16 Sep 14

White Paper

Subject: Science and Technology Lines of Effort for a Future Expeditionary Army

1. Purpose: The primary purpose of the S&T Lines of effort is to provide clear and concise articulation of the capabilities needed and leading technologies that stand to fundamentally change the force in the decade of the 2030s. The Army requires expeditionary technology driven capabilities allowing rapid deployment of scalable, operationally significant forces on short notice to austere locations to conduct the full Range of Military Operations immediately upon arrival, often in persistent anti-access / area denial environments.

2. Background: Analysis of the Operating Environment suggests that under our current investment strategy, the U.S. will retain our technology advantages to the end of this decade. After that we will begin to experience erosion of our overmatch, and between 2030 and 2040 we can expect to lose our edge in several key areas. This paper contends that for the US Army to be ready, expeditionary, and remain the premier Land Force we must begin to balance the needs of Soldiers today with investments in innovation to enable the Soldiers of tomorrow.

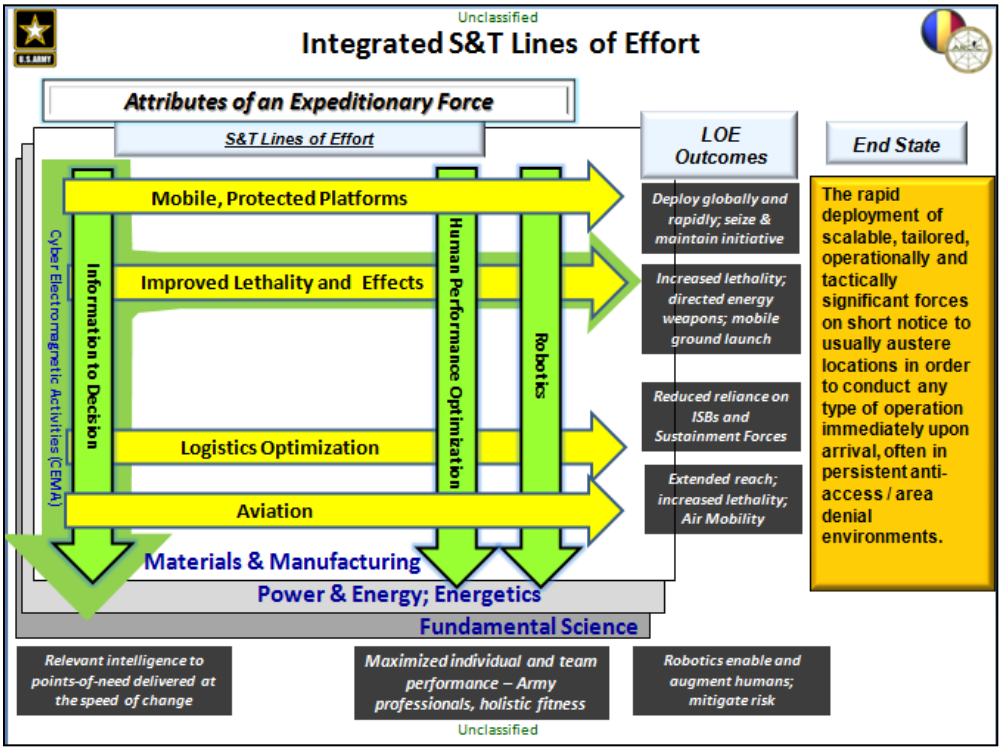


Figure 1. ARCIC S&T Lines of Effort after January 2014 Strategic Trends Seminar

3. Line of Effort Origin & Structure: Starting in 2013 TRADOC / ARCIC began synthesized key insights from the Campaign of Learning yielding eight key Lines of Effort (LoEs) intended to focus key science and technology efforts held as critical to achieving prioritized Army future capabilities.

a. Structure. The S&T Lines of effort shown in Figure 1 are broken into two categories:

Baseline LoEs
1. Mobile Protected Platforms
2. Improved Lethality and Effects
3. Logistics Optimization
4. Aviation

Cross-cutting LoEs
5. Cyber Electromagnetic Activities (CEMA)
6. Information to Decision
7. Human Performance Optimization
8. Robotics

b. S&T LoE Foundations. The following serve as scientific foundations that underpin all the LoEs:

1) Fundamental science: Sustain investment in BA 6.1 (basic research) that advance the frontiers of our understanding of fundamental scientific phenomena driving long-term, game-changing capabilities.

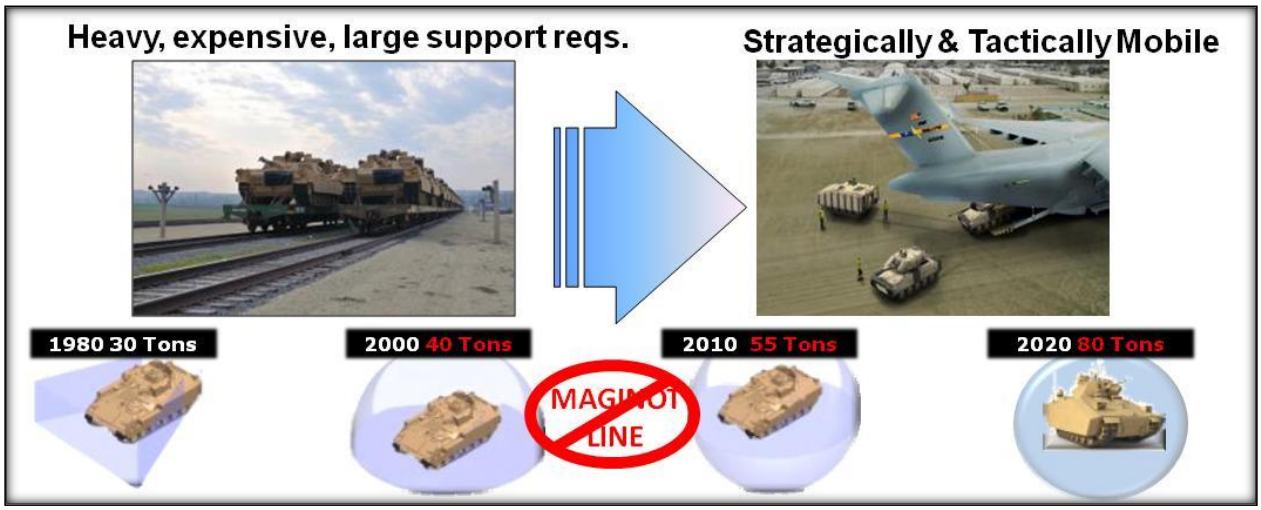
2) Power & Energy / disruptive energetics: Breakthroughs in fuel and energy efficiency and energy storage are critical to enabling a more effective expeditionary force with a reduced footprint. Advancements in energetics must focus on an up to 10-fold time increase in effectiveness at reduced cost.

3) We must continue research aimed at developing the capability to design materials at the atomic level to provide the optimal properties. We must strive to develop a "materials by design" capability for electronic and protection materials to provide greater weight savings, increased life cycle, and reduced cost.

c. Relation to Force 2025 efforts and Way Ahead. Concurrent efforts aimed at aligning technology against specific objectives for Force 2025 (e.g., maintain overmatch, expeditionary, adaptive army leaders, leaner, and continuously upgrade the network) set a waypoint for fundamental change in 2030-2040. The S&T lines of effort is a "living document" that will continue to be refined in a manner that best facilitates exploration and concepts development in TRADOCs wargaming and experimentation activities.

4. Discussion: Baseline LoEs:

a. **Mobile Protected Platforms:** Deploy globally and rapidly; seize & maintain initiative



1. **Problem** To be globally responsive the Army must, with little to no notice, rapidly deploy operationally significant forces into hostile theaters anywhere on the globe. The places of entry are normally austere, unsophisticated, lack significant infrastructure, and is a bottle neck in the flow of Soldiers and their equipment to the point of need. These brigades also require large logistics support, with roughly two-thirds of the personnel strength required to sustain the one-third combat power. Over the last decade plus, the weight of the Armored Brigade Combat Teams has steadily increased to counter increased blast threat of our adversaries. The Ground Combat Vehicle with its modular armor is estimated to weigh up to 80 tons to provide the desired protection level. This comes at the cost of mobility and maneuver.

2. **Desired Attributes**: BCTs require the ability to rapidly deploy using significant less air and sealift asset. Maneuver forces require greater tactical, operational, and strategic mobility. Combat vehicle systems weight and volume must be significantly reduced through the use of lighter materials and novel protection solutions that no longer demand the parasitic weight of passive armors. Sensors must locate and identify threats pro-actively so protection systems can anticipate, and dynamically adjust to counter these threats. These improvements will allow systems and formations to maneuver out of contact. Weapons systems require enhanced lethal and non-lethal capabilities, at extended ranges (LOS/BLOS) with the ability to defeat threats in defilade or under cover. Future combat vehicles must be more fuel efficient, significantly increase the “Mean Time between Failure” (MTBF) and the greater ease of maintenance. Desired characteristics for Mobile Protected Platforms of 2030-2040 include:

a) The ability to conduct expeditionary, joint vertical maneuver with mounted and dismounted forces into austere environments and unimproved entry locations.

b) Order of magnitude decreases in vehicle weight to enhance strategic, expeditionary, and tactical mobility.

c) Advanced, lightweight armor and systems that provide 360 degree hemispherical protection against a wide range of threats, both kinetic and non-kinetic.

d) Heavy maneuver support platforms and specifically improved strategic lift (air/sea) that dramatically decrease strategic throughput times.

e) Maximize the use of passive and active sensor systems (pre-shot detection) to locate and identify hemispherical threats before our platforms are within reasonable engagement range.

f) Development of lighter weight and multifunctional materials, in conjunction with novel armors and defensive aid suites to reduce the platform signature, weight and volume while increasing survivability, mobility and force protection against all threats.

g) Active or passive methods to protect against both kinetic and non-kinetic threats. The ability to fend off ballistic projectiles or to disrupt explosively formed penetrators from the air, surface and underground.

h) An order of magnitude increase in the MTBF standard, to reduce the maintenance burden on the BCT formation.

i) Advanced vehicle maintenance systems that anticipate failure of component systems and provide self-diagnostics once a part has failed with information automatically provided to the crew and maintenance personnel.

j) Reduction in the number and type of mechanical components, and replacing them with electronic and electrical systems where possible.

k) Greater use of common and modular components.

l) High levels of energy efficiency, permitting individual platforms to operate for extended periods of time without resupply of any classes of supply.

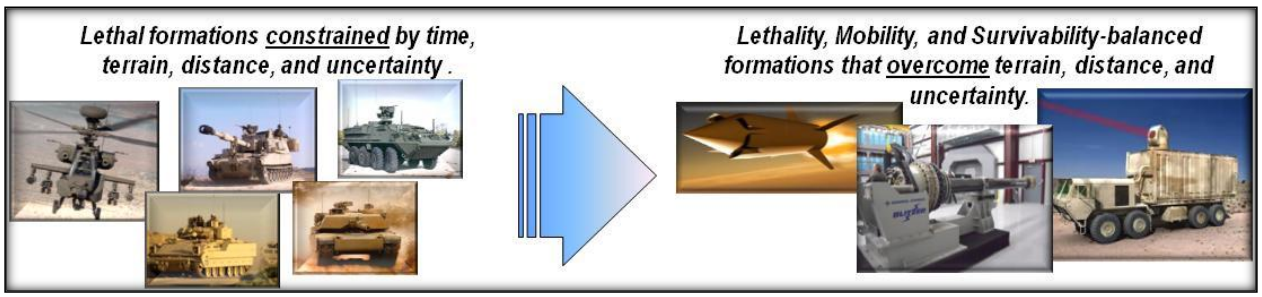
m) Increased power generation and storage with same or reduced SWAP designed into the vehicle to provide an operating margin for additional systems of when components fail.

n) Reduced vulnerability to electromagnetic pulse, electromagnetic interference, and cyber threats.

o) Integration of unmanned ground an air platforms into formations to serve as force multipliers across all WfFs

p) Increased system reliability and resilience to increase force effectiveness and enable a more expeditionary force by reducing the size of the logistical footprint, reducing demand, increasing unit self-sufficiency, and allowing re-distribution of manpower.

b. Improved Lethality & Effects: Increased lethality; directed energy weapons; mobile ground launch



1. **Problem:** The Fires Force must be globally expeditionary, with greater strategic and tactical mobility through lighter, more capable, and more survivable platforms. Fires must be equipped with a wide array of overmatching, long range capabilities that enable Soldiers to detect, identify, and defeat enemy surface and air combatants and systems. The ability to employ and synchronize Joint, Army and Unified Action Partners' fires will facilitate delivery of tailorable effects to achieve the Combatant Commanders' objectives while preventing fratricide and minimizing collateral damage. Investments in improved accuracy and range are paramount to scalable and precise ground based effects on stationary and moving surface and aerial targets in all conditions.

2. **Desired Attributes:** Fires must have the ability to engage the full range of targets, in all conditions, and in all domains (e.g. land, sea, air, space, & cyberspace). Expanded and refined use of the electromagnetic spectrum using kinetic energy, directed energy, and hypervelocity munitions will enhance Fires' ability to deliver desired effects on target. Some specific examples are:

   a) Equipping the force with reliable, ultra-high speed, global Mission Command capabilities that enable the detection, identification, and engagement of multiple threat targets (ranging from light mortar rounds to ICBMs) by Joint, Army, and UAP systems at extended stand-off ranges.

   b) Common Air and Missile Defense and Field Artillery platforms and systems that allow the emergence of true "Fires" capabilities, MOS consolidation, reduced logistics, and reduced training.

c) Employment of an Air and Missile Defense (AMD) shield capability will allow the Army to protect critical assets, personnel and infrastructure. These AMD capabilities will enable fires forces to conduct offensive and defensive operations that can disrupt, degrade, destroy, and deter the full threat spectrum in support of homeland defense, counter-ballistic missiles, and unified land operations (ULO).

d) Extended range precision surface-to-air and surface-to-surface fires that overcome anti-access and area denial threats and enable assured access to global commons.

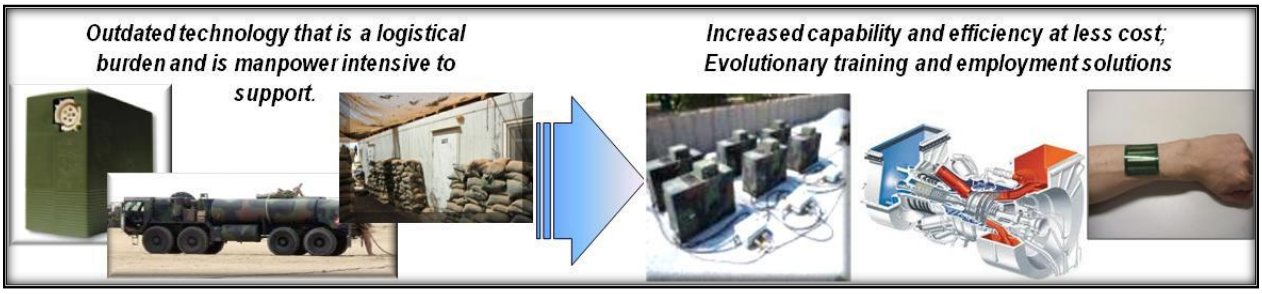
e) Discriminate, scalable, tailorable effects, both kinetic and non-kinetic, that achieve the Combatant Commanders' objectives in a contested environment while preventing fratricide and minimizing collateral damage.

f) Delivering strategic effects with enabled, multifunctional strategic and tactical formations, including multiple, simultaneous entry operations of rapid and modular forces able to fight and sustain themselves on arrival.

g) Renewable, tactical directed energy resulting in “bottomless munitions stowage” and order-of-magnitude standoff range increase.

h) Commanders empowered by autonomous systems substituted to conduct the most hazardous battlefield tasks.

c. Optimized Logistics: Reduced reliance on ISBs and Sustainment Forces.



- **Problem:** Our current force requires an enormous amount of resources to deploy and sustain campaigning. Approximately the majority of our force structure is dedicated to logistical support. Our heavily armored vehicles require enormous amounts of fuel. Base camps require vast logistical support in order to provide the needed water and power/energy. Our forces depend on access to Air and Sea Ports of Debarkation (APODs/ SPODs) and staging bases. Our increased dependence on electronics drives the need for large quantities of batteries. Furthermore, we often lack the ability to be fully self-sustaining and place a reliance on the host-nation which is unpractical during for forced entry operations.

1) **Desired Attributes:** In order to have an expeditionary capability and to fight in a contested environment we must increase our logistical efficiency, reduce demands, and increase the "tooth to tail" ratio. We need to decrease our dependence on APODs and SPODs and be able to fight from multiple points of entry with or without host-nation support. We need to increase our efficiency by reducing our fuel requirements, decreasing our generation of waste, making more efficient use of power and energy, and being able to provide just-in-time logistics and precision resupply. The following lays out some of the needed attributes in more detail Desired characteristics for logistics optimization include:

   a) Ability to provide logistic support for forced entry, early entry, and non-contiguous operations.

   b) Faster efficient/effective deployments, enhanced ability to sustain the forces via improved platforms & techniques, and use of unmanned platforms

   c) Equipment with increased reliability needing fewer tools for maintenance to reduce required logistical support.

   d) Vehicles equipped with high efficiency components, intelligent power management, and incorporating compact auxiliary power generation technology to enable engine-off operations.

   e) The ability to rapidly assess, establish and upgrade multiple unimproved A/SPODs to support movement and maneuver.

   f) Intelligent anticipatory tools and sensors able to manage, track, and distribute supplies in an automated manner.

   g) Solar, wind, and hybrid-electric technologies resulting in "Net Zero" installations and lighter footprint forward basing options.

   h) Contingency basing that includes: energy efficient shelters, hybrid power solutions with micro-grids, bottled water at the point of use, waste water reuse systems, and "water from air technology" and maximizing the use of alternate energy sources.

   i) Scalable, embedded power-management, supported by materials, techniques, and software to intelligently manage multiple power sources, to reduce demand, to balance load, and to improve efficiencies.

   j) Capability to use an expanded suite of alternative energy sources that supplement or replace current logistical approaches.

   k) Standardized rechargeable batteries with integrated hybrid power and recharging solutions.

d. Aviation: Extended reach; increased lethality; increased responsiveness.

1) Problem: As battlefields grow more complex, America's enemies will increasingly attempt to deny the U.S. the ability to rapidly deploy its forces. By denying the use of airfields and landing zones, future threats will seek to increase the distance and time required for American forces to respond. The Army's aviation platforms remain the best in the world; however, future threats will seek to exploit capability shortfalls in order to prevent operationally-significant units from reaching their objective areas. As older platforms reach the end of their service lives, merely upgrading current designs will not be enough to overmatch increasing enemy capabilities.

2) **Desired Attributes**: The future operational environment will still require the Army to deliver decisive combat power to austere points of need, with the speed that matters*.* Desired attributes for future Army aviation include:

a) Advanced technology aircraft which enable significantly improved speed (two times greater than current systems) and responsiveness without sacrificing Vertical Take-off and Landing (VTOL) performance.

b) Aircraft capable of significantly improved range and endurance; twice that of current systems.

c) Improved air and sea transportability. Rapid/self deployment capability. Shipboard compatibility.

d) Seamless interoperability with the supported Joint and ground force.

e) Advanced integrated sensors and decision aids which enable safer and more effective/efficient operations in degraded visual environments, in all flight regimes and in complex terrain and urban environments.

f) More effective and efficient manned-unmanned teaming.

g) New generation of Unmanned Aerial Systems (UAS) with improved autonomy.

h) Reduced crew options (to include Optionally Piloted Vehicles).

i) Hostile Fire Indication (HFI) Systems with integrated countermeasures.

j) Greater lethality options – modular missile technology and scalable effects.

k) Increased reliability and availability of systems with a reduced logistical footprint.

5. Discussion: "Cross-Cutting" Lines of Effort:

a. Cyber Electromagnetic Activities (CEMA)

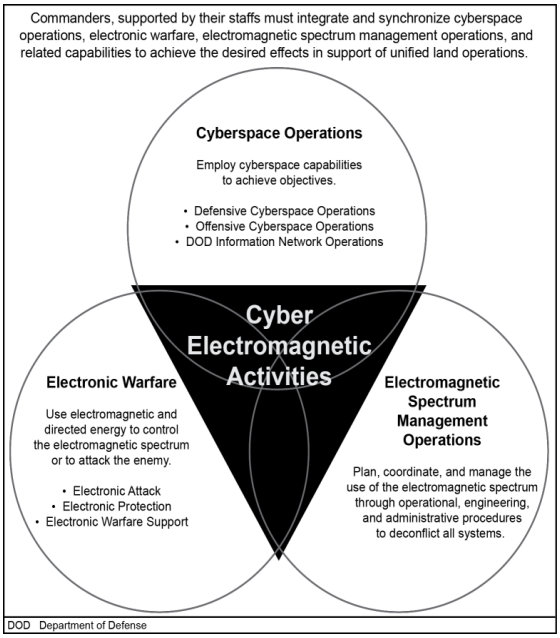


Figure 2. Cyber Electromagnetic Activities (CEMA); FM 3-38 February 2014

1) **Problem:** Currently, DoD Information Technology (IT) comprises thousands of operational systems, hundreds of globally unconnected data centers, and millions of computers and IT devices. We are left with an information technology and computing enterprise that is often unwieldy, vulnerable, incompatible, and expensive to operate, maintain, and defend. Globally integrated operations demand a far greater capacity to see, understand, access, operate in, and defend cyberspace. Our ability to do this is undermined by the lack of assured, robust, agile, manageable, easily deployable, reliable, and integrated technology, along with the associated costs. Together, these factors limit our ability to integrate an information environment within dynamic joint force operations.

2) **Desired Attributes:**

   a) Collapse multiple C4ISR/EW/PNT functions into a common modular chassis. Future Army forces require the capability to provide timely flow of information (including the capability of operating in a degraded mode) in accordance with the commander's priorities with integrated, protected, layered, and secure communications capable of LOS and BLOS reach to achieve unity of effort in unified action during decentralized full-spectrum operations.

   b) Upgrades to tactical networking waveforms to increase capacity, flexibility, robustness and simplicity of operation. A robust network transport. Future Army forces require the capability to integrate, protect, layer, and secure

communications capable of line-of-sight and beyond line-of-sight means to enable the timely flow and ensure the accuracy of information in accordance with the commander's priorities during unified land operations.

c) Develop secure information systems and defensive cyberspace operations platforms that can automatically maneuver against and monitor for, detect, and characterize anomalous activity to mitigate and eradicate cyber threats. Provide the ability for the network to survive and achieve mission assurance under cyber attack.

d) Develop advanced antenna and Dynamic Spectrum Access capabilities providing access and control of the EMS to enable all phases of operations to the tactical edge. The increased use of wireless systems – including the use of commercial off-the-shelf items – makes the available EMS a high-demand resource. The resulting electromagnetic environments in which forces operate are highly contested and congested, making unencumbered access to the EMS problematic.

e) Develop Offensive Cyberspace Operations (OCO) at the Operational and Tactical levels to conduct cyber exploitation and attack capabilities to deny, disrupt, degrade, or destroy the adversary's use of the cyber domain.

f) Develop space forces to protect Army access to space capabilities and the networks that enable mission command functions. Space control effects may include actions to deceive, disrupt, deny, degrade or destroy a threat force's access to space capabilities. Army space forces provide fixed and expeditionary capabilities to plan and integrate space control effects in support of land component and Joint forces commander's requirements.

b. Accelerated Data to Decision: Information to the point-of-need at the speed of change.

1) **Problem:** Soldiers and leaders dealing with the most complex problems are the least enabled and most overburdened in terms of the means and methods of achieving decision advantage.

2) **Desired Attributes:** Accelerated data to decision will play a major role in addressing the challenges of the dynamic and complex future. The end state is a decision advantage that comes with full situational awareness. The intent of this line of effort is to achieve an order of magnitude increase in performance from our Soldiers through full situational awareness/understanding without cognitive overload. Accelerated information to decision is predicated on a level of Joint Force interoperability never before possible and is realized through a combination of the following:

a) Sensors, Integrated Collection Network: A collection mechanism using both military and non-military sensors capable of discerning information from noise, and of discovering significant or unexpected events, in an increasingly complex urban environment where adversary deception and stealth plays a growing role.

b) Discerning Data: The ability to ingest, and leverage exponentially more data than ever before from a growing family of sensors. Subsequently, the ability to conduct analytics on this data requires capabilities such as autonomous hypothesis generation and information discovery to turn big data into near real-time actionable information. Current approaches are exploring methods of pushing high performance computing and distributed processing capabilities down to the tactical edge as a means of shortening decision making time.

c) Decision Advantage: Achieving a common operating picture and subsequently automating the information management network to get real-time and relevant information to the point of need and down to the lowest tactical level. This requires relevant information pushed (instead of pulled) using a hands-free interface that reduces cognitive burden while giving Soldiers and leaders complete situational awareness with the ability to zoom in and zoom out as the tactical and operational situation unfolds.

c. Human Performance Optimization: Enhanced cognitive, physical, and social development

1) Problem: Soldiers represent our number one capital investment and the foundation of our Army, and we need to maximize our return on this critical resource. A few decades ago, the Army focused on large-scale armored warfare. Science and technology programs concentrated primarily on the materiel aspects of Warfighting.

The past decade of conflict has shown that success in ground combat requires much more than lethal effects and technological superiority. Strategic success is winning the battle of wills, which requires Army Soldiers and leaders to out-think and out-smart potential adversaries by processing information and adapting faster. As the character of conflict changes, S&T initiatives and research efforts must include a greater investment in the human and behavioral sciences such as medicine, psychology, economics, sociology, anthropology, and political science. Investments in cross-disciplinary approaches such as network science, human performance science, neuroscience, and information science are also critical. Recent advances in many of these research arenas show significant promise and potential for shaping and expanding human performance and development.

2) **Desired Attributes:** We must leverage science and technology to maximize human performance, and ease the cognitive, physical, and social burden on the Soldier. This can be accomplished through various means. Technology as well as science can be applied to physically and psychologically optimize the human performance of the Soldier, or to perform cognitive, physical, or social tasks for the Soldier. Efforts should be applied to simplify the human machine interface and therefore make equipment easier to use effectively and with less training. Technology and scientific research could also be utilized to increase the speed, effectiveness and retention of training. (Expedite experience). Desired attributes of human performance optimization include:

a) Reduced time and cost required to develop leaders; increased cognitive, physical, and social potential by compressing “the 10,000 hours” (10,000 hours equates to five years of training and development. The Army would like to produce quality leaders with relevant experience in less time).

b) The ability to impart enhanced skills, in a faster manner, with greater retention, at less cost, making the most of our Soldiers.

c) Increased cognitive capacity which enhances data into decisions quicker; enables greater overmatch in the increasingly complex environment

d) The ability to enable effective decision making at the point of need and the speed of war; reducing the need to rely on decisions at higher echelons before taking action.

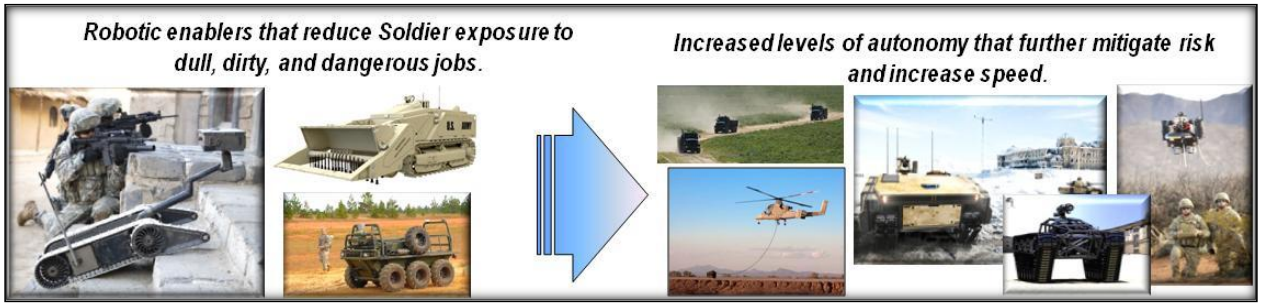
e) Improved accessions; match Soldiers’ cognitive, physical, and social aptitudes to the most appropriate MOS; identify those more susceptible to injury and / or ethical lapses and employ means to prevent them.

f) The ability to baseline and screen out those with higher levels of potential for high risk behaviors.

g) Improved mental, moral and physical capacity and performance, better performance, lower life-cycle costs (life cycle reflecting the entirety of the Soldiers career from accession into the military through transition to Veteran's Affairs).

h) Soldiers enabled by technology and cognitive, medical, and social sciences that allow them to excel in small unit competence, to dominate increasingly complex operational environments, and that optimize cognitive, physical, and social performance.

d. Robotics: Robotics mitigate risk, enable, and augment humans:



1) Problem: Robots have seen widespread use for more than a decade supporting OIF / OEF. Unmanned systems reduce Soldier exposure to dull, dirty, and dangerous jobs. Presently robots are primarily used for IED Defeat. Technologies are currently being developed to enable unmanned convoy logistics patrols as well as squad level follower robots used as carriers for supplies, ammo, food, fuel and individual equipment. Increased autonomy has been demonstrated in a few systems being developed by industry as well as the Joint Capability Technology Demonstration for the Autonomous Mobility Appliqué System. Re-use strategies are being worked for these platforms as they come out of theater. Many of these platforms are tele-operated or possess very limited autonomy. There is limited integration across current lines of effort.

2) **Desired attributes:** Over the next 25 years the US Army should develop affordable, interoperable and increasingly autonomous Unmanned Ground Systems (UGS) and small UAS in order to enhance the endurance, reconnaissance, security, persistence and protection of Soldiers and units across the range of military operations. The goal in the mid-term, is that robotics will deploy as force multipliers at all echelons from the squad to the BCT, and across all war fighting functions. Realization of this will decrease physical and cognitive workloads on the Warfighter, while increasing their combat capabilities. The end state is an Army equipped with affordable, interoperable, autonomous unmanned systems enabling integrated manned-unmanned teaming for improved movement and maneuver, protection, intelligence and sustainment. Increases in autonomy will enable robotic wingmen, robots as squad members, nano/micro robots used for situational awareness, autonomous appliqué kits, exoskeletons etc. Each will increase levels of autonomy that further

mitigate risk, and increase speed, reduce burden (cognitive and physical). These attributes can further be broken down into:

a) Robotics augmenting humans to:
   - Mitigate Risk.
   - Expand Reach.
   - Reduce Physical Burdens.
   - Prevent Surprise.

b) Robotic followers augmented into logistics resupply operations as "members of the unit":
   - Optionally manned vehicles reduce weight and restore balance to platform Mobility / Lethality / Protection.
   - Robots as squad members.
   - Micro air vehicles for situational awareness.
   - Unmanned Air / Ground Vehicle integration, collaboration, and control; airspace management.
   - Artificial intelligence / machine learning that enables understanding of voice and hand and arm signals.
   - Conduct of lethal and non lethal engagements with varying human supervision.
   - Common platforms with modular mission payloads.

c) Single user, multi-robot command permits combined arms maneuver capabilities at tactical level.

d) One-to-Many Control: Enable one operator to control / supervise multiple autonomous systems expands individual Soldiers area of influence (especially for RSTA, Communication Relay and EW).

e) Increased span of control through processing, significant autonomy, and robotic "competence" will be limited by 2025 but is forecasted to achieve much higher levels of independence in 2040.

6. Conclusion: Our current path is unlikely to sustain our current competitive advantage infinitely due to the nature of how technology becomes pervasive in the environment. It is a fact that 80% of the Army of 2020 is in the force or in the budget today, and that today's security capability advantages are a direct result of decisions made in the late 90s and early 2000s. It is critical that we not lose focus that our investments today must enable the capabilities to meet the needs of the Nation today tomorrow. Only through balancing innovation and evolution can we sustain our military effectiveness, and retain the ability to influence events at the speed that matters.

7. Point of Contact: ARCIC S&T Division