internet of computing devices embedded in everyday objects, enabling them to send and receive data. Oxford Dictionary Online.

c. Robotics and autonomous systems. As we expand utilization beyond today's unmanned drones, robots and autonomous systems will redefine the role of the Soldier in combat. Indeed, there may be formations of robots or semi-autonomous systems controlled by command nodes conducting a wide array of tasks to literally reduce the human footprint. Future autonomous systems may provide logistics, transportation, security, or construction services. These systems must be able to be networked with a human-in- the loop allowing one Soldier to control many thereby realizing the personnel savings envisioned in the AOC. Additionally, future Army command posts must be tailorable and modular to account for the systems and personnel changes that accompany future adoption and proliferation of autonomous systems.

d. 3D and 4D printing. The 3D printing that exists today will give rise to creating objects from a variety of materials, including plastic, metal, ceramic, glass, paper, and even living cells. Future 3D printers will be able to print objects made from multiple materials that incorporate electronics, batteries, and other components. This will help satisfy specific requirements at the point of need and potentially streamline logistics needs for command nodes. 4D printing will extend additive manufacturing by creating objects that can self-assemble or change shape on their own. The ability for command nodes across formations and echelons to self-supply and potentially become supply centers in and of themselves will have far-reaching impacts on Army structures, organizations, and capabilities.

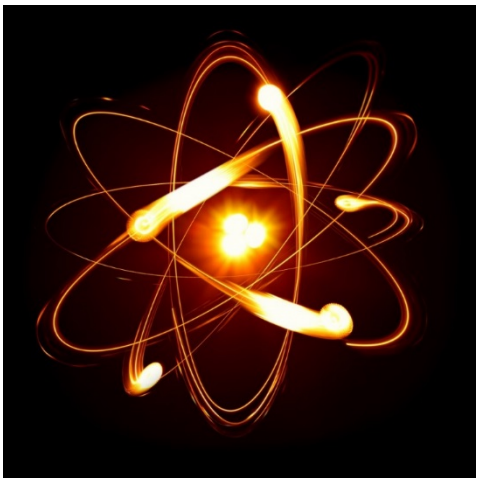
e. Analytics and Big Data.[15] The Army has become adept at collecting information, but analysis is still largely a human endeavor. Mining, sifting, and producing useful and understandable products from that information will continue to be burdensome. The continued proliferation of drones and the advancement of wearable sensors will add to the pace of information creation. Algorithms must be able to process ever larger data sets and increase the analyst's capability to make sense of complex data to help commanders make decisions. Simulating these results or potential decisions many times over will provide commanders and staffs insight into unintended consequences or

[15] Extremely large data sets that may be analyzed computationally to reveal patterns, trends, and associations, especially relating to human behavior and interactions. TRADOC Pam 525-3-3, p. 93.

areas where additional information is needed. These tools, available to Soldiers at the lowest echelons, must run on hand-held or personal devices such to enable smaller teams of analysts to support larger nodes and reduce the load on the Army information network.

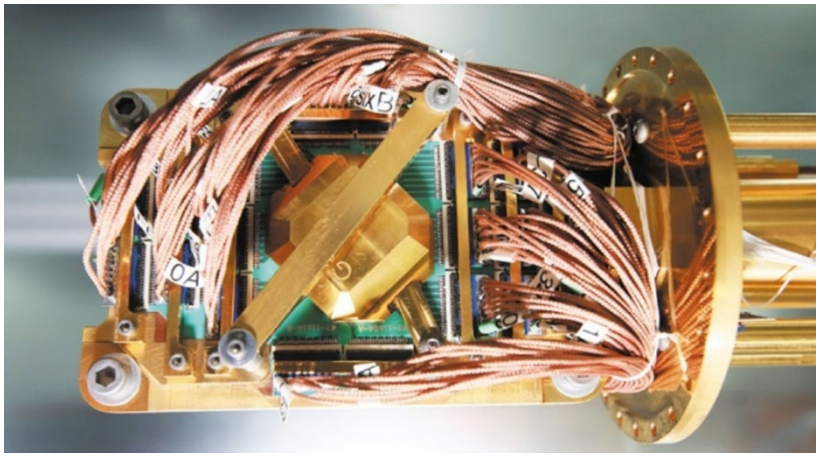
f. Mobile and Cloud Computing.[16] The civilian mobile revolution ushered in powerful handheld computers coupled with high resolution screens at affordable prices. Future leaders will be able to untether from command nodes while maintaining situational understanding, and having the ability to leverage vast cloud computing capabilities that process stores of information. Moreover, leaders will be able to customize their displays to role, function, or priority. Command nodes will be easier to establish requiring less infrastructure, yet be more powerful while leveraging mobile and cloud computing. This will enable the Army to continue to distribute tasks and further decentralize mission command. S&T developments and military applications to leverage mobile and cloud computing are critical to fully realizing future Army concepts and success on the future battlefield.

g. Energy. The Army's increasing reliance on electronics means the Army must have continuous access to energy sources sufficient to power its devices. Advances in energy management, generation, and harvesting will enable commands to ease logistical demand, while also enabling the Army to be more expeditionary. Technology advances in energy will also improve the function and capabilities within Army command nodes, allowing formations to fully utilize other advanced technologies such as autonomous systems or quantum/high performance computing. Additional benefits can come from advancements in directed energy devices yielding additional applications in a variety of functions such as communications and force protection.



[16] Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction. NIST Special Publication 800-145, p. 2.

h. Quantum and High-Performance Computing.[17] Future Army forces will possess advanced processors in computers which will increase computing capacity by orders of magnitude. This new breed of devices will also have a corresponding decrease in power consumption. Command nodes may not always be able, or need to, continuously reach for access to the computing power the cloud will offer. Future sensors will process large amounts of data and run powerful algorithms locally, for extended periods of time reducing resupply or service rates. Power, communications, manpower, and other demand reductions will allow commanders focus limited human cognitive effort to other tasks. Advancements in algorithms, hardware, software and operating systems to maximize the value of multi-core processors and future high-performance computing platforms must be a focus area for future S&T investments.



[17] Quantum computing is the area of study focused on developing computer technology based on the principles of quantum theory, which explains the nature and behavior of energy and matter on the quantum (atomic and subatomic) level. Development of a quantum computer, if practical, would mark a leap forward in computing capability far greater than that from the abacus to a modern-day supercomputer, with performance gains in the billion-fold realm and beyond. The quantum computer, following the laws of quantum physics, would gain enormous processing power through the ability to be in multiple states, and to perform tasks using all possible permutations simultaneously. WhatIs.com.

"To fight and conquer in all your battles is not supreme excellence. Supreme excellence consists in breaking the enemy's resistance without fighting"

Sun Tzu
"The Art of War"

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