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parallel and distributed computation and models [redacted]ithms for the control of heterogeneous concurrent computing. Also of interest is research on tools f[redacted]velopment of parallel algorithms and expert systems for computation and visualization of solutions to par[redacted]ential equations. Exploring fundamental techniques that optimize I/O communication is a research area of[redacted]ategic importance.

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3.5. Cooperative Systems The objective of this [redacted]kage is to study and take advantage of the combined power of collaborative systems pertaining to grou[redacted]ots and other complex systems. An example is the cooperative activity of robots or communication [redacted]with changing relative topology in the battlefield. Research areas include the mathematical foundati[redacted]stem theory, communication nets, the swarming phenomenon, game theory, large data set manipu[redacted]cision-making, and data processing related to intelligent systems.

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RESEARCH AREA 4
ELECTRONICS

4.0 Electronics. Electronics is widely recognized as a key force multiplier, underpinning the Future Combat System, as well as the Objective Force as an essential means to achieve technological superiority. The U.S. Army Research Office's Electronics Division seeks to support scientific and engineering endeavors in research areas that possess the potential to define new electronic capabilities or to enhance future electronic performance. The Electronic research sub-areas are Solid State Devices, Optoelectronics, Quantum Electro-Magnetic Devices, Sensors and Detectors, Electromagnetics and RF Circuit Integration, and Terahertz Science and Technology. We invite proposals for research to advance our understanding of electronic devices, materials, and processes with a strong prospect for use in future Army technology.

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 or white paper.

4.1. Solid State Devices. This research area emphasizes efforts to establish a new and comprehensive base of knowledge for the electronic, photonic, acoustic and magnetic properties of solid-state materials, structures and devices. Functions such as very intelligent surveillance and target acquisition; command, control, and communications; electronic warfare; and reconnaissance, must be accomplished with the high data rates and real-time capability that are essential for these applications. To support the U.S. Army vision of Objective Force and Future Combat System of Systems (FCSS), these systems will need to operate at much higher speeds and frequencies, have greatly increased functionality, and have much higher levels of integration than present day technology provides. Therefore, fundamental research in the area of Solid State Devices is the corner stone and an essential requirement in the development of these future systems for military defense.

To establish the needed science base for future Army battle-space capabilities, innovative research is sought in the general areas of; novel electronic materials for advanced devices, nanoscale processing and fabrication science, nano/molecular electronic science and technology, nanoscale physical modeling and advanced simulation, ultrafast electronics, advanced device concepts, mixed technologies (electronic, photonic, acoustic & magnetic), heterogenous devices and technologies, micromachined devices and ultra-low-power technologies. Therefore, the program currently emphasizes fundamental research in, (1) Nanoscale Growth and Processing Science, (2) Nanoscale (Semiconductor) Electronics, (3) Molecular Electronics and (4) Advanced Device Concepts, with a focus towards identifying and overcoming existing scientific barriers. Important science and technological barriers include, but are not limited to, the discovery and implementation of new and revolutionary growth techniques for engineering materials and for mixing and matching diverse material systems; the development of novel processing, fabrication and self-assembly techniques for realizing effective integration of diverse materials and devices into ultra-dense and complex solid-state electronic systems; the establishment of a theoretical base of knowledge into conventional and non-traditional (molecular) nanoscale electronics for bridging the gap between today's microelectronics to the future where molecular devices will be integrated with nanoscale semiconductor devices and components; the development and implementation of accurate physical models and robust simulation tools for identifying novel ultra-small device concepts and complexly-coupled nanosystems and accurately predicting their behavior; the development of a comprehensive science base that will provide fundamental insights into quantum-confined structures with time dynamic, nonequilibrium, dissipative electronic processes that are imbedded in practical circuits with realistic interconnects; and the development of new and effective integration techniques for realizing complex heterogeneous devices (i.e., devices utilizing different materials and operating on different physical principals) and mixed technology systems.

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4.2. Optoelectronics. Research in this subarea includes novel semiconductor structures, processing techniques, and integrated optical components. The generation, guidance and control of optical/infrared signals in both semiconductor and dielectric materials are of interest. The Army has semiconductor laser research opportunities based on quantum dot and quantum well semiconductor materials operating in the eye-safe (>1.55), 3-5, 8-12, and 18-24 microns regions for various applications, such as ladar, IR countermeasures, and free space/integrated data links.

Research is necessary in semiconductor materials growth and device processing to improve the efficiency and reliability of the output of devices at these wavelengths. High performance devices and components will be optimized for applications including high-data-rate optical networks. Interfacing of opto-electronic devices with electronic processors will be investigated for full utilization of available bandwidth. Electro-optic components will be studied for use in guided wave data links for interconnections and optoelectronic integration, all requirements for high speed full situational awareness. Optical interconnect components are needed in guided-wave data links for computer interconnection and in free-space links for optical switching and processing. For optical processing of images, research leading to two-dimensional (2-D) arrays of surface-emitting lasers is necessary. Research addressing efficient, novel optical components, such as optical micro-electro-mechanical systems (MEMs) is needed. Emitters and architectures for novel display and processing of battlefield imagery are important.

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4.3. Quantum Electro-Magnetic Devices. The Army has a need for devices and components that exploit multi-field interactions in suitable materials leading to a new class of quantum-effect devices for sensing, display, data storage, and information handling. Research on the generation, detection and control of electronic, optical, and magnetic signals in both semiconductor and dielectric materials is of interest. In particular, novel electro-magnetic processes leading to greater manipulation and increased sensing/data handling capabilities are to be considered. Crystalline and amorphous wide bandgap semiconductor materials are of interest as host materials for rare earth and transition metal ions. Typical applications for these materials include robust, multicolor, multi-layer thin film displays and spin-polarized sensors for chem.-bio detection. Such devices will be especially critical in the development of miniature, unmanned platforms operating in hostile environments. In order to realize such devices it is necessary to explore the electrical, optical, magnetic, and acoustical multi-field interactions in advanced materials, such as AlGaInN, AlGaP, and ZnO. Novel structures, at the micro- and nano-scale level, need to be developed to optimize the multi-field quantum-effect interactions. Device concepts that exploit these interactions for enhanced sensing, display, data storage, and information handling need to be explored. In order to establish the science base for this new class of quantum-effect devices, innovative research is sought in the general areas of:

a. Methods for altering the electronic, optical, and magnetic properties of semiconductor materials,

b. Rare-earth and transition metal doping of semiconductors and dielectrics,

c. UV-visible photonics in III-V nitride compound semiconductors,

d. Efficient, eye safe lasers leading to high power operation,

e. Control of photonic-magnetic interactions in nanostructures.

Research is to include demonstration of proof of principle devices employing novel phenomena and interactions. Research issues relating to design, modeling, and fabrication of these devices are of interest. Characterization of materials and devices at the nanoscale is to be performed to determine the electrical, optical, magnetic, and piezo-electric properties of prototype devices. This knowledge is to be used to understand the limitations of such quantum-effect devices and to establish the basis for unique sensing, display, data storage, and information handling opportunities. These investigations are necessary to determine the ultimate performance ranges of field-controlled, quantum-effect nano-devices and to provide increased functionality and capabilities for the Objective Force.

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4.4. Sensors and Detectors. The Army requires high resolution, high sensitivity, but also affordable, multi/-hyperspectral and polarization sensitive, active and passive, IR sensors for target acquisition, recognition, and identification in the digital battlefield. Research opportunities include components based on quantum confined devices and semiconductor materials operating in the infrared 1-24 microns regions, as well as ultraviolet (UV) detectors. Studies involving growth, defects, interfaces, doping, and other electronic characteristics will be considered. Efforts aimed at raising the operating temperature of conventionally "cooled," high performance, infrared detectors (to >120K for TE cooling in vacuum and >190K for TE cooling w/o vacuum), as well as, increasing the performance of "uncooled" infrared detectors are also sought. Research involving novel multispectral structures including adaptive spectral selection will be considered. In addition, the next generation IR imaging systems will use large area, multispectral, staring arrays with considerable front end processing to provide multi-wavelength spatial and temporal detection. Development of the necessary architectures and the optical processing components provide additional research challenges. New device concepts are needed for all the above applications.

The sensing of vehicles, personnel, chemicals, landmines, and biological agents is critical for battlespace deconfliction, and new or improved sensing methods to increase battlespace situational awareness are needed. Sensing technologies currently include acoustic; seismic; radar (RF to millimeter wave) and passive electromagnetic; hyperspectral, etc. Other, novel, sensors will be considered, as well as, sensor fusion and networking that results in a sensor system for Army applications.

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4.5. Electromagnetics and RF Circuit Integration. The Army Transformation to the network-centric Objective Force is driving the need for basic research supporting mobile, multifunctional, reliable, and high-performance communications and sensor systems. The increasing need for high data rate communications and all-weather operating capability is pushing design frequencies into the millimeter wave regime, where the unique propagation characteristics of short wavelengths can produce system size reduction, high-resolution imaging, and large bandwidth. The proliferation of radio systems has increased the need for rugged, compact, multifunctional, low signature, lightweight, low-cost, and electronically steerable antennas. High average energy efficiency and low instantaneous operating power are required to reduce the logistics burden on deployed forces. Extensive modeling and simulation of the systems and their interaction at close proximity and at long range over varied terrain is required for design, analysis, and optimization. In Electromagnetics and RF Circuit Integration, research falls into the following general technical areas: computational electromagnetics, antennas, RF component development, RF circuit integration, and mine detection.

Problems of interest in computational electromagnetics can be divided into two regimes: device, circuit, package, and antenna modeling at short length scales, and radio wave propagation modeling at large length scales. Advanced models and simulations tools must be developed to accurately predict device, circuit, package, antenna, and system performance. Of special interest are physically-based models that enable the simulation of integrated circuits and modules as the levels of integration become higher and higher, as the circuits become denser and more complex, and as new circuit types such as leaky wave, quasi-optical, and active antennas must be addressed. The coupling of radiation into and out of complex structures is a problem of special interest. For increasingly complex systems, new analysis concepts, techniques, and methodologies are needed with improvements in algorithm speed and efficiency including order reduction and design for inherently low computational dispersion. The human interface for these tools should simplify the problem setup, data presentation and analysis process, possibly including knowledge-based tools, and allow the integration of multiple computational engines.

Propagation effects have a major impact on communications and radar systems. Research is sought leading to innovative and efficient techniques for near-real-time propagation modeling, capable of point-to-point calculations over paths that include urban, rural, and foliated environments with natural and man-made structures including tunnels, validated with appropriate experimental data, with effective interactivity and information delivery to the user.

Innovative approaches are needed to increase the performance and decrease the size and signature of tactical antennas operating from the HF to W frequency bands. Novel and new materials, configurations, and fabrication techniques for multifrequency, multiband operation are of interest. Broad impedance bandwidths and pattern bandwidths are required for spread spectrum systems. Fast frequency switching circuits and techniques for tunable antennas that minimize nonlinear effects over a wide band of frequencies are required for frequency hopping systems. Efficient coupling of electromagnetic energy into the ground is required for ground penetrating radar antennas. In addition, radically innovative approaches are needed to increase the performance and reduce the cost of electronically steerable apertures (ESA), including novel feed networks that improve antenna performance and reduce the cost of support circuitry. Furthermore, completely new approaches are sought for a new class of antenna elements that are efficient, point sensors and radiators of the vector electromagnetic fields with little or no mutual coupling for highly oversampled antenna arrays giving improved direction finding capabilities and radiation pattern control.

The electronic systems of the future will operate in an increasingly dynamic and complex spectral environment. This drives the need for innovative concepts that will produce devices and components with extremely high dynamic range, extremely wide instantaneous bandwidth, extremely high linearity, and multi-channel phase tracking. The requirements for dynamic range, bandwidth, and linearity apply to active devices such as power amplifiers and low-noise amplifiers, as well as to passive components such as filters, mixers, couplers, etc. Because these devices and components will be used in mobile systems and because energy storage technology has not kept pace with developments in electronic technologies, the active components must also be energy efficient with low instantaneous peak power requirements and the passive components must have low losses. Optimal partitioning between digital and analog technology combined with new circuit topologies will be critical.

Integration technologies provide millimeter-wave/microwave circuits at small size, lightweight, low cost, and high reliability. Novel techniques for integrating circuits are of special interest at higher frequencies in order to overcome loss, coupling, and spurious radiation problems. Hybrid techniques that combine high performance from component optimization with low fabrication cost due to compatibility with high volume production processes are needed. Fabrication and integration techniques including dense 3-D and heterogeneous integration must be developed that give the system designer access to transmission lines with constant impedance over wide frequency range, inter-layer high-frequency and optical interconnect, hermetic self-packaging, and ease of assembly and handling. Thermal/mechanical effects must be analyzed and minimized. Innovative approaches such as micromachining will provide significant advantages for circuit integration and the production and integration of passive components, including integrated antennas.

Innovative electromagnetic and hybrid approaches are needed for the detection of mines and buried ordinance. Radar, acoustic electromagnetic induction, gravitometers, nuclear and infrared techniques have been applied in traditional approaches. Innovations on the traditional approaches and hybrid combinations with potential improvements in usability and probability of detection with significant reduction in false alarm rate are of interest to this program.

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4.6. Terahertz Science & Technology. This research area emphasizes efforts to establish a new scientific foundation for understanding and utilizing terahertz (THz) frequency sensing as a new tool for the detection, identification and characterization of chemical and biological (CB) agents on the battlefield. This research area also includes a parallel thrust to identify and develop advanced device concepts that are suitable for realizing THz-frequency sensors and sensor systems that are militarily useful (i.e., compact, robust, cost effect, etc.) in realistic battlefield scenarios.

To establish the needed science and technology base for future Army battle-space capabilities, innovative research is sought in the general areas of THz frequency sensing science and advanced device concepts that facilitate robust functionality at frequencies within the submillimeter-wave or THz frequency regimes (i.e., the part of the electromagnetic spectrum between approximately 1 mm (300 GHz) and 100 µm (3 THz). To improve device performance, the Army is interested in new device and circuit concepts, including quantum transport devices such as resonant tunneling structures, and quantum-transition devices in which photon emission can occur through intersubband transitions between quasi-bound states. It also includes traditional devices with revolutionary circuit and packaging techniques to improve performance. The components of particular interest are electrically-driven room-temperature sources, cw or pulsed, operating between ~ 0.3 and 3 THz. Innovative and novel methodologies should be explored until an effective approach is discovered or developed. Here, the development of efficient sources and integrated semiconductor-based components and systems is a priority.
In addition, a key application of interest for terahertz and ultrafast electronics is battlefield remote sensing of biological agents. Another second class of application is point detection of biological/chemical agents and explosives, such as RDX and TNT that also interact with THz radiation via low-frequency vibrations and rotational modes. Rapid, unambiguous identification of chemical agents, precursors, and degradation products is required in many areas of the DoD including treaty verification and counter-terrorism. The ultra-high resolution offered by THz spectroscopy may provide this rapid identification even when the substance is in a complex mixture. A final, and possibly even more far-reaching application of THz electronics, is in the development of concepts for extending ultra-wideband sensing and communications. Indeed, the fusion of an advanced THz-frequency sensing capability with conventional sensor-network communications and high-speed data processing has the potential for significantly enhancing the network-centric capability of the Army's Future Combat System of Systems (FCSS) concept. Here, THz electronics will collectively impact spectroscopic sensing, radiometric imaging and data transmission/ processing. Furthermore, commercial local-area-wireless networks can already be envisioned at frequencies as high as 400 GHz, therefore, THz electronics has a strong duel use potential and the potential for significantly impacting the high-frequency electronics of the future.

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RESEARCH AREA 5
COMPUTING AND INFORMATION SCIENCE

5.0. The Army has determined from its experience in Gulf Wars that it needs a force that can be deployed rapidly to any conflict area in the world. The delay incurred in deploying a heavy force with 70 ton tanks is no longer acceptable nor is the logistics tail needed to support them. The Army has embarked on a transformation to a lighter more rapidly deployable and supportable force. This, according to The Army Vision, will be a strategically responsive force that can deploy combat-capable forces anywhere in the world.

The operational concept of the Objective Force includes smaller units with higher mobility and weapons of greater precision and lethality. Since forces will not be highly massed and vehicles will have less physical protection, the key to providing survivability of this force is real-time information on the friendly and enemy situations available continuously so that decisions can be made and actions taken within the decision cycle of the enemy.

Information processing on the move is critical to the success of operations of the Objective Force which will be almost constantly moving. Information must be communicated; and, since the force is mobile, the communications required is unique mobile wireless communications networks that are adaptive and operate without any geographically fixed infrastructure. There will be numerous unmanned robotic and tele-operated aerial and ground vehicles serving as sensor, communications relay, and weapons systems platforms. Information sources on the battlefield will grow rapidly. Computing and information processing research will have to provide the technology to process this information in real-time and to insure that soldiers and commanders are not overburdened with data, rather than succinct information, to a degree that adversely affects their performance and victory in battles.