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THE U.S. ARMY RESEARCH, DEVELOPMENT AND ENGINEERING COMMAND SOLDIER AND SQUAD PERFORMANCE OPTIMIZATION (S2PO) SCIENCE & TECHNOLOGY STRATEGY

by
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U.S. Army Natick Soldier Research, Development and Engineering Center
Natick, Massachusetts 01760-5000

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14. ABSTRACT

The Soldier and Squad Performance Optimization (S2PO) strategy was designed to actualize the S&T focus areas of the Army Operating Concept including human performance optimization, logistics optimization, autonomy-enabled systems and information to decision. The strategy was also designed to provide solutions to the three major risks described in the Army Human Dimension Strategy that center around governance challenges, unity of effort, and a common operating picture for ongoing human dimension efforts. The S2PO strategy promotes innovative and collaborative S&T initiatives across the Army to deliver cutting edge knowledge, equipment and enhancing technologies (materiel and non-materiel) to empower Soldiers and squads with optimally integrated knowledge, skills, abilities, equipment and technologies to help them achieve superior individual and team performance.

The S2PO strategy establishes a vision of *Ensuring the U.S. Soldier is the decisive edge on the battlefield through cognitive/physical dominance and social intelligence, optimal integration of the Soldier with his/her equipment, technologies and platforms, and innovative and collaborative S&T with clearly defined and established transition paths*. It consists of a single strategic objective and four comprehensive and interacting Lines of Effort (LOE), with detailed supporting objectives. LOEs 1-3 are technically focused and provide a framework of the S&T investments needed to address capability gaps in Soldier & Squad performance and will guide the development of execution roadmaps associated with the S2PO strategy. The fourth LOE focuses on the "enabling" aspects of this strategy. The four LOEs are:

LOE 1: Optimizing and capitalizing on the Soldier & Squad Cognitive-Physical-Social (CPS) Knowledge, Skills, and Attributes
LOE 2: Optimizing the Soldier-system/Equipment Integration and Interaction.
LOE 3: Enhancing Human Performance Optimization (HPO) Solutions (materiel and non-materiel).
LOE 4: How to Achieve Optimization Vision & Transition.

The strategy is a living document that will evolve as more detailed investment roadmaps and governance processes are developed.

15. SUBJECT TERMS

S2PO	OPTIMIZATION	SOLDIER SYSTEM	KNOWLEDGE SHARING
ENABLING	LINES OF EFFORT	PHYSICAL FITNESS	PERFORMANCE(HUMAN)
STRATEGY	QUALITY OF LIFE	HUMAN DIMENSION	MEASURES OF EFFECTIVENESS
COGNITION	CAPABILITY GAPS	SOLDIER READINESS	SQUAD LEVEL ORGANIZATIONS
LOGISTICS	ARMY PERSONNEL	SOCIAL PSYCHOLOGY	S&T(SCIENCE AND TECHNOLOGY)

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Soldier and Squad Performance Optimization (S2PO)

Science & Technology Strategy

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SOLDIER AND SQUAD PERFORMANCE OPTIMIZATION STRATEGY

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Table of Contents

Executive Summary 4

1. Introduction 6
2. S2PO Strategic Environment and Meeting the Challenges 7
3. S2PO Vision 9
4. Strategic Objective and Lines of Effort (LOEs) 10

   LOE 1: Optimizing and capitalizing on the Soldier & Squads' Cognitive-Physical-Social Knowledge, Skills and Attributes 11

   LOE 2: Optimizing the Soldier-system/Equipment Integration and Interaction..... 14

   LOE 3: Enhancing Human Performance Optimization (HPO) Solutions (materiel and non-materiel) 17

   LOE 4: How to Achieve Optimization Vision & Transition 23

5. Challenges 26
6. Conclusions 28

Appendix A – Enabling Laboratories and Facilities 31

Appendix B – Systems Engineering Approach 38

Glossary 40

   Definition of Acronyms 40

   List of Referenced Documents – Guiding and/or Referenced 43

Executive Summary

Based on a tasking from the Commanding General of the Research, Development and Engineering Command (RDECOM), the Natick Soldier Research Development and Engineering Center led an effort in developing a RDECOM science and technology (S&T) strategy focused on optimizing the performance of all Soldiers to enable more capable future formations.

The strategy was developed by a group of cooperative partners from each of the RDECOM Centers, the Army Research Laboratory, the U.S. Army Research Institute of Environmental Medicine, the U.S. Army Research Institute for the Behavioral and Social Sciences, the Army Capabilities Integration Center, the Program Executive Office Soldier, the Assistant Secretary of the Army for Acquisition, Logistics and Technology and the U.S. Army Maneuver Center of Excellence.

The Soldier and Squad Performance Optimization (S2PO) strategy was designed to actualize the S&T focus areas of the Army Operating Concept including human performance optimization, logistics optimization, autonomy-enabled systems and information to decision. The strategy was also designed to provide solutions to the three major risks described in the Army Human Dimension Strategy that center around governance challenges, unity of effort, and a common operating picture for ongoing human dimension efforts. The S2PO strategy promotes innovative and collaborative S&T initiatives across the Army to deliver cutting edge knowledge, equipment and enhancing technologies (materiel and non-materiel) to empower Soldiers and squads with optimally integrated knowledge, skills, abilities, equipment and technologies to help them achieve superior individual and team performance.

The S2PO strategy establishes a vision of *Ensuring the U.S. Soldier is the decisive edge on the battlefield through cognitive/physical dominance and social intelligence, optimal integration of the Soldier with his/her equipment, technologies and platforms, and innovative and collaborative S&T with clearly defined and established transition paths*. It consists of a single strategic objective and four comprehensive and interacting Lines of Effort (LOE), with detailed supporting objectives. LOEs 1-3 are technically-focused and provide a framework of the S&T investments needed to address capability gaps in Soldier & Squad performance and will guide the development of execution roadmaps associated with the S2PO strategy. The fourth LOE focuses on the "enabling" aspects of this strategy. The four LOEs are:

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This strategy is a living document that will evolve as more detailed investment roadmaps and governance processes are developed. It will be reviewed annually and updated as necessary.

1. Introduction

The U.S. Army has published several documents that speak to future conflicts and the investments needed to win those conflicts. In particular, the *Army Operating Concept* (AOC) details the importance of optimizing human performance[1], and highlights the role of science and technology (S&T) in both developing advanced technologies, and, crucially, in getting those technologies into the hands of Soldiers[2].

> *The U.S. Army's differential advantage over enemies derives, in part, from the integration of advanced technologies with skilled Soldiers and well-trained teams.*
>
> *The Army Operating Concept 2014*

The *Army Human Dimension Concept* (HDC) reinforces these ideas by "redefining the parameters of the human dimension as encompassing [the] cognitive, physical, and social components[3]." Further, the HDC states that the Army must practice human performance optimization – the process of applying knowledge, skills, and emerging technologies to preserve and improve the capabilities of Department of Defense (DoD) personnel to execute essential tasks[4]. The HDC guides our thinking that technological advancements for the Soldier and squad impact both cognitive and physical loads and that the Army must find the balance that optimizes performance and minimizes adverse health effects.

Lastly, the *Army Human Dimension Strategy* (HDS), informs the Army Warfighting Challenges and focuses on aspects of human performance that aim to optimize Soldiers' abilities to think critically and broadly while possessing social intelligence and the highest standards of ethics. The HDS vision is to optimize the human performance of every Soldier in the Force and to build cohesive teams of trusted professionals who thrive in ambiguity and chaos[5].

> *Investment in the cognitive, physical, and social components better optimizes the human performance of Soldiers.*
>
> *The Army Human Dimension Strategy 2015*

Under the direction of the Commanding General of the Research, Development and Engineering Command (RDECOM), a working group of scientists and other representatives from the various RDECOM Centers (RDECs) and the Army Research Laboratory (ARL) were joined by partners from the U.S. Army Research Institute of Environmental Medicine (USARIEM), the U.S. Army Research Institute for the Behavioral and Social Sciences (ARI), the Army Capabilities Integration Center (ARCIC), the Program Executive Office (PEO) Soldier, the Assistant Secretary of the Army for Acquisition, Logistics and Technology (ASA(ALT)) and the U.S. Army Maneuver Center of Excellence (MCoE) to refine the guidance in the above documents and establish a S&T strategy for Soldier & Squad Performance Optimization (S2PO). This strategy is a living document that strives to meet that mandate. It will help guide research and development efforts that contribute to optimizing Soldier & Squad performance, but also addresses the critical issues of human systems integration (HSI)

and transitioning of technology and non-materiel solutions to the Soldier. The scope of this strategy document is not limited to the Infantry Soldier or Infantry squad. It is recognized that there are a myriad of military occupation specialties and fighting formations and therefore many talent sets are required. However, every Soldier, at the most fundamental level, must be able to perform certain basic infantry skills. For that reason, the supporting objectives in this strategy might be construed as heavily favoring the optimization of the dismounted Soldier. The reality is that this strategy champions S&T that will contribute to optimizing all Soldiers and squads whether dismounted, mounted or aviator.

2. S2PO Strategic Environment and Meeting the Challenges

The squad is the cornerstone and foundation of the Army with the individual Soldier as its centerpiece.[6] [7] The AOC (October 14), the HDC (May 14), and the HDS (June 15), as well as earlier documents including the *U.S Army Study of the Human Dimension in the Future* (April 08), and the *Initial Capabilities Document (ICD) for Army Human Dimension* (June 12) all stress the fundamental need to address the human dimension of future conflict – the cognitive, physical, and social aspects of individual Soldier development and team building. These documents and others clearly describe the operational and non-operational environments of the future. This future is envisioned as being increasingly complex and unpredictable and is characterized by an enemy that may employ unconventional or hybrid strategies, demographic changes in societies and cities, the spread of advanced cyberspace capabilities, the proliferation of weapons of mass destruction, and the increased velocity of human interactions. This document will not reiterate or attempt to further characterize these principles and the reader is referred to those earlier documents for a detailed description of the strategic environment.

The complexity resulting from these trends requires Soldiers to adapt physically and mentally to varying environments much faster than ever before. As a result, optimizing the attributes and competencies of the Soldier & Squad is imperative to future success. Because advances in S&T will play a critical role in this process, this document lays out a coherent S&T strategy for S2PO. This S2PO strategy is not meant to address every supporting objective and key task in the HDS but it will guide S&T that can impact portions of that strategy.

The *Army Force 2025 and Beyond* initiative conceptualizes an Army that is leaner, smarter, more lethal, and flexible[8]. Fiscal austerity measures and a shrinking of the force require optimizing the remaining personnel to thrive in chaotic environments while facing a combination of regular and irregular threats. The HDS focuses mostly on early segments of the Soldier life cycle such as talent management and training. This makes sense since the Army must be able to increase its proficiency in selecting the right individuals, placing them in the right jobs, training them effectively, and accelerating leadership qualities, decision making skills, and ethical maturity. To support human performance in these areas, S&T can identify how to optimize mental and physical performance and resilience, reduce injury, and accelerate recovery[9]. S&T may allow accelerated learning, and can result in improved judgment and leadership qualities through advances in decision support guidelines and technologies. S&T can also lead

to improved Soldier resiliency through: temporary and long-term nutrition supplementation, promoting and training self-regulation and emotion-regulation strategies, and mitigating the impact of acute and chronic stress.

AR 602-2 Human Systems Integration in the System Acquisition Process details how the implementation or inclusion of robust HSI in the Research, Development, Test & Evaluation (RDT&E) of materiel and non-materiel systems is a critical factor in achieving successful Soldier-system (i.e. the Soldier with his/her mission-essential gear, performing operationally relevant tasks) optimization on the future battlefield. The increasing complexity of equipment, missions and operational environments will drive a need to maximize the human capability while operating in a multifaceted and perhaps unknown battlespace. At the same time, the knowledge and understanding of human cognitive and physical capabilities and limitations are necessary components that must be considered and integrated into technology and equipment requirements for this foreseeable complex future. In order to achieve an optimally functioning Soldier-system and realize the full benefits afforded by novel equipment and technology intended to enhance capabilities, the Army must fit equipment/technologies to the Soldiers rather than the other way around. While HSI traditionally accomplishes its mission throughout the acquisition process, starting at Milestone B, it is widely and wisely recognized that initiation of human sciences S&T that is focused on researching, understanding and translating human performance and HSI earlier in the process (pre-Milestone A) will yield critical guiding information that will inform and influence design requirements, thus contributing to the development and fielding of optimally functioning Soldier-systems. The Army's long-range equipping and sustaining needs, as described in the Long Range Investment Analysis (LIRA), must be communicated to and be informed by S&T and materiel developers in order to stimulate and initiate HSI efforts early enough to influence the next generation of equipment.

There are many organizations within the Army that contribute to the optimization of the Soldier-system, but the processes used by those organizations to integrate human dimension concerns into the Soldier-system should be better coordinated. Within the Army, improvements are needed to link policy, capability gaps, resources, solutions and S&T for implementation of Soldier performance priorities. There is no *Center* to integrate applied research, materiel and non-materiel solutions to resolve cognitive, physical and social needs of the Soldier. The result is a lack of shared understanding and a common operating picture, a lack of unity of effort, a lack of governance, and potentially insufficient non-materiel capability development or transitions.

The S2PO Strategy recognizes that there is no unified approach to addressing the issues outlined above in order to achieve the vision presented. Rather, a combination of tactics that are unique, yet complementary and synergistic will drive the Army in the direction to attain the dominant and resilient future force for which we are striving. The strategy will ensure progress across the RDECOM enterprise toward the unified vision of delivering unparalleled Soldier-optimization capabilities. With the current and anticipated continued participation of the non-RDECOM partners, the strategy will build towards unifying that vision across the entire Army.

3. S2PO Vision

To ensure the U.S. Soldier is the decisive edge on the battlefield through:

- **cognitive/physical dominance and social intelligence**
- **optimal integration of the Soldier with his/her equipment, technologies and platforms**
- **innovative and collaborative S&T with clearly defined and established transition paths.**

Near, mid, and far-term goals have been established regarding the optimization of the human performance of Soldiers and the building of cohesive teams of trusted professionals who thrive in ambiguity and chaos. These goals will drive us towards better preparing Soldiers through a coherent S&T strategy focused on the human dimension and HSI.

Near 2017-2021[10]: ADAPT: IDENTIFY WHAT THE ARMY IS DOING NOW THAT CAN BE TRANSITIONED. The Army needs to understand the mechanisms, principles, and properties governing the differences between individual humans that are expected to lead to new algorithms, capabilities, and methods for predicting dynamic individual performance within a range of settings from small units to societies. The Soldier is the centerpiece of a system consisting of the human, equipment, and technology. The S&T community needs to work with materiel developers and the user community to improve the integration of existing systems with the Soldier & Squad to enhance human perceptual, cognitive, physical, and social capabilities and optimize squad performance. To support these efforts, the Army needs to 1) better enable the S&T community's ability to transition current knowledge to the Soldier & Squad, and 2) continue to identify future technologies and develop program plans to take advantage of those technologies.

Mid 2022-2031: EVOLVE: LINK RESEARCH TO MISSION OUTCOMES. The emphasis will be on ensuring US Army Soldier & Squad overmatch, which may require reassessing and readjusting S&T investments today. Also important will be the continuation of engineering change proposals to improve equipment and the identification of technologies that will provide leaner formations with equal or greater capabilities. Technology transitions will be timely and supported by effective and personalized training. Research efforts must evolve to support theoretical frameworks and models combining anthropometric, cognitive, behavioral, and physiological data to better predict mission outcomes. Other research efforts leveraging human sciences work will focus on materiel solutions to unburden and enhance the capability of Soldiers. All efforts will use operationally valid metrics to quantify performance impact and rapidly transition prototypes that have demonstrated value in operational assessments. This body of work will lead to a more highly trained and capable force.

Far 2032-2046: INNOVATE: DEVELOP TAILORABLE EQUIPMENT AND HUMAN/MACHINE INTERFACE. Future S&T solutions should adapt to the

characteristics of individuals, their current state, and the task being performed in the context of the environment, and augment these through physical, cognitive, nutritional, automated and other interventions. Materiel research will continue to provide the Soldier with advanced capabilities tailored to his or her needs including full integration with unmanned systems. The end result will be the most adaptable, capable, dominant, and resilient Soldier and effective teams.

4. Strategic Objective and Lines of Effort (LOEs)

The S2PO strategy defines a single strategic objective that will achieve the vision, aligns with the Army HDC and HDS and is oriented on the Soldier and the squad: continuously improve the human performance of the Soldier and the squad through the conduct and application of science and technology. The strategy consists of four comprehensive and overarching Lines of Effort (LOE) that are focused on the objective, are independent, and yet at the same time, are interdependent (see Figure 1). Three of these LOEs are technically-focused (T-LOE) and provide an outline or framework of the S&T investments needed to address gaps and required capabilities associated with Soldier & Squad performance and will guide the development of execution roadmaps associated with the S2PO strategy. While these three LOEs form the foundational and guiding elements of the S2PO strategy, it is equally important to acknowledge and highlight areas, or "enablers" that must be addressed in order to attain the full potential of this vision. Thus the fourth line of effort focuses on the "enabling" aspects of this strategy (E-LOE). The supporting objectives define more detailed S&T targets that are necessary to achieve the strategic objective.

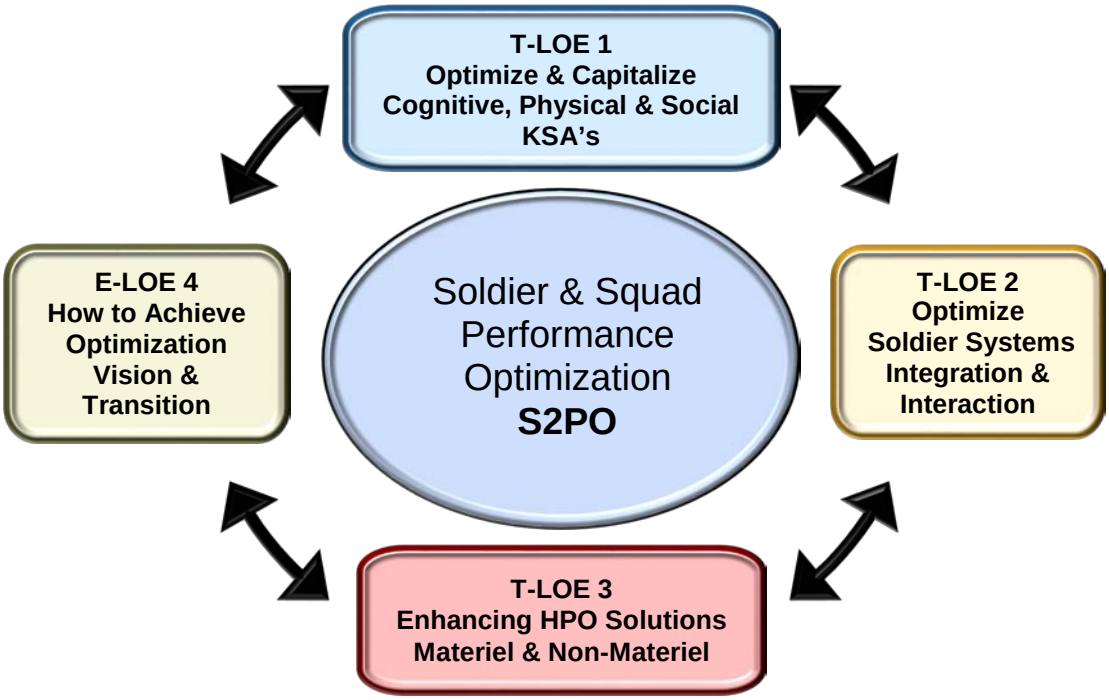

Figure 1

LOE 1: Optimizing and capitalizing on the Soldier & Squads' Cognitive-Physical-Social Knowledge, Skills and Attributes

To meet the challenges and complexities of the future operational environment, the Soldier & Squad will be required to perform at a high level with conditions set for continual improvement. It is incumbent on the Army, as an organization, to understand, characterize, define and measure the attributes and skills that are needed of the operating force in a mission/task context in order to influence human performance at the individual and team levels so that the Soldier & Squad entering the battlefield are equipped with the proper and decisive cognitive, physical and social (CPS) skills.

The specific purpose of this LOE is to understand what levels of CPS attributes are applicable to the Soldier & Squad, in an operational context, so that the S&T community can tailor solutions for use by the Soldier & Squad.

Applying the appropriate S&T solutions to optimize performance of the Soldier & Squad requires that we know three things: 1) Where are we now? 2) Where do we need to be? 3) What is the difference between our current state and our goal state, i.e. what is the gap? With regard to the CPS domains, we are referring to the particular cognitive processes, physical abilities, and social skills that are necessary for the Soldier & Squad to accomplish any assigned mission. Accordingly, Supporting Objectives 1.1, 1.2, and 1.3 call for formal S&T efforts to solidify this understanding. These supporting objectives align closely with the HDS Strategic Objectives 1.5, Human Performance Research and Assessment & 2.4, Team Performance Research and Assessment. See Figure 2 for a work breakdown structure (WBS) of LOE 1.

Supporting Objective 1.1: Individual and Team Assessment of CPS Skills [Baselining]

Our intent is to reliably and sensitively assess the CPS competencies that a Soldier must call upon to perform his or her typical tasks. To begin to understand how to optimize and enhance performance, we must develop a "living baseline". Such a baseline depends on 1) successful decomposition of task requirements into the measureable CPS attributes that combine to form the competencies relevant to perform those tasks and 2) the measurement of those attributes and competencies in individual Soldiers and in squads. By "living baseline," we mean that the baseline is updated at regular intervals; is not monolithic but instead relevant for the different tasks, Military Occupational Specialties (MOS) and contexts in which Soldiers must work; and is stored and presented in an easily accessible manner. The measures that are useful for individuals and the measures that are useful for squads are likely different. One can predict cognitive task performance quite well from an attribute such as individual intelligence, but an average team intelligence score might predict group performance less successfully than knowledge of the social group dynamics. Therefore, special attention needs to be paid to 1) the individual attribute scores that predict good performance, 2) the group attribute scores that predict good performance, and 3) how the relative mix of individual attribute scores Soldiers bring to a squad combines to form a measureable competency that affects overall squad performance. As a recurring

concept, the contrast between relatively static (e.g., height, general intelligence) and relatively dynamic measurements (e.g., fatigue) is important in determining when and how often to take specific measurements.

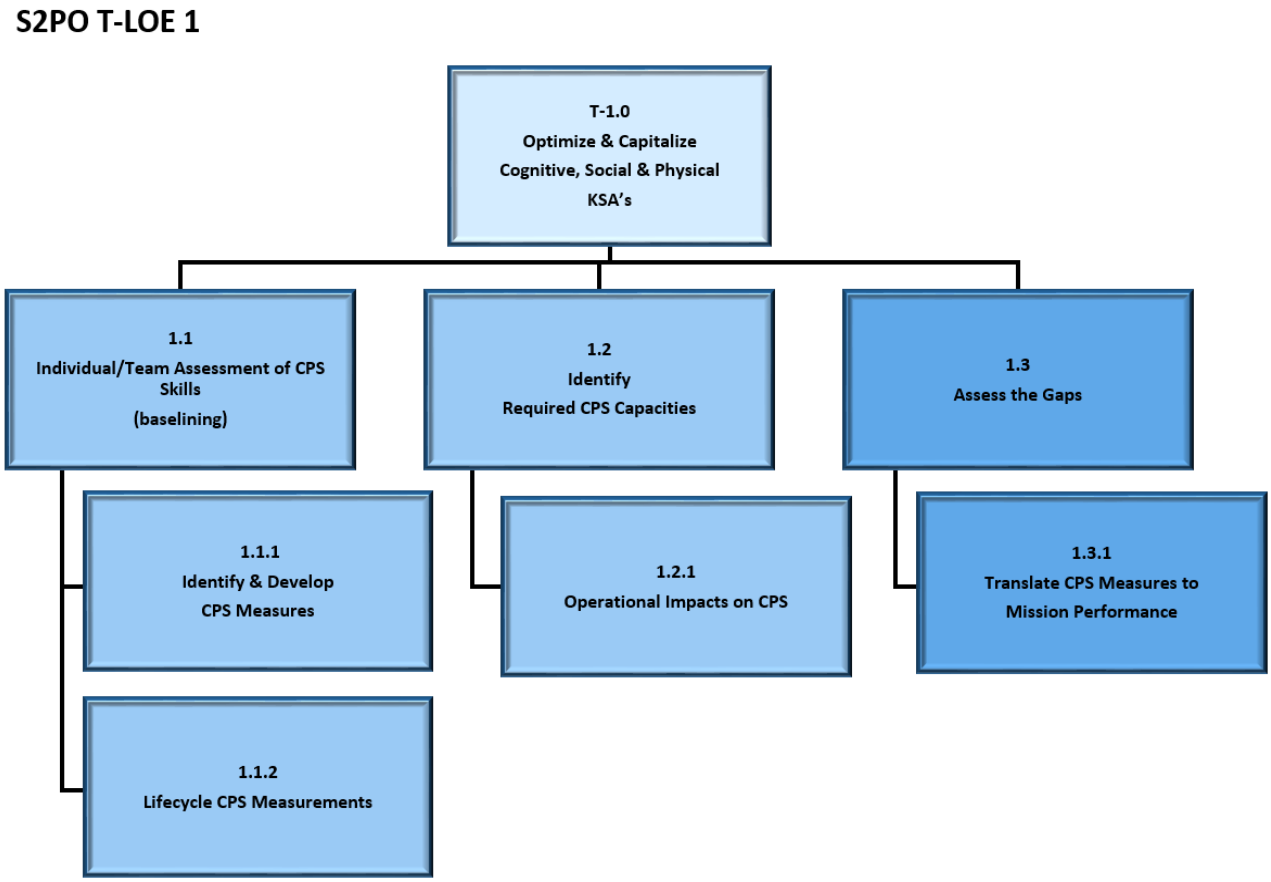

Figure 2 WBS LOE 1

Supporting Objective 1.1.1: Identify and develop CPS measures. Soldier operational objectives and requirements are typically stated in terms of mission outcomes. To support S&T objectives we need to distill those mission outcomes into the base-level, human competencies that can support mission success. We must be able to identify current measures that can be predictive of Soldier success and we must be able to develop and validate new measures. This supporting objective can occur iteratively as new measures and requirements are developed.

Supporting Objective 1.1.2: Lifecycle CPS measurements. The lifecycle of a Soldier occurs over a sufficiently long time-scale that his or her specific CPS attributes and skills might change as a result of combat exposure, maturation, training, and other outside social influences. These parameters might change over short time scales (e.g., hydration status), or over long time scales (e.g., physical fitness) and thus choosing the

measure that matches best with the change we aim to capture is crucial (e.g., self-report, continuous electronic sensing, etc.). This supporting objective will ensure that we consider whether specific measures (i.e. skills) are dynamic, and if so, at what timescales we intend to capture them, and under which contexts. Many of the squad-level metrics we will use are subject to change both as a squad matures in age, as its members gain more experience with one another, or as members rotate out for various reasons; capturing how squad team-effectiveness evolves over time thus becomes crucial. Further, this supporting objective is critical in aiding our goal of accurately and reliably measuring attributes and skills at the right times to influence the development of enabling solutions to optimize Soldier & Squad performance.

Supporting Objective 1.2: Identifying the Required CPS Capacities

This supporting objective aims to answer the question "Where do we need to be?" To do this, we intend to analyze current operational requirements and standards and develop measures to assess the CPS attributes and competencies necessary to perform the required tasks. Multi-level analysis will be necessary to assess the individual and team/squad level requirements and performance. Fundamental to this objective, task analysis methods will be needed to translate between the abstract level of requirements and the more concrete level of the specific CPS attributes and skills that enable achievement of those competency requirements. For squad dynamics, this supporting objective will specify 1) the range of acceptable CPS attribute and competency scores that individual Soldiers must bring to the squad, and 2) the ranges of scores found within a squad that will allow successful performance on specific tasks.

*Supporting Objective 1.2.1: Operational impacts on CPS***.** Dynamics in the operational environment both constrain and enable task performance in ways that must be captured in order to gain an accurate picture of required CPS attributes and competencies. Training and doctrine requirements are updated at regular intervals, but it is still likely that the particular context Soldiers find themselves in (desert, megacity, GPS-denied, etc.) will influence actual (as opposed to textbook) requirements in ways that do not respect neat timelines for the updating of manuals. We need to develop procedures and tools to ensure that the stochastic nature of the operational environment (broadly defined, e.g., coups, elections, fiscal, leadership, natural disasters, terrorist events, etc.) is captured and modeled. This will allow us to better understand how changing missions can be analyzed to yield the changes in the CPS attributes and competencies necessary to accomplish Soldier tasks and the mission and to translate that information into performance measures for developmental feedback, training evaluation, and for enhancing materiel or non-materiel solutions.

Supporting Objective 1.3: Assessing the Gaps – Understand and Develop methods to close the gap between knowing what CPS skills are needed vs. the CPS skills that the Soldier possesses

This strategic objective aims to map the results from the previous objectives to one another. We will understand and develop methods to close the gap between knowing

what CPS skills a Soldier has and what skills a Soldier needs. This information may influence training programs and talent management as well as Soldier & Squad performance.

Supporting Objective 1.3.1: Translate CPS measures to mission performance. This supporting objective identifies the need for theoretical frameworks and analysis work to translate between the measures we obtain in the prior supporting objectives, and mission-relevant outcomes. Previously, we identified that decomposing requirements into the relevant CPS parameters was critical; here we note that being able to *predict* mission outcomes based on those CPS parameters is equally critical. Such an effort will allow us to map directly between the nebulous and "soft" human dimension parameters, and hard metrics like mission success, measures of effectiveness, and measures of performance. This supporting objective is a crucial effort in the realm of gap analysis because it allows us to post solid, actionable metrics against those gaps, which in turn will allow for simpler understanding of why specific enabling solutions will optimize Soldier & Squad performance.

LOE 2: Optimizing the Soldier-system/Equipment Integration and Interaction.

The primary focus of this LOE is on understanding the underlying principles associated with the human sciences and applying that knowledge to influence materiel and non-materiel RDT&E and acquisition/fielding in order to optimize the Soldier-system relationship and mission effectiveness. This not only optimizes Soldier performance, but allows the functional potential of the equipment/technologies to be fully realized by putting those capabilities into the hands of the Soldier & Squads who can use them safely and effectively. The materiel/non-materiel areas of interest requiring the application of human sciences and HSI include but are not limited to: weapons systems/technologies (the human component that enables lethality, accuracy, etc.), platforms – air/ground (workspace envelopes, ingress/egress, control systems layout, etc.), human-machine/human-technologies (interfaces), autonomous/semi-autonomous systems/robotics/unmanned automated vehicles (UAVs) (control mechanisms/interfaces), manned-unmanned systems, wearable systems (understanding body shape/size and physical limitations, interfaces), communications-electronics systems, human-computer/human-control interaction (systems interface/cognitive processing), Soldier-borne, worn or integrated protective equipment and mission-essential gear (integration/interface), force projection and sustainment supporting technologies/equipment, complex information systems, human-agent teams, cybersecurity, and organizational and social networks. See Figure 3 for a WBS of LOE 2.

Supporting Objective 2.1 Reassessment & Characterization of Individual and Squad Performance as impacted by equipment/technologies

Similar to SO 1.1, there is a need to develop measures of cognitive and physical capabilities and limitations of the Soldier, but in the context of the Soldier-equipment integration. This will allow us to study and to understand the impacts that equipment,

tasks, operational and regional environments will have on Soldier performance. This foundational knowledge of the Soldier-equipment-task interrelationships is imperative in order to determine, influence, or predict the potential for performance optimization and, just as important, identify the factors that might contribute to and/or influence performance degradation of the Soldier.

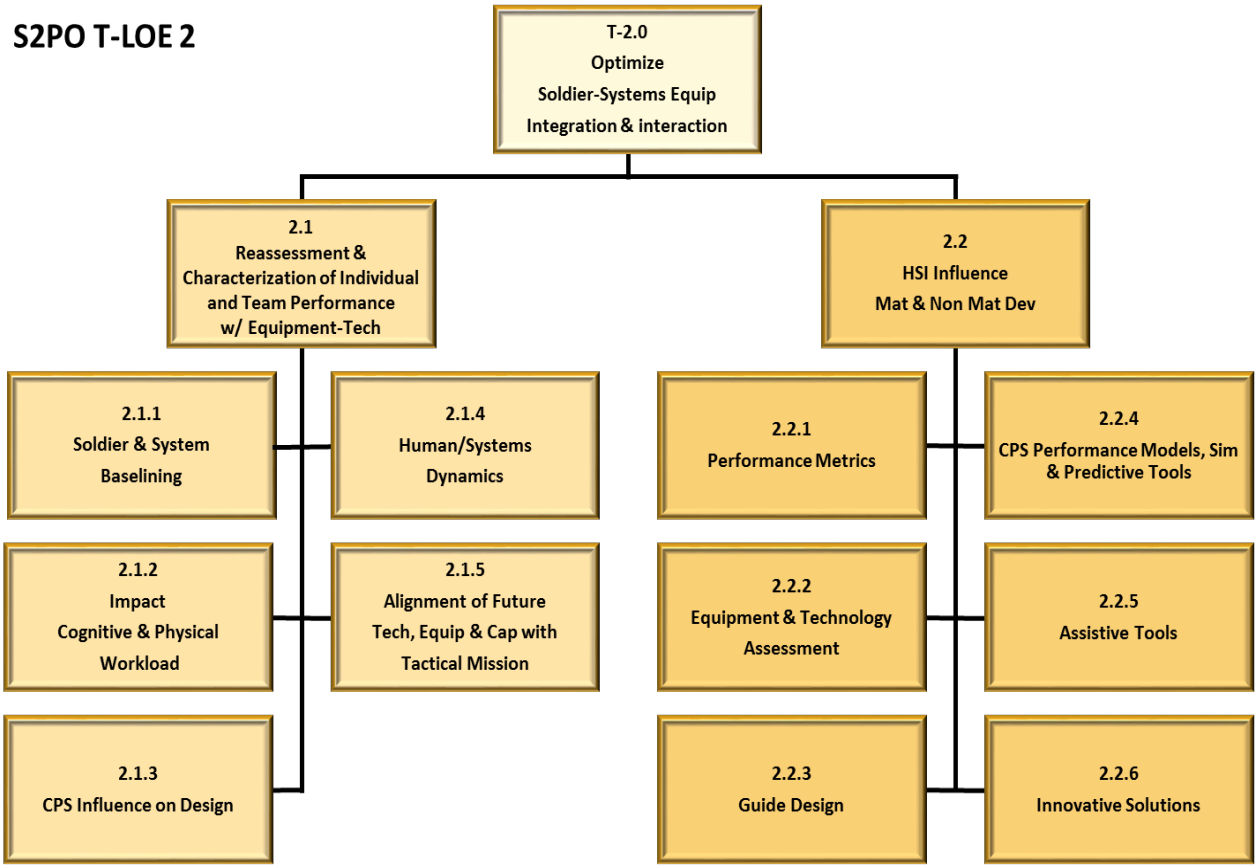

Figure 3 WBS LOE 2

Supporting Objective 2.1.1 Soldier-system Baselining. Establish measures [Baselining] of the physical and cognitive performance of the Soldier-system. This includes, but is not limited to characterizing the impacts of the equipment/tasks/environment and other contributing factors such as nutrition and hydration on the physical (to include physiological) attributes and the cognitive capacity of the human. This S&T will allow understanding of how the complex dynamics of the human mind and body –unencumbered and encumbered with gear – contribute to and/or interfere with successful accomplishment of mission-relevant tasks and employment of equipment and technologies. It will also allow understanding of how the complex social dynamics of the human collective contribute to the same.

Supporting Objective 2.1.2 Impact of Cognitive and Physical Workload. Understand and quantify the impacts that varying degrees of cognitive and physical workload or burden have on Soldier performance. The aims are: 1) to understand what specific factors influence cognitive and physical performance, 2) to understand how and at what point (e.g., the breaking point) the cognitive and physical stressors/load begin to negatively impact performance, 3) to quantify the benefit/detriment of unburdening/overburdening the cognitive and physical demands on the Soldier & Squad – e.g., what amount and what type of "unburdening" and/or supplementation is needed to make a significant difference/positive impact on Soldier performance.

Supporting Objective 2.1.3 CPS Influence on Design. Understand and/or identify the factors that contribute to design features/attributes of materiel and non-materiel solutions/capabilities that, if optimized from a CPS perspective, will allow and enable safe, efficient, effective interaction and use by the Soldier & Squad. The information gleaned will contribute to a body of generalizable knowledge that can be tailored and applied to future design efforts.

Supporting Objective 2.1.4 Human/Systems Dynamics. Discover, understand, and exploit fundamental principles governing the influences of the human-in-the-loop system to human dynamics and effectiveness. We must also examine the human influences on overall system design, and effectiveness on human-agent teams, cybersecurity, and organizational and social networks.

Supporting Objective 2.1.5 Align Future Technology, Equipment and Capability with Tactical Mission. Understand the needs and employment tactics of the Soldier & Squad as they relate to the development of evolutionary and revolutionary emerging technologies, equipment, and capabilities.

Supporting Objective 2.2 HSI Influence on Materiel/Non-materiel development

Apply fundamental principles of HSI across domains to influence materiel/non-materiel development. Through S&T of the Soldier-system, we will develop and transition Soldier performance metrics, tools, models, test methodologies, and clearly understandable and measurable human science/human performance-related requirements/criteria. These are for inclusion and consideration in the acquisition/product development process in order to affect the RDT&E and fielding of materiel and non-materiel equipment/technology solutions/capabilities that are optimized for the Soldier & Squad.

Supporting Objective 2.2.1 Performance Metrics. Develop human performance metrics that translate the CPS capabilities and limitations into well-defined, measurable requirements language.

Supporting Objective 2.2.2 Equipment and Technology Assessment. Develop standard test methodologies, tools and analysis techniques that allow for a consistent, common practice approach across the Soldier communities to evaluate the effects of equipment/technology on Soldier & Squad performance.

Supporting Objective 2.2.3 Guide Design. Develop design guidance that materiel/non-materiel developers can implement in the production of their systems that will positively contribute to the Soldier-system optimization. This guidance will allow for the consideration of human influences on overall system design, effectiveness, and ease-of-use, and will inform the development of training techniques that are easily understandable and successfully employed.

Supporting Objective 2.2.4 CPS Performance Models, Simulation and Predictive Tools. Develop models, simulation and predictive tools that accurately incorporate and reflect the Soldier & Squad physical (stature, weight, bulk, physique, range of motion/maneuverability, posture, stance, etc.), social (leadership, hierarchy, cohesion), and cognitive characteristics/attributes and the interactions with external (e.g., gear, environment, etc.) factors. This will allow for the early assessment of the HSI implications of developmental concepts or synthetic prototypes, enable prediction of Soldier performance as influenced by the development of the materiel/non-materiel solutions, or predict effectiveness of the HSI of those systems.

*Supporting Objective 2.2.5 Assistive Tools***.** Develop tools, standards and information that can assist and/or be implemented by human scientists, HSI practitioners, such as the developmental HSI Progress-Risk Specification Tool (HPRST), and materiel/non-materiel developers to recognize and assess HSI requirements, consequences and potential HSI risks more readily and earlier than would otherwise take place. These tools can also be used to assist with trade-off analysis by understanding the impacts of design decisions on human performance. This in turn supports development and testing, and evaluation within the acquisition life cycle of product development, thereby fostering a climate for Soldier-system success.

Supporting Objective 2.2.6 Innovative Solutions. Conduct the underlying science and develop applied, transitionable design criteria or knowledge/information that is focused on innovations in core areas essential to HSI and human performance. This is necessary to influence and inform development of novel interfaces; stable, robust, and effective control systems, as well as innovative and emerging materiel and non-materiel human performance optimization solutions (as discussed in LOE3), such as but not limited to human augmentation (off-loading, enhancing, or wearable/implanted cognitive or physical mechanisms); situational awareness techniques/tools; robotics; physical/cognitive real-time monitoring systems; intervention/sustainment solutions; Soldier readiness solutions; personalized, on-demand systems; fully integrated protective and enabling ensembles (those that have integrated, synergistic capabilities and/or sensors); and pioneering technologies (emerging/innovative).

LOE 3: Enhancing Human Performance Optimization (HPO) Solutions (materiel and non-materiel)

When considering capability recommendations for the Soldier & Squad, it is critical that those capabilities enable optimization and enhancement of the Soldier & Squad's CPS capacity while operating in a complex, joint, interagency, intergovernmental, and

multinational environment. In order to achieve overmatch, the squad must be capable of mastering combined arms operations and generating situational understanding before, during, and after operations.

Squads must "last longer," in part, by being smarter, faster, more lethal and precise and S&T will help inform and develop solutions that ultimately improve performance, readiness, resiliency and mission effectiveness.

Appendix C (Science &Technology) of TRADOC PAM 525-3-6 Functional Concept for Movement and Maneuver, September 2015, along with other doctrine, helped shape the materiel and non-materiel solutions recommended in this LOE[11]. These solutions are not meant to be prescriptive but should serve as a start-point for planning and may form the basis for creation of Army science and technology objectives (STOs). See Figure 4 for a WBS of LOE 3.

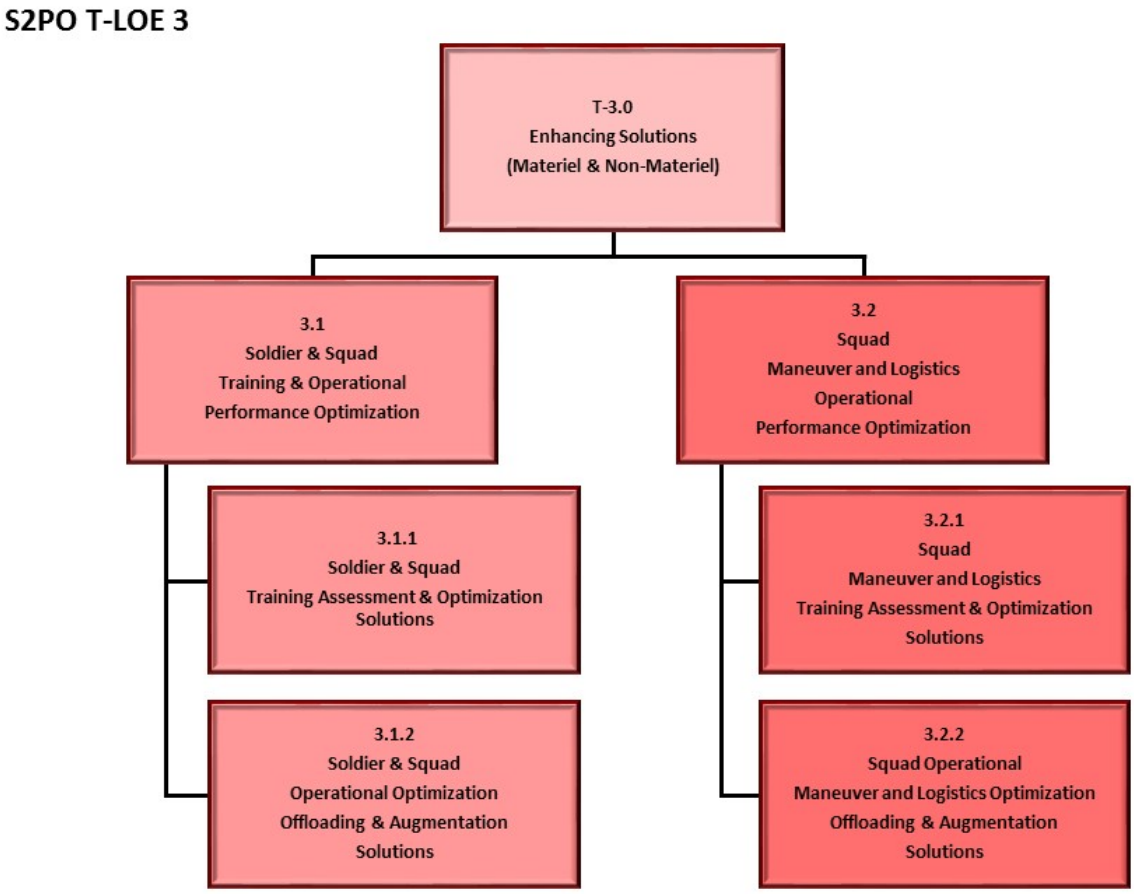

Figure 4 WBS LOE 3

Supporting Objective 3.1 Soldier & Squad Training and Operational Performance Optimization

Capabilities and methods to assess, train, offload and augment the Soldier & Squad have not kept pace with the complex training and operational environment. This supporting objective recommends pursuing capabilities and methods that enable the Soldier & Squad to be assessed and then either augmented or offloaded during tasks conducted both in training and the operational environment. This recommendation is designed so that Soldier & Squads develop broad, flexible knowledge and skills during training and rehearsal that can be applied across the full range of mission demands[12]. This approach will identify the necessary offloading and augmentation capabilities or other innovative solutions to improve Soldiers' CPS competencies for task performance. Educating leaders is a key element of increasing awareness and support for the CPS domains. While emphasizing the cognitive and physical domains, leaders must also understand the importance and value of the social domain in relation to human performance. Without this understanding, social capability development will be a low priority.[13] It is also critical for leaders to be able to articulate to their subordinates the importance and relevance of the social domain, and to incorporate social elements into training and development plans.

Supporting Objective 3.1.1 Soldier & Squad Training Assessment and Optimization Solutions. In an effort to develop fully prepared Soldier & Squad, S&T must contribute to improved training processes and capabilities to meet the demands of a complex environment. Simulators, monitors and classrooms must provide useful measurements and data to the training developer and adequately prepare Soldier & Squads for the demands of the current and anticipated fight. Flexible processes that allow for innovation and disciplined initiative are paramount to training for future operations.

Although current Army simulations are valuable in training a wide variety of skills, they are not sufficiently rich and varied to train intuitive decision-making[14]. Through S&T, the Army must apply cognitive, social, and neurological science as well as technological advancements to train Soldiers & Squads to thrive in ambiguity and chaos. The Army must capitalize on emerging technologies and couple them with innovative learning methods to educate the total force, and to develop critical CPS skills.

To be effective, training and assessment capabilities must have the following components: A diverse array of realistic tactical scripts; A model of how "battle savvy" improves over time; the ability to break down and train the components of intuitive thinking; Modeling complex, high-stakes decision making across a variety of missions.

In addition, training systems must be: Relatively small and portable; stand alone, without need for technicians or other external support; durable —it will be used in all sorts of conditions by many different users; easy to program different tactical scenarios; provide real-time feedback to the trainee; be networked to other users; and include self-motivating functions such as score keeping.

Recommended focus areas include but are not limited to:

- Portable, multidiscipline analytics for situational awareness for individual Soldier and collective Squads
- Physiological monitoring during training
- Assess team dynamics with support equipment (sensors, unattended vehicles)
- Functional movement screening
- Resiliency assessment
- Modeling/simulation of threats in emerging operational environments
- Systems level tools and design guidelines to optimally assess and integrate augmentation with training to enhance Soldier & Squad complex, dynamic decision-making capabilities
- Training effectiveness for simulations
- One world synthetic environment – computer science
- Adaptive tutoring systems technology – modeling research and sensing
- Augmented reality – optical visual system research, AR components and integration
- Virtual humans – artificial intelligence and machine learning
- Load configuration learning for injury prevention
- Institutionalized nutritional learning for Soldier & Squad for both training and operational environments
- Behavioral and psychological learning that improve the cognitive and social capacity of the Soldier & Squad, e.g. social –emotional regulation techniques

Supporting Objective 3.1.2 Soldier & Squad Operational Optimization, Offloading and Augmentation Solutions. Reducing the CPS burden imposed on Soldiers & Squads through the assistance of technology solutions is essential to optimizing operational mobility and capacity. Soldiers & Squads employ systems which are physically and cognitively demanding and often inhibit performance and result in permanent injuries. For example, new capabilities that optimize the Soldier & Squad performance capacity, such as mission and recovery specific nutrition, tailorable-worn environmental protection, efficient power management for extended operations, adaptable load carrying augmentation devices, manned and unmanned systems that enable stand-off, and early situational awareness technologies are necessary to both reduce and optimize the Soldier & Squad CPS burden. Together these improvements will contribute to an optimized Soldier & Squad that is necessary in a force structure that is being reduced at the same time our adversaries are becoming more capable and global.

Recommended focus areas include but are not limited to:

- Nutrition - On demand combat rations that enable individual Soldier & Squad performance
- Load carriage - Load carriage augmentation devices
- Protection –

- Blast and Ballistic Protection: Anthropocentric, modular design and materials for significant improved performance with reductions of PPE weight and thermal burden
- Vision and Hearing Protection: Single lens system for integrated vision and hearing protection without degrading auditory or visual situational awareness
- Headborne Protection: Improved performance, integrated headborne protection systems that reduces adverse impacts on Soldier performance and situational awareness
- Signature Management: Individual concealment technologies to counter advanced multispectral sensors, and to allow the Soldier to maneuver in various terrains and situations. Technologies for signature management include Camouflage, Concealment, Deception and Obscuration.

- Network - Network, optimized Cyber defense and Wireless capability
- Situational Awareness -
  - Advanced low cost, multifunctional displays, electronics and sensors systems that reduce size, weight, power and cost (SWaP-C) and provide leap ahead Hostile Fire Detection /Localization, situational awareness, degraded visual environment mitigation and threat warning
  - EO/IR: advanced weapon sight technologies, smart sights and future advanced vision and weapon systems
  - Route and mission planning tools to provide mission command capabilities to enable tactical overmatch, avoid surprise, increase lethality, improve survival and mission effectiveness
  - Position Navigation and Timing (PNT)
- Hazard identification: Identify battlefield hazards (to include WMD) using an array of technologies to include explosives detection (for IEDs), NBC sensors, night vision and other situational awareness techniques including a variety of networked sensors.
- Augmented reality visual systems
  - Soldier-borne and operated Intelligence, Surveillance, Reconnaissance capability
  - Unmanned/semi and autonomous intelligence systems for situational awareness
  - Precision aerial delivery of systems, sensors, and supplies
- Power and Energy
  - Soldier-borne energy harvesting technologies (mechanical, photovoltaic)
  - Soldier-borne power control and management standards and technologies
  - Wireless power distribution concepts and technologies
- Lethality
  - Novel lethal armaments
  - Scalable effects armaments
  - Non-lethal weapons effectiveness testing methods and metrics
  - Target detection and identification methods (through use of physiological/electroencephalographic signatures of potential adversaries)
  - Neural linkages to fire control
  - Fusion technologies for multiple sensor platforms

- Crew-served weapon to vehicle integration methods
- Decision-making with complex armaments
- Social/communication patterns for crew-served armaments

Supporting Objective 3.2 Squad Maneuver and Logistics Operational Performance Optimization

To improve the squad's ability to conduct expeditionary maneuver and sustain high tempo operations at the end of extended supply lines, the squad must increase logistical efficiencies and self-sufficiency. New technologies must enable increased maneuver and sustainment efficiency through mission tailored nutrition, enhanced endurance mobile protected combat and tactical platforms, base camps that provide both adequate environmental protection and a quality of life to sustain readiness, lower power consumption, power and energy generation, and timely and agile logistics and precision resupply. The Army must develop technologies to enable automated and autonomous ground and air resupply. Increased reliability, maintainability, and efficient small unit base camps will reduce force structure requirements as well as logistical demand. These technologies will minimize the logistical footprint resulting in reduced risks to squads, enhanced troop to task ratio, and preservation of freedom of maneuver and action.

Supporting Objective 3.2.1 Squad Maneuver and Logistics Training Assessment & Optimization Solutions. S&T is a key enabler to maintaining squad maneuver and superior logistics and requires resource priority to meet future operational needs. S&T efforts must address challenges in optimizing squad readiness through reducing the maneuver supporting logistics footprint and improving survivability and providing a performance enhancing quality of life in order to achieve mission effectiveness while operating from austere locations. Understanding these challenges requires that squads are assessed in training environments that accurately represent the future operating environment and allow for baseline development to inform future requirements.

Recommended focus areas include but are not limited to:

- Through collaboration and integration, establish RDECOM and S&T partners data sharing mechanisms that represents the likely operational environment necessary for Soldier & Squad optimization assessment.
- Synchronized modeling, simulation and analysis activities across RDECOM and S&T supporting partners that focus on understanding and optimizing human to human, human to enabling technology, human in the contested environment and human to systems interactions.
- Establish scenario driven baselines to enable solutions for Soldiers & Squads that include: worn equipment for extended operations; resupply; nutrition for extended operations; power and energy, dismounted, mounted and at austere basecamps; operational quality of life at basecamps and mounted platforms to determine impact on squad readiness and effectiveness.

- Integration of S&T assessment personnel and capabilities at the Army's premier training locations and experimentation venues such as AWA, NIE, JRTC, NTC, CMTC, etc. to further understand Soldier & Squad needs.

Supporting Objective 3.2.2 Squad Operational Maneuver and Logistics Offloading and Augmentation Solutions. Expeditionary capabilities that support and sustain squad or small unit mounted and dismounted maneuver operations are necessary to achieve overmatch. Minimizing troop to task ratios to both operate with and operate from these capabilities is critical to sustaining CPS performance capacity needed for optimal and repeatable mission effectiveness. By designing easily deployable, modular systems with low maintenance demands, squads will maintain a higher level of readiness needed to retain the initiative during high tempo decentralized operations.

Recommended focus areas include but are not limited to:

- Resupply: High accuracy, low cost aerial delivery systems for Soldier & Squad tactical resupply; high accuracy, low-cost, minimal-retrograde aerial delivery; reduce signature of aerial delivery systems; continue to develop robotic and autonomous systems and manned-unmanned teaming.
- Power: tactical power generation – alternative, power harvesting sources, and storage; primary and rechargeable batteries for Soldier-borne gear; self-sufficient basing technologies that decrease consumption while lessening sustainment support.
- Shelters: modular, tailorable, and rapidly deployable habitation and organizational equipment; integrated, activity sensing shelter lighting technologies to improve awake and sleep cycles for Soldier recovery; expeditionary insulation systems.
- Personal Hygiene: self-sufficient sanitation and personal hygiene systems.
- Nutrition: improved portability, rapid detection and instant identification of food borne pathogens and chemical toxins; mission tailorable, customizable, and regionally aligned operational rations; fresh-like quality food produced or delivered on-demand in austere environments; develop sustainment technologies to optimize human performance via nutritional enhancements, and combat feeding/base camp technologies leading to improved Soldier readiness.

LOE 4: How to Achieve Optimization Vision & Transition

An essential part of the S2PO Strategy lies in addressing "**how**" the Army must go about successfully achieving the vision of optimizing the performance of its Soldiers. The previous T-LOEs describe the "**what**" with regards to the S&T initiatives that are needed to reach this goal, but there are a multitude of supporting, underlying requirements associated with the strategy that must be discussed, addressed and planned for to attain the full potential of the vision. See Figure 5 for a WBS of LOE 4.

S2PO E-LOE 4

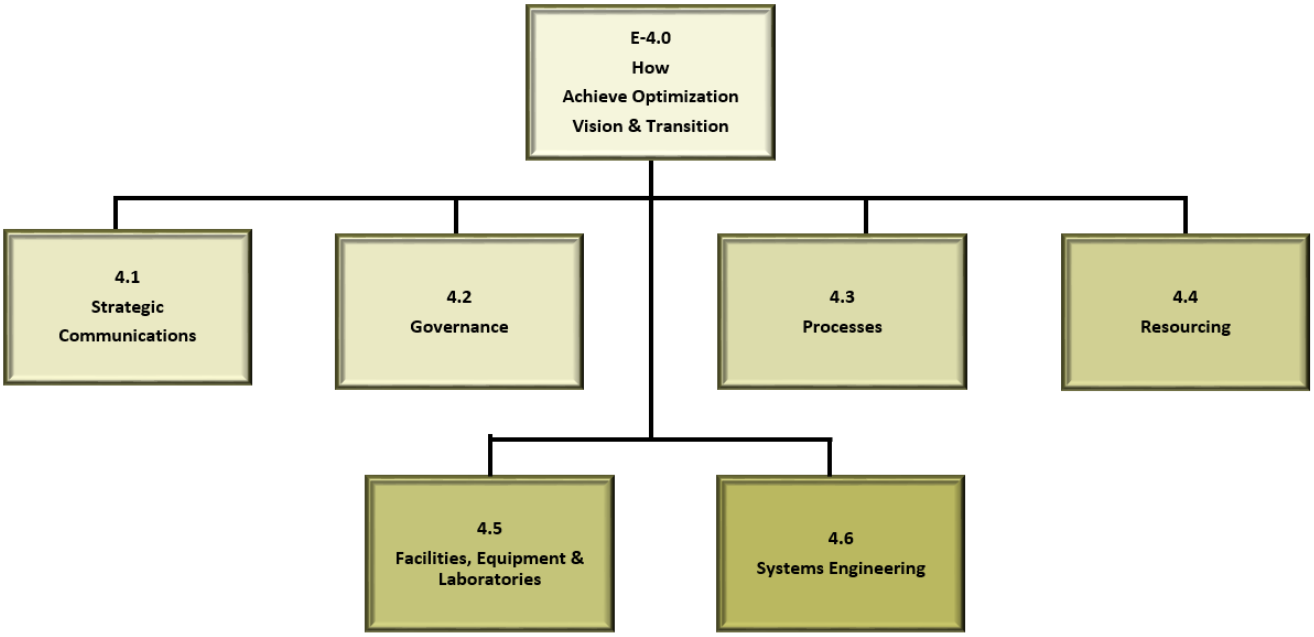

Figure 5 WBS LOE 4

Supporting Objective 4.1 Strategic Communications

We must foster communication and collaboration among the S&T community as well as with transition partners, stakeholders and the user community. This will allow for those with a vested interest to become engaged in and maintain awareness of ongoing, proposed and state-of-the art initiatives/visions, etc. associated with S2PO. The communication methods established will serve as a bridge between the scientific community, the transition community, and those who need and/or are seeking solutions to performance issues/concerns. These principles should be codified in a formal communication and marketing plan at the RDECOM level to be targeted Army-wide.

Supporting Objective 4.2 Governance

Establish an enterprise consortium or a Soldier Performance Center (SPC) to enact a holistic business and scientific approach to HSI and HPO across Soldier & Squad S&T,

requirements, & acquisition communities. The SPC governance would be responsible for linking policy, research, capability gaps, resources, solutions and implementation of the S2PO strategy. It would facilitate communication, cooperation and collaboration in the areas of Soldier & Squad optimization and assure a common understanding of RDECOM's direction in this environment. The key functions of this governance community, a collective representation of RDECOM and other ARMY organizations, are to:

a. Oversee and enable the efficient execution of the T-LOEs within the S2PO strategy, drawing on the resources (laboratory and subject matter experts) of the various contributing agencies, to enable the Army to achieve optimized Soldier cognitive, physical dominance and social intelligence.
b. Formalize the HPO community by bringing together unique and interdisciplinary communities of scientists and engineers as partners to advance the state-of-the-art and the state-of-the-possible in the areas of human sciences.
c. Understand, capture and synchronize S&T efforts across the Army (and in conjunction with the other services, industry & academia) that is focused on HPO.
d. Stimulate and influence the establishment of collaborative partnerships that will minimize potential for redundancy, duplication of effort and enable synergy.
e. Maintain vigilance (and to understand/monitor the ethical implications) of emerging and potential technologies.
f. Develop and/or oversee S&T implementation strategies that allows the Army to focus on Army-unique requirements while leveraging the work of others (OGAs, industry, academia, DARPA, etc.) in areas that the Army does not lead.
g. Promote innovative and collaborative S&T initiatives across the Army to deliver cutting edge knowledge, equipment and enabling technologies (materiel and non-materiel) that cultivates the optimal Soldier-system who is cognitively and physically dominant and socially intelligent.
h. Identify and support transition paths and goals to include ensuring requirements generation and maturation is synchronized with R&D initiatives.

Supporting Objective 4.3 Processes

As is true of any successful endeavor, the establishment and adherence of well-defined, agreed upon and supported processes is needed. These processes are the "enablers" for efficient execution and realization of the resulting products of the strategy efforts by the S&T community and consist of the following:

a. Methods to propose, prioritize and resource S&T initiatives that align with the T-LOEs and Supporting Objectives.
b. Transitions: Methods to capture/package deliverables (knowledge products, data, training information or techniques, design guidance, etc.) resulting from S&T initiatives and deliver/transition them to the intended recipient so that they will be actionable/useable.
c. Mechanisms to identify transition partners early and work iteratively with them.

Supporting Objective 4.4 Resourcing

Flexibility and authority are required to sustain, maintain & reshape core competencies to effectively execute the S&T strategy. Adequate and appropriate resourcing of funds are required to execute the necessary S&T initiatives and to maintain and sustain a world-class cadre of scientists and engineers in technology areas where the Army must lead.

Supporting Objective 4.5 Facilities/equipment/laboratories

Support and sustainment of the necessary facilities, equipment, and laboratories are needed for conducting relevant and cutting-edge S&T. Consider the establishment of a Soldier-centric applied research facility whereby the focus will be on human/Soldier/squad optimization. It will be a center to guide, facilitate, educate, develop and integrate all Soldier-system capabilities and will be the necessary bridge between laboratory research and the operational/mission environments by blending sound scientific research capabilities with simulated and actual mission activities/tasks, led by renowned SMEs across academia, industry and government in the areas of life/human sciences. See Appendix A for a list of enabling laboratory facilities.

Supporting Objective 4.6 Systems Engineering

Support the development of knowledge integration into a useful framework that can inform and influence recruitment, selection and training of the next generation of Soldiers, as well as design, accessions, human and materiel system requirements via the establishment of a robust systems engineering methodology. See Appendix B for a description of the systems engineering approach – Soldier Systems Engineering Architecture (SSEA).

5. Challenges

A. Cultural inertia.

There will be tendencies for the stakeholders to maintain the status quo. There is a wide-held belief that the scientific community is already supplying the user community with optimization materiel solutions. Individual stakeholder organizations with limited core competencies and competition for limited resources increase the likelihood of duplicative work and unrealized synergistic effects of combining resources.

B. Industry and academia S&T visibility.

Limiting scientists and engineers from attending non-DoD conferences leads to 1) Army research falling behind academic research because the most current science is shared at conferences and not in journals, and 2) inefficient use of time and money

navigating the onerous approval processes to attend conferences on the occasion that this is allowed.

C. Relationships between S&T organizations and requirements generating organizations. Relationship between S&T and operational community.

A major risk to achieving these objectives is the institutional culture within RDECOM and the wider Army that makes it difficult for scientists to find the right contacts to initiate transition agreements and to disseminate their work to a wider audience. Lack of defined, established methods to transition knowledge/information from the RDECs to appropriate partners (e.g., TRADOC, PMs) interferes with and leads to difficulties in getting knowledge and training into requirements documents or the schoolhouses where it would prove most effective. Additionally, a clear method for acceptance and incorporation of the knowledge/information by the appropriate partners must be institutionalized.

D. Collaboration among Army S&T organizations.

Collaboration among Army S&T organizations is made difficult by the streamlining of processes within agencies but not across agencies. Scientists at the individual project officer level have significant investment of time in their primary research projects, and so it should fall to individuals dedicated to work across agency boundaries to smooth the path to form cross-agency collaborations. Such individuals could provide 1) common knowledge of research efforts across agencies to avoid duplication, 2) updated lists of contacts and research projects to allow for rapid dissemination of the knowledge of who is working on what and in what capacity, and 3) a bridge between scientists and program integrators so that the program integrators can more easily speak about the nature of research that is being conducted at each center.

Recently, some of this is being addressed through Communities of Interest (OSD level), Communities of Practice (Army level), and RDECOM's Portfolio Working Groups (RDECOM level). These collaborative endeavors need to mature, become more formalized, and expand their inclusiveness to ensure the entire community is part of the effort.

E. Communication with the Soldier community.

The communication between the Soldier community and the scientific community is itself often less than optimal. There is a lack of personnel with a high level of scientific knowledge and expertise, coupled with a high understanding of military needs and the ability to communicate the science to that community. The Army should consider grooming personnel who can bridge the communication/understanding gap between science and Soldier. A model to consider can be found in the pharmaceutical industry. There, Medical Science Liaisons (MSL) help to ensure that products are utilized effectively, serve as scientific peers and resources within the medical community, and are scientific experts to internal colleagues at companies. However, the primary purpose of the MSL role is to establish and maintain peer-peer relationships

with leading physicians, referred to as Key Opinion Leaders, at major academic institutions and clinics[15]. In the same way, the Army could expand the current cadre of personnel who perform the liaison function between the scientists, the Program Managers, and the Centers of Excellence but can "speak the language" of each community. Also, the Army could better utilize the assigned military scientists/researchers within the S&T community as a contributing solution toward this challenge area.

Further recommendations from the CSA Strategic Studies Group[16] identified obstacles for progress (risks) that need to be mitigated and are equally relevant to the S2PO effort. Specifically,

- Lack of a well-defined institutional advocate for HPO
- Insufficient structure or incentives for communication among DoD entities conducting or sponsoring HPO research, leading to excessive duplication of effort.
- HD and HPO programs being developed without adequate input by appropriate subject matter experts, chiefly psychologists. This can result in an adoption of "flashy" HPO solutions that lack empirical validation and will likely fail over the long run.
- A reluctance to engage in cutting edge research and development, especially in neuroscience, for fear of how it may be interpreted by the media. This prevents the Army from sponsoring high risk/potentially high payoff research and development in cognitive and behavioral neuroscience, the fields most likely to significantly impact HPO in the future.

6. Conclusions

Maintaining the Army's differential advantage over enemies is critical, and that advantage is created, in part, by advanced technologies integrated ***with*** skilled Soldiers and well-trained teams. Future human and cognitive sciences (technologies) may "revolutionize the way the Army recruits, educates, trains and develops leaders and Soldiers."[17] Greater emphasis on the human dimension to support the development and effectiveness of Army the Soldier & Squad reflects increased momentum of human interactions through modern social networks and media.

The Soldier & Squad Performance Optimization Science & Technology strategy has been designed to actualize the S&T technology focus areas of the Army Operating Concept including human performance optimization, logistics optimization, autonomy-enabled systems and information to decision. The strategy has also been designed to provide solutions to the three major risks described in the Human Dimension Strategy that center around the lack of governance, unity of effort and a common operating picture. As stated previously, this strategy is a living document that should be periodically revisited and updated.

The Soldier & Squad Performance Optimization Science & Technology strategy promotes innovative and collaborative S&T initiatives across the Army to deliver cutting edge knowledge, equipment and enabling technologies (materiel and non-materiel) to

empower Soldiers with optimally integrated knowledge, skills, abilities, equipment and technologies and help them achieve superior individual and team performance.

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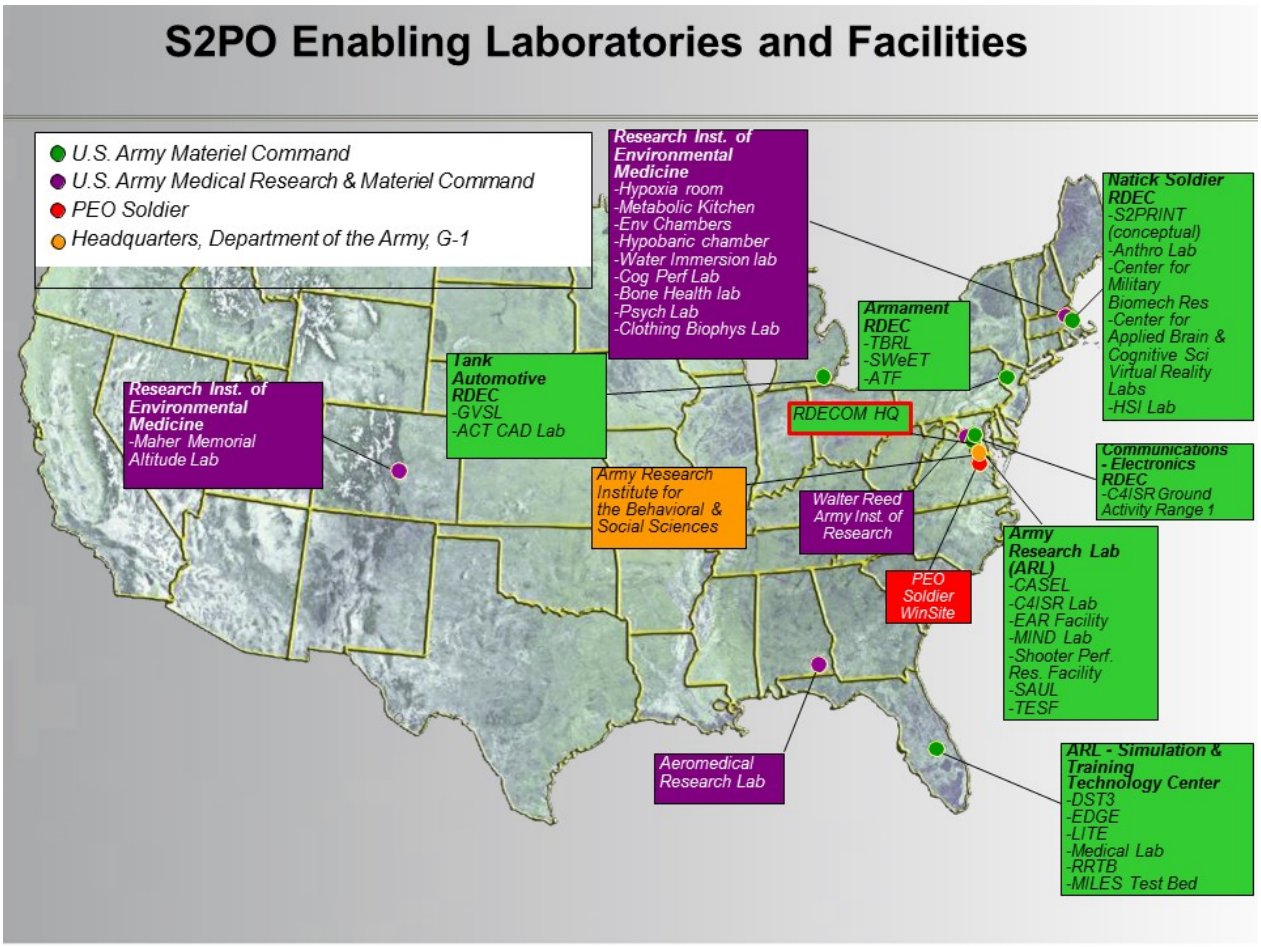
[1] TRADOC Pamphlet 525-3-1, 20, p. 39.
[2] Ibid, p. 36.
[3] TRADOC Pamphlet 525-3-7, p. 5.
[4] Friedl, K., Deuster, P.A., O'Connor, et al. (2007)
[5] Army Human Dimension Strategy 2015, p. 5.
[6] TRADOC PAM 525-3-7-01, The U.S. Army Study of the Human Dimension in the Future 2015-2025, Apr 08, p. iii
[7] TRADOC PAM 525-3-1, The U.S. Army Operating Concept, Win in a Complex World, p. 8
[8] Army Force 2025 and Beyond, p. 6.
[9] TRADOC Pamphlet 525-3-7, p. 24.
[10] IAW LIRA 18 as of 5 Oct 2015; these near, mid and far dates will change as this living document is updated.
[11] TRADOC PAM 525-3-6, Functional Concept for Movement and Maneuver, (pg. 31, App C), Sep 2015
[12] Maneuver Cent3er of Excellence S&T Priorities Memorandum, April 2015
[13] CSA Strategic Studies Group HPO Concept Team, June 2015, p. C-2
[14] Ibid.
[15] Medical Science Liaison Society. http://www.themsls.org/what-is-an-msl. Web. 13 Nov 2015.
[16] CSA Strategic Studies Group HPO Concept Team, June 2015, p. 8
[17] TRADOC Pamphlet 525-3-1, 20, p. 5.

APPENDIXES

Appendix A – Enabling Laboratories and Facilities

The following is a list of existing or planned facilities across the Army that support studies related to the assessment of Human/Soldier-system Performance. (Note: this list may not be all inclusive as it is still under development)



ARDEC Facilities

Armament Technology Facility (ATF)

ATF is an 80,000+ square foot full-service ballistic and non-ballistic, research, design, development and evaluation lab, with the capability for small and medium caliber (up to and including 40 mm) weapons, ammunition and their ancillary equipment.

Simulated Weapon Environment Testbed (SWeET)

This user-in-the-loop testbed puts the warfighter in an immersive virtual environment, giving them the ability to evaluate actual weapon systems without firing live ammunition. The major focus of the system is to evaluate small caliber weapons, ammunition, and fire control technologies in virtual firing ranges and operational environments.

Target Behavioral Response Laboratory (TBRL)
Research at the TBRL is split into two areas of concentration, the first includes HSI testing, or human response to less-than-lethal weapons and systems, scalable effects, and emerging technologies. The other area of focus is HSI where total system performance can be quantified by recruiting Soldiers to perform their duties using ARDEC armament systems. The TBRL includes an indoor flash-bang range, squad Performance Test Bed, Indoor Room Clearing Test Bed, Virtual Employment Test Bed, Mine Detection Test Bed, Virtual Simulation Behavioral Lab (to be completed in 2017), Agile Data Collection System, and a Behavioral Coding System.

ARL Facilities

Cognitive Assessment, Simulation and Engineering Laboratory (CASEL)
(Aberdeen Proving Ground, MD)
CASEL is a standalone behavioral research facility used to better understand and improve individual Soldier and team cognitive performance, and examine knowledge management in stressful, militarily relevant scenarios.

Command, Control, Communications, Computers, Intelligence, Surveillance and Reconnaissance (C4ISR) Laboratory (Aberdeen Proving Ground, MD)
C4ISR Laboratory is designed to allow researchers to study the effect of information and communication on individual and small team performance in a first person simulation environment.

Dismounted Soldier Training Technologies Testbed (DST3) (Orlando, Florida)
The DST3 supports research efforts in prototyping the next generation Mixed-Augmented Reality (M-AR) and Virtual Immersive Training Technologies (VITT) for the US Army and Joint Forces Dismounted Soldier Training.

Enhanced Dynamic Geo Social Environment Lab (EDGE) (Orlando, Florida)
EDGE is a government owned prototype designed to provide a highly accurate virtual environment representing relevant operational environments utilizing the latest commercial multiplayer online game technology.

Environment for Auditory Research Facility (EAR) (Aberdeen Proving Ground, MD)
The EAR is a world-class auditory perception and communication research facility. The EAR can re-create a multitude of indoor and outdoor military environments, which is necessary to measure Soldier listening performance in realistic conditions.

Learning in Intelligent Tutoring Environment (LITE) Laboratory (Orlando, Florida)R&D in the LiTE Lab supports TRADOC and includes adaptive computer-based tools and methods to support one-to-one and one-to-many tutoring environments for tailored, self-regulated learning.

Medical Lab (Orlando, Florida)
The Medical Simulation Research Laboratory at the Simulation Training Technology Center (STTC) conducts research and development of simulation and training devices to support the military medical community.

Mission Impact through Neuro-inspired Design (MIND) Laboratory (Aberdeen Proving Ground, MD)
The MIND Laboratory is an all-inclusive environment for neuroscience research designed for studying Soldier-system interactions in support of ARL's neuroscience research.

Risk Reduction Test Bed (RRTB) (Orlando, Florida)
The RRTB initiative is a collaborative effort between ARL, STTC and the Program Executive Office for Simulation, Training and Instrumentation's, Project Manager for Constructive Simulation. The primary objective is to identify capability gaps, related to PM ConSim Programs of Record or PoRs and develop potential technology solutions that address these gaps, reduce risk and maximize technology transition opportunities to PEO STRI PoRs.

Shooter Performance Research Facility (Aberdeen Proving Ground, MD)
The Shooter Performance Research Facility at M Range is a live fire range designed to allow researchers to understand the effects of weapon configuration and accoutrements on shooting performance consisting of 4 firing lanes with targets located from 10 to 550 meters.

Soldier Performance and Equipment Advanced Research (SPEAR) Facility (Aberdeen Proving Ground, MD)
The SPEAR facility was designed to allow researchers the ability to study the interactive effects of physical and cognitive stress on Soldier performance. The facility consists of a biomechanics laboratory, an instrumented obstacle course and a cross country course.

STTC Multiple Integrated Laser Engagement System (MILES) Test Bed Facility (Orlando, Florida)
R&D work in the lab focuses on prototypes for next generation Live Training and Army Testing capabilities. The principle research is in tactical engagement, simulation sensor technology and Army testing using modeling and simulation.

System Assessment and Usability Laboratory (SAUL) (Aberdeen Proving Ground, MD)
The SAUL provides an environment to enable more quantitative usability analysis for a variety of Army systems and prototypes. SAUL is equipped to examine HSI issues via small-scale table-top evaluations or in military simulation environments.

Tactical Environment Simulation Facility (TESF) (Aberdeen Proving Ground, MD)

The TESF houses the Immersive Environment Simulator (IES). The IES enables the study of the effects of the combination of cognitive and physical workload on dismounted Soldier performance in a controlled, repeatable, simulated environment.

CERDEC Facilities

C4ISR Ground Activity's Range 1

Range 1 provides various types of resources and facilities for supporting C4ISR emerging technologies with existing military systems in a realistic field environment. Range 1 makes up one of more than 100 ranges and tactical areas comprising the Fort Dix Joint Training Complex of Joint Base McGuire-Dix-Lakehurst (JB-MDL) in New Jersey.

NSRDEC & Partner Facilities

Anthropometry Lab

The anthropometry lab enables the collection of traditional anthropometric measurements as well as 3D whole body and head/face images for the purposes of body size description and related human system interface applications.

Center for Applied Brain & Cognitive Sciences Virtual Reality Laboratories

The Center for Applied Brain and Cognitive Sciences, a collaboration between NSRDEC and Tufts University, will house three full 180˚+ horizontal field of view multi-panel virtual reality systems that provide ambulatory immersive experiences on behalf of multiple users working together toward common operational goals. Small unit-level behavior can be elicited on behalf of multiple users engaged in immersive, scripted scenarios, and measured through location and orientation tracking, eye tracking, physiology, and neurophysiology (i.e., electroencephalography, functional near-infrared spectroscopy).

Center for Military Biomechanics Research

The Center for Military Biomechanics Research is collaboratively funded and jointly staffed by the NSRDEC and USARIEM. Its purpose is to conduct basic and applied research in Biomechanics with the goal of developing a fundamental understanding of the interaction between individual Warfighters and their equipment in order to optimize Soldier performance during mission related tasks.

Clothing and Individual Equipment (CIE) Fightability Course

The CIE Fightability Course is comprised of an obstacle course designed to measure the effects of equipment on a Soldier's mobility, agility and speed in a combat environment. The course includes nine outdoor obstacles and a two-story building with stairs, doorways, windows and halls for evaluation of Military Operations in Urban Terrain (MOUT).

Human Systems Integration Lab

The Human Systems Integration (HSI) Laboratory is used in the development of test methodologies, data collection tools and evaluations of HSI issues of Clothing and Individual Equipment (CIE), Shelters, Food Equipment, and Airdrop Equipment.

Soldier and Squad Performance Research Institute (S2PRINT) (conceptual)
The proposed facility, jointly operated by NSRDEC and USARIEM, will be an unparalleled platform for evaluating technological, material, nutritional and mechanical innovations at multiple system levels of analysis. It will support scenario-driven exercises that follow the mission cycle from baselining and planning to movement, action, and recovery.

PEO Soldier Facilities

PEO Soldier WinSite
WinSite at Fort Belvoir is a collaborative design environment that provides the technical, virtual and physical representation of the Soldier-system. Capabilities include CAD, 3D scanning and printing, load bearing manikins and system-equipment effectiveness tools to provide modular tailorable solutions to examine trade-offs regarding the weight, size, and cost of new equipment and to provide a rapid prototyping capability.

TARDEC Facilities

Advanced Concepts Team (ACT) Computer-Aided Design (CAD) Laboratory
The ACT CAD lab is equipped to create ground vehicle design concepts for the development and improvement of space optimized interior workstations.

Ground Vehicle Simulation Laboratory (GVSL), (Warren, MI)
The Ground Vehicle Simulation Laboratory (GVSL) is home to unique simulation capabilities to conduct experimentation and evaluation of Soldier-centric ground vehicle systems. The GVSL creates real-time simulations immersing Soldiers in operationally relevant scenarios within realistic virtual environments consisting of: simulated vehicle platforms, geo-specific/representative virtual terrains, real-time vehicle dynamics, crew station / SMI models, OPFOR/SAF, comms/radio models, and sensor simulations/stimulations.

USARIEM Facilities

Bone Health Lab/Body Composition Laboratory
This facility is for research into adaptations that occur in healthy bone as the result of strenuous physical training. Laboratory equipment includes peripheral quantitative computed tomography, dual x-ray absorptiometry, and tibial ultrasound. Additional equipment and methods, which include an isokinetic dynamometry and dynamic gait analysis, is available to assess muscle performance variables associated with bone health.

Environmental Chambers
Environmental and biophysical evaluation chambers of various sizes that can be controlled for temperature (-10°C to 50°C), relative humidity, and wind speed provide

ample research space for testing. Eight environmental chambers are available for use with human research volunteers and animal models.

Hypobaric (Altitude) Chamber
This facility simulates global atmospheric conditions by reducing ambient barometric pressure using vacuum pumps in combination with precise manipulation and control of temperature and relative humidity. The facility consists of a large (9.7 x 20.6 ft) and a small (9 x 12 ft) chamber, both connected to an airlock. It also includes a shower, toilet, and running water for sustained multiday periods of operation. The chambers can be controlled for pressure (sea level to 9,000 meters), temperature (-32°C to 43°C), and relative humidity (20% to 80%).

Hypoxia Room
The Hypoxia Room supports long-duration normobaric hypoxic exposures with ambient oxygen partial pressures ranging from 159 to 37 mmHg or simulating an altitude exposure from sea level to 30,000 ft.

Metabolic Kitchen
Used for researching specialized diets/meals to include nutrient-controlled, weighed, and metabolic meals. Researchers used the facility to assess various feeding and drinking alternatives aimed at improving Warfighter health and optimizing both physical and cognitive performance under various environmental conditions.

Psychology Laboratory
This facility provides testing stations for computer-based assessment of cognitive and behavioral Warfighter performance. Operational stressors that can be studied include extended mental alertness, simultaneous task performance, and nutritional and pharmacological interventions. Laboratory equipment enables the assessment of physiological state through eye tracking and trans-cranial Doppler brain blood flow systems.

Thermal Manikins and Clothing Biophysics Laboratories
Five biophysical evaluation chambers containing fully sensored, articulated, moveable copper manikins, and other metallic models of feet and hands are available for testing of thermal and vapor-resistance values of clothing.

USARIEM Maher Memorial Altitude Laboratory, Pikes Peak, Colorado
This 2,100 square foot facility is located on the summit of Pike's Peak (altitude 4,300 meters [14,110 ft]), and consists of two laboratory rooms, a medical aid room, a dormitory (accommodating up to 16 research volunteers), a kitchen, and a bathroom with showers. This field laboratory is ideal for altitude studies involving multiple volunteers and longer exposure times.

Warfighter Cognitive Performance Laboratory
This 800 square foot facility houses the EST 2000, a widely used weapon engagement simulator that can mimic the ballistic characteristics of 25 different weapons. The

enhanced capabilities of the EST 2000 make it possible to test several measurement paradigms: Marksmanship, Shoot—Don't Shoot, Vigilance (or Information Overload), Discrimination of Friend versus Foe, and Motor Steadiness under varied situations. These include workload (information or physical), simulated sustained operations, fragmented and inadequate sleep, physiological or metabolic disruption, fatigue (central systemic or localized muscle), and therapeutic strategies.

Water Immersion Laboratory

This facility simulates cold and hot environments by changing water temperature in a 10,000 gallon concrete vessel. The facility provides the ability to test human performance while exercising on a single underwater walking treadmill or with two cycle ergometers while sitting on accompanying bolted-down stainless steel chairs. Water temperature can be controlled in a range of 5°C to 50°C.

Appendix B – Systems Engineering Approach

Soldier Systems Engineering Architecture

The Army must understand and exploit the balance between human capabilities (Soldier) and technological advancements (Equipment) as seen through task accomplishment. A Soldier Systems Engineering Architecture (SSEA) is being developed that will utilize the Soldier-Equipment-Task (SET) framework to promote scientific community collaboration, and to establish a reference architecture that will serve as an authoritative source to guide the design and development of future Soldier/Small Unit solutions. Comprehensive and integrated assessment of the Soldier/Small Unit under dynamic conditions is critical to optimizing performance while balancing human capability and technological advancements in terms of mission accomplishments. SSEA is being deliberately built in segmented, expansion phases including *populate*, *exercise*, and *enterprise* in order to allow the capability to mature over time and ease integration/influence across modernization lines of effort such as the Human Dimension framework and LIRA. SSEA will be the analytical foundation for future "Soldier as a System" utility, optimization, design and tradeoff analyses.

NSRDEC will serve as the coordinative body to integrate and synchronize efforts in support of SSEA. SSEA will fuse the SET framework with appropriate modernization agencies to ensure a broader influence/transition strategy is developed and delivered. NSRDEC will develop a first of its kind Soldier as a System reference architecture to serve as an authoritative source that guides and constrains the instantiations of multiple architectures and solutions ensuring repeatability, traceability, reuse and commonality across the Soldier enterprise. It will implement a tailored systems engineering process to ensure all lines of effort across the full complement of programs have an opportunity to influence the analytical underpinnings for optimized Soldier/Squad as a System performance. It will support the development of common assessment criteria for total Soldier as a performance metrics that will highlight the cognitive, physical and social aspects of the task completion on mission outcome.

ARL will provide human performance, simulation, and training research, analytical tools, and data to enable development and utilization of SSEA to address known Soldier/Small unit requirements and gaps. It will contribute to a distributed Soldier simulation which will provide a more cohesive/complete representation of the Soldier. It will produce a model based predictive analysis of dismounted infantry missions that integrate HSI and systems engineering inputs to examine critical task combinations, cognitive workload, Measures of effectiveness (MOEs), and Measures of Performance (MOPs) for dismounted infantry missions. It will develop System of Systems simulation architectures, technologies and systems engineering processes which ease the integration and use of SSEA and Modeling and Simulation (M&S) for Army decision makers.

CERDEC will support the development of SSEA through providing the analytical tools, data, technical and human performance parameters and known requirements/gaps in Soldier-borne C4ISR to include sensor and display systems, power & energy, mission

command, positioning, navigation & timing and communications while conducting studies/tech development/experimentation to enable Army trade space analyses.

The US Army Medical Research and Materiel Command (MRMC) will create a biomedical Soldier system data architecture based on a foundational systems biology approach that will cut across all of the human performance optimization efforts and links to the overarching SSEA. Experimental data and innate Soldier characteristics (i.e., 'omics,' morphological, physiological, etc.) collected within the components of the architecture will help create a model that articulates the performance impacts of external forces and/or events and how these performance effects can impact the wear and use of Soldier equipment. This will result in an integrated data set comprised of innate biological Soldier data, Soldier exposures, and experimental data that can be used to create an adaptable unit and human system integration models that predict cognitive and physical performance based on a systems biology enterprise. The effort will provide architectural knowledge to identify biomarkers required for assessment, monitoring, and prediction of health, fitness, and performance as well as standardized experimental metrics which will help to incorporate medical data into non-medical requirements and capabilities.

TARDEC is creating CAD accommodation models to allow ground vehicle designers the ability to address Human Systems Integration (HSI) earlier in the acquisition cycle. These models can be utilized during the Material Solution Analysis Phase prior to Milestone (MS) A and up through and including MS B. The models can also be used when upgrading existing ground vehicle platforms and for assessing commercial off the shelf (COTS) systems. Human Factors Engineers can also benefit by working with TARDEC vehicle designers to perform virtual assessments in CAD when there is not enough time and/or resources to perform detailed human figure modeling. The CAD accommodation models are being developed in collaboration with University of Michigan Transportation Research Institute (UMTRI), ARL Human Research and Engineering Directorate, and NSRDEC. These models represent the posture and position variability for the entire Soldier population that is selected for vehicle packaging (e.g. central 90% of Soldier population, 15% female, 85% male). TARDEC is also collaborating with PEO Soldier to create CAD boundary manikins which represent geometric extremes of the Soldier population. Boundary manikins are especially beneficial when used in conjunction with the accommodation models, to add detail, and address unique situations for which the creation of an accommodation model is not realistic.

Glossary

Definition of Acronyms

Acronym	Definition
ASAALT	Assistant Secretary of the Army, Acquisition, Logistics and Technology
AMA	Analysis of Materiel/Non-Materiel Approaches
AMEDD	Army Medical Department
AMRDEC	Aviation and Missile Research, Development and Engineering Center
AoA	Analysis of Alternatives
AOC	Army Operating Concept
ARDEC	Armament Research, Development and Engineering Center
ARL	Army Research Laboratory
CERDEC	Communications-Electronics Research, Development and Engineering Center
C4ISR	Command, Control, Communications, Computer, Intelligence, Surveillance and Reconnaissance
CPS	Cognitive, Physical, Social
CSA	Chief of Staff of the Army
DARPA	Defense Advanced Research Projects Agency
E-LOE	Enabling Line of Effort
HD	Human Dimension
HDC	Human Dimension Concept
HDS	Human Dimension Strategy
HPO	Human Performance Optimization
HPRST	HSI Progress-Risk Specification Tool
HSI	Human Systems Integration
ICD	Initial Capabilities Document
IRB	Institutional Review Board
JRTC	Joint Readiness Training Center

KSA	Knowledge, Skills and Attributes
LIRA	Long-Range Investment Requirements Analysis
LOE	Line of Effort
MANPRINT	Manpower and Personnel Integration
MCoE	Maneuver Center of Excellence
MILCON	Military Construction
MOE	Measures of Effectiveness
MOP	Measures of Performance
MOS	Military Occupational Specialty
MRMC	Medical Research and Materiel Command
M&S	Modeling and Simulation
NIE	Network Integration Evaluation
NSRDEC	Natick Soldier Research, Development and Engineering Center
NTC	National Training Center
PEO Soldier	Program Executive Office Soldier
POM	Program Objective Memorandum
PoRs	Programs of Record
PPE	Personal Protective Equipment
R&D	Research & Development
RDT&E	Research, Development, Test & Evaluation
RDECOM	Research, Development and Engineering Command
RDECs	Research, Development and Engineering Centers
SE	Systems Engineering
S&T	Science and Technology
SET	Soldier, Equipment, Task
SO	Strategic Objective
S2PO	Soldier and Squad Performance Optimization
S2PRINT	Soldier and Squad Performance Research Institute

SSEA	Soldier Systems Engineering Architecture
T-LOE	Technical-Line of Effort
TARDEC	Tank Automotive Research, Development and Engineering Center
TRADOC	United States Army Training and Doctrine Command
USARIEM	U.S. Army Research Institute of Environmental Medicine

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