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Inventory of Efforts & Evaluation (IE&E) Maximizing Human Potential Line of Effort 1: Optimize Health & Enhance Human Performance

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Inventory of Efforts & Evaluation (IE&E)

Maximizing Human Potential Line of Effort 1: Optimize Health & Enhance Human Performance

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Introduction

The performance of Soldiers, Leaders and Senior Leaders of the future force, will be a critical factor in the success or failure of future operations. The future operational environment of 2035 and beyond (FOE 2035+) will place unprecedented demands on these personnel, pushing them to the extreme limits of their cognitive, physical, and emotional capabilities. It will be critical to maximize human cognitive, physical, and emotional potential in future operations by optimizing the health and resilience of Soldiers, Leaders and Senior Leaders and providing safe, impactful, and ethical human performance solutions. Optimizing the health and resilience is the foundation from which to enhance human physical, cognitive and emotional performance of Soldiers, individually and within hybrid human-system teams, to ensure overmatch in the future operational environment. Optimizing and enhancing human performance will maximize individual and unit operational effectiveness within the Army's future formations.

The Army Futures Command (AFC) Maximizing Human Potential (MHP) sprint team has been tasked with understanding the human-level demands of the FOE 2035+, documenting the human performance requirements of the operational force; identifying critical areas for research; development, test and evaluation (RDT&E); and supporting the modernization of how the Army acquires, develops, and manages its personnel. The MHP operational approach defines three lines of effort (LOE):

- **LOE 1: Optimizing Health and Human Performance**
- LOE 2: Optimizing Human-System Performance
- LOE 3: Optimizing Talent Management

The U.S. Army Medical Research and Development Command (MRDC) has been designated as the lead for LOE 1. As acting LOE1 lead organization, U.S. Army Research Institute of Environmental Medicine (USARIEM, MRDC subordinate lab), with support from other MRDC subordinate labs and AFC subordinate S&T organizations (including Combat Capability Development Command or DEVCOM and relevant Program Executive Offices, Cross Functional Teams and Capability Development Integration Directorates), is working to synchronize efforts in support of the MHP mission. LOE1 has developed key milestones that include the execution of a series of activities in support of Senior Leader engagements and decision points with MHP efforts. This includes a "See Ourselves" exercise to review and document S&T efforts across the AFC S&T portfolio that impact LOE1, to include activities that target near- (up to 2028), mid- (2028-2035) and far-term (2030+) transitions, to identify gaps and opportunities for future S&T efforts, and to increase situational awareness between Army organizations in order to better synchronize as we move forward to address the necessary S&T to optimize health and enhance human performance in the FOE 2035+.

This interim report describes the process developed and followed, as well as initial results of LOE1 efforts pertaining to this "See Ourselves" exercise. The product deliverables of this exercise include: the initial operational capability (IOC) of the "Inventory of Efforts & Evaluation" (IE&E) – a data resource containing aggregated data that describes LOE 1-related S&T activities – and the results of initial analyses as reported herein.

The current report, published as a MRDC Technical Note, will persist as a living document, i.e., it may undergo updates periodically (e.g., annually) to reflect additions, refinements, and changes to the data

and any resulting changes to the analysis results. For example, future analyses will improve the alignment and synchronization of AFC S&T investments with MHP. The intent of the IE&E is to enable Army organizations to identify gaps and capitalize on opportunities within the LOE 1-related S&T efforts to address the human-level required capabilities and performance requirements of the FOE 2035+. Required capabilities will be defined in the forthcoming Maximize Human Potential Cross-Functional Annex (MHP CFA). The MHP CFA is planned for release following the publication of the next Army Operating Concept (AOC) at the end of FY22.

Methods, Assumptions, and Procedure

Data Aggregation

Effort Overview

The initial task of this exercise was to coordinate across the human health and performance communities (i.e., LOE1 member organizations) to synchronize language and develop a general framework, or general process, by which we optimize health and enhance human performance (Figure 1). This framework integrates human health and performance communities that drive priorities and supports force aim points and the required capabilities that will be emphasized in the MHP concept.

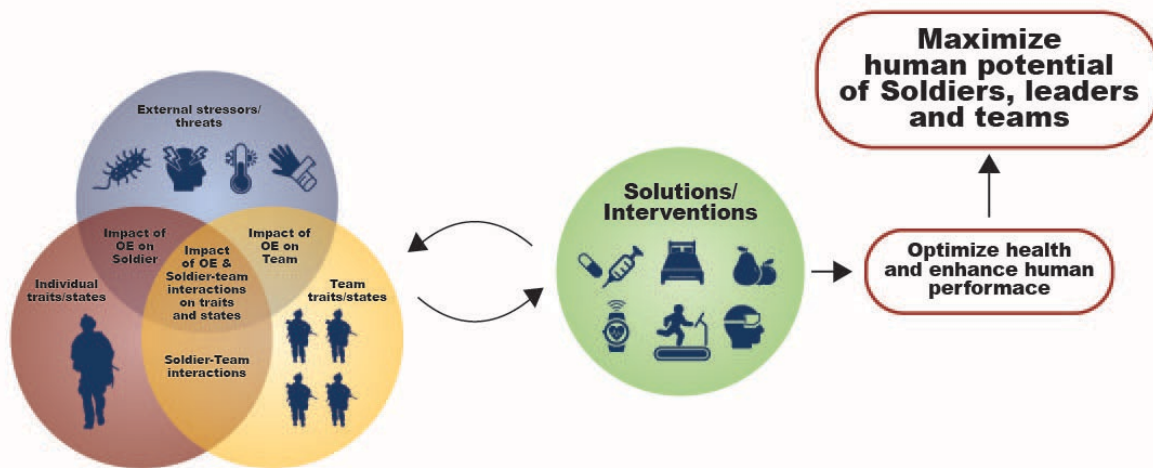


Figure 1. General framework for optimizing health and enhancing human performance.

Figure 1 conveys a sense of the process by which we will maximize human potential from the LOE1 perspective. The Venn diagram on the left shows the dynamic interplay between individual/team traits and states and the environment and how our understanding of those relationships informs innovative solutions/interventions that leads to optimizing health and enhancing human performance (which ultimately maximizes human potential of Soldiers, leaders and senior leaders). The circle arrows articulate the continuous back and forth between stressor/traits/states and solutions.

Once we established the framework and defined terms within each category (i.e., stressors, domains, and solutions; Table 1), we took a “bottom-up” approach to gathering data. The primary data included

in this analysis were aggregated from organizational representatives of each of the LOE1 member organizations (i.e., organizations with S&T investments in the LOE1 space). Collected data provided an overview of each candidate effort (title and brief description), along with the lead performing organization and collaborating organization(s) and efforts were organized to facilitate further identification, sorting, and analysis of efforts across multiple categories. The categories and brief definitions are included in Table 1.

Table 1. Categories and Definitions

Category	Definition
Title and description	Title of the effort and brief description to provide enough granularity to distinguish efforts from one another.
Lead performing organization	Army organization that leads the effort.
Collaborating organizations	Collaborating organizations that participate in the design, execution, analyses, and reporting of the effort.
External stressors/threats ¹	Examples of external stressors and/or threats that impact the health and performance of Warfighters during the competition-conflict continuum.
LOE1 domains (states and traits) ²	Cross-cutting, state-of-the-science domains pertaining to the LOE1 objective. In order to achieve the desired state of dominance in human performance, we must recognize that human performance is influenced by multifaceted, interrelated cognitive, physical, and emotional factors. We must optimize/enhance these domains (representing multi-dimensional states) while considering the individual's inherent traits/characteristics in order to maximize performance to dominate in the FOE 2035+.
Solutions	Innovative, multidisciplinary, cross-cutting solutions that may be applied to the domains to optimize and enhance human performance.

¹These are fluid and may be revised during the MHP concept development process.

²Traits and states are multi-dimensional, i.e., they interact with one another holistically and they are influenced by an individual's historical status (e.g., each individual has their own baseline that shapes their capacity)

Note: Funding data were not included in the data collection process, because this additional information was not of primary importance to the main goals of this exercise. Further, many efforts are a consolidation of multiple research studies with different budget activity levels (6.1-6.3 and advanced development work, where noted) and associated funding. Detailed funding information (by strategic plan, end-state goal, and/or functional objective level) may be garnered from LOE1 member organizations (e.g., the MRDC Principal Assistant of Research and Technology office and DEVCOM labs).

Data Analysis

Assumptions and Limitations

The primary data upon which the analyses were conducted here are limited to efforts obtained from organizational representatives of each of the LOE1 member organizations (i.e., MHP governance

Advisory Board members with S&T investments in the LOE1 space). Information gathered is generally at the functional objective (FO) level, and in some cases technical objective (TO) level (i.e., if more specificity was required to differentiate from other efforts). Adapted from definitions within MRDC strategic plans, a functional objective is a statement that describes materiel or knowledge solutions (end products) that address a general operational capability and operational impact, and a technical objective is a statement that describes one of the technical solutions (a specific item) required to address the functional objective. These FO and TO-level data typically reflect multiple S&T sub-efforts, with a number of sub-efforts and funding levels spanning a wide range. It is assumed, however, that the number of efforts, in combination with the data derived in the executed analyses with respect to MHP LOE 1 objectives, provide an appropriate level of description to meet the goals of the “see ourselves” exercise.

Finally, as approved by AFC Commanding General, GEN John M. Murray, the adjustment in the timeline for the publication of the MHP CFA at the end of 1Q FY23 to synchronize with publication of the next AOC to the end of 4Q FY22/1Q FY23, means that as of the writing of this interim report, MHP-related Required Capabilities have not yet been defined. As such, for the current IE&E IOC, identification of gaps and opportunities based on the analyses conducted herein are generally limited to the current distribution of investments across the LOE1 member organizations. The publication of the MHP CFA will enable more specific identification of gaps and opportunities within the Army S&T space, in the context of required capabilities in the FOE2035+ and this IE&E IOC is intended to provide a baseline for data-informed decisions in these future analysis and Army S&T planning efforts.

MHP Thrust Mapping

Following the initial data call to each LOE1 member organization representative(s), each candidate effort was reviewed and confirmed for its relevance to LOE 1 objectives. A final set of derived data categories were identified to describe each project’s relevance to the development of future Army solutions to optimize health and enhance human performance. These categories were synthesized during multiple discussions amongst LOE1 member representatives and each LOE1 member organization representative(s) confirmed the thrust mapping of each effort with their respective point of contacts (POCs).

Each effort was mapped according to the following main categories: 1) stressor that the effort is addressing; 2) cross-cutting, state-of-the-science domain; and, 3) solution(s) that the effort is using to address the problem. In addition, brief descriptions of each effort were also captured. Table 2 contains detailed descriptions of cross-cutting, state-of-the-science domains; i.e., capabilities that we must target to maximize human performance in 2035+. Each effort seeks to manipulate at least one, and sometimes more than one, domain, with the end goal to optimize and enhance operational performance for overmatch.

Table 2. Descriptions of cross-cutting, state-of-the-science domains

Domain	Definition In order to maximize human performance in the FOE 2035+, we must:
Cognitive & Neurobehavioral	Maximize cognitive capabilities and executive functions; maximize cognitive readiness; identify and exploit mechanistic and applied solutions to sustain combat effectiveness under stress, or after injury, disease, occupational, or hazard exposure.
Socio-emotional	Maximize psychological resilience, emotional and behavioral capabilities, mental readiness, and the ability to work as a social network or team.
Physiological	Maximize the body’s functional systems (e.g. cardiorespiratory, nervous, and musculoskeletal systems) and develop solutions to sustain combat effectiveness after injury, disease, or hazard exposure.
Biomechanical	Maximize the interface between biological function and mechanical demands, both intrinsically (e.g. gait and lifting mechanics) and extrinsically (e.g. man-technology interface).

Table 3 contains the solutions (e.g., interventions, modality, strategies, etc...that the effort is using to address the problem). Note, these solutions are those currently used by LOE1 member organizations and may be expanded as new approaches emerge. These solutions all operate in the context of internal and external stressors and threats.

Table 3. Descriptions of solutions

Category	Definition
Nutrition	A nutrition-based intervention (e.g., macro- or micro-nutrient manipulation, feeding strategy, education, etc...) to optimize or enhance some aspect of health and/or performance.
Assessment ¹ & Training Tools	Skill-based training, assessments, training aids or methods to identify emerging health threats. Solutions in this category seek to optimize or enhance some aspect of health and/or performance.
Pharmacological	A pharmacological-based intervention to optimize or enhance some aspect of health and/or performance.
Microbiome manipulation	An intervention to manipulate some aspect of the human microbiome (e.g., skin, gastrointestinal tract, oral cavity, lung) to optimize or enhance some aspect of health and/or performance.
Ergonomic aids	Any engineered enhancement that makes human beings more comfortable, healthy or productive while

	performing tasks in which people and technology interact).
Neuromodulation	Application of technology to alter neural activity to optimize or enhance some aspect of health and/or performance.
Leadership/ Team Development	Strategies centered on leaders/teams
Other enabling technologies & biomeasures	Other enabling technologies and biomeasures not included in other categories; e.g., exoskeleton, sensor technologies and status monitoring, data science (e.g., modeling), predictive biomarkers, augmented reality/virtual reality, and physiologically aware virtual systems.

¹Assessments. Solutions in this category gather and integrate data to evaluate a person’s (or small group’s) behaviors, abilities, and other characteristics. The purpose of assessments is to diagnosis status and make a recommendation based on that status. These assessments cover a broad range of psychological constructs, for example, cognitive workload and situational awareness. These assessments are gathered through a variety of measures and means, for example, interviews, observations, tests, self-report, or digital apps. Assessments that include status monitoring are not included in this solution set.

The taxonomy and detailed coding scheme (i.e., to include main and sub-categories) of cross-cutting, state-of-the-science domains and innovative, multidisciplinary, cross-cutting solutions are detailed in Appendix 1.

Descriptive Statistics

Quantitative descriptions of Army LOE1-relevant S&T efforts gathered via this exercise were computed across many primary and derived data categories defined above. The data was first reviewed to highlight existing collaborations across Army orgs and across other services, academia, and industry. Data were then sorted and aggregated in various ways to synthesize conclusions. For example, data was sorted by scientific domain to gain situational awareness of organizations working in each specific topic area (e.g., to identify unique focus areas of LOE1 member organizations and/or areas where we can better synchronize). Data was also sorted by stressor to highlight which organizations are doing work to optimize health and/or enhance performance when Soldiers/teams are exposed to challenging environmental conditions or noise, blunt force, blast exposure, chemical insults, biological weapons, etc...; e.g., to identify the different ways that LOE1 organizations are optimizing health and/or enhancing performance when Soldiers/teams are exposed to challenging environmental conditions. Additionally, data was sorted by “solutions,” to identify unique capabilities of each organization and opportunities for synchronization. Together, the results provide an overview of current S&T efforts within the initial operational capability of LOE1, with a focus on broad program and modernization equities and LOE 1-focused issues.

Results

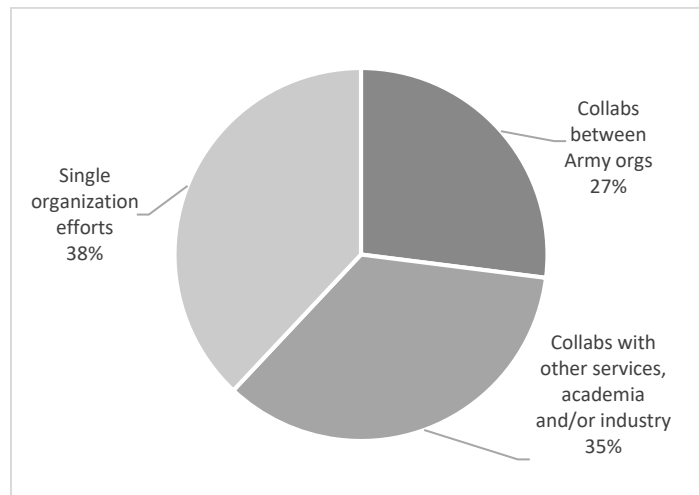
The gathered data resulted in 88 identified efforts from LOE1 organizations. Results are presented according to various sorting strategies; e.g., existing collaborations, scientific domains, external stressors and solutions to optimize health and enhance human performance.

Existing collaborations

MHP LOE1 member organizations collaborate with numerous intramural laboratories, DoD and government agencies, industry and academic institutions (Figure 2). In the context of this report, collaborations are operationally defined as efforts where two or more S&T orgs are working together on at least two of the following: study design, data collection, data analyses or report writing. In instances when an organization is collecting data with military personnel, the unit is not considered a collaborator unless another criterion is met (i.e., unit is contributing to study design, data analyses, or report writing). The 27% of collaborative efforts between Army organizations include various intramural collaborations within MRDC, cross-collaborations between MRDC and DEVCOM-SC, and MRDC and West Point. The 34% of collaborative efforts between Army S&T organizations and other services, academia, and industry include two notable academic collaborations:

- DEVCOM-SC’s alliance with Tufts University. Soldier Center manages a cooperative research center, Center for Applied Brain and Cognitive Sciences (CABCS), along with individuals from Tufts University spanning diverse scientific and technical domains. Some of the Measuring and Advancing Soldier Tactical Readiness and Effectiveness (MASTR-E) work, for example, is in collaboration with the CABCS. Founded in 2015, CABCS provides an innovative environment for conducting collaborative applied research focusing on measuring, predicting, and enhancing cognitive capabilities and human system interactions for individuals and teams working in naturalistic, high-stakes environments.
- MRDC’s USARIEM (Military Nutrition Division, MND) has a unique collaborative partnership with the Pennington Biomedical Research Center (PBRC, located at Louisiana State University campus) for the past 32 years. More recently, MND and PBRC have expanded the scope of their partnership by collaborating on the development and conduct of clinical research trials that leverage the subject matter expertise of MND and PBRC scientists and the world-class facilities at the PBRC. This alliance between USARIEM and PBRC results in significant improvements in operational rations, understanding of Warfighter energy and nutritional requirements, modifications in garrison feeding, and the identification of safe and effective biomedical material solutions to optimize and enhance Warfighter health and performance.

Figure 2. Collaborations

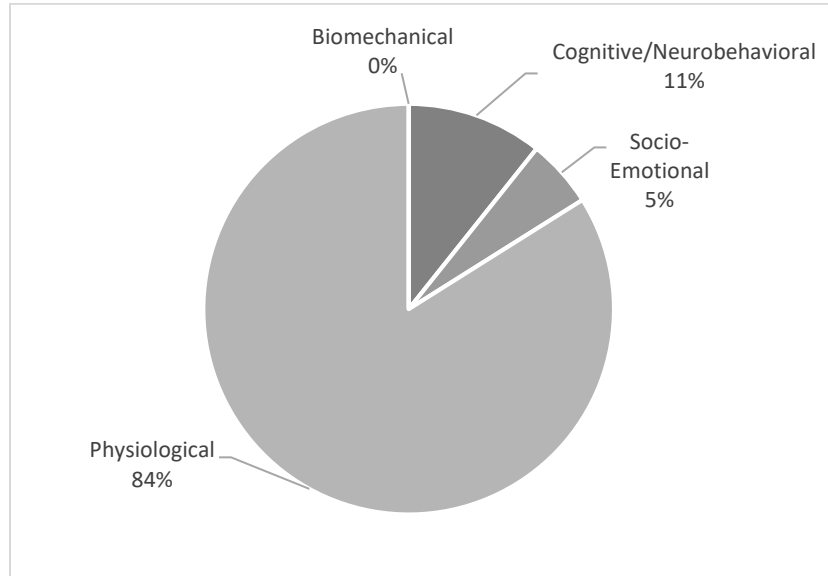


Scientific Domains

Scientific Domains: Overview

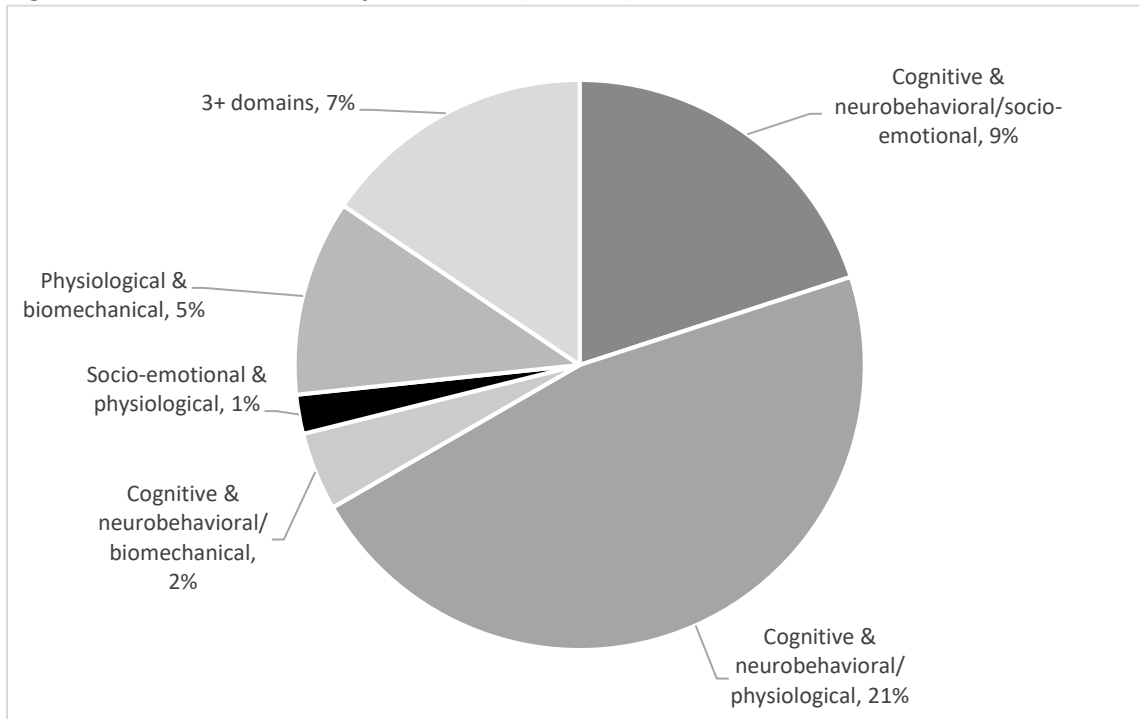
Approximately 56% (49/88) of efforts (Figure 3) are focusing on multiple aspects within one particular scientific domain; i.e., optimizing or enhancing cognitive/neuro (WRAIR; USARIEM; DEVCOM-SC), socio-emotional (WRAIR), or physiological aspects of performance (WRAIR; USARIEM; USAARL; USAMMDA; DEVCOM-SC).

Figure 3. LOE1 Efforts – Single Domain (49 of 88)



Approximately 38% (33/88) of the efforts (Figure 4) are addressing a combination of two scientific domains, i.e., optimizing or enhancing cognitive/neuro & socio-emotional (WRAIR; DEVCOM-SC; USARIEM), cognitive/neuro & physiological (WRAIR; USARIEM; USAARL; USAMMDA; DEVCOM-SC), cognitive/neuro & biomechanical (DEVCOM-SC), socio-emotional & physiological (DEVCOM-SC/MRDC) or physiological & biomechanical (DEVCOM-SC; USARIEM). Six efforts are targeting three or more domain categories, i.e., cognitive/neuro, socio-emotional & physiological (three efforts, USAARL/USAMMDA/USARIEM) or cognitive/neuro, socio-emotional, physiological & biomechanical (three efforts, DEVCOM-SC).

Figure 4. LOE1 Efforts – Multiple Domains (39 of 88)



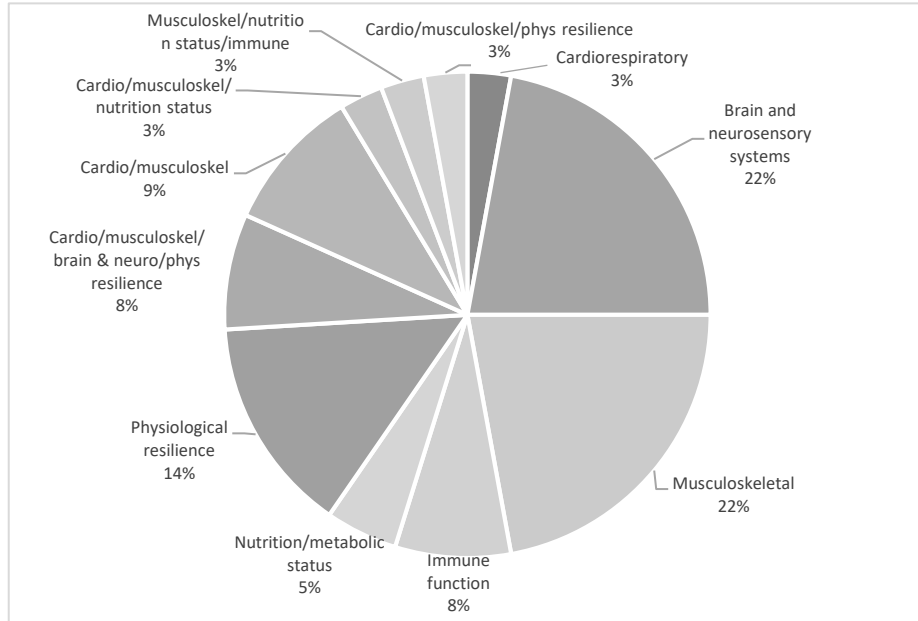
Scientific Domains: efforts targeting single domain with sub-category analyses

Of the 48 efforts that are focusing on one particular domain:

- Five efforts are seeking to optimize or enhance cognitive/neuro state (DEVCOM-SC; WRAIR; USARIEM) and all are addressing multiple aspects of cognitive capabilities (e.g., executive functions, attention/situation awareness, learning and memory, decision-making, divergent thinking and cognitive flexibility) and none appear to be duplicative with one another.
- Three efforts are seeking to optimize the socio-emotional state (WRAIR), addressing small-team culture and connection; morally-related decisions/challenges; and, health practice guidelines for medic use at point of care.
- Forty efforts (Figure 5) are optimizing or enhancing the physiological state. Of these, 30 efforts are focusing on optimizing or enhancing one aspect of physiological health and performance: cardiorespiratory health and fitness (i.e., pharmacological enhancement of aerobic performance) (USARIEM); brain and neurosensory systems broadly (WRAIR; USAARL; USAMMDA), and advanced development efforts addressing PTSD and TBI (USAMMDA); musculoskeletal health and performance (USARIEM and USAMMDA), with one effort in advanced development (USAMMDA) and others targeting pharmacological interventions, nutritional interventions and prediction metrics, assessment metrics, solutions and countermeasures related to musculoskeletal injuries and return to duty; infectious disease risk prevention/mitigation (USARIEM; USAMMDA); optimizing nutrition/metabolic status (DEVCOM-SC/USARIEM collaboration; USARIEM); and, optimizing physiological resilience (USARIEM). Ten efforts address various aspects of physiological state (USARIEM, USAMMDA, DEVCOM-SC). In particular, four of these efforts are in advanced development (USAMMDA), i.e., three efforts are decision aids related to heat strain, cold weather exposure and exposure to other

environmental conditions (air, water, soil-borne hazards) and one effort is a smart phone application to optimize nutrition status, cardiorespiratory health and fitness and musculoskeletal health and performance.

Figure 5: Efforts targeting physiological domain



Scientific Domains: efforts targeting multiple domains with sub-category analyses

Of the 88 total efforts, 40 are addressing more than one domain:

- Eight efforts are optimizing and/or enhancing cognitive/neuro & socio-emotional (WRAIR; DEVCOM-SC; USARIEM). Five efforts address cognitive capabilities in general and either psychological resilience, emotional/behavioral capability or resilience and/or interpersonal relationship/team dynamics. Three efforts specifically address executive function and/or decision-making along with psychological resilience and emotional/behavioral resilience.
- Nineteen efforts are optimizing and/or enhancing cognitive/neuro & physiological (WRAIR; USARIEM; USAARL; USAMMDA; DEVCOM-SC). Ten efforts address cognitive capabilities in general and the brain/neurosensory system (along with immune function in one case). Seven efforts address cog capabilities in general and cardiorespiratory health/fitness and/or musculoskeletal health/performance; and, two efforts specifically address executive function and learning & memory and brain/neurosensory systems.
- Two efforts are optimizing and/or enhancing cognitive/neuro & biomechanical (DEVCOM-SC) and these include design guidance to head-borne design (LOE1/LOE2 cross-synchronization).

- One effort is optimizing and/or enhancing physiological & socio-emotional (DEVCOM-SC/MRDC), specifically optimizing the human weapon system (CCDC-SC/MRDC) wherein socio-emotional focus is secondary.
- Four efforts are optimizing and/or enhancing physiological & biomechanical (DEVCOM-SC; USARIEM). Sub-categories include musculoskeletal health and performance & multiple aspects of biomechanics.
- Six efforts are addressing three or more states and working to predict health status and/or addressing Soldier tasks as outcome. Three of these efforts are focusing on optimizing and/or enhancing cognitive/neurological, socio-emotional states and physiological states, e.g., strategies to maintain aircrew performance under stressful operational conditions; providing input to scalable autonomy system design (USAARL); and, the advanced development (USAMMDA) Health Readiness and Performance System (HRAPS) program. The latter includes continual real-time physiological status monitoring hardware testing and associated software development efforts for forward predicting service members with impending environmental injury (data generated from USARIEM).
- Three efforts are focusing on all four state categories (sub-efforts of the MASTRE program), to include individual level assessment of marksmanship lethality output and Soldier ability to self-regulate, decide, and eliminate threats under tactical stress; identify, develop, and evaluate multiple modeling frameworks refined through an iterative design cycle to deliver robust models with high predictive accuracy for close combat task performance; and, squad and platoon level predictive models and accompanying tools/techniques (metrics and methodologies) that quantify squad performance and performance decrements through accurate and continuous sensing and instrumentation of dismounted Soldier operational performance.

External Stressors: Environmental Conditions

Of the 88 efforts, there are ~20 research areas across LOE1 orgs that are seeking to optimize health and/or enhance performance when Soldiers/teams are exposed to challenging environmental conditions.

- Four efforts in advanced development (USAMMDA; S&T foundational work USARIEM)
- Additional S&T efforts, not yet in the advanced development stage, are at various budget activities (mainly 6.2)
 - Multiple research efforts seeking to deliver capabilities related to performance in a variety of environmental conditions (i.e., these efforts will transition to USAMMDA for advanced development) (USARIEM)
 - Characterizing High Altitude Exposure Impact on the Human Gut Microbiome, Emotion and Cognition (USARIEM/DEVCOM-SC collaboration)
 - "Deployed Medicine" to improve the training effectiveness of deployed medical simulation based training (usable in austere environmental conditions) (DEVCOM-SC)

- Toolkit of strategies to maintain aircrew performance under stressful operational conditions (e.g., air, water, soil-borne hazards, and altitude) (USAARL).
- Modernized RTD guidelines to ensure medical readiness for operations in extreme environments (novel biomarkers of acclimatization status & decay to optimize & sustain performance at environmental extremes) (WRAIR). This effort involves substantial crosstalk b/w WRAIR and USARIEM.

There are 11 research areas across LOE1 orgs that are specifically seeking to optimize health and/or enhancing performance when Soldiers/teams are exposed to noise/blunt/blast, chemical insults, biological weapons*, etc...

- Five efforts in advanced development (USAMMDA; foundational work WRAIR, USAARL, ONR)
- Additional S&T efforts, not yet in the advanced development stage, are at various PEs:
 - Design guidelines for algorithms connecting blast to cognitive decline; development of injury risk assessment/guidance/criteria to inform/support wearable sensing technologies and mitigation strategies against current and emerging threats (e.g., blast, blunt, ballistic, and accelerative); blast exposure monitoring system (BEMO); development of injury risk assessment/guidance/criteria to inform/support next generation whole body PPE; individual health hazard assessment strategies to protect against current and emerging threats from blast-initiated exposures (WRAIR).
 - Future Vertical Lift mission equipment that accommodates range of expected human ability and performance; and, human performance risk assessment/criteria to inform medical standards of aircrew operating FVL (noise and blunt force exposure) (USAARL)
 - Evaluation of heavy metal exposure in bone (USARIEM)
 - Improving the training effectiveness of deployed medical simulation based training (DEVCOM-SC)

There is only one near-term (up to 2028) effort investigating the effects of chemical insults and no near-term efforts in directed energy and other insults relevant to FOE. This analyses does not include efforts within the CBRNE portfolio.

Solutions: development and application

The analyses also considered innovative solutions that LOE1 organizations are using to solve problems.

The following solutions were identified during the exercise:

1. Nutrition interventions (DEVCOM-SC; USARIEM; WRAIR; USAARL). USARIEM leads efforts in nutrition interventions. Focus areas include enhancing muscle mass, function, and physical performance during strenuous operations; promoting of immune recovery from operationally-relevant stress; optimizing and enhancing aerobic exercise performance; mitigating the effects of underfeeding, facilitate muscle recovery, and promote whole-body protein homeostasis during strenuous operations in austere environments; and, optimizing energy substrate metabolism, accelerate muscle glycogen recovery, and enhance cognitive and physical performance during strenuous

operations conducted in extreme environments. There is a long-standing collaboration between USARIEM's MND and DEVCOM-SC Combat Feeding Division, wherein MND transfers findings to DEVCOM-SC for advanced development. DEVCOM-SC is optimizing nutritional interventions (6.2, 6.3) for research studies, developing ration components and increase knowledge of muscle/immune and intestine/immune interactions; increasing knowledge of moderate fat content on physical performance, dietary perceptions, circulating metabolic status biomarkers, and GI health of warfighters (USARIEM collaboration); and, identifying the association between condensed food form and fat level on satiety (thus, positively influencing Soldier comfort and performance) (6.1 effort). USAARL and WRAIR are also planning to use nutrition interventions to enhance aircrew performance above the baseline, well-rested, state and enhance Soldier physical and mental performance, respectively.

2. Microbiome manipulation (DEVCOM-SC; USARIEM). These efforts (6.1 and 6.2) are highly synchronized and collaborative. USARIEM-led efforts focus on the influence of the microbiome on immune outcomes during operationally-relevant stress; evidence-based recommendations for pre/pro-biotic supplementation on cognitive and physical performance during stress; targeted microbiome manipulation to enhance muscle mass, function, and physical performance during strenuous operations; and, pre/probiotic formulations to optimize and enhance cognitive and physical performance during strenuous operations conducted in extreme environments (e.g., high altitude). DEVCOM-SC-led include the MASTRE program's "Enhanced Gut", which includes existing work with USARIEM and planned collaborative intervention studies in FY23 and FY24 to mitigate decrements in muscle recovery, cognition, and GI distress. Additional opportunities for synchronization exist, wherein other organizations may exploit microbiome manipulation to address problems that they are addressing.
3. Neuromodulation (WRAIR, USARIEM, USAARL, DEVCOM-SC). Electrical stimulation is largely being used, but USAARL is also using magnetic stimulation. Efforts are targeting diverse objectives/outcomes and some of the methods are different (e.g., targeting different nerves). LOE1 organizations may consider future synchronization opportunities. While not an Army organization, it should be noted that Air Force Research Lab (AFRL) is a leader in this area and consultations and collaborations with AFRL exist.
4. Solutions specifically related to leadership/team development (WRAIR). This area is of importance given MHP's goal of maximizing human potential of not only individuals, but leaders, senior leaders and teams.
5. Exoskeleton (DEVCOM-SC and USARIEM). DEVCOM-SC is developing highly effective and adaptive physical augmentation systems that significantly increase Soldier performance in operational environments; and, USARIEM is developing evidence-based guidance regarding potential MSKI risk assessment associated with exoskeleton/human augmentation. These are complementary efforts and biomechanists from both teams are synchronizing with one another.
6. Predictive/novel biomarkers (USARIEM, WRAIR, DEVCOM-CBC). There are two advanced development efforts in this area and future opportunities for synchronization were discussed, e.g., capabilities to perform complex biomarker analyses.

There are existing collaborations across the Army organizations in a number of these areas; however, further analyzing the data to consider the development and application of solutions may identify opportunities for synchronization. For example, perhaps an organization may have a unique solution capability that another organization may find useful to address their research question(s).

Discussion

This report describes initial analyses based on the Initial Operational Capability (IOC) of the Maximizing Human Potential (MHP) Line of Effort 1 (LOE 1), Optimizing Health and Enhancing Human Performance Inventory of Efforts & Evaluation (IE&E). The IE&E is a data resource that documents ongoing and planned Army S&T efforts addressing LOE 1 objectives or aspects, thereof.

The IE&E IOC identifies current and planned S&T efforts across the Army Modernization Enterprise that are addressing, directly or indirectly, MHP LOE1 objectives. The following presents preliminary observations based on the analysis of the data in the IE&E, which has been gathered by SMEs as part of the “coalition of the willing” participating in the LOE 1 S&T community. The data and analyses presented are intended to provide information for assessing the current S&T efforts with respect to LOE1 objectives, as well as serving as a foundation for the identification of future S&T gaps and opportunities within the framework of required capabilities that will be defined in the forthcoming MHP Cross Functional Annex in the next AOC.

Gaps and Opportunities

One of the primary purposes of the IE&E data resource is to provide information for organizations and Army Senior Leaders upon which to ground efforts to prioritize far-, mid-, and near-term S&T investments to meet Army strategic objectives. The analyses presented in the current report based on the data contained in the IE&E IOC show current MHP LOE1-focused Army investments are varied across multiple organizations and research areas, with heavy emphasis on efforts in the physiological domain (either solely or in combination with other domains). Additionally, the LOE1 community is simultaneously identifying gaps and opportunities through “bottom-up” efforts during the concept development process; and, will reassess gaps and opportunities upon publication of the MHP cross-functional annex, given the need for continuing advancement of the science and synchronization across S&T communities. Two broad S&T areas that LOE1 should focus on include, from the IE&E IOC and discussions among the LOE1 community:

1) Further development and validation with regard to accurately assessing, quantifying, and predicting operational performance for individuals and teams to inform actionable decisions.

This involves development of validated metrics of operational performance both at the Soldier and Small Unit level. These will allow for testing the efficacy of human performance solutions/interventions.

Additionally, this objective includes the development of novel approaches and analytic techniques (e.g., machine learning and artificial intelligence) to better understand the relationship between human health, traits, states and performance outcomes.

Example gaps in current S&T understanding under this broad S&T objective:

- What are the validated metrics of operational performance?

- What biotech tools can we use to assess health and performance risk (e.g., functional fabrics, acoustic sensors, digital twin real-time modeling)?
- How can we use novel approaches and analytical techniques to identify relationships between human health, physiology/neurobiology, attributes, states and performance outcomes?
- What are the emerging relationships between human health, physiology/neurophysiology, attributes, states and performance outcomes?

2) Preventing and mitigating (or reversing) health and performance decrements, and enhancing multiple aspects of performance, in order to maximize and sustain lethality of the Force. We'll do this with validated and targeted scientific solutions.

This focus area includes optimizing health and optimizing or enhancing human performance which requires us to directly apply established, emerging, and pioneering scientific solutions to the Soldier, leader and/or team. These solutions integrate across multiple scientific domains and identifying and implementing these solutions will require multidisciplinary, collaborative efforts between military, academic, and private sector scientists.

Example gaps in current S&T understanding under this broad S&T objective:

- How can we enhance injury and disease resistance to novel biophysical threats and unanticipated exposures??
- How can we enhance mental endurance in the face of intense, rapidly changing, fatiguing conditions?
- How can we create hyper-mindful Soldiers who can self-regulate and persevere under extreme stress?
- What training approaches can we use to optimize and enhance cognitive and physical capabilities?
- What innovative approaches (e.g., neuromodulation, pharmacology, nutrition, etc...) are effective and safe for enhancing cognitive and physical capabilities?
- What innovative approaches (cross-adaptation) are effective for optimizing and enhancing performance in operational extremes (e.g., Arctic, urban)?
- How can we expand and enhance unique capabilities of the modern, digital-generation Soldier?

Cross-LOE coordination in addressing these gaps and opportunities will provide critical opportunities to leverage LOE-specific S&T investments to jointly address Required Capabilities defined in the forthcoming MHP Cross Functional Annex.

Examples of synchronization opportunities between LOE1 and LOE3 (Optimizing Talent Management): near-term LOE1 efforts are identifying the key metrics that need to be measured to quantify and predict individual and unit readiness (performance optimization), performance in the context of Soldier tasks, and resilience (physiological, psychological and cognitive). Each of these key areas synchronize with the Talent management pillars. For example, LOE1 efforts to measure and predict readiness and performance synchronizes with Talent Management efforts, wherein fitness evaluation and assessment

is part of the framework and, the solutions of these LOE1-related efforts (e.g., technologies, algorithms and decision aids) can specifically inform the development of methods and tools to enable the Army to employ the right individual in the right job and right team, at the right time to maximize the effectiveness of each Soldier and team (LOE3). These findings may also inform the development of training, education and other approaches to help ensure that every soldier and leader can reach their full potential. Additionally, LOE1's work in predicting resilience (physiological, psychological and cognitive), produces models and metrics that may be used by leadership and medical professionals to identify factors (biological, physiological, demographic, genomic, psychological) that can be manipulated through nutritional, training, or other interventions to improve training outcomes and reduce injuries. These products, again, inform the development of training, education and other approaches to develop the force as well as retaining talent. Also related is enhancing training efficiency, wherein LOE1 efforts underpin the science basis of learning (i.e., learning and performance from a neuroscience perspective) and developing related training tools to optimize learning, which aligns with talent management's integrative system to train and organize military personnel.

Examples of synchronization opportunities between LOE1 and LOE2 (Optimizing Human-System Performance): LOE1 provides the science basis for human-system integration efforts (e.g., providing design guidance to headborne system developers and delivering scientifically-grounded recommendations and knowledge products for human-centered augmented reality information display and innovative tools and applications). Physical Augmentation is another synchronization area between LOE1 and LOE2, wherein LOE1 efforts feed into technology for human interactions and physical augmentation (PA), i.e., highly effective and adaptive PA systems that significantly increase Soldier performance and understanding adaptation to systems and movement intent for advanced controls. Additionally, leveraging sensors and non-human systems, where current efforts are embedding sensor technology into mission planning and execution software (future possibility: think google maps inserted into heads-up display to identify "best route"). Lastly, future vertical lift program is adding human monitoring capabilities to next generation aircraft (to include health monitoring)¹, which optimizes human-system effectiveness (e.g., real-time info sent to onboard autonomy system for decision making to optimize status).

Next Actions and Path Forward

This interim report is based on the initial operational capability (IOC) of the MHP LOE 1 IE&E, which focuses on MRDC and DEVCOM identified efforts, data for which was gathered from organizational representatives during FY21 (Q1/2), reflecting FY22 planning. MRDC and DEVCOM identified efforts comprise ~82% (72/88) and 18% (16/88), respectively of all LOE 1-related efforts (not taking into account budget contributions) identified from the exercise, and the IE&E IOC includes all verified and validated primary and derived data for these efforts. This exercise will be updated to reflect FY23 efforts and eventually will be cross-referenced with the required capabilities to further define the gaps and opportunities to better align Army S&T investments to MHP LOE1's primary objective optimize health and enhance human performance for the FOE 2035+.

Appendix 1

The overarching LOE1 taxonomy of **stressors**, cross-cutting, state-of-the-science **domains**, and innovative and multidisciplinary **solutions** are shown in Figure 1. The ninety efforts from each LOE1 organization were categorized and sorted by applicable domain(s), to include high-level categories (Table 1) and sub-categories (Table 2); and, by applicable solution(s) (Table 3) that are applied to the domain(s) to optimize health and enhance performance.

Figure 1. LOE1 Taxonomy (main categories and sub-categories)

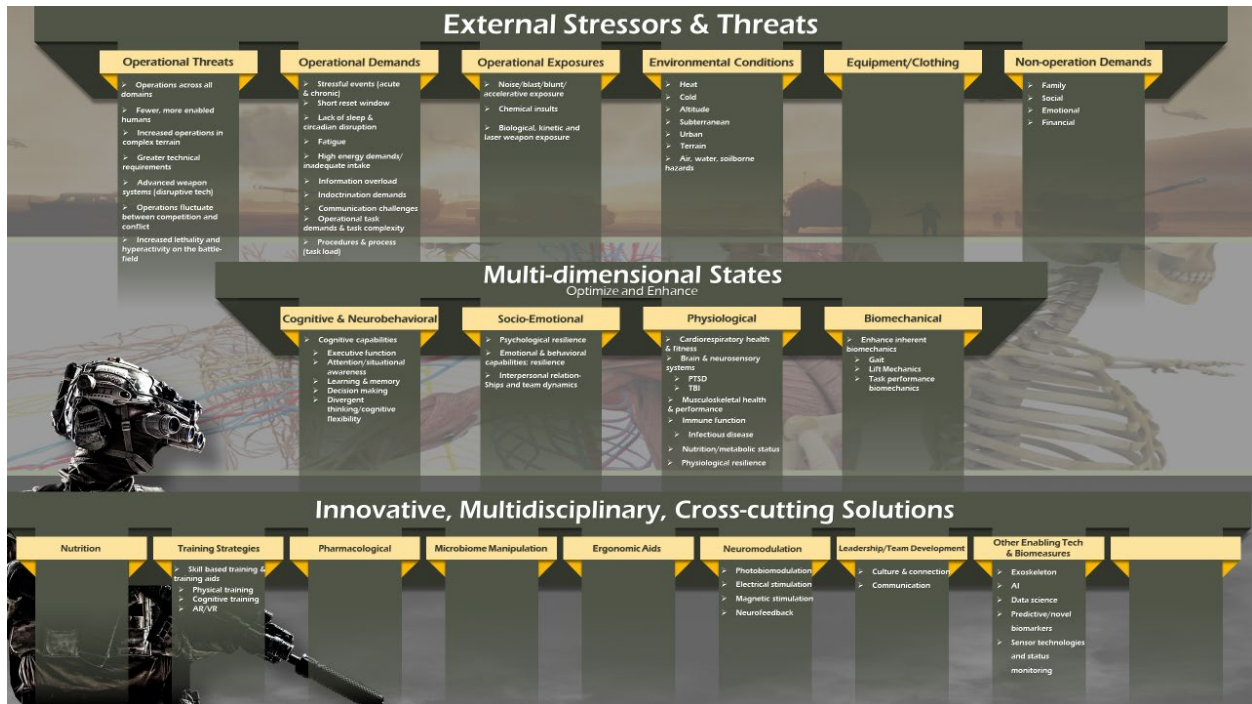


Table 1. LOE1 cross-cutting state-of-the-science domains: taxonomy and coding of main categories for sorting data

LOE1 cross-cutting, state-of-the-science domains We must optimize/enhance multi-dimensional states, while considering the individual's inherent traits/characteristics) to maximize performance to dominate in MDO					
	[Optimize and enhance] Cognitive & Neurobehavioral [states]	[Optimize and enhance] Socio-emotional [states]	[Optimize and enhance] Physiological [states]	[Optimize and enhance] Biomechanical [states]	If the effort addresses more than two states:
[Optimize and enhance] Cognitive & Neurobehavioral [states] = 1	1 = Cog/neuro	5 = Cog/neuro + socio-emotional	8 = Cog/neuro + physiological	10 = Cog/neuro + biomechanical	11 = Cog/Neuro + socio-emotional + physiological
[Optimize and enhance] Socio-emotional [states] =2		2 = Socio-emotional	6 = Socio-emotional + physiological	9 = Socio-emotional + biomechanical	12 = Cog/Neuro + socio-emotional + physiological + biomechanical
[Optimize and enhance] Physiological [states] = 3			3 = Physiological	7 = Physiological + biomechanical	13 = Cog/Neuro + physiological + biomechanical
[Optimize and enhance] Biomechanical [states] = 4				4 = Biomechanical	

Table 2. LOE1 cross-cutting state-of-the-science domains: taxonomy and coding of subcategories for sorting data

LOE1 cross-cutting, state-of-the-science domains We must optimize/enhance multi-dimensional states, while considering the individual's inherent traits/characteristics) to maximize performance to dominate in MDO				
Main Category	1 = Cog/neuro	2 = Socio-emotional	3 = Physiological	4 = Biomechanical
Secondary level of detail (superscript after main identifier) & tertiary level of detail (superscript decimal)	Cognitive capabilities = 1¹ -executive function = 1 ^{1.2} -attention/situation awareness = 1 ^{1.3} -learning & memory = 1 ^{1.4} -decision making = 1 ^{1.5} -divergent thinking and cognitive flexibility = 1 ^{1.6}	Psychological resilience = 2¹	Cardiorespiratory health & fitness = 3¹	Enhance inherent biomechanics = 4¹ -Gait = 4 ^{1.1} -Lift mechanics = 4 ^{1.2} -Task performance biomechanics = 4 ^{1.3}
		Emotional & behavioral capabilities/resilience = 2²	Brain and neurosensory systems = 3² -PTSD = 3 ^{2.1} -TBI = 3 ^{2.2}	
		Interpersonal relationships and team dynamics = 2³	Musculoskeletal health & performance = 3³	
			Nutrition/metabolic status = 3⁵	
			Physiological resilience = 3⁶	

Table 3. LOE1 cross-cutting solutions to optimize and health and enhance performance: taxonomy and coding of main categories and subcategories for sorting data

Innovative, multidisciplinary, cross-cutting solutions These may be applied to the domain(s) to optimize health and enhance performance								
Main Category	Nutrition = A	Assessment ¹ & Training Tools = B	Pharmacological = C	Microbiome manipulation = D	Ergonomic Aids = E	Neuromodulation = F	Leadership/ Team Development = G	Other enabling technologies & biomesasures = H
Second Level Detail (superscript after main identifier)	N/A	Skill-based training (physical, behavioral or cognitive) = B ¹	N/A	N/A		Photobiomodulation = F ¹	Culture & Connection = G ¹	Exoskeleton = H ¹
		Assessment (physical, behavioral, cognitive) = B ²				Electrical stimulation = F ²	Communication = G ²	AI = H ²
		Training Aids = B ³				Magnetic stimulation = F ³		Sensor technologies & status monitoring = H ³
		Identification of emerging health threats = B ⁴				Neurofeedback = F ⁴		Data Science (modeling) = H ⁴
								Predictive / novel biomarkers = H ⁵
								AR/VR = H ⁶
								Physiologically aware virtual systems = H ⁷

¹Assessments. Solutions in this category gather and integrate data that evaluate a person's (or small group's) behavior, abilities, and other characteristics. The purpose of assessments is to diagnosis status and make a recommendation based on that status. These assessments cover a broad range of psychological constructs for example, cognitive workload and situational awareness. These assessments are gathered through a variety of measures and means for example, interviews, observations, tests, self-report, digital apps. Assessments that include status monitoring would not be in this solution set.

Appendix 2

Figure 1: S&T Gaps and Opportunities

