ERDC BASIC RESEARCH

STRATEGIC RESEARCH AREAS

FOR

PE: 601102A

PROJECT: AB2

Adaptive Protection, Maneuver, Geospatial, and Natural Sciences Research

FY2023

Definitions of Research and Development

Basic research is a process that seeks to discover certainty in an uncertain world. This is achieved through the integrated application of experimental methods, theories and models of phenomena and instrumentation to make precise measurements of fundamental phenomena. An important outcome of basic research is the ability to reliably predict natural phenomena.

Government-Wide

OMB Circular No. A-11 (1998)

Basic Research – Systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and of observable facts without specific applications toward processes or products in mind.

Applied Research – Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.

Development – Systematic application of knowledge toward the production of useful materials, devices, and systems or methods, including design, development, and improvement of prototypes and new processes to meet specific requirements.

DOD-Unique

DOD Financial Management Regulation (Volume 2B, Chapter 5)

Basic Research (6.1) – Systematic study directed toward greater knowledge or understanding of the fundamental aspects of phenomena and/or observable facts without specific applications toward processes or products in mind.

Applied Research (6.2) – Systematic study to gain knowledge or understanding necessary to determine the means by which a recognized and specific need may be met.

Advanced Technology Development (6.3) – Includes all efforts that have moved into the development and integration of hardware for field experiments and tests.

TRL Levels

Level	Definition	DoD DAG Description
1	Basic principles observed and reported	Lowest level of technology readiness. Scientific research begins to be translated into applied research and development. Examples might include paper studies of a technology's basic properties.
2	Technology concept and/or application formulated.	Invention begins. Once basic principles are observed, practical applications can be invented. Applications are speculative and there may be no proof or detailed analysis to support the assumptions. Examples are limited to analytic studies.
3	Analytical and experimental critical function and/or characteristic proof of concept.	Active research and development is initiated. This includes analytical studies and laboratory studies to physically validate analytical predictions of separate elements of the technology. Examples include components that are not yet integrated or representative.
4	Component and/or breadboard validation in laboratory environment.	Basic technological components are integrated to establish that they will work together. This is relatively "low fidelity" compared to the eventual system. Examples include integration of "ad hoc" hardware in the laboratory.
5	Component and/or breadboard validation in relevant environment.	Fidelity of breadboard technology increases significantly. The basic technological components are integrated with reasonably realistic supporting elements so it can be tested in a simulated environment.
6	System/subsystem model or prototype demonstration in a relevant environment.	Representative model or prototype system, which is well beyond that of TRL 5, is tested in a relevant environment. Represents a major step up in a technology's demonstrated readiness.
7	System prototype demonstration in an operational environment.	Prototype near, or at, planned operational system. Represents a major step up from TRL 6, requiring demonstration of an actual system prototype in an operational environment such as an aircraft, vehicle, or space.
8	Actual system completed and qualified through test and demonstration.	Technology has been proven to work in its final form and under expected conditions. In almost all cases, this TRL represents the end of true system development. Examples include developmental test and evaluation of the system in its intended weapon system to determine if it meets design specifications.
9	Actual system proven through successful mission operations.	Actual application of the technology in its final form and under mission conditions, such as those encountered in operational test and evaluation. Examples include using the system under operational mission conditions.

Foreword

The following Strategic Research Area (SRA) document gives a view of what has been identified as critical, fundamental knowledge gaps in the core competency areas of the US Army Corps of Engineers, Engineer Research and Development Center (ERDC). These core competencies include but are not limited to: Blast and Weapons Effects on Structures and Geo-materials, 3D Mapping and Characterization, Civil and Military Engineering, and Cold Regions Science and Engineering, Computational Prototyping of Military Platforms, Coastal, River, and Environmental Engineering, and Military Installations and Infrastructure with the mission of anticipating the Army's challenges by solving the impossible problems of the future mission space. By expanding our basic understanding of these core competency areas and the fundamental knowledge gaps described throughout this document, the ERDC can support future Applied Research and Advanced Technology Development in approximately 10-15 years, by which the sustainability, readiness, decision-making, and prediction capabilities of the Army can be significantly improved and support the Multi-Domain Operations Concept and Future Operational Environment.

The information outlined in this document has incorporated guidance provided by the Assistant Secretary of the Army for Acquisition Logistics and Technology (ASAALT) and Army Futures Command Directors for Basic Research, as well as rigorous review by the ERDC Senior Scientist (ST) cadre, Research Development Area Leads, Senior Scientific Technical Managers (SSTMs), and the Board of Directors. This document will be reviewed annually to anticipate future battlespace needs while maintaining relevance to existing problems through proactive flexibility, adaptation, and vision. Each year, the revised SRA document will be presented to the ERDC Deputy Director for approval, to implement in the upcoming fiscal year. Each of the SRAs included within this document is mapped to the specific direct funding TASK line that will support approved new starts for FY23 as outlined in the table below.

PE/PROJECT/TASK	TASK TITLE	STRATEGIC RESEARCH AREA BY TASK
601102A/AB2/01	Fundamental Mapping, Remote Sensing, Signature Physics and Terrain State Research	Geospatial Interactions and Processes from Heterogeneous and/or Complex Geospatial Data (Patterns in Space and Time)
		Geospatial Analysis and Intelligence
601102A/AB2/02	Fundamental Adaptive Protection and Projection Research	Environmental Interfaces of Engineering Systems
		Multi-Scale Characterization and Modeling of Materials
		Engineered Materials by Design
		Future Transformative Technologies for Military Engineering
601102A/AB2/03	Fundamental Infrastructure Science	Innovative Material Science for Infrastructure
		Computational Science and Complex Military Systems
		Resilient Installation Science
601102A/AB2/04	Fundamental Biological, Chemical, and Physical Science	Informed Threat Environment
		Biotechnology for Warfighting Functions
		Unique Biological, Chemical, and Physical Processes

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Basic Research Motivation

ERDC Basic Research is driven to solve and understand fundamental problems and phenomena underlying Army technical priorities or that may result in leap ahead technologies/capabilities with a timeline of 15 to 30 years before maturation into technology in the hand of the soldier or user. As a result of the need to accelerate research and development to overmatch capabilities of peer or near-peer adversaries, the Army has adopted 6 priority technology areas to which it is focusing its applied research funding: Long range precision fires, Next generation combat vehicle, Future vertical lift, Network/3CI, Air and missile defense, and Soldier lethality (U.S. Army Posture Statement, 2018) with additional Army Priority Research Areas: Disruptive Energetics, Radio Frequency Electronic Materials, Quantum Information Sciences, Hypersonic Flight, Artificial Intelligence, Autonomy, Synthetic Biology, Materials by Design, and Science of Additive Manufacturing. There is also interest in Cold regions due to warming environments. Within this timeline, the Army anticipates future conflicts in Multi-Domain Operational Environments, and must continue its support of the Joint Forces, as outlined in the National Defense Strategy and face challenges in Future Operational Environments. In response to the Army's aforementioned strategies, ERDC has identified seven core competencies: (1) Blast and weapons effects on structures and geo-materials, (2) 3D mapping and characterization, (3) Civil and military engineering, and (4) Cold regions science and engineering, (5) Computational prototyping of military platforms, (6) Coastal, river, and environmental engineering, (7) Military installations and infrastructure. These are generally broad capabilities and their details can be found at https://intranet.usace.army.mil/erdc/programs/pages/home.aspx. ERDC applied 6.2 and 6.3 programs have been directly re-aligned to support the Army modernization priorities, Multi-Domain Operations Concept, and ERDC core capabilities. When appropriate, basic research is expected to transition into planned ERDC 6.2 programs or result in new capabilities and new future efforts. Basic research proposals should be able to link the proposed effort as eventually supporting or leading to applied research aligned with Army priorities and ERDC core competencies to further develop the concept/technology. Key needs in fundamental research and planned future applied research efforts are described below for each Research Development Area.

Strategic Research Areas

1. **Geospatial Interactions and Processes from Heterogeneous and/or Complex Geospatial Data (Patterns in Space and Time) (PE 601102A/Project AB2/Task 01)**

This SRA supports core competencies (2) 3D mapping and characterization (3) Military engineering, and (4) Cold regions research through fundamental and novel research on understanding Earth surface attributes and processes impacting synchronization and optimization of military multi-domain operations from a geospatial perspective. Supporting a variety of topics relevant to mission command, this area seeks new knowledge on unconventional techniques to tie physical processes, particularly at fine-scale details of terrain features or time-series of properties, to signature characteristics and remote sensing, signal propagation, and unconventional methods for predicting surface and near-surface attributes difficult to directly observe.

2. **Geospatial Analysis and Intelligence (PE 601102A/Project AB2/Task 01)**

This SRA supports core competencies (2) 3D mapping and characterization, (3) Military engineering and (4) Cold regions research through fundamental research with the potential to improve Soldiers' capabilities to prepare the operational environment, calibrate force posture geographically, and to visualize, plan and make decisions more effectively in far less time than is currently required. Through the discovery of a new generation of geospatial analysis tools, this area seeks basic research investigating novel techniques for identifying emergent patterns or behaviors from complex geospatial and ancillary numerical and/or semantic data, discovering linkages and relationships among functional data, and minimizing the complexity of multi-dimensional causal networks.

3. **Environmental Interfaces of Engineering Systems (PE 601102A/Project AB2/Task 02)**

This SRA supports core competencies (3) Military engineering, (2) 3D mapping and characterization, (4) Cold regions research through the development of fundamental scientific knowledge of the environmental phenomena that impact engineering system performance. Investigations into the impacts of the environment on engineered performance to increase survivability of critical assets and protection of personnel in all operational environments and to ensure entry and maneuver across the complex battle space. This area emphasizes understanding, characterization, prediction and control of the interaction of force protection and force projection engineering systems with complex, natural, extreme, and man-made environments. Research to develop future environmentally informed predictive models and innovative control concepts for engineered systems is encouraged.

4. **Multi-Scale Characterization and Modeling of Materials (PE 601102A/Project AB2/Task 02)**

This SRA supports core competencies (1) Blast protection of structures, (3) Military engineering, (7) Military installations and infrastructure, (5) Computational prototyping, and (6) Coastal, river, and environmental engineering. Proposals are encouraged that pursue application-inspired discovery through basic research on

new materials, understanding of mechanisms, and foundational models to support and transition to future applied R&D initiatives. Specific interest is on multi-functional materials, multi-physics modeling and simulation, ultra-high rate damage mechanics, and AI/ML enabled materials modeling. Research that informs multi-scalar understanding and predictive methodologies for comprehensive materials engineering for multiple aspects including, but not limited to, predictable substrate performance, energy and thermal absorption and dissipation abilities, utility in novel sensing methods, electro-optical tunability, and manufactural scalability is of interest.

5. Engineered Materials by Design (PE 601102A/Project AB2/Task 02)

This SRA supports core competencies (1) Blast protection of structures, (3) Military engineering, and (7) Military installations and infrastructure. Transformative basic research that investigates the discovery and design of engineered materials with enhanced performance, improved function, and reduced weight is critical for future force protection and force projection applications. Proposals are encouraged on topics that include materials discovery, processing, characterization, multi-scalar technology, computational materials sciences and engineering, heterogeneous materials, organic materials, composite and hybrid materials, interface/phase science, and chemistry. Investigations may focus on static and dynamic loads under a range of extreme conditions. Research is sought to generate understanding and inform predictive methodologies for future comprehensive materials designs for a variety of applications.

6. **Future Transformative Technologies for Military Engineering (PE 601102A/Project AB2/Task 02)**

This SRA supports core competencies (1) Blast protection of structures, (3) Military engineering, (7) Military installations and infrastructure, and (4) Cold regions research. Proposals are encouraged that support ERDC's core competencies in areas of future concern for force protection and force projection. Investigations should focus on the fundamental science and engineering challenges of the future.

7. Innovative Material Science for Infrastructure (PE 601102A/Project AB2/Task 03)

This SRA supports core competencies (1) Blast protection of structures, (3) Military engineering and (4) Cold regions research through innovative materials research to rapidly construct future obstacles, bridges and other infrastructure. Fundamental research is sought to understand how novel adhesives or binding materials, indigenous and/or easily transported materials (to include Arctic materials such as snow, ice, and frozen ground) may be used with advanced or autonomous equipment to build structures that can withstand extreme environments. Basic research into advanced structural materials and assembly methods harnessing engineering processes that enable self-healing, self-assembly and integrated materials systems with lower embodied energy and carbon to support future capabilities and requirements to deter and defeat adversaries is of interest.

8. Computational Science and Complex Military Systems (PE 601102A/Project AB2/Task 03)

This SRA supports core competencies (1) Blast protection of structures, 2) 3D mapping and characterization, (3) Military engineering, (4) Cold regions research, 5) Computational prototyping, (6) Coastal, river, and environmental engineering, (7) Military installations and infrastructure through seeking fundamental research that significantly reduces the time and computational effort required to conduct high-fidelity, physics-based simulations of physical, environmental, and military systems and/or the advancement of data science to promote use of unstructured, complex, real-time sensor data. This research may investigate new algorithms, formulations, or computing methods that could provide future equivalent (or better) simulation accuracy as current generation methods but execute faster by orders of magnitude. Fundamental research is also sought that can understand, analyze, and predict physical, environmental, and military system behavior using large quantities of complex data and/or understand fusing computational models of complex systems with real-time sensor feeds. This research may focus on investigation of fundamental methods and concepts that could improve data management, data analysis, data complexity, data linkages, and data visualization when data sizes exceed the capability of current analytic systems. Basic research on biologically inspired Army resource management is also of interest.

9. Resilient Installation Science (PE 601102A/Project AB2/Task 03)

This SRA supports core competencies (7) Military installations and infrastructure, (3) Military engineering, (3) Cold regions research, and (6) Coastal, river, and environmental engineering through investigation into innovative materials research, novel natural and manmade processes, and human systems approaches that could support future resilient and intelligent facilities, ranges, airfields, and support infrastructure. There is specific interest on basic research to support systems that are resilient in the context of a changing climate. Fundamental research is sought to inform efficiencies in energy production and use, water harvesting/recycling, and energy harvesting. Basic research supporting on-demand energy storage and delivery to support military installations and infrastructure is of interest. Basic research which provides a foundation for development of next generation sustainment capabilities and improves scientific understanding of materials and mechanisms for future adaptive and integrative operations and real-time decisions is of interest.

10. Informed Threat Environment (PE 601102A/Project AB2/Task 04)

This SRA supports core competencies (2) 3D mapping and characterization (3) Military engineering, and (4) Cold regions research through fundamental research into novel biological mechanisms or natural and geological processes. Basic research is sought which will include identification, prediction or mitigation of potential impacts of environmental hazards that could adversely affect the Army mission in a wide range of environments including extreme environments (such as Arctic, Xeric, Pyrogenic, Compound flooding) or inform future sensing capabilities. Basic research is also needed to gain a fundamental understanding of geochemical

properties and behavior of environmental matrices (soil, plant, atmosphere, sediment, surface, and ground water) to better understand their complexity and heterogeneity.

11. Biotechnology for Warfighting Functions (PE 601102A/Project AB2/Task 04)
This SRA supports core competencies (1) Blast protection of structures, (3) Military engineering and (4) Cold regions research. Fundamental research into natural processes/organisms, engineered organisms, or novel biotechnology/synthetic biology approaches that could result in the understanding of enhanced materials, technology, or structures for future Army capabilities in the areas of Warfighting platforms (mobility, lethality, intelligence, signature management and threat protection), and reduced logistics and supply chain risks to enable defeat of adversaries in Multi-Domain Operations is encouraged. Basic research into multifunctional materials that can elucidate, detect, sense, respond, compute using biological processes/components/organisms is of interest. Fundamental research is also sought to understand how biological networks at different hierarchical levels (cells, individual, population, community, ecosystem, or biosphere) maintain function/behavior under extreme conditions.

12. Unique Biological, Chemical, and Physical Processes (PE 601102A/Project AB2/Task 04)
This SRA supports core competencies (2) 3D mapping and characterization, (4) Cold regions research, and (5) Computational prototyping through fundamental research into understanding of complex environmental, chemical and biological processes and features which could inform future Army planning and Multi-Domain Operations. Proposals may investigate new approaches in artificial intelligence, analysis, visualization, and/or extraction of useful information from large, diverse, heterogeneous, and distributed data sets to inform future tool and/or software development. Investigation into extreme atmospheric phenomena, biogeophysical, and biogeochemical processes to inform, respond, and adapt to changing biospheric conditions are relevant. Innovative research is sought to provide fundamental understanding of complex biological, chemical, physical, and ecological processes to develop data-enabled advancements beyond that of individual activities in traditional computational, experimental, observational, and theoretical scientific approaches.

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Deputy Director