ARL Technical Strategy: Executive Summary

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To meet the challenges of future conflict, the U.S. Army must remain agile, adaptive, and innovative to ensure mission readiness in the face of increasing complexity in an ever-uncertain world. Since the future is impossible to predict, the U.S. must be prepared to deter or defeat a variety of adversarial threats across all domains of battle -- air, land, space, cyberspace, and maritime, within a congested electromagnetic spectrum. There is a high likelihood that all domains will be contested; U.S. forces can no longer assume superiority in any one domain.[1,2] To maintain overmatch in a multi-domain conflict, against a diverse set of threats ranging from capable non-state actors to peer threats, the U.S. Army is considering employing a range of breakthrough technologies. As the Army's corporate research lab, ARL is conducting relevant, transformative research that is rooted in the tenets of discovery, innovation, and transition to deliver science and technology (S&T) options for multi-domain battle concepts.

ARL focuses its investment strategy to address the Chief of Staff of the Army's (CSA) priorities and shape how the future Army will fight and win in a complex world. ARL has identified Essential Research Areas (ERAs) that are critical to reducing technology uncertainty, filling knowledge gaps, and identifying technology risk associated with delivering new capabilities. The ERAs represent ARL's highest-priority work. While the ERAs do not encompass the entire breadth of the ARL S&T portfolio, they embody the S&T the Army deems essential to delivering advanced capabilities to the Warfighter.

ARL Science & Technology (S&T) Campaigns

The S&T Campaigns form ARL's intellectual framework for planning technical strategy, aligning and synchronizing resources, people, and infrastructure. To align and synchronize ARL's S&T across multiple disciplines and functional units, and with external stakeholders, ARL organizes its technical work into eight S&T Campaigns. The S&T Campaigns are *Human Sciences, Information Sciences, Sciences for Maneuver, Sciences for Lethality and Protection, Materials Research, Computational Sciences, Assessment and Analysis,* and *Extramural Basic Research.* These S&T Campaigns operate in concert to provide ARL with a robust technological foundation to execute its mission. The ARL Technical Strategy document defines the S&T Campaigns and the compendium to the Technical Strategy (ARL S&T Campaigns: 2015-2040) outlines the strategic posture of each Campaign. The technical posture of each Campaign is described in detail in ARL's Technical Implementation Plan (TIP), the foundational document for ARL's technical planning.

Each Campaign consists of both Key Campaign Initiatives (KCIs) and Core Campaign Enablers (CCEs) that address foundational knowledge pertaining to all of ARL's technical work. The KCIs describe the research necessary to achieve specific technical objectives. The CCEs are underpinning research areas necessary to maintain enduring competencies that are vital to Army S&T needs.

ARL uses the TIP on an annual basis to guide and develop its Biennial Performance Plan (BPP), or execution plan, for the next two years. The BPP outlines enterprise metrics for science, technology, personnel, and infrastructure and describes the projects ARL has selected to address the technical goals of each Campaign's KCIs and CCEs.

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[1] TRADOC PAM 525-3-1 *Win in a Complex World*, 7 Oct 2014
[2] Multi-Domain Battle: Combined Arms for the 21st Century
(http://www.tradoc.army.mil/MultiDomainBattle/docs/MDB_WhitePaper.pdf)

ARL Essential Research Areas

ERAs encompass connected research projects that are designed to build cumulative knowledge that converges on specific outcomes covering a range of future capabilities. The ERAs underscore the importance of autonomous systems and human-intelligent agent teams to operations on the future battlefield; recognize novel means of producing desired effects by exploiting adversary vulnerabilities in contested and congested environments; address innovative ways to enhance independence and agility, and unburden maneuvering tactical units; and pursue discovery, in which scientific opportunities drive the development of new capabilities, and which lies at the core of ARL's mission. Each S&T campaign has KCIs that specifically address one or more of the ERAs.

On the future battlefield, humans will collaborate closely with artificially intelligent systems. Intelligent systems will be team members and will serve to extend the reach and capability of individual units to enable unprecedented capabilities. Three ERAs focus on related challenges: ***Human-Agent Teaming, Artificial Intelligence and Machine Learning,*** and ***Accelerated Learning for a Ready and Responsive Force,*** which address, respectively, enabling highly effective information exchange between Soldiers and intelligent systems in performing Warfighting functions as a cohesive team; increasing the intelligence of engineered systems to become the true teammates of Soldiers; and preparing humans to engage with intelligent systems within their team to create an effective fighting force.

The complexity of the virtual realm and its melding with the physical leads to the following three ERAs: ***Cyber and Electromagnetic Technologies for Complex Environments, Distributed and Cooperative Engagement in Contested Environments,*** and ***Manipulating Physics of Failure for Robust Performance of Materials.*** The reliance of intelligent systems on wireless communication and networked processes makes them vulnerable to cyber, physical, and electronic attacks. Thus, it is necessary to develop technologies that keep systems functional in the face of such attacks and mitigate their risks. Distributed and Cooperative Engagement in Contested Environments pursues specific applications of dispersed entities that deliver overwhelming kinetic and non-kinetic effects while combining omni-speed (from low to high speed), radical maneuverability, and extremely efficient payload kill mechanisms. Enabling such systems requires integration of technologies in machine intelligence and human-agent teaming, among others. Finally, to enhance protection properties of friendly assets, as well as the lethality of munitions, ARL is working to imbue materials with an ability to sense their environment and change their state as a consequence.

To ensure that the foundational advances pursued in the previous ERAs are also combined with innovative ways to enhance independence and agility and unburden tactical units, two ERAs consider logistics-related innovations: ***Tactical Unit Energy Independence*** and ***Science of Manufacturing at the Point of Need.*** Energy independence is essential to maintaining forces in the field without resupply and the reliance on intelligent systems creates an increased demand and an acute need to ensure sufficient reserves of power. Further, Science of Manufacturing at the Point of Need considers how the Army can make the capabilities it desires available as commodities on a battlefield for an agile expeditionary force.

Discovery is the process of identifying, creating, developing, and exploiting innovative yet Army-relevant science and engineering advances. Discovery is essential to ARL's mission. It helps to ensure the Army's continuing and future technological superiority, and creates future offset against our adversaries while avoiding technological surprise.

Within Discovery lies ARL's highest-risk foundational efforts in *Quantum Sciences*, to exploit the "2nd quantum revolution" for fundamentally new and leap-ahead capabilities across C4ISR; *Living Materials*, to develop responsive materials imparting living functions for disruptive capabilities in austere Army environments; *Topological Matter*, to fundamentally understand new realms of electronic and photonic matter, and create phenomena never before seen and materials with new functions; *Social Dynamics*, to use advances in biometric and geospatial tracking, along with breakthroughs in data availability and analytic methods, to understand, predict, and control emergent social dynamics, e.g., group behavior; and *Complexity and Emergence*, to discover and apply new math, big data, network science, neuroscience, physics and related areas, to understand emergent behaviors including the complex and unknown failure modes of complex Army systems.

Summary

ARL's S&T portfolio is strategically balanced to enable future technological offset and is shaped through the priorities of our higher headquarters, the Army Materiel Command and the Research, Development, and Engineering Command, with the intent of operationalizing S&T for the Army. ARL's S&T program is grounded in a vision of the future that provides Army leadership with the knowledge and understanding to inform decisions on options for disruptive Warfighting capabilities with reduced uncertainty and calculated risk. Given its best assessment of the future threat environment, ARL aligns and synchronizes research to address the CSA's priorities and fill Training and Doctrine Command gaps for emerging concepts. In development of the ERAs, ARL has set strategic goals in areas it deems essential to enable the CSA's priorities and shape how the future Army will fight and win in a complex world by incorporating aspects of nearer-term capabilities such as asymmetric vision[3], decide faster[4], manned-unmanned teaming[5], and project and protect fires.[6,7,8,9] Through its S&T Campaigns, ARL defines specific technical goals to address not just its ERAs, but also its foundational mission program to discover, innovate, and transition. Progress toward these technical goals are assessed annually and the assessments are used to determine the near-term execution plan and outline a path toward becoming the Nation's premier laboratory for land forces.

PHILIP PERCONTI
Director

[3] SAAL-ZT – Information paper: Army's Science and Technology (S&T) vision for Asymmetric Vision
[4] SAAL-ZT – Information paper: Army's Science and Technology (S&T) vision for Decide Faster
[5] SAAL-ZT – Information paper: Army's Science and Technology (S&T) vision for Manned-unmanned Teaming
[6] The four (asymmetric vision, decide faster, manned-unmanned teaming, and project and protect fires) listed capabilities were strategically down-selected as a direct result of the LRDDPP-GC, PAWG, and subsequent AROC.
[7] Fountain III, Augustus W., 7-8 MAR 2017, Mad Scientist Conference, (https://community.apan.org/wg/tradoc-g2/mad-scientist/)
[8] SAAL-ZT - Army's Science and Technology (S&T) vision for Manned-Unmanned Teaming, Asymmetric Vision, and Decide Faster
[9] Asymmetric Vision/Decide Faster Workshop Report - (05-06 APR 17), DRAFT Report out for review

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