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reaction mechanisms is highly encouraged. Thi[redacted]des characterization of radiative and convective stimuli delivered by plasma injection sources as well as [redacted]rmal, kinetic, and mechanical responses of the propellant. Complementary model development and numeri[redacted]ution of these same ignition and combustion processes are also essential. There is also need to understand [redacted]planned or accidental ignition of energetic materials due to stimuli such as electrostatic discharge, impact, f[redacted] etc. This requires, for example, research on the processes of energy absorption and energy partitioning in the[redacted]als, the effect of mechanical damage on the ignition events, and other topics relating to the safety of energeti[redacted]rials.

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RESEARCH AREA 2
ENVIRONMENTAL SCIENCES

2.0. The Environmental Sciences Division of the Army Research Office supports fundamental research in the Atmospheric and Terrestrial Sciences, i.e. research in the physical sciences of planet Earth in support of Army requirements. The need for research in the environmental sciences stems from the impact that the environment has upon virtually all aspects of Army activities. As military technology become ever more complex and sophisticated, both systems and operations are increasingly influenced by the natural environment and variability in environmental conditions. Despite continuing Army efforts to develop an all-weather/all-terrain capability, environmental conditions still constrain Army operations. Thus, the potential impact and leverage of environmental factors must be clearly understood in order to increase existing system capabilities and performance, take advantage of environmental weakness within adversary systems, and optimize the design of new systems. The ability of the Army to function properly and efficiently in all these environments requires equipment and tactics designed with full knowledge of the potential effects of the environment. Intelligent planning for the battlefield must take advantage of the environment. An in-depth understanding of individual environments on micro- to macro-scales and capabilities to predict environmental effects and behavior for places and times differing from the “here and now” are required. Advanced simulators for training and mission rehearsal require realistic behavior of atmospheric processes and terrain. Domains of specific interest range from the shallow subsurface, the land surface and the earth-air interface, to the lower atmosphere and cover surficial environments which vary from the polar regions to the tropics under all weather conditions, both favorable and adverse.

The Army is also committed to be a national leader in environmental and natural resource stewardship for the present and future generations as an integral part of its mission. Responsibilities in this arena include the restoration of sites contaminated through prior Army activities, as well as achieving a state of environmentally sustainable operations on all military installations, particularly those utilized for training and testing. Cost-effective land use and restoration requires in-depth knowledge and understanding of the physical principles and processes operating in the terrestrial and atmospheric domains across a variety of scales which range from the microscopic to megascopic.

The natural environment is, by nature, a multifaceted and dynamic system so that there is an increasing need for multidisciplinary approaches to address the complex research issues that presently characterize the atmospheric and terrestrial sciences. Because of limited resources, not all subjects that fall within the broad interest areas defined below can be included in the current ARO Environmental Sciences research program at any point in time. Emphasis areas are reviewed periodically and funding concentrated in specific areas on a 3-5 year time frame. The submission of white papers is strongly encouraged. For Terrestrial Sciences funding consideration, white papers should be submitted in November of each fiscal year. Offerors whose pre-proposals are evaluated and are found to have significant technical relevance and merit will be requested to submit a complete proposal during the April-May time frame of each fiscal year.

Potential offerors are encouraged to contact the appropriate Technical Point of Contact (TPOC) for preliminary discussions on their ideas. The TPOC may invite the offeror to submit a preproposal.

2.1. Terrestrial Sciences. In general, the Terrestrial Sciences program is concerned with the impact of the Earth's surficial environment on Army activities. Program interests cover a broad spectrum, ranging from terrain characterization and analysis, mobility considerations under combat conditions and military engineering, to the management and stewardship of its installations as regards the impact of Army activities on the natural environment. Primary emphasis is directed toward understanding the behavior of the land surface and the near-surface environment, understanding the natural processes operating upon and within these domains, and modeling these environments for predictive and simulation purposes. Special emphasis is given to the need to better understand, model/simulate, and predict those environments/conditions that are most extreme, dynamic, or restrictive to systems performance or military operations. The three areas of current interest to the Terrestrial Sciences program are:

2.1.1. Terrain Properties and Characterization. Terrain affects all aspects of Army operations. The effective understanding and use of terrain is critical to military success on the battlefield. It is in effect a force multiplier, affecting mission planning, system performance, unit mobility and effectiveness, and training readiness. At present, the Army cannot rapidly and efficiently perform the terrain analysis that is required before personnel, vehicles, and weapons are deployed. A 'rapid mapping' capability to remotely sense and interpret the features of and upon the earth's surface and an automated capability/methodology for handling and analysis of large aggregates of remotely sensed data are critical for the 21st Century Army. Terrain information may be considered elevation data, soil and environmental characteristics, natural terrestrial features and man-made structures, and urban environments. A capability to remotely sense and interpret the features of and upon the earth's surface, together with an automated capability/methodology for handling and analysis of large aggregates of remotely sensed data, are critical for the improved terrain characterization capability required for most of the technology areas important to the *Army Objective Force*. Research related to terrain characterization is directed toward fostering the development of advanced geoscience-based capabilities for the rapid post-acquisition generation, analysis, and utilization of terrain data acquired through remote sensing technology. Characterizing terrain features and conditions from sparse data plus the accurate detection of short-term dynamic surface conditions and terrain feature change are high priority research issues. A problem of particular importance is the accurate remote sensing measurement of soil moisture at the scales of Army operations (*e.g.* 10^2-10^3m). Knowledge of the properties and phenomenology of the surface and near-subsurface is critical to support military operations on land, ranging from operational mobility, the detection of landmines and unexploded ordinance, natural material penetration/excavation, military engineering activities, to training and testing land sustainability. Effective military action requires a rapid and accurate assessment of the influence of soil and rock properties. Strength and deformation properties of geomaterials are highly variable due to the intrinsic heterogeneity of bedrock geology and soil formation processes and moisture content over variable spatial scales, rock mass competency, and groundwater pressure over small spatial scales. A thorough understanding of the behavior of geomaterials under different environmental and dynamic loading conditions is a critical need for mobility prediction and as input for projectile penetration prediction to destroy hardened and deeply buried targets. Also of concern is the issue that soil and rock properties and behavior measured in the field are typically much different than observed in the laboratory. This dilemma has profound consequences for predicting geomaterial behavior. Specific research is need to provide new approaches to (or techniques for) the non-intrusive geophysical characterization of subsurface materials and their spatial distribution; the prediction of location, frequency, and scale of subsurface heterogeneity; the detection and discrimination of buried objects (particularly landmines, unexploded ordinance, hazardous wastes, and contaminant plumes), tunnels and underground structures; and high-resolution field data sets for non-intrusive measurement validation. The ability to discriminate subsurface features and objects in the presence of surface roughness, natural geologic heterogeneity, and anthropogenic clutter requires advanced signal processing and analysis techniques.

2.1.2. Terrestrial Processes and Landscape Dynamics. Environmental factors can directly affect the Army's strategy, mobility, field operations, and logistics. With the expected increased sensitivity of the future *Objective Force* to these factors, the importance of this information will become even more critical. Therefore, the focus of this research area is the development of an improved understanding of surficial processes within the terrestrial environment that can affect Army operations. The dynamics of natural processes and systems operate over a wide range of scales and are only poorly understood at the time and space scales required by the Army; hence much of what is needed is a fundamental understanding of the appropriate ways to couple processes of highly differing scales and types. A continuous dynamic interaction takes place between solid earth materials and the most abundant fluids, water and air. A variety of dynamic environmental parameters and conditions affect the performance of geophysical sensors. Fluvial processes are dominant in shaping the continental surface through both erosion and deposition. In more arid regions, eolian processes can give rise to both erosional and depositional landforms. Military problems arising from these interactions include localized flooding in battle areas, deterioration of trafficability, and obscuration from blowing dust and sand. The nearshore zone is a complex boundary region where air, land, and sea interact over a wide range of space and time scales. It is also a region in which incident energy is often dissipated or transformed to motions at other scales. The result is a highly non-linear, coupled, dynamic system. Surface waves, coastal circulations, and sediment transport all have important impacts on Army operations within this region; however, information on these processes is essentially nonexistent for most areas around the globe. At 0°C, water changes from the liquid to solid phase, resulting in the formation of snow, ice, and frozen ground. Such conditions dramatically alter the battlefield environment and affect the performance of systems and materiel. Icing is a particular issue for aircraft, rotorcraft, optical sensors, and antennas. An improved understanding of the fundamental character and dynamic nature of the surface environment and its evolution through time, as well as the consequences of military interaction with this environment, is essential for the continued development, improvement, and sustainability of Army training and testing activities. In particular, there is a need for the development of first-principle physical/chemical process models and computer-based techniques for monitoring, modeling, and simulating the natural environment, as well as improved technologies and methodologies for environmental characterization and prediction. Special emphasis is given to the need to better understand, model/simulate, and predict those environments/conditions that are most dynamic or restrictive to systems performance or military operations. The development of an improved understanding, physical representation, and quantification of terrestrial processes affecting Army operations are of particular interest to this research area. Improved measurements and theoretical treatments are needed to treat the complex, often nonlinear dynamics governing these processes, which are a result of both physical and biologic processes and the interaction of these processes with terrain evolution. Such processes operate over a wide range of discontinuous time and space scales, which make them extremely difficult to characterize, quantify, and model. Explicit consideration of these processes and their interactions will lead to critically needed improvements in the ability to predict environmental effects on Army operations. Important in this context is research that seeks tounderstand the response of landscape to modification by Army use and the fundamental nature of subsurface flow and mass transport and then numerically model these complex processes. Critical to developing an engineering-scale understanding of the properties and behavior of surface environments is a fundamental knowledge about the natural processes that operate on surficial materials at a variety of scales. Field observation, laboratory experiments, and computational modeling must be integrated to solve well-formulated problems. Predictive geotechnical models, based upon well-characterized constitutive relationships, are required to identify controlling processes and parameters across a spectrum of scales. Extreme environments (hot, cold, dry, and wet, or combinations thereof) pose unique challenges to future Army systems and personnel because deserts, tropics, and cold regions are extremely hostile environments that dramatically affect human and materiel performance, thus inducing a negative effect on the performance of military systems and operations. Extreme environments also are important because they can exhibit unusual recovery rates following disturbance. Within the US, approximately 70% of DOD lands occur in highly sensitive arid and semi-arid environments. The character of terrain in arid environments can determine how military operations are conducted on these lands and military activities can directly impact the terrain in a manner that causes both short-term and long-term stresses on the surficial environment and ecosystem. The repeated use of such lands for military purposes, particularly training and testing activities, increases the risk of soil disturbance, damage to vegetative cover, degradation of water quality, and the disruption of animal populations and archeological sites. These impacts can be particularly adverse over the long term as battlefield readiness and sustainable training requirements place significant demands on the delicate terrains that characterize arid and semi-arid environments.

2.1.3. Terrestrial System Modeling and Model Integration. One the objectives of research to characterize the natural environment and understand terrestrial processes is to better prepare the soldier for combat through the development of the next generation of battlefield decision aids. An important application of this research is to develop or enhance integrated system models and simulators. A vision of terrestrial system models for the *Objective Force* includes products that enhance mission success through improved decision-making. The future battlefield will generate massive amounts of data that describe this space. Synthetic models will be essential to supporting leaders in the real-time analysis of battlespace terrain data and in selecting the best courses of action for a particular terrain or environmental situation. The Army maintains various modeling and simulation systems, such as the SYNTHERM cold climate energy balance model, NATO Reference Mobility Model, the Engineer Obstacle Planning System, the Surface Water Modeling System, the Groundwater Modeling System, the Watershed Modeling System, the Army Training and Testing Area Carrying Capacity Model, and the Integrated Dynamic Landscape Analysis and Modeling System to name but a few. These current systems allow for the computation of a variety of outputs, including mobility analyses, watershed response, groundwater flow and transport, military reservation land use response, and prediction of winter specific engineering effects. The Army is continually developing new features for existing numerical models and, in some instances, new environmental model systems, such as the emerging Land Management System. Research products, to be fully useful, must be integrated into modeling systems. This is often a non-trivial undertaking. The integration of the output from existing models offers many challenges related to different computational domains, resolution, and time scales. The ability to integrate advances in fundamental theory and process understanding is necessary to fully exploit these advances. The Army also faces a host of management and logistical issues, ranging from traditional training and testing to installation range management and coastal logistics, which require the coupling of models and analysis tools of highly contrasting scale for more effective decision making and long-term planning. Not atypically, differing processes exist at often radically different, but interrelated time and space scales. A fundamental understanding is needed of the appropriate ways to consider heterogeneous and dynamic terrain properties, couple natural processes of highly differing spatial scales, and the most efficient methods to model interrelated physical and ecological phenomena.

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2.2. Atmospheric Sciences. The Army has the responsibility to provide fundamental knowledge of the atmospheric boundary layer over land to all US armed services since that boundary layer is the primary theater for Army operations. Intelligence preparation of the battlefield depends on a full knowledge of atmospheric conditions and their effects on operations, weapon systems, and the soldier. It requires an ability to estimate atmospheric details at specific locations and at present and future time to maximize strategic weather advantages. Knowledge of the atmosphere and its effects on soldiers and sensor systems are essential for command and control as well as visualization of the battlefield at all echelons. The Army lead responsibility for chemical and biological defense requires detailed knowledge of the threat once it is induced into the air. In garrison, Army training and preparedness depend on accurate representation of atmospheric test conditions and on physically correct portrayal of atmospheric processes and effects in simulations.

The research program is broadly based to address the wide spectrum of conditions and influences of the atmospheric boundary layer on Army operations and systems. It is divided into three general research areas of the boundary layer problems: atmospheric effects on sensors and systems, characterization of the atmosphere at high resolution, and management of atmospheric information

2.2.1. Atmospheric Effects on Sensors and Systems. The Army depends heavily on propagation of electromagnetic and acoustic signals through the atmosphere for detection, ranging and operation of smart munitions as well as reconnaissance and information dominance of the battlefield. Atmospheric turbulence can severely impact the performance of optical and infrared sensors as well as acoustic detection systems by affecting the propagation, imaging, and coherence of the received signals from active or passive systems. Furthermore the effects of surface and natural environmental conditions on propagation of images and signals must be considered because of the near-ground operation of many Army systems.

2.2.2. Characterization of the Atmosphere at High Resolution. Research efforts concentrate on increasing Army knowledge of physical processes in the atmospheric boundary layer at the engagement scale of the battlefield. This scale, characterized by horizontal distances to 20 km at resolutions at 10's of meters and times of seconds to hours, is the most inhomogeneous and changeable portion of the atmosphere.

The principal research concern is the diurnal evolution of the turbulent and stable atmospheric boundary layer. Research topics span a full spectrum of atmospheric boundary layer dynamical conditions including, but not limited to: parameterization and scaling of boundary layer processes for micro scale and mesoscale predictive models; surface conditions from simple to heterogeneous terrain elevation and slope, vegetation, and moisture; surface energy budgets; scale interactions; temperature and moisture fluctuations, especially as they affect the atmosphere as a medium for propagation of acoustic and electromagnetic signals; and natural or induced obstructions to visibility. A principal focus of the boundary layer dynamics is their application to prediction of the mean and fluctuating concentrations of chemical and biological agents in realistic terrains on appropriate scales.

Comprehensive measurements of wind velocity, temperature, moisture, surface energy exchanges and fluxes at resolutions showing their scales of variability in the atmospheric boundary layer are essential for advancing understanding of boundary layer processes affecting Army operations and systems. The variables should be measured in space and time to clearly define the evolution of three-dimensional physical processes within a volume of interest. Such measurement programs should highlight both the instrumentation development and the interpretation of the physical processes from the sensed data.

These topics are considered from perspectives of theory, field experiments, and analyses of the faithfulness and validity of models and simulations of these processes. The research results are expected to contribute to improved models of boundary layer processes for visualization and field use through strong interactions with appropriate Army laboratory scientists.

2.2.3. Management of Atmospheric Information. Providing useful atmospheric effects information to the soldier and decision maker is the focal point of the Army's atmospheric sciences effort. The information needs of each user may be very different. Furthermore, the information must be in a form that is readily understood in light of the user's needs. At the same time, the path from data to information must have a fundamental scientific basis. The science issues behind the information management include an ability to obtain data from multiple sources, friendly or adverse, quantitative and qualitative; fusing the data into a comprehensive representation of the present and future atmospheric state; understanding of the uncertainties of the data and their effects on the application; and communicating the complex four dimensional atmospheric state in the language and application of the user. To accomplish the goals of information management, improved computational methods are needed to assimilate and integrate the data, assess the atmospheric present and future state, and disseminate the user's needed information in a timely and effective manner.

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RESEARCH AREA 3
MATHEMATICAL SCIENCES

3.0. Mathematical and computational methods pervade research, development, testing, and evaluation problems encountered by the Army. Furthermore, increasing demands are being placed on research in the mathematical sciences because of their fundamental role in the analysis and modeling issues that arise in military science, engineering and operations. Although these problems are often and quite naturally stated in terms of their system or operational implementation, their solutions are usually dependent on a number of mathematical subdisciplines. For example, some promising approaches to computer vision for automatic target recognition (ATR) require research in a wide range of areas including constructive geometry, numerical methods for stochastic differential equations, Bayesian statistics, tree structured methods in statistics, probabilistic algorithms, and distributed parallel computation. Another example is furnished by simulation. Here improvements depend on a large number of research areas including large scale scientific computing and real time computing for embedded systems. Similarly, recent research on dynamical systems, control theory, logic and concurrency is being applied to the extraction and verification of digital control programs for continuous systems.

In this announcement, the Army Research Office areas of interest will be described to the potential researcher and user mainly by means of research topics within mathematical sciences. This procedure has the benefit that our program managers can amplify the worth of their programs by funding research topics that have impact on many different problems.

To be able to respond to the increasing demands on the mathematical sciences, the ARO attempts systematically to advance fundamental knowledge that focuses on the needs of the Army. To accomplish this objective, the Division supports extramural basic research in the five areas that follow. A program represents each of these five areas. The research supported by the Division does not cover all or even the majority of topics in these areas. Rather, it covers only certain sub areas that are of strategic importance for the Army. Programs typically have two to four foci. There are unavoidable overlaps between programs. The sub disciplinary boundaries within the Division and the disciplinary boundaries in the ARO are not rigidly drawn and there is strong interest in and appreciation for multidisciplinary research in which the mathematical sciences play a major role.

Potential offerors are encouraged to contact the appropriate Technical Point of Contact (TPOC) for preliminary discussions on their ideas. The TPOC may invite the offeror to submit a preproposal.