2008
DARPA FACT FILE
A Compendium of Programs

Defense Advanced Research Projects Agency

June 2008

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FOREWORD

Purpose: DARPA's mission is to prevent the technological surprise of the United States, and to create technological surprise for our enemies. This document provides short abstracts of DARPA programs in FY 2008 and FY 2009, and it is a reference for those interested in DARPA's research portfolio. To better illustrate the goals of the programs, the programs have been grouped into the nine Strategic Thrusts that form DARPA's strategy as described in *Defense Advanced Research Projects Agency Strategic Plan* (February 2007)[†]:

DARPA's Strategic Thrusts

1. Robust, Secure, Self-Forming Networks
2. Detection, Precision ID, Tracking, and Destruction of Elusive Targets
3. Urban Area Operations
4. Advanced Manned and Unmanned Systems
5. Detection, Characterization, and Assessment of Underground Structures
6. Space
7. Increasing the Tooth to Tail Ratio
8. Bio-Revolution
9. Core Technologies

An index table in the back of the document helps locate individual programs and cross-references them to Program Elements in the President's FY 2009 budget.

This document is designed to be used in conjunction with *Defense Advanced Research Projects Agency Strategic Plan* and the Descriptive Summaries in the FY 2009 Budget Estimates (February 2008).[*] The *Strategic Plan* describes, in broad terms, DARPA's current top-level strategy. The Descriptive Summaries provide more detail on DARPA's programs.

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† Available online at "http://www.darpa.mil"

* Available online at "http://www.darpa.mil/body/budg.html"

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DARPA's Strategic Thrusts

Through the years, DARPA has continuously refocused its work in direct response to evolving national security threats and revolutionary technological opportunities. In February 2007, DARPA published *Defense Advanced Research Projects Agency Strategic Plan*, which describes how the agency is pursuing its central mission through today's changing circumstances. That report details the nine strategic thrusts that DARPA is emphasizing today:

- Robust, Secure, Self-Forming Networks
- Detection, Precision ID, Tracking, and Destruction of Elusive Targets
- Urban Area Operations
- Advanced Manned and Unmanned Systems
- Detection, Characterization, and Assessment of Underground Structures
- Space
- Increasing the Tooth to Tail Ratio
- Bio-Revolution
- Core Technologies

The following sections contain brief descriptions of each thrust, along with abstracts of programs within them.

ROBUST, SECURE, SELF-FORMING NETWORKS

The DoD is in the middle of a transformation towards "Network-Centric Operations." The promise of network-centric operations is to turn information superiority into combat power so that the U.S. and its allies have better information and can plan and conduct operations far more quickly and effectively than any adversary.

At the core of this concept are robust, secure, and self forming networks that must be at least as reliable, available, secure, and survivable as the weapons and forces they connect. They must distribute huge amounts of data quickly and precisely across a battlefield, a theater, or the globe, and deliver the right information to the right place at the right time. They must form, manage, defend and heal themselves so they always function at the enormously high speeds that are the key to the advantages they provide; this means that people can no longer be central to establishing, managing, and administering them.

Tactical networks must locally link effects to targets and be agile, adaptive and versatile. Strategic and operational networks must globally link air, ground, and naval forces for operational maneuver and strategic strike and enable knowledge, understanding, and supply throughout the force.

DARPA is also bridging the gap between these two families of networks to allow strategic and tactical levels to rapidly and effectively share information and insight. We are developing technologies for wireless tactical net-centric warfare that will enable reliable, mobile, secure, self-forming, ad hoc networking among the various echelons with the most efficient use of available spectrum.

TECHNOLOGY FOR TACTICAL (WIRELESS) NETWORK-CENTRIC WARFARE

The goal of the **Advanced HF Communications** program is to provide always-available, high-rate communications at long ranges for Special Operations Force teams using miniaturized equipment. The program will develop antenna and radio technology to provide high-rate communications at long ranges using ground wave and near-vertical incidence skywave propagation.

The goal of the **Local Area Network droid (LANdroid)** program is to provide warfighters reliable communications in urban settings by creating robotic radio relay nodes that move autonomously to configure and maintain a communications mesh by reasoning about their positions relative to one another and relative to the warfighters. LANdroids will move as the warfighters move, keeping them covered with communications throughout their operations, and they will be pocket-sized so that warfighters can carry several and drop or deploy them as they move through a given area.

The **Next Generation (XG)** program goals are to develop both the enabling technologies and the system concepts to provide dramatic improvements in assured military communications to support a full range of worldwide deployments through dynamic spectrum access. XG's approach is to develop the theoretical underpinnings for dynamic access to the spectrum, the technologies and subsystems that enable dynamic access, and the system prototypes to demonstrate applicability to legacy and future DoD radio frequency emitters. The program plans to leverage the technology base in microelectronics, with new waveform and medium access and control protocol technologies to construct an integrated system.

The goal of the **Polarized Rotation Modulation (PZRM) Communications** program is to develop a new, extremely high data-rate, point-to-point, or point-to-multipoint wireless communications waveform using the PZRM/Orthogonal Signal Spectrum Overlay (OSSO) communications concept to exploit the presently unused polarization and rotation dimensions of radiation. The PZRM Communications program will investigate the use of polarization, including OSSO, modulation and the ability for conventional radios to carry all information over the transmitted signal amplitude, phase and frequency. A radio with four polarization possibilities would transmit four times the information with all other aspects of the waveform held constant, and OSSO enables multiple orthogonal signals to overlay one another in the same radio bandwidth, thereby increasing spectral efficiency.

Tactical implementation of virtual private network (VPN) requires operators to log into gateways in the continental U.S. to connect to each other – a problem because it can reveal who and where operators are located. The **VPN for ad hoc Networks** program will define VPN encryption requirements, limitations of field computing devices (FCDs), and employ recent breakthroughs in ad hoc networking to enable tactical VPN connectivity. Operational requirements include the need for client-to-client VPN connectivity on FCDs with ad hoc, peer-to-peer connectivity. VPN for ad hoc Networks will enable covert operators to exchange mission-critical information, while maintaining covertness in the field.

The goal of the **Wireless Network after Next (WNaN)** program is to develop and demonstrate technologies and system concepts enabling densely deployed networks in which distributed and adaptive network operations compensate for limitations of the physical layer of the low-cost wireless nodes that comprise these networks. WNaN networks will manage node configurations and the topology of the network to reduce the demands on the physical and link layers of the nodes. The technology created by WNaN will provide reliable and highly available battlefield communications at low system cost.

LINKING STRATEGIC AND TACTICAL NETWORKS

The **DARPA Interference Multiple Access (DIMA) Communications** program will develop a networked radio system for voice and data. The goal of this program is to demonstrate a network that is dynamically controllable using techniques such as reconfiguration, optimum resource allocations based on mission priorities, and dynamic policies, as opposed to relatively passive reactions to changes by the commercial infrastructure. The program will develop and demonstrate a system based on multi-user detection concepts that can take advantage of overloaded channels, while operating in an environment absent of infrastructure.

The **Expeditionary Distributed Common Group System (DCGS) Global Information Grid (GIG) for Exploitation Services (EDGES)** program will provide layered and persistent intelligence, surveillance and reconnaissance of asymmetric and irregular warfighters in support of Marine Corps and Special Operations by intelligently interpreting warfighter requests for situation assessment data, accessing local tactical threat data bases, and fusing multi-sensor data for accurate, timely target detection, tracking, and identification. EDGES couples the deployment of a dedicated UAV system responsive to these small units with data preprocessing and feature extraction to enable the efficient and timely transmission of actionable combat information to the troops. Using two-way communications with wideband reach-back, information and observations received from the small operation unit will be integrated into the EDGES information data base and communicated to the higher commands.

The goal of the **High Bandwidth Maritime Communications** program is to increase underwater communications performance (throughput and range) by over an order-of-magnitude from what is achievable today by developing and exploiting nonlinear optical processes to efficiently translate an arbitrary optical waveform from one wavelength band to another, which allows use of commercial laser components, signal-processing techniques, and advanced photonic technology in underwater communications.

The **Optical & Radio Frequency Combined Link Experiment (ORCLE)** program seeks to improve battlespace communications by developing combined radio frequency (RF) & free space optical (FSO) communications, as well as networking technologies that exploit the benefits of complementary path diversity. ORCLE will develop RF and FSO propagation channel analysis, coding techniques, and modeling to include weather, atmospherics, and aero-optics to provide the joint force commander assured high-data rate communications. The technical objective is to prototype and flight-demonstrate hybrid FSO/RF air-to-air-to-ground links that combine the best attributes of both technologies and simulate hybrid network performance.

The **Quint Networking Technology (QNT)** program is a modular, multi-band, network data link program focused on closing the seams between four nodes: manned aircraft; weapons; tactical unmanned air vehicles (UAVs); and air control ground units. The program designs, develops, evaluates, and demonstrates robust, affordable data link technologies suitable for use by weapons, tactical UAVs, and air control units. These data links enable precision strike and efficient machine-to-machine targeting against time critical and mobile targets, support combat identification of targets, disseminate tactical UAV and ground sensor data, and provide bomb impact assessment.

The **Tactical Combined Fiber-Optical & Free-Space Edge Network** program will make it possible for the U.S. military to create a rapidly deployable, self-healing, tactical wavelength-division-multiplexed fiber-optical network, combined with free-space optical and directed radio frequency networks, that can provide substantial communications capability to command centers deployed in support of forward operating bases. Protocols will be developed to enable the connection of this network to tactical wireless networks, as well as to existing fixed networks, allowing the efficient transmission of a combination of internet protocol, digital video streams, as well as analog and digital radar, electronic warfare, and radio frequency signals.

The goal of the **Visualizing the Info Ops Common Operating Picture (VIOCOP)** program is to provide a commander with a standardized and logical way of depicting the impact of information operations on conventional missions. VIOCOP will provide an informationally rich and succinct visual representation of non-geographic, non-kinetic information operations needed to assess progress during an information operations campaign, as well as to understand interactions with ongoing conventional operations.

Creating Global Network Capability

The **Control Plane** program will improve end-to-end network performance between the continental U.S. operating base and forward deployed tactical units. Control Plane seeks to develop the ability for individual hosts to learn essential characteristics about the network, allowing the hosts to shape the network and network traffic to optimize network loading, prioritize traffic, and create communities of interest. Additionally, when multiple network paths are available, hosts will be able to choose the best path/community or simultaneously transmit over multiple paths/communities.

The goal of the **Data in Optical Domain Network (DoD-Network)** program is to develop and demonstrate four key photonic technologies to meet the challenges of electronic data-routing bottlenecks in optical networks: (i) all-optical routing; (ii) all-optical data buffering; (iii) optical logic and circuits; and (iv) all-optical (multi-wavelength) regenerators. These photonic technologies will lead to intelligent all-optical networks. The program will focus on developing: (i) new photonic technology essential for photonics to play a significant role in higher order processing and routing in optical networks; and (ii) novel architectures that will fully exploit the new photonic technology and bring new and increased functionalities to optical networks.

The **Next Generation Core Optical Networks (CORONET)** program will revolutionize the operation, performance, security, and survivability of the United States' critical inter-networking system by leveraging technology developed in DARPA's photonics component and secure networking programs. The program will transform the fundamental networking concepts that form the foundation upon which future internet hardware, architecture, protocols, and applications will be built. These network-based functions will support the real-time, fast-reaction operations of senior leadership, major commands and field units.

The **Strategic Communication Assessment and Analysis System (SCAAS)** program will develop new theories, concepts, tools, and systems to formulate and assess sound strategic communication strategies and measure their effectiveness in communicating with allies, adversaries, and other constituencies around the world. This capability would have dramatic value to Combatant Commands in communicating with diverse peoples and organizations abroad.

The **Transmission, Switching and Applications for Next-Generation Core Optical Networks** program will develop the technology and applications to realize the next-generation dynamic multi-terabit networks that can deliver advanced internet protocol and optical services. This will be accomplished by: (i) greatly increasing network capacity through the use of more efficient fiber-optical transmission techniques; (ii) implementing agile, high capacity, all optical switching platforms, and (iii) developing the software and hardware interfaces, as well as the migration strategy, to enable new applications that can take full advantage of dynamic multi-terabit core optical networks.

ENHANCING NETWORK-CENTRIC WARFARE NETWORK CAPABILITIES

The **Adaptive Reflective Middleware Systems (ARMS)** program is focusing on the total ship computing environment that is used in the DDG-1000 Future Surface Combatant family of ships and associated network-centric DoD systems. The program created a fully flexible computing system and information architecture that executes all tasks and mission applications, optimized regardless of the health and status of individual computers, thereby allowing computing workload to be adjusted dynamically as mission needs evolve. The program will develop automated certification technology that will deliver assured deployment of dynamically managed computing systems.

The goal of the **Advanced Speech Encoding (ASE)** program is to achieve an order-of-magnitude reduction of bit rates over current state-of-the-art voice encoders in noisy military environments. Such a reduction will significantly decrease the probability of detection of transmitted signals and will also decrease the required transmit energy, thereby increasing battery lifetime. ASE will pursue two novel approaches. One builds on multiple, noise-immune sensors that have been combined with coding algorithms to achieve significant improvements in intelligibility and quality in harsh noisy environments. The second extracts laryngeal and sublingual muscle signals that are produced when a person generates sub-vocal speech to provide a revolutionary capability in situations where stealth is of the utmost importance, or in situations where acoustic signals cannot be used, such as under water.

The **Chip Scale Atomic Clock (CSAC)** program aims to demonstrate a low-power, chip-scale atomic-resonance-based time-reference unit with stability better than one part per billion in one second. Possible uses of this technology include a time reference unit that can be used to maintain networks when the time signal from a global positioning satellite is not available.

The **Control-Based Mobile Ad Hoc Networks (CBMANET)** program will develop an adaptive networking capability that dramatically improves performance and reduces life-threatening communication failures in complex communication networks. CBMANET will exploit recent optimization-theoretic breakthroughs, recent information-theoretic breakthroughs, and comprehensive cross-layer design to develop a "network stack" from first principles with specific attention to DoD applications, such as multicast voice and situation awareness.

The **DARPA Future Information Assurance Initiatives** will identify promising technologies to push the state of the art for information assurance. Included in this initiative is the development of secure, efficient network protocols to exploit tomorrow's network-centric technologies, such as networked weapons platforms, mobile ad hoc networks, and end-to-end collaboration.

The **Defense Against Cyber Attacks on Mobile Ad Hoc Network Systems (DCAMANETS)** program researched, prototyped, and evaluated defenses that sensed failures and attacks on military tactical wireless networks and auto-reconfigured in real-time to provide continuous service of mission-critical activities. The next step of the program will be to develop an intrinsically assurable mobile ad hoc network to directly support the integrity, availability, reliability, confidentiality, and safety of mobile ad hoc network communications and data.

The goal of the **Defensive Autonomous Systems** program is to develop novel software that allows the military to more closely monitor and identify remotely-controlled computers (bots) and bot slaves within military and government networks, as well as increase the monitoring capability of our defenders.

The **Disruption Tolerant Networking (DTN)** program is developing network protocols and interfaces to existing delivery mechanisms to provide high-reliability information delivery using communications media that are not available at all times, such as low earth satellites, unmanned air vehicle over-flights, orbital mechanics, etc. The program is developing a single model for bundling information and ensuring its delivery, through a series of episodic communications links, from generator to user.

The goal of the **Dynamic Quarantine of Computer-Based Worms** program is to develop defenses for U.S. military networks against large-scale malicious code attacks, such as computer-based worms, by developing the capability to automatically detect and inoculate DoD networks against never-before-seen computer-based worm attacks.

The objective of the **Intrinsically Assured MANETs** program is to develop an intrinsically assurable mobile ad hoc network (IAMANET), which will directly support integrity, availability, reliability, confidentiality, and safety of mobile ad hoc network (MANET) communications and data. The broad objectives of the IAMANET program are to address internet-paradigm problems and related challenges such as: increasing the probability that bad behavior will be detected; increasing work factor and uncertainty for an adversary; and explicitly identifying a minimal set of critical components that must be evaluated and protected from life cycle attacks.

The goal of the **Malicious Network Mitigation** program is to reduce malicious networks, which are now the largest threat facing the Global Information Grid (GIG) and the internet. There are currently three to four times as many networked remotely-controlled computers (bots) as there are hosts on the GIG, which represents a significant denial-of-service threat that cannot be addressed by hardening the GIG alone. In order to maintain awareness and defend against attacks from bot networks, we must automate the tools we currently use to monitor and mitigate them. Operational goals of this botnet mitigation system include the ability to detect, reverse engineer, and remediate botnets with over 99 percent accuracy and within minutes of detection.

The **Micro-Beam Clock** program will extend the accuracy of Chip Scale Atomic Clock (CSAC) by exploiting the precision of nuclear particle transport. Major innovations in the miniaturization of conventional beam clocks are possible due to microscale implementation: microscale xenon atom sources, micromachined permanent magnets, and micromechanical atom flux detectors. This approach will not only improve the stability over the existing Chip-Scale Atomic Clock, but will further reduce the required power. Such a compact, low-power, atomically precise clock will enable time-dependent secure communications systems to operate in the presence of jamming.

The **National Cyber Range (NCR)** will provide an environment for realistic, qualitative and quantitative assessment of potentially revolutionary cyber research and development technologies. The range must be capable of testing a variety of technological thrusts. The goal of the NCR is to enable a revolution in the Nation's ability to conduct cyber operations by providing a persistent cyber range with many capabilities.

The prevailing method for securing information transmitted across DoD and Intelligence networks is through the use of end-to-end encryption, which requires frequent secure distribution of encryption keys across the network. Quantum key distribution could offer this capability across the network, resulting in enhanced security from eavesdropping, code-breaking, and spoofing. The objective of the **Quantum Key Distribution over Wide-Area Fiber Optic Networks** program is to develop an end-to-end quantum key distribution capability that works over a wide-area fiber-optic network, with the goal of demonstrating this capability experimentally over an existing DoD wide-area test network.

Rootkits are software tools intended to conceal running processes, files, or system data from the operating system. The **Rootkit Detection** program will assess the current and emerging state-of-the-art rootkit technology, detection, and mitigation in the context of the DoD. This program will establish knowledge of future rootkit trends and detection mechanisms, and will address the growing threat of rootkits to DoD information technology systems and networks. Goals include identifying trends in rootkit developments, anticipating next generation threats, and developing advanced detection and mitigation techniques.

The goal of the **Scalable Network Monitoring (SNM)** program is to provide new approaches to network-based monitoring that provide maximum coverage of the network (i.e., from the gateway down) with performance independent of the network size and computational costs that remain a constant (or decreasing) fraction of the computational power of the total network being defended. This technology will provide gateway-and-below (i.e., providing approximately 100 percent coverage) network traffic monitoring approaches that scale no more than linearly with network size. The end deliverable of this program will provide network defense technologies with performance capabilities orders-of-magnitude better than conventional approaches.

The **Self-Regenerative Systems (SRS)** program is designing, developing, demonstrating and validating architectures, tools, and techniques for fielding information systems capable of adapting to novel threats, unanticipated workloads, and evolving system configurations. The program will employ innovative techniques like biologically-inspired diversity, cognitive immunity and healing, granular and scalable redundancy, and higher-level functions such as reasoning, reflection and learning to make critical future information systems more robust, survivable and trustworthy. SRS will also develop technologies to mitigate the insider threat, and SRS-enabled systems will be able to reconstitute their full functional and performance capabilities after experiencing accidental component failure, software error, or a cyber attack.

The goal of the **Situation-Aware Protocols in Edge Network Technologies (SAPIENT)** program is to exploit attributes of human cognition, such as learning and self-improvement, to enable networks to recognize and automatically respond to situations encountered in tactical military networks, e.g., weak signals, propagation obstructions, message priorities, and security requirements. Technology developed in the SAPIENT program will have military utility wherever tactical communications are deployed.

Spread spectrum communication technology significantly improves security against a variety of network attacks and identification profiles by spreading energy over a broad bandwidth, thereby providing an adversary with a signal that is both difficult to detect and jam. The **Spread Spectrum Networking** program expands these same goals by addressing not just the physical layer, but also the entire network stack. Similar to frequency-hopping spread spectrum, this program will develop and demonstrate algorithms that provide hopping between internet protocol addresses, and then expand to hopping between different permutations of layer one to three protocols.

The goal of the **System for Planning Information Operations and Nonkinetic Effectiveness (SPINE)** program is to develop: (i) measurement techniques to quantify the effectiveness of Information Operations (IO) weapons; and (ii) a planning system to give the combatant commander the ability to determine which combination of kinetic or non-kinetic weapons they should use during operations. SPINE seeks to: (i) improve operational effectiveness, operational tempo, tool performance, and tool development; (ii) decrease training requirements; (iii) enable scalable operations not possible today; and (iv) demonstrate the full potential of IO capabilities.

The goal of the **Trustworthy Systems** program is to provide foundational trustworthy computer platforms for DoD. This program seeks to develop technologies such as novel computer processing architectures, hardware, firmware, or microkernels to guarantee network and workstation security, and will initially focus on network-based monitoring approaches that provide maximum coverage of the network with performance independent of the network size. This technology will protect Defense systems from a wide range of software problems, ranging from worms and Trojan horses, to bug-ridden software.

The **Wide Area Network (WAN) Monitoring** program seeks to develop distributed network monitoring capabilities and devices that can be used to identify, characterize, enable, optimize, visualize, and protect the WANs that compose the DoD enterprise Global Information Grid (GIG). This program will develop advanced capabilities to monitor the WANs to detect malicious behavior, routing problems, or compromised mission capability. Program goals include improved detection and false-alarm performance over conventional intrusion detection systems, and scalability to the larger networks.

Detection, Precision ID, Tracking, and Destruction of Elusive Targets

For many years, the Department of Defense has steadily improved its ability to conduct precision strike against both stationary and moving ground targets. America's adversaries have realized that, if they are to survive the United States' superior precision strike capabilities, they either have to move, hide, or "blend-in" in cluttered environments.

DARPA is responding by assembling sensors, exploitation tools, and battle management systems to rapidly find, track, and destroy forces that operate in difficult terrain such as mountains, forests, and swamps; ground troops that abandon open country for more defensible urban terrain; and insurgents whose whole organization – finance, logistics, weapon fabrication, attack – is embedded in civilian activities.

To do this, we must seamlessly layer surveillance and battle management systems using a network of platforms that provide both capable sensors and effective weapons. We are developing radars that can scan wide areas of open or forested terrain and laser detection and ranging (LADAR) sensors to obtain high-resolution, three dimensional imagery of potential targets. We are exploiting video, in all regions of the spectrum, to track elusive targets as they move around. By networking them together, and coordinating their movements and tasking, we can achieve wide area coverage, high resolution, high frame rates and high revisit rates. And we can achieve significant persistence by focusing this capability when and where it is needed.

The research includes three general areas:

- **Sensors to Find Targets**;
- **Sensor Exploitation Tools** to identify and track targets; and
- **Battle Management Systems** to plan and manage the use of sensors, platforms, and weapons throughout the battlespace.

Sensors to Find Targets

The goal of the **Adaptive Focal Plane Arrays (AFPA)** program is to demonstrate high-performance focal plane arrays that are widely tunable across the entire infrared spectrum, thus enabling "hyperspectral imaging-on-a-chip." The program will also allow for broadband forward-looking infrared imaging with high spatial resolution.

The objective of the **Advanced Sensing Technologies** program is to enable revolutionary advances in sensing capability. The program will emphasize radical concepts that may contain high technical risk but, if enabled, would have commensurate high military payoff. Technical topic areas include: assured command, control, and communications; intelligence preparation of the battlesphere; and asymmetric lethality.

The **Autonomous Real-time Ground Ubiquitous Surveillance – Imaging System (ARGUS-IS)** (formerly Advanced Optical Sensing (AOS)) program will develop the next generation of airborne optical surveillance systems, while also developing and demonstrating the ability to obtain very high dynamic range, high resolution hyper-spectral, and polarimetric information from airborne imagers. The program will develop advanced digital signal processing to support onboard image reconstruction, atmospheric correction, and system calibration.

The goal of the **Close Air Support Technology for Loitering Engagement (CASTLE)** program is to develop alternatives to current, manned systems, and explore approaches to provide persistent on-demand overhead fire support with gunship-like precision, tailored lethal effectiveness, and unit-directed responsive command and control.

The goal of the **Combat Laser Infrared Countermeasure (IRCM) Proactive Survivability System (CLIPSS)** program is to enable air dominance at low altitude and at night against current and near term near infrared and mid-wave infrared based threats, including man portable air defense, by demonstrating an initial, integrated proactive and reactive IRCM pod-based flight system that addresses shorter-range, high duty cycle threats for vulnerable low altitude platforms in the near-mid infrared wavebands. CLIPSS will provide a near-term demonstration and transition of this proactive capability and serve as a pathfinder for the longer range, all-band objectives of the Multifunction Electro-Optics for Defense of U.S. Aircraft (MEDUSA) program by providing U.S. aircraft the same ability to geolocate, evade, jam, or destroy optically based air defenses. This would evolve U.S. capabilities from reactive end-game countermeasures to proactive capabilities that increase threat-warning times, deny launch and put electro-optical/infrared air defense threats at risk.

The goal of the **Dual Beam Lynx** program is to enhance the capabilities of the Lynx radar system to track slow-moving vehicles more accurately. The program will modify a Lynx I radar to create two beams with different phase centers, and will use space time adaptive processing to detect moving targets in the main beam clutter. The objectives of this program include improving minimal detectable velocity, geolocation accuracy, and achieving low manufacturing cost.

The goal of the **Forensic Target Motion Analysis** program is to develop and demonstrate exploitation tools to analyze ground moving target indicator radar tracks of multiple targets to separate militarily-interesting target movement (e.g., infiltrators, envelopments, defensive site preparation, logistics support) from nominal background traffic (e.g., civilians, coalition operations). The program will develop libraries of movement patterns, logic to generate hypotheses about which patterns are being observed, algorithms to correlate sensor data to those patterns, and mechanisms to quantitatively score the consistency of the data with each hypothesis. It also includes tools to provide short-term (five- to ten-minute) predictions of target motions, thereby supporting some forms of predictive threat analysis.

The **Geiger Mode Avalanche Photodiode (GmAPD)** program will assist the technology transfer for the production of high-speed, ultra sensitive photodetectors to systems requiring operation at very low photon counts. This will support long range sensors that can detect highly obscured targets under canopy/camouflage.

The **Glowing Path** program will develop material in an aerosol form that possesses unique detectable characteristics that can be applied unobtrusively on various surfaces (such as soil, metal, concrete, and others). This system will directly address the challenge of developing a way to provide automatic and immediate detection of change. The concept underlying the project is to create an artificial homogeneous surface that is not visible to an adversary, and in which any change in the homogeneity can be discovered and reported.

The goal of the **Hemispherical Array Detector for Imaging (HARDI)** program is to exploit the benefits of a hemispherical imaging surface by fabricating a million pixel detector array on a hemispherical substrate with a one centimeter radius of curvature using organic semiconductors and novel fabrication strategies. HARDI will combine this array with a single lens to produce a wide 120 degree field-of-view, small form factor camera for the visible-near-infrared-shortwave infrared bands.

The **Integrated Sensor is Structure (ISIS)** program is developing a sensor of unprecedented proportions that is fully integrated into a stratospheric airship for persistent wide-area surveillance, tracking, and engagement for hundreds of time-critical air and ground targets in urban and rural environments. ISIS is achieving radical sensor improvements by melding next-generation technologies for enormous lightweight antenna apertures and high-energy density components into a highly integrated, lightweight, multi-purpose airship structure – completely erasing the distinction between payload and platform.

The **Large Area Coverage Search-while-Track and Engage (LACOSTE)** program will enable persistent tactical-grade ground moving target indication (GMTI) in dense urban areas. The LACOSTE program will provide wide area surveillance, simultaneous tracking, and target engagement with optical and infrared sensors for tactical GMTI operations by developing a sensor with a very wide field of regard (90-degree cone angle), and a wide instantaneous field of view that is rapidly scanned in a search-while-track mode – tracking up to 10,000 targets in an urban area. Additionally, the LACOSTE sensor will provide next-generation precision tracking to enable engagement on a large number (of the order of 100) targets in dense urban areas within that same field of regard, with a minimal penalty on the search-mode area coverage rate.

The **Laser Geospatial Referencing (LGR)** system will allow ground troops to designate targets for engagement by air forces where the pilot or unmanned air vehicle operator can see the designated spots within the field of view of their visible or forward looking infrared system. LGR would provide nearly instantaneous target location, identification, and designation capabilities to weapon platforms supporting urban or other ground operations, enabling these assets to be immediately directed by dismounted Soldiers. LGR technology could dramatically reduce the time required for targeting existing firepower in the form of man-portable missiles, light armor, tanks, artillery and ground attack aircraft.

The **Lasers Through Clouds** program will use wideband ultrashort pulses to enhance laser propagation through clouds. Recent analysis by Air Force Research Laboratory/HEX suggests algebraic vice exponential attenuation of transient-like electromagnetic pulses. If this is correct and can be successfully implemented, this would allow laser applications at ranges and in environments precluded today.

The **Multifunction Electro-Optics for Defense of U.S. Aircraft (MEDUSA)** program will develop the technologies and systems to give the U.S. air dominance at low altitude and at night. These technologies will leap-frog reactive end-game countermeasures and enable increased threat warning times, denial of launch, and put electro-optic/infrared air defense threats at risk.

The **Multipath Exploitation Radar (MER)** program will address radar deficiencies due to discontinuous bandwidth, including reduced range coverage, denial in certain geographic regions, interoperability issues, and reduced range resolution. This will involve a system-wide redesign of radar optimized over the full radio frequency spectrum, not individual stove-piped tasks, and will integrate sparse bandwidth returns (including passive signals of opportunity), adaptive transmitter and waveform diversity, and agile frequency-diverse hardware. MER will exploit multipath bounces to detect and track moving targets within urban canyons, and extend the area coverage rate of airborne sensors by a factor of ten or more over physical line-of-sight limits. If successful, the urban coverage improvement could enable cost-effective airborne surveillance of an area the size of a large metropolitan region using a handful of airborne sensors.

The **Networked Bionic Sensors for Language/Speaker Detection** program will develop and demonstrate low-power micro-sensor devices and networks for language/speech detection and recognition processing to detect voice activity, including speaker identification in villages known to be insurgent recruitment "hot-spots." The system will use ultra-low power signal conditioning/processing front-end processors with language/speaker recognition algorithms for distributed sensor network applications in the battlespace. Networked bionic sensors will be able to make detections within meters from the target, providing high signal-to-noise ratio with sufficient recognition performance in an urban (non-telephonic) environment. This program will provide the ability to discretely monitor buildings, human presence detection/tracking in other sensitive areas, enable force protection, and provide battle damage information.

The **Next Generation RF Antenna System** program will develop and demonstrate an ultra-sensitive radio frequency (RF) receiver made from lightweight, non-reciprocal materials for precise direction and frequency sensing, tunable over a broad frequency range. This system will enable signals intelligence at extended ranges by detecting faint or distant signals with accurate incident angle and frequency determination, and will provide improvement over existing amplifiers and antenna systems.

The **Polar Bear** program will provide a missile seeker that uses polarimetric processing and three-dimensional registration with target folders to generate precision terminal guidance. The system will enhance target identification capabilities and enable precision aim-point selection on the target by sensing polarimetric long-wave infrared signals generated by target and background, deriving the surface shapes of the target and background, and matching the target shape to three-dimensional target folders. The precision potentially attainable by Polar Bear would be suitable for a kinetic-kill weapon, and the sensor cost would be comparable to existent uncooled infrared missile sensors.

The goal of the **Rapid Eye** program is to develop a high-altitude, long-endurance, unmanned aircraft that can be rocket-deployed from the continental United States world-wide within one to two hours to perform intelligence, surveillance, reconnaissance (ISR), and communication missions. Rapid Eye will provide decision makers rapid-reaction ISR and persistent communication capability for emerging situations.

The goal of the **Remote Detection of Suspicious Vehicles (RDSV)** program is to develop and demonstrate an ultra low-cost, unattended ground sensor (UGS) network with long radio frequency communication ranges and specialized algorithms.

The RDSV UGS system provides vigilance in urban and rural operations at a low cost, and features a unique high radio frequency link margin that permits signals to be transmitted between buildings and walls to command and control radios, including UAVs. The results of this effort will provide the tactical warfighter the ability to detect activities of interest and determine appropriate courses of action to minimize loss of life and assist in mission accomplishment.

The **Retro-directive Ultra-Fast Acquisition Sensor (RUFAS)** program will design, construct, and demonstrate an X-band noise-correlating radar with a retrodirective antenna. This effort will research and develop a new type of radar sensor based on the correlations of the Gaussian noise received by an antenna array from a small object located in the far field of the antennas and the retrodirective re-radiation of the correlated noise. Combining and tailoring noise correlating interferometry and retrodirective antenna arrays into retrodirective noise-correlating radar will allow the radar to operate in omnidirectional search mode, which would enable a new type of search-mode radar having promising performance in terms of short acquisition time and low probability-of-intercept.

The **Scalable MMW Architectures for Reconfigurable Transceivers (SMART)** program is developing an integrated, surface-emitting panel architecture for millimeter wave (MMW) transceiver arrays. SMART will culminate in a demonstration of a large (at least 400-element), coherent, active electronically steerable array achieving an output power density of five watts per square centimeter, and a total layer thickness of less than one centimeter Taken together, these values would represent a vastly greater "functional density" (e.g., power density, expressed in watts per cubic centimeter) than achievable with current MMW architectures, without compromising performance in other areas (e.g., receiver noise figure).

The goal of the **Sensing and Exploitation of Urban Movers (SE-UM)** program is developing technology for the detection of dismounted troops in combat situations using airborne radars. SE-UM is developing the capability to detect, classify, track and recognize the behavior of human beings using radar data. Specifically, SE-UM will exploit these data by detecting each individual, classifying the individual as human and according to speed and gait, tracking many individuals (forward and backwards in time), and automatically recognizing common, anomalous and significant actions/behaviors.

The **Short Wave Infrared through Fog (SWIF) and Clouds** program will develop and demonstrate advanced signal processing and optical imaging technology to allow detection of collision and grounding threats in fog and clouds at useful ranges (day , or night). Fog substantially degrades performance in precision handling operations. Humans are able to operate successfully with sensor assistance, but situational awareness degrades significantly with fog. Successful development of this technology will restore this situational awareness to tactically relevant distance and time scales.

The **Spatially Processed Image Detection and Ranging (SPIDAR)** program is a coherent imaging method that allows one to form a large effective optical aperture from a set of smaller, lighter telescopes, providing for very high-resolution three-dimensional and two-dimensional ladar imagery of distant targets with a compact system configuration. SPIDAR's capability would be very well suited for long-range engagements from airborne or space-based platforms, and could significantly enhance the current synthetic aperture imaging approaches by providing the desired cross-range resolution along the axis perpendicular to the direction of travel.

Laser speckle has reduced sensitivity to adverse turbulence-induced distortion and offers the potential of providing a viable signal at ranges exceeding those projected for other active laser systems. The goal of the **Speckle Exploitation for Enhanced Reconnaissance (SEER)** program is to provide long-range, non-cooperative identification of moving/stationary targets using incoherent scattered laser speckle reflected off a target surface. By extending the operating range of current active electro-optic sensors, SEER will enable friendly platforms to stand off beyond the maximum operating range of hostile sensors/weapons, while performing targeting and directing weapons against targets.

The **Standoff Precision ID in 3-D (SPI 3-D)** system will provide commanders with significantly improved long-range identification of enemy ground targets, as well as targeting information to support coordinate guided weaponry. Employing optics and focal plane arrays and gimbals combined with a novel Pockels cell range measurement technique, the program is developing an affordable sensor package capable of high-resolution three-dimensional images for confirmatory target identification at long ranges (greater than 10 kilometers).

The **Synthetic Aperture Ladar for Tactical Imaging (SALTI)** program is developing and demonstrating an airborne synthetic advanced laser radar (ladar) imager capable of producing high-resolution, three-dimensional imagery at long ranges. The SALTI approach combines the long-range day/night access afforded by conventional synthetic aperture radar with the interpretability of high-resolution optical imagery and the exploitability of three-dimensional imagery, for deployment within a tactical-sized package. The technical objective of the SALTI program is to provide a proof-of-concept for operation at tactically relevant altitudes and ground ranges.

The goal of the **Ultra-Wide Band Multi-Function Photonic Transmit and Receive (ULTRA T/R) Modules** program is to develop a wideband microwave antenna interface and corresponding antenna elements that would replace the conventional electronic transmit and receive module-antenna combination, and offer multiple modes of operation (e.g., simultaneous transmit and receive, or switched mode) with fiber interface to/from either digital or analog beamformer at significantly reduced size, weight, and power.

The **Vehicle and Dismount Exploitation Radar (VADER)** program will develop an airborne radar and an exploitation system that uses the radar return to detect, track and classify ground moving vehicles and dismounts with high reliability. The radar will be deployed as a wing-mounted pod on the Extended Range MultiPurpose Warrior and will be demonstrated in this configuration.

The **Wide Band Gap Semiconductor Electronics for RF Applications (WBGS-RF)** program is developing high-performance, cost-effective high-power electronic devices that exploit the unique properties of wide band gap semiconductors. This program seeks to develop monolithic microwave integrated circuits (MMICs) for emitting high-power microwave and millimeter-wave radiation.

SENSOR EXPLOITATION TOOLS

The **All Things Repository** program will develop a system capable of ingesting 400 terabytes per day of multisensor all-source imagery, moving target indicator data, and signals. The program will build a fully automated metadata and features extraction framework to process all incoming data, and it will develop the distributed, very large database technologies required to provide both the raw sensor data and extracted features data to a multi-level exploitation user community, which consists of both human users and automated agents.

The **All-Source Target Characterization** program is developing a collection and measurement capability to characterize new targets as they emerge on the battlefield. The program is developing tools to permit rapid user interaction with imagery, sensor data, and processing results, and provides real-time feedback to operators indicating target key features and other discriminates.

The **AudiVis** program seeks to extract high-rate (greater than kilohertz) temporal data from a foveated vision infrared sensor to optimize data processing at the pixel level, including data fusion in real time at the pixel level. This approach goes well beyond foveated vision and bandwidth sensor compression concepts by enabling a low-light sensor to not only act as an intelligent cueing device but also to shift to a high frame rate mode. A networked array of these high-frequency capable low light sensors in an urban environment will provide autonomous situational awareness.

The **Boreal** program will develop and demonstrate a rapidly deployed, wide-area surveillance system for detection, tracking, precision location, and engagement of high-value targets under dense foliage. The Boreal system would be installed on a high-flying, fixed-wing aircraft, and would rapidly search large areas for fixed- and moving targets under foliage, providing simultaneous ground moving target indicator (GMTI) and synthetic aperture radar (SAR). The GMTI will detect and locate dismounts and vehicles moving under foliage and the SAR will reveal buildings, vehicles and lines of communications under foliage. The goals of this program include demonstrating real-time onboard wide-area GMTI and simultaneous SAR and achieving precise geolocation (seven to ten meters) of moving dismounts.

The **Dynamic Tactical Targeting (DTT)** program is developing sensor control and data fusion technologies to find, identify, track, target, and destroy mobile, time-sensitive targets. DTT is designing and demonstrating a system that will: (i) leverage existing national/theater intelligence, surveillance, and reconnaissance (ISR) processes for timely extraction of critical data; (ii) fuse organic sensor data with ISR data from all sources to continuously estimate target location, identity, and activity; (iii) dynamically task standoff, organic, and embedded sensors to fill ISR coverage gaps and provide relevant sensor observation in areas of tactical interest; and (iv) process and manage the voluminous data produced by various sensors in time to provide the warfighter information required to prosecute time-sensitive targets.

The **Exploitation of 3-D Data (E3D)** program has developed techniques for rapidly exploiting three-dimensional sensor data. The initial program effort consisted of three distinct processes: target acquisition, target recognition, and modeling. The resulting software tools were integrated into operational ground stations processing three-dimensional sensor data.

The **Hyperspectral Framing** program will develop and demonstrate a system for collecting and processing hyperspectral data operating as a framing sensor, instead of as a line scanner with the constraints of current sensors. The system will accept wide spectral content over hundreds of bands, permitting extremely powerful air- and space-borne reconnaissance for real-time target detection. The resulting sensor and processing system will provide a two to three order-of-magnitude increase in the combination of area coverage rate and resolution, as well as a one to two order-of-magnitude decrease in sensor system size, weight, and power consumption.

The **Integrated Sensing and Processing** program is developing and applying novel mathematical optimization strategies for integrating sensing, processing, and information exploitation functionality in sensor systems to enhance the performance of broad classes of DoD sensor systems and networks.

The **NetTrack** program will extend and improve capabilities for persistent tracking and targeting of moving vehicles from airborne radars. NetTrack will network radars together to gather "signatures" of vehicles and pass them over the radar network. The system will compare vehicle signatures taken before and after confusing events to maintain the track of the target vehicles. Extended long-term airborne radar tracking will be an important long-range, all-weather, capability.

The **River Eye** program will provide a new capability to predict or assess, in real-time, river and estuary conditions to enable special operations mission planning and execution. New techniques will be developed to indirectly determine current speed and direction by remotely sensing advection of scene features. Using advanced modeling techniques, indirectly sensed current data will be used to extract bathymetry data.

The **Tactical Sensor Network Technologies (TSNT)** program developed detection, tracking, identification, and pattern analysis capabilities that operate in all nodes (fixed or mobile) within a networked, distributed, multi-sensor system. TSNT has demonstrated resilience to the failure of any node, while maintaining sufficient consistency to support commanders' collaborative tactical planning.

If a signal is received in the presence of multiple scattering, both the message and the location of the transmitter are revealed. If these signals are stored, they can be mathematically retransmitted to form an image of the transmitter. The goal of the **Time Reversal Methods** program is to develop and extend this novel approach to exploit multiple scattering in order to extract an image of a target from the surrounding clutter.

The **Urban Photonic Sandtable Display (UPSD)** project seeks to develop and demonstrate interactive holographic display of complex volumetric three-dimensional data to replace current three-dimensional visualization technologies that are either static or have limited effective field of view. The UPSD project is developing an affordable three-dimensional display system that operates at full video rate, includes color, supports a wide viewing angle, and increases display size. The result will be the world's first full-motion, three-dimensional imaging technology system.

Battle Management Systems

The **Advanced Ground Tactical Battle Manager** program is developing automated decision support tools for Army and Marine tactical commanders at the division level and below. The tools will elicit skeletal courses of action through a graphical interface with unit commanders, and will extend plans by applying adversarial reasoning techniques to identify vulnerabilities and opportunities in the predicted enemy course of action. The program will also provide support for combined operations employing dismounted Soldiers, manned platforms, and autonomous vehicles.

The goal of the **Increased Command and Control Effectiveness (ICE)** program is to develop and incorporate cognitive systems technology into operational command, control, and intelligence systems within each service. DARPA's cognitive systems programs have been developing the machine learning, reasoning, and human-machine dialogue technologies necessary to create cognitive assistants. This new technology promises to enable information systems to adapt – during deployment, in real time – to the changing conditions that military commanders confront. Information systems will automatically adjust to new environments and new users, helping commanders adapt to evolving situations and priorities, and accelerating the incorporation of new personnel into command operations.

The **Joint Air/Ground Operations: Unified, Adaptive Replanning (JAGUAR)** program will provide dynamic planning tools for complex air campaigns that employ new air platforms featuring precision sensors, precision weapons, and communications relays. JAGUAR will use targeting information (both for sensor targets and for strikes), rules of engagement and procedural constraints, and availability of platforms, weapons, sensors and communications equipment to produce ingress routes, flight schedules, and patrol zones, while assuring airspace and electronic deconfliction.

The **Joint Mission Rehearsal** program is integrating high-fidelity, mainframe-based combat simulations with situation assessment and planning tools to allow rehearsal of joint missions, while participants are en route to operations or remain at their home stations. Visualization systems permit the warfighters to interact with the simulation in a manner consistent with their role in the mission, allowing them to practice and fine-tune mission plans for joint military operations and enabling commanders and staff to participate from their current location instead of a training facility.

The **Network-Centric Situation Assessment** program will develop and deploy technologies to assess military situations at levels of interest above individual targets. The program uses all-source data to reconstruct unit organizations, mission relationships, logistics connections, and communications connectivity, and analyzes data over time to infer movement, communication, and supply patterns. The objective is to understand potential capabilities and intentions of opposing forces by providing greater understanding of opponents' force structures, capabilities, and operational practices.

The **Predictive Analysis for Naval Deployment Activities (PANDA)** program is developing technology to automatically learn normal activity models (motion and emission) for maritime surface vessels, automatically detect anomalous behavior, provide context modeling to resolve known categories of anomalies (e.g., due to weather and business rule changes), and provide alert processing. The resulting technology can be extended and applied to a wide range of applications including ground vehicles, troop movements, and individual targets of interest (e.g., suspected insurgents) as the methods for tracking those targets improve.

The **Predictive Battlespace Awareness** program is developing tools to interactively draw upon a distributed network of human experts, allowing them to collaboratively anticipate an opponent's future actions. The program will enable commanders to pre-position sensors, weapons, and information to counter the opponent's actions – significantly enhancing today's primarily manual, slow, planning and analysis processes.

The **Real-time Adversarial Intelligence and Decision-making (RAID)** program is developing technologies that will help a tactical commander and staff characterize and predict likely enemy courses of action, relate the history of the enemy's performance to its current and future actions, and associate these predictions with opportunities for friendly actions and effects.

URBAN AREA OPERATIONS

Urban area operations can be the most dangerous, costly, and chaotic form of combat. Adversaries seek to fight in urban areas as a way to counter U.S. forces' superior detection and strike capabilities that work so well against fixed and mobile targets in open and semi-concealed terrain. By moving into cities, our adversaries hope to limit our advantages, draw more of our troops into combat, inflict greater U.S. casualties, and cause mistakes that harm civilians and neutrals.

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DARPA programs in Urban Area Operations are aimed at creating technology to help make U.S. operations in cities as effective as operations in non-urban areas by seeking new urban warfare concepts and technologies that would make a smaller U.S. force conducting operations in an urban area more effective, suffer fewer casualties, and inflict less collateral damage.

If successful, these new urban warfare concepts and technologies would enable U.S forces fighting in or stabilizing an urban area to achieve the same or greater overall effect as a larger force using today's technology.

DARPA's Urban Area Operations thrust includes research in:

- **Improved Urban Intelligence, Surveillance, and Reconnaissance** to vastly improve U.S. capabilities to understand what is going on throughout a complex urban environment, including the ability to detect adversaries hiding in buildings and other structures, and to find hidden explosives or WMD.
- **Tagging, Tracking and Locating Capabilities** to persistently monitor targets or equipment of interest; tag, track and locate enemy activities; track and detect weapons fabrication and movement; and precisely discriminate threat from non-threat entities against severe background clutter.
- **Weapons for Urban Operations** to develop ultra-precise, beyond-line-of-sight infantry weapons for use in congested urban areas.
- **Asymmetric Warfare Countermeasures** to develop technology to detect, prevent, or mitigate asymmetric attacks, such as suicide bomber attacks, improvised explosive device attacks, and WMD attacks – including radiological dispersal devices.
- **Pre- And Post-Conflict Capabilities** to model and understand social indicators that precede the onset of hostility and conflict, coupled with tools to develop strategies to stabilize an urban area and assist U.S. civil affairs units.
- **Command, Control, Communications, and Intelligence (C3I) for Urban Warfighting** to develop new approaches to all-echelon C3 and new intelligence analysis tools specifically suited for urban operations that allow warfighters to see and understand what is happening throughout the urban battlespace in real time.

Improved Urban Intelligence, Surveillance, and Reconnaissance

The **Active Electro-Optical Mapping and Navigation System (AONS)** program will provide global positioning system (GPS)-denied navigation and detailed building interior mapping to Soldiers in urban environments. AONS will employ electro-optics for image registration and precision range to track and map a Soldier's position continuously. Using image-flow methods, a compact, power-efficient camera and optional laser radar system will track the imagery from frame-to-frame and estimate camera pose and position information to provide the Soldier a very precise determination of current position, as well as a continuously updated map of the building or underground facility being traversed.

The **Advanced Soldier Sensor Information System and Technology (ASSIST)** program is developing an integrated information system that exploits Soldier-worn sensors to augment the Soldier's ability to capture, report, and share information in the field – capabilities that are vital for enhanced situational understanding and overall operational effectiveness in urban combat and post-conflict stability operations. The system will create knowledge-based representations as an input to an array of products, including augmented maps, situational analysis tools, and query and answer capabilities.

The **Auto Metadata Extractions** program will build a system that automatically (with no person-in-the-loop) extracts metadata from terabytes of multi-sensor imagery and signals per day. Extracted metadata will include both platform-generated information (classical metadata) and algorithmically extracted features and internals. The extracted metadata will be produced in a unified framework, and will be sufficiently rich, semantically, to support both semantic information fusion and multi-dimensional predictive models. The system will provide all of the fundamental extracted data required for advanced exploitation technology development.

The **Brood of Spectrum Supremacy (BOSS)** program will provide actionable situational awareness to the warfighter in complex radio frequency (RF) environments. BOSS makes cooperative use of the computational, communications, and sensor capabilities in a software radio, in aggregate, to generate breakthrough capabilities in the warfighter knowledge of their surroundings, with a particular focus on RF-rich urban operations.

The **Combat Zones That See (CZTS)** program improves the situational awareness, effectiveness, and safety of U.S. military forces in foreign urban environments by providing sensing and extended reconnaissance capabilities using video sensors.

The **Digital Media Exploitation (MEDEX)** program will develop technology to extract intelligence of tactical value from digital media found on computers captured in the field of operations, with goal of reducing the exploitation time for digital media from months to minutes. MEDEX will develop multiple exploitation algorithms that can quickly index, search, and analyze all digital file types, enabling it to automatically search content found on computers captured in the field and identify data of high intelligence value.

The **Exploiting Vibrations to Monitor Activities in Buildings** program will develop procedures and sensors to characterize activity inside structures based on acoustic/seismic information. The types of information sought include number and location of personnel, foot traffic, operation of building mechanicals (e.g., ventilation, cooling, and heating systems, and plumbing) as indicators of human activity, operation of other machinery, door openings and closings, and speech. Algorithms that infer internal layout of the building from the pattern and location of these activities will be investigated, along with fusing surveillance information from other sensors.

The objective of the **High Operating Temperature - Mid-Wave Infrared (HOT MWIR)** program is to develop technology for high-speed sampling and high spatial resolution infrared focal plane arrays that operate in the mid-wave infrared wavelength region without cryogenic cooling. The high sampling speed is required for both threat detection and for imaging from fast moving platforms. Technology goals are to achieve greater than an order-of-magnitude reduction in currents contributing to detector noise in a high density, large area detector array format of up to 1280 x 720 elements.

The **Multispectral Adaptive Networked Tactical Imaging System (MANTIS)** program is developing, integrating, and demonstrating a Soldier-worn visualization system that will provide the warfighter with digitally fused, multi-spectral video imagery in real-time (from helmet-mounted sensors) displayed on a helmet-mounted visor. MANTIS will enable the warfighter to see where the enemy cannot, giving the warfighter the advantage in operations at night and in smoke and fog, and it will provide the warfighter with augmented reality and increased situational awareness.

The goal of the **Seismic/Acoustic Vibration Imaging (SAVI)** program is to develop the capability to locate both near-surface tunnels and landmines with active seismic and acoustic sources. These systems will employ well characterized seismic and acoustic sources to stimulate targets from a remote platform. The interaction of the near-surface seismic waves with tunnels and other objects will be observed with a multi-pixel laser interferometer system, and will be used to assess the depth and extent of the targets in the midst of natural and man-made clutter. Similarly, focused acoustic sources will be employed to remotely stimulate plastic or metal antipersonnel and antitank mines.

The **Smart Dust Sensor Networks Applied to Urban Area Operations** program will provide persistent staring reconnaissance, surveillance, and target acquisition of the three-dimensional urban battlespace using a dense network of ground sensors. The system concept consists of ubiquitous and inconspicuous low-power, small and easily concealed ground sensors distributed throughout the urban landscape. The program includes the development of ultra small sensor nodes for easy deployment and concealment in a crowded urban environment, and data fusion algorithms to exploit the abundance of new information provided by a dense urban spatial network.

The goal of the **Stealthy, Persistent, Perch and Stare (SP2S)** program is to develop the technology to enable an entirely new generation of perch-and-stare micro air vehicles, based on the Wasp platform, capable of: (i) vertical launch; (ii) forward flight to a target; (iii) transition from forward flight to hover; (iv) vertical landing at the target site; (v) secure, stable attachment to its "perch;" (vi) sustained perch-and-stare missions, to include data collection; and

(vii) at mission's end, SP2S would re-launch from the perch and fly home. During perch-and-stare, SP2S would perform surveillance and transmit live video/still images beyond line-of-sight back to the home base, utilizing other low altitude UAVs as relay links, as required. Anticipated service users include the Army, Marines and Special Forces.

The goal of the **Terahertz Imaging Focal-Plane Technology (TIFT)** program is to demonstrate large, multi-element (over 40,000 pixels) detector receiver focal plane arrays that respond to radiation in the terahertz (THz) band. The sensor system will be able to operate effectively at standoff range (over 25 meters) with a high spatial resolution of less than two centimeters, limited only by beam diffraction. The imaging receiver will produce a two-dimensional image in which each pixel records the relative intensity of the THz radiation received on the focal plane within the appropriate section of the field-of-view of the scene being sensed. The program seeks to achieve intensity sensitivities as close as possible to the thermal background limit at room temperature. Size, weight, and electrical power requirements will be consistent with portability.

The **Urban Reasoning and Geospatial Exploitation Technology (URGENT)** program will develop a three-dimensional urban object recognition and exploitation system that enables advanced mission planning and situation analysis capabilities for the warfighter operating in urban environments. The program will develop techniques for the rapid exploitation of electro-optic and lidar sensor data to recognize urban objects in a city.

The **Visibuilding** program is developing technologies and systems for new surveillance capabilities to detect personnel within buildings, to determine building layouts, and to locate weapons caches and shielded enclosures within buildings. Visibuilding is developing techniques to inject and recover probing waveforms and to unravel the complicated multipath in the return signals to enable the mapping and characterization of buildings.

Tagging, Tracking and Locating Capabilities

The goal of the **Handheld Through-Wall Synthetic Aperture Radar (SAR)** program is to provide a synthetic aperture imaging capability of the interior of a room by sweeping a small, handheld system over the face of an exterior wall to create an arbitrarily large (synthetic) aperture that improves the imaging capability by compensating for the physical propagation and dispersion limits of the wall.

The **Networked Embedded Systems Technology (NEST)** program is developing robust coordination services for networks of small, low-power sensor nodes. NEST is building a suite of software services to operate under extreme resource constraints of power, timing, memory, communication, and computation, while simultaneously being highly scalable and robust.

The **Persistent Operational Surface Surveillance and Engagement (POSSE)** program is creating a system of systems framework in which a mix of surveillance assets, both operational and developmental, can be coordinated and exploited to yield persistent surveillance of insurgent activities. The program focus is on the Iraqi theater, using a spiral approach designed to insert enhanced counter-insurgency capabilities into operational use as soon as possible, followed by improvements and enhancements as they become integrated through a domestic testbed.

The **Radar Scope** program is a quick-response effort to provide pre-production prototypes of a hand-held through-wall personnel detection radar. Radar Scope will be able to sense through common wall materials to detect potential enemies before warfighters enter a room or building. The final product will be a small sensor with a simple interface that will weigh less than two pounds, including batteries. The unit will detect individuals through typical non-metallic wall materials (e.g., concrete, concrete block, adobe, wallboard, plywood, etc.) up to twelve inches thick.

The **Rescue Transponder (RT)** program will investigate the use of a unique localization and tracking technology to provide a very low probability of detection call-for-help signal. The system is expected to use a wide band radio frequency signal with low power and extremely low duty cycle. The goals of the RT program are to develop a small, rugged, transponder that provides a call-for-help to friendly forces. The RT system will operate over ranges that enable rescue forces or surveillance systems to receive its signals. It will support accurate localization by rescue forces, and permit transmission of identifying, authenticating, and status information.

The objective of the **Unique Signature Detection** (formerly Odortype Detection) program is to determine whether there are unique signatures in emanations that can be used to identify and distinguish specific high-level-of-interest individuals within groups of enemy troops or combatants, and, if so, to develop enabling technology for detecting and identifying those specific signatures. Once the nature of a chemosignal has been characterized, performers will determine the impact of non-genetic factors (e.g., diet, stress, health, age) on the signal to determine whether it can be robustly extracted from a complex and varied chemical background. If an exploitable, robust signature is identified, the program will develop a detector.

The **Video Verification and Identification (VIVID)** program is developing technology to automate moving target strike operations for remotely piloted aircraft to support both precision strike operations and military surveillance. VIVID will enable the handoff of targets between wide area coverage intelligence, surveillance, and reconnaissance systems and local video surveillance platforms. The technology will provide techniques for precision target identification in video, including fingerprinting techniques and related technology to permit reacquiring previously observed vehicles.

WEAPONS FOR URBAN OPERATIONS

As part of the High Precision Long Range Laser Designator/Locator (HPLD) program, the goal of the **All Weather Sniper Scope (AWSS)** program is to develop a sniper sight that enables shooters to see through fog and haze for increased accuracy and lethality in low visibility conditions. This program will investigate infrared imaging and advanced on-focal-plane processing technology to achieve revolutionary improvements in form factor, speed, cost and accuracy.

The **Close Combat Lethal Recon (CCLR)** program is developing an agile, low-cost, expendable loitering weapon/unmanned air vehicle for deployment in urban environments that can be used against non-line-of-sight targets. The guided munition will be capable of striking targets from significantly expanded avenues of approach, e.g., over the tops of buildings and around corners from a distance of up to ten blocks, depending upon the specific terrain and buildings.

The key objective of the **Crosswind Sensor System for Snipers (C-WINS)** program is to enable snipers to accurately hit targets with the first round, under crosswind conditions, at the maximum effective range of the weapon. For this purpose, the system developed must provide a measure of downrange crosswind (wind) and range to target. This information will then be used compensate the bullet trajectory to offset crosswind and range related deviations of the bullet, resulting in substantially increased probability of success.

The **EXtreme ACcuracy Tasked Ordnance (EXACTO)** (formerly Laser Guided Bullet) program will develop and demonstrate a maneuvering bullet that follows a laser beam to an intended target. Program technology development includes the design and integration of aero-actuation controls, power sources, and laser sensors into a limited volume (two cubic centimeters) projectile to withstand a high acceleration environment. When integrated and tested, this system will make every shooter with any 50-caliber weapon a precision sniper at greater than two-kilometer range.

The **Guided Projectiles** program is developing and demonstrating highly maneuverable gun-launched projectiles, and associated fire control and launch systems, for employment against critical enemy infrastructure and point targets, such as command, control and communication nodes and radars. This program will develop enabling technologies to give U.S. warfighters the ability to allow weapons platforms, such as mortars, to receive updated target information from other munitions or sense target changes on their own. This program will leverage innovative low-cost optical seeker technology to develop an affordable fuse-guidance package that converts a conventional 81-millimeter or 120-millimeter mortar round into a precision-guided munition. And the program will further extend this development to the development of laser-guided munition systems wing-dropped from tactical UAVs and guidable from the on-board laser designator to any target within the field of view of the designator.

The goal of the **High Precision Long Range Laser Designator/Locator (HPLD)** program is to develop an affordable laser target designator/locator that allows the user to observe, track, and designate a target at operationally significant ranges. The focus of this effort is to develop new target-in-the-loop active optics approaches and novel, high-accuracy pointing methods to enable a single operator to precisely determine the global positioning system coordinates of a target that is several kilometers away. Once precisely determined, the operator will be able to observe, track, and laser-designate the target using a single device.

The **Magneto Hydrodynamic Explosive Munition (MAHEM)** program will demonstrate magnetohydrodynamically formed metal jets and self-forging penetrators with significantly improved performance over explosively formed jets and fragments for precision strike against targets such as armored vehicles and reinforced structures. MAHEM could be packaged into a missile, projectile, or other platform and delivered close to the target for final engagement and kill for stressing missions such as: lightweight active self-protection for vehicles (potential defeat mechanism for a kinetic energy round); counter-armor (passive, reactive, and active); mine countermeasures; and anti-ship cruise missile final-layer-of-defense.

The **Scalable Precision Strike (SPS)** program will leverage the innovative low-cost optical seeker technology from the Optically Designated Attack Munition program to develop an affordable fuse-guidance package that converts a conventional 81-millimeter or 120-millimeter mortar round into a precision-guided munition with a 1-3 meter circular error probable accuracy. SPS will further extend this development to the development of laser-guided munition systems wing-dropped from Class III/IV unmanned air vehicles and guidable from the on-board laser designator to any target within the field of view of the designator.

The **Super-Resolution Vision System (SRVS)** program will develop and build a field prototype Soldier-portable optical system with target recognition and identification range significantly improved over existing systems. SRVS will exploit an atmospheric turbulence-generated micro-lensing phenomenon to generate better-than-diffraction-limited images. Through enhanced resolution imaging, SRVS will: (i) extend target recognition and identification to decisively longer distances; (ii) overcome atmospheric turbulence, which now limits the resolution of current optics; and (iii) increase target identification confidence to reduce fratricide and collateral damage.

Asymmetric Warfare Countermeasures

The **Asymmetric Materials for the Urban Battlespace** program is investigating a novel class of materials that, either by themselves or as part of a system, provide asymmetric capabilities in visible signatures, ballistic/fragment/blast protection, and personnel transport. Friendly forces will be able to see through this material and shoot through it, but hostile forces will not. Asymmetric, or "one-way," materials will support basic unit operations such as raids, cordon and search activities, snap checkpoints, and fire fights.

The goal of **Compact Directional Neutron Source/Phase II** is to develop a soldier portable neutron interrogation system for the standoff detection of improvised explosive devices and highly enriched uranium.

The **Concealed Weapons Detection** program will explore phenomenologies for detecting concealed weapons. Imaging-based approaches will be developed using an integrated silicon-based antenna array receiver device to produce whole radar arrays on a single die. Alternative sensor approaches are also being explored to provide a multi-mode, multi-sensor solution targeted at improved discrimination, incorporating x-ray, terahertz, and millimeterwave radar to provide multispectral tomographic capability.

The goal of the **Counter Improvised Explosives Laboratories (CIEL)** program is to develop the infrastructure and methodology for novel chemo-sensors that will identify labs that are building improvised explosives with a very high degree of specificity and reliability. CIEL will also develop the infrastructure and tools for safe handling of improvised explosives and their mixtures.

The **Crosshairs** program seeks to develop a vehicle mounted threat detection and countermeasure system that will detect, locate, and engage shooters, and defeat a variety of threats including bullets, rocket propelled grenades, anti-tank guided missiles, and direct fired mortars, both while stationary and moving. Threat identification and localization will be done in sufficient time to enable both automatic and man-in-the-loop responses.

Based on promising results obtained under the Crosshairs program, the **C-Sniper** program will develop the capability to detect and neutralize enemy snipers before they can engage U.S. Forces, with the goal of delivery of a field testable prototype suitable for experimentation as an integrated part of the DARPA Crosshairs system. The C-Sniper system will operate day and night from a moving military vehicle and provide the operator with sufficient information to make a timely engagement decision.

The **DARPA Hardwire Armor Development** program is pursuing a lightweight composite armor that uses the steel wire reinforcement found in steel-belted radial tires. If successful, this novel material could be a moldable, low-cost, easily manufactured, lower-weight alternative to conventional steel armor, while providing the same or greater protection to our warfighters. Initial ballistic tests on these new materials have demonstrated significant advantages of this system.

Explosively Formed Projectiles (EFPs) have become the "threat of the future" for insurgent forces as they can penetrate all of today's armored vehicles, including tanks. Since EFPs penetrate largely by virtue of their momentum, they are not susceptible to simple forms of reactive armor. The objective of the **Defeat of Explosively Formed Projectiles (DEFP)** program is to develop a new generation of "smart armor" that combines sub-millisecond sensing and processing with directable explosively driven counter-EFP devices to counter EFPs. This armor would reduce, re-direct, and disperse the penetrating elements of the EFP to a point such that the base armor of a Bradley Fighting Vehicle would not be perforated. DEFP seeks to provide this capability at an added weight of less than 40 pounds per square foot.

The goal of the **Dielectric Detection of Explosives** program is to develop a system for the detection of explosives in urban operations by measuring low frequency dielectric spectral signatures through clothes, walls, and other non-metallic surfaces. Depending on the size of the sensor system, these signatures can potentially be measured at ranges up to several meters to enable portal defense applications, vehicle inspection, and even monitoring of explosive materials through walls.

The **Effects Based Network Targeting** program is developing technology to identify, determine vulnerabilities in, target, and anticipate workarounds in enemy networks. An aim is to elicit operational objectives for urban interventions, expressed in terms of desired and undesired effects. The technology will use these objectives to find vulnerabilities in the networks and then nominate targets to maximize desired effects, while minimizing undesired effects. In particular, the program will focus on radio frequency networks: identifying transmitters, receivers, and links between them.

The **Explosively Formed Projectile Armor (EFPA)** program will develop technologies to protect military vehicles from EFP weapons at significantly reduced weight compared to existing systems, using both passive and reactive elements in innovative material systems.

The goal of the **Human-carried Explosive Detection Stand-off System (HEDSS)** program is to develop a system that can rapidly identify human-carried explosives (HCEs) at a stand-off range between 50 and 150 meters. While alternative technologies exist for HCE detection, they necessitate close-in sensing, are expensive, and require extended processing times.

Iron Curtain is an active protection counter-munition system that could be integrated with Crosshairs to defeat rocket propelled grenades (RPGs).

The **Maneuver and Control on the Urban Battlefield** program will develop new, high-speed, lightweight, and portable tools including bar cutters, rotary cutters, 5-25 ton spreaders, door jamb breakers, deployable personnel barriers, and rooftop access devices. The ultimate program goal is to reduce the weight of existing access tools by 80 percent, as well as deliver new and unique capabilities, such as direct and rapid rooftop access and rapidly deployed personnel barriers.

The **Polymer Ice (Traction Control for Mobility Assurance)** program is developing a polymer-based artificial ice material that achieves effective mobility control by the precise and reversible reduction of ground traction for a broad range of hot, arid environments, such as found in Iraq and Afghanistan. A non-toxic reversal agent, carefully matched to the chemical characteristics of Polymer Ice, will be developed to rapidly restore traction when applied to a Polymer Ice-coated surface. Most importantly, incorporation of the reversal agent into combat boots and tires, to achieve instantaneous traction restoration on contact, will provide true asymmetric mobility capabilities to our warfighters.

The **Quarantine Toxic UAV Payloads** program will develop a system which can safely and effectively sequester (entomb) toxic chemical and biological agent payloads located on hostile force unmanned air vehicles. While technology for detection, tracking, and destruction of these platforms exists, the destruction step is problematic since the process can inadvertently disperse the toxic agent over the intended (or other) targets. To safely, effectively, and inexpensively sequester chemical payloads and transport them to the ground, the program is focused on the development of a system that integrates tracking and detection capabilities with gentle methods of entombment (i.e., quarantine) of the active agent.

The goal of the **Recognize Improvised Explosive Devices and Report (RIEDAR)** program is to exploit laser-based optical techniques to develop a revolutionary approach to detect explosives from a large distance in sub-second time scales with significant area search rate capability. To achieve this goal, RIEDAR will demonstrate unique, combined, compact, high-power UV-tunable and near-infrared, nanosecond and femtosecond pulsed lasers. These lasers are expected to have broad impact in operational environments where high-power, compact, tunable lasers enable rapid detection of chemical signatures. The program also seeks to develop a robust compact laser system capable of continuous operation in standard rugged military environments in a package less than a cubic meter in size.

The **Reversible Barriers (ReBar)** program will develop personnel and vehicle barrier technology that is extremely lightweight, easy to erect, virtually impenetrable, but can be rapidly removed by U.S forces. Such technology would free many personnel currently assigned to guard a variety of high-value, access-denied areas (e.g., weapons caches, fuel depots). An example ReBAR system might consist of a rapidly expandable foam that cures within minutes and rapidly dissolves when exposed to an agent controlled by U.S. forces.

The **Rocket Propelled Grenade (RPG) Pre-launch Detection and Cueing** program will enable the development of an omnidirectional, visual, and vehicle mounted surveillance system for threat detection using cognitive swarm recognition technology to rapidly detect and identify the locations of attackers with RPGs before they are launched. Minimizing false alarms and false positives will be key, as will be true day/night operation and the simultaneous identification of up to five threats.

The goal of the **RPGNets** program is to utilize special high-capability nets to dud, break, or otherwise disable rocket propelled grenades (RPGs). The defined net systems will be tested in an extensive live fire program and incorporated into defensive systems currently under development as a low-cost, low collateral damage RPG defense mechanism

The goal of the **Sonic Projector** program is to provide the Services with a method of surreptitious audio communication at distances over one kilometer. The Sonic Projector will be designed to be a man-deployable system, using high-power acoustic transducer technology and signal processing algorithms which result in no, or unintelligible, sound everywhere but at the intended target.

The goal of the **Stand-off Solid Penetrating Imaging** program is to detect and identify explosive threats at a stand-off distance, which is critical to force protection, especially in urban scenarios. A microsystem approach with multiple, synergistic sensor technologies integrated in a compact package is critical for widespread deployment of this sensor capability. The microsystem approach involves the identification of significant attributes from multiple non-overlapping perspectives, such as shape and chemical signature, at stand-off ranges of fifty meters to, potentially, one hundred meters.

The goal of the **Surveillance and Threat Neutralization in Urban Environments** program is to develop systems to detect and defeat threats specific to conflict and stabilization operations in the urban environment, including roadside bombs, car bombs, suicide bombers, snipers, rocket propelled grenades, and mortars launched from inside urban boundaries.

PRE- AND POST-CONFLICT CAPABILITIES

The **Conflict Modeling, Planning, and Outcomes Experimentation (COMPOEX)** research effort is developing technologies to enhance the capability of leaders to plan and conduct government campaigns. This includes a comprehensive suite of decision support tools that help leaders with: (i) visualizing and understanding the situation and the complex operational environment they must operate in; (ii) constructing and managing plans that enable the commander to synchronize and integrate interdependent effects over a long period of time; (iii) employing the best sequence of unified actions to produce the desired effects; and (iv) generating and exploring options and courses of action to understand the range of outcomes and appreciate the side effects that may occur.

The **Integrated Crisis Early Warning System (ICEWS)** program is developing a unified information system to support theater security cooperation by monitoring, assessing, and forecasting leading indicators of events that make countries vulnerable to a variety of national and international crises. ICEWS tools will allow combatant commanders and their staff to understand and anticipate conditions that precipitate instability and conflict, while there is still time to influence them, and will help anticipate unintended consequences of actions taken to influence or remediate situations.

The **Multilingual Automatic Document Classification, Analysis and Translation (MADCAT)** program will address the recurring military problem of understanding the content of captured documents and images (including signs and graffiti) during tactical operations, which often contain machine printed and handwritten text in various combinations and orientations in one or more languages. The MADCAT program will substantially improve document analysis and optical character recognition, integrate it tightly with translation technology, and assemble technology demonstration prototypes for field trials. MADCAT devices would enable Soldiers to convert these documents to readable English in the field.

The **RealWorld** program provides any U.S. warfighter with the ability to open a laptop computer and rehearse a specific mission in the relevant geo-specific terrain, with realistic physics. RealWorld is not a simulation; it is a simulation builder with applications across the spectrum of modern kinetic and non-kinetic warfare. The program is constructing tools that allow warfighters to rapidly and easily build their own missions though the introduction of new methodology for building simulation software. Because the system will be scalable and distributed, warfighters can practice by themselves, in small groups, or with as many other warfighters as needed for the mission over a local or distributed network, and across all relevant platforms (dismounts, vehicles, helicopters, fast movers).

The **Training Superiority** program will create new approaches to training our warriors to win in the high-technology, complicated, and often isolated environment of future conflicts. This will include cognitive training systems that incorporate elements of human-tutor interactions and the emotional involvement of computer games, coupled with feedback from the Services' training centers.

COMMAND, CONTROL, COMMUNICATIONS, AND INTELLIGENCE (C3I) FOR URBAN WARFIGHTING

The goal of the **Coordination Decision-Support Assistants (COORDINATORs)** program is to develop a new class of cognitive systems that learn and reason about mission performance, resources, and conditions in order to provide dynamic activity coordination and decision support to the warfighter. The program seeks to dramatically improve the coordination of warfighter activity in dynamic operational environments, including real-time rescheduling of tasks, resources, and power.

The **Deep Green** program combines anticipatory planning with adaptive execution, providing military decision makers with capabilities on the battlefield that the IBM computer "Deep Blue" brings to the chessboard. The goal of Deep Green is to explore closed-loop simulation to integrate planning and execution, and will incorporate continuous learning. The technology will also employ software agents to monitor the execution of the current operation against the plan, identify variations as the scenario unfolds, and consistently explore the possible future states of the battlefield.

The **Deep Speak** program is developing new networking, coding, and waveform techniques that enable communications signals to penetrate surrounding buildings and underground facilities. Deep Speak will maintain the warfighters' links to each other and the global network, thus magnifying striking power.

The **Mobile Networked Multiple-Input/Multiple-Output (MIMO) (MNM)** project is pursuing MIMO communication systems, which have the potential to increase data rates by 10-20 times above current systems by using a multipath to create parallel channels in the same frequency band, thereby increasing spectral efficiency. This program will demonstrate the MNM capability under dynamic urban non-line-of-sight multipath channel conditions, where conventional techniques are degraded.

The **Networking in Extreme Environments (NetEx)** program will create a wireless networking technology for the military user for robust connectivity in harsh environments, e.g., areas prone to multipath interference, such as urban settings where buildings and other structures cause radio frequency energy to "bounce" off in-and-among the buildings/structures. NetEx will support development of new and emerging sensor and communication systems by developing an improved physical layer for networked communications based on a family of new, ultra wideband devices.

The **Next Generation Routing and Addressing** program seeks to develop networks that use topographically distributed addresses (e.g., geographically or by organizational unit). Current network routing methodologies use internet protocol (IP) address numbers that are distributed with no defined pattern or methodology. As a result, current routing systems spend large amounts of time and computing power updating and maintaining tables that "point" to where different IP addresses are located geographically. The development of new network addressing schemes will reduce the load on routers, as well as greatly simplify router configuration. These networks will be a paradigm shift in that numbered IP addresses will no longer exist, and changes to the Domain Naming Server (DNS) system will allow for services to mobile users.

The goal of the **ULTRA-VIS** program is to develop an integrated system that includes a conformal, see-through, optical waveguide visor that displays intra-squad commands, alerts, and even icons that are attached to the urban landscape to provide Army and Marine small unit leaders with the ability to conduct daytime operations in an urban environment. ULTRA-VIS will allow the squad leader to hand off actionable information and direct alerts to the squad /fire teams for real-time collaboration without overload.

ADVANCED MANNED AND UNMANNED SYSTEMS

DARPA is working with the Army, Navy, Air Force, Marine Corps, and Special Operations Command toward a vision of a strategic and tactical battlespace filled with networked manned and unmanned air, ground, and maritime systems, and the technologies they need to navigate and fight. Unmanned systems provide autonomous and semiautonomous capabilities that free Soldiers, Sailors, Airmen and Marines from the dull, dirty, and dangerous missions which might now be better executed robotically, and enable entirely new design concepts unlimited by the endurance and performance of human crews.

DARPA is seeking to improve individual platforms so that they provide new or improved capabilities, such as unprecedented endurance or survivability, while expanding the level of autonomy and robustness of robotic systems. A network of collaborating manned and unmanned systems will be far more capable than the sum of its individual components.

The research in this strategic thrust can be broadly grouped into:

- **Improved Platform Performance** to provide new or improved capabilities, such as unprecedented endurance or survivability;
- **High Level Platform Autonomy with Increased Mission Complexity** to free warfighters from missions that might now be better executed robotically; and
- **Seamless Networking between Manned and Unmanned Platforms** to improve autonomy and robustness by forming a more tightly coupled combat system that will improve our knowledge of the battlespace, enhance our targeting speed and accuracy, increase survivability, and allow greater mission flexibility.

IMPROVED PLATFORM PERFORMANCE

The **A160** program will exploit a hingeless, rigid-rotor concept operating at the optimum rotational speed to produce a vertical take-off and landing (VTOL) unmanned air vehicle (UAV) with low disk loading and low rotor tip speeds, resulting in an efficient, low-power loiter, high-endurance system. This unique concept offers the potential for significant increases in VTOL UAV range (more than

2000 nautical miles) and/or endurance (more than 20 hours).

The **Acoustic Arrays for Torpedo Defense** program will demonstrate the feasibility of using an array of transducers to form a destructive pressure pulse capable of disabling an enemy's torpedo. The beam-formed pressure pulse must be of sufficient amplitude and duration to destroy a torpedo at tactically significant ranges. Critically important steps in the technology development include accurately predicting non-linear pressure pulse propagation effects and corresponding timing delays used during pressure pulse generation and beamforming.

The goal of the **Active Rotor** program is to develop and demonstrate technologies to greatly enhance rotor control and performance for a 25-50 percent improvement in endurance, range, and payload of existing helicopters. The Active Rotor program will mature the technologies to enable military aircraft such as the Black Hawk to operate effectively in high/hot conditions, focusing on development and demonstration of advanced technologies for application to future platforms, with demonstration on a fielded system to facilitate upgrade of current multi-service rotorcraft rotor systems.

The goal of the **Adaptive Morphing Super-Maneuver Aircraft (AMSMA)** program is to demonstrate a technology leap forward to a generation-after-next aircraft vehicle concept that can provide revolutionary military utility in a number of applications and missions. The program will employ a combination of enabling technologies, including asymmetric wing sweep, fore and aft wing translation, and aero-elastic wings with adaptive hingeless control actuation.

Studies conducted under the **Advanced Aerospace System Concepts** program will examine and evaluate emerging aerospace technologies and system concepts for applicability to military use, as well as the degree and scope of potential impact/improvements to military operations, mission utility, and warfighter capability. The program also analyzes emerging aerospace threats and possible methods and technologies to counter them.

The **Aluminum Combustor** program seeks to develop an energy-dense, air-independent underwater power source as a propulsion system for future naval undersea warfare systems. This program will optimize the design for a small aluminum combustor and silane fuel treatment process, and will develop the auxiliary power system components needed to control and sustain operations. In addition to the combustor, the aluminum fuel feed subsystem, aluminum-steam separator subsystem, and closed-loop control subsystem will be designed, built, and integrated with a turbine to successfully demonstrate a power system in a laboratory.

The goal of the **Battlefield Helicopter Emulator (BHE)** is to develop a system capable of emulating rotorcraft signatures, compatible with installation as a payload on a small UAV. The system's capability to defeat threats with an off-board system offers the opportunity to protect a large number of military aircraft assets and crews over long periods without aircraft performance impact

The **Chemical Robots** program is developing soft, flexible, mobile objects that can identify and maneuver through openings smaller than their static structural dimensions and restore their size, shape, and functionality afterwards; carry meaningful payloads; and perform tasks. ChemBots represent the convergence of soft materials chemistry and robotics to create a fundamentally new class of soft, mesoscale robots.

The goal of the **Disc-Rotor Compound Helicopter** program is to design and demonstrate the technologies required for a new type of compound helicopter capable of high-efficiency hover, high-speed flight, and seamless transition between these flight states. The aircraft would be equipped with a rotating circular wing having blades that can be extended from the disc edge, enabling the aircraft to takeoff and land like a helicopter; transition from helicopter flight to airplane flight would be achieved by gradually retracting and stowing the blades as the circular wing assumes the task of lifting.

Images seen through an air-water interface are distorted by multiple refractions from the water surface. The **Distortion-free Seeing Through the Air/Water Interface** program will develop high-resolution imaging and image exploitation technology to provide new capabilities for detection and discrimination of objects, such as surface crafts, and underwater objects for significantly improved near-surface operations and safety.

The **Distributed Embedded Propulsion** program will explore fully integrated engine/wing designs to take maximum advantage of a fully coupled engine/wing system. The program will conduct a series of design, sizing and demonstration efforts, culminating in either a wind tunnel or flight test of a circulation control wing using distributed propulsion.

The **Evaporative Cooling Turbine Blades** program will develop and demonstrate an evaporative cooling system for gas turbine engine turbine blades. Evaporative cooling has the potential to improve engine specific fuel consumption by up to 20 percent in a technology area where tenths of a percent improvement is considered a breakthrough. Blade design has been completed, and the upcoming phase will establish efficiency in a full engine system.

The goal of the **Extremely Long Endurance Unmanned Surface Vehicle (ELEUSV)** program is to develop technologies that allow a robotic naval vessel to operate for years with minimal human interaction, which would significantly expand naval presence and provide potential advantages in counter-mine and anti-submarine warfare, emergency response and rescue operations, and intelligence gathering. ELEUSV will also investigate unique payload systems that would benefit from the extended periods of uninterrupted operations.

The **Fiber-Optical Network for Aerospace Platforms** program will facilitate building or upgrading military aircraft and other aerospace platforms with a fiber-optical networking infrastructure with many capabilities that are well beyond those of current copper-based technology. The program will focus on technologies that will provide advanced capabilities to a multitude of military aircraft, shipboard, and aerospace platforms, including: (i) scalability in bandwidth and number of connected devices; (ii) immunity to electromagnetic interference and cable cross-talk; (iii) reduced cable and overall system weight and volume; (iv) increased reliability without an associated weight or volume penalty; (v) ease of integration and future upgradeability; and (vi) the ability to carry mixed analog and digital signal formats.

The **Heavy Fuel Engine/Low Friction Engine** program will develop and demonstrate a heavy-fuel, lightweight, and efficient engine for air vehicles. The Low Friction Engine (LFE) is designed to operate without conventional piston rings, which are a principal cause of internal combustion engine friction and which diminish the amount of useful work that is available from an engine.

The goal of the **Helicopter Quieting (HQP)** program is to identify, develop and demonstrate advanced rotor technologies that can dramatically improve the survivability of military rotor systems, with minimal negative impact on performance, affordability, availability and suitability. A critical element toward this goal is to create and demonstrate a physics-based design toolset that enables analytical design of novel rotor systems and rotorcraft for reduced acoustic susceptibility (detection and recognition) by the human threat.

The **Heliplane** program will design, develop and flight test an air vehicle that combines the vertical take-off and landing and low disk loading characteristics of a helicopter with the speed and efficiency characteristics of a fixed-wing aircraft. The Heliplane demonstrator aircraft will be tailored to a combat search and rescue mission with a 400 mile per hour cruise speed, a 1,000 pound payload, and an unrefueled range of 1,000 miles.

The goal of the **Integrated Compact Engine Flow Path** program is to develop a structurally integrated, load bearing, composite, thrust vectoring nozzle. Designed to take airframe loads through the nozzle and built of a high-temperature ceramic, this program will design, develop, and demonstrate a full-scale, fluidic thrust vectoring nozzle in a direct-connect engine test.

The **Laminar Flow Flight Demonstration** program will explore the development of an extended laminar flow wing, with the potential for a drag reduction of up to 25 percent compared to a typical fully turbulent wing.

The goal of the **Lightweight High Efficiency Aircraft Power Generation** program is to develop a lightweight, fuel-efficient system that delivers up to two megawatts of electrical power to support high-energy laser weapons on airborne platforms. The program will develop and demonstrate a novel power generation system capable of providing full power (one to two megawatts at 25,000 feet/Mach 0.8) within 0.1-2.0 seconds, and that can operate in a fuel-efficient standby mode.

The **Multi-Modal Missile** program will explore the development of an integrated, networked man-portable weapon system capable of performing surface-to-surface, and surface-to-air missions with an emphasis on extreme precision targeting accuracy in both direct and indirect fire modes against multiple targets, and beyond line-of-sight functionality including: (i) armored and soft ground vehicles; (ii) bunkers; (iii) personnel; (iv) helicopters; and (v) unmanned air vehicles. The Multi-Modal Missile capability will integrate a variety of existing weapons-systems functions, and provide both mounted and dismounted Soldiers with an affordable compact system that is lightweight, simple to operate, and affordable.

The **Nano-Flapping Air Vehicles** program will develop flapping air vehicle technology leading to a bio-inspired flapping and rotary air vehicle with less than two-inch wingspan and gross takeoff weight of approximately 10 grams or less. Urban terrain operations require sensors that can be inserted without being detected, and that can navigate in difficult terrain. Small air vehicles that could be camouflaged or that blend into the surrounding landscape and that can navigate interiors without GPS could autonomously carry out a number of high-risk missions currently done by warfighters.

The goal of the **Oblique Flying Wing (OFW)** program is to develop and demonstrate an asymmetric flying wing that can vary its wing sweep in flight with increasing speed to optimize aerodynamic performance. The variable sweep is achieved asymmetrically, with one end of the wing swept forward and the other swept aft. A supersonic aircraft capable of long loiter times would have a revolutionary impact on the battlefield, necessitating fewer combat aircraft and fewer tankers to accomplish mission objectives.

The **Precision Inertial Navigation Systems (PINS)** program will develop an entirely new class of inertial navigation instruments using atomic inertial force sensors. These sensors use the quantum mechanical wave-like nature of atoms in the atomic analog of an optical interferometer to provide unprecedented sensitivity to accelerations and rotations. The atomic sensors will further be used to measure the local gravitational field gradient to ensure that instrument alignment is properly maintained throughout vehicle maneuver, thus mitigating gravity-induced navigation errors.

DARPA's **Prognosis** program has been developing physics-based materials damage models that accurately describe damage accumulation from flight operations in both aircraft and engine structures. By combining these models with sensor and usage information, Prognosis aims to develop better predictive models for specific applications including the Navy's EA-6B and P-3 aircraft, the F-100 and F-110 engines, and the gearboxes in Army and Navy helicopters.

The goal of the **Riverine Crawler Underwater Vehicle** program is to develop unmanned underwater vehicle concepts that can travel underwater in riverine and shallow water coastal environments to carry out surveillance/reconnaissance and deployment tasks in denied, sensitive, or contested areas. The program will study how to operate an unmanned submerged craft in riverine shallow water areas (nominally at operational environment depths less than 40 feet) including rivers, estuaries, and harbors involving challenging surface and sub-surface conditions such as obstructions, turbidity, wave action and currents.

The goal of the **Robust Surface and Sub-Surface Navigation (RSN/SSN)** program is to provide the U.S. warfighter the ability to navigate effectively when the global positioning system is unavailable due to hostile action (e.g., jamming) or when blocked by structures and foliage. The RSN/SSN program will use signals of opportunity and specialized signals from a variety of ground-, air-, and space-based sources and judiciously placed low frequency radio frequency beacons. These will be received on the warfighter's forthcoming software-defined radios, and will use specially tailored algorithms to determine position.

The **SandBlaster** program is developing a passive pilot enhancement system that fuses visible, infrared, and millimeter wave radiation to enable multiple helicopters to land safely during severe brown- and white-out. SandBlaster will exploit the low attenuation property of dust, fog, and snow on millimeter wave radiation to develop a passive millimeter wave system that precludes detection and prevents interference, as would be expected from multiple active systems operated in close proximity. SandBlaster will address four fundamental piloting situational awareness enablers: (i) pilot's ability to "see" in limited visibility conditions; (ii) pilot's awareness of helicopter drift; (iii) pilot's awareness of slope of terrain; and (iv) display technology matched to mission and human factors considerations.

The **Small Combat Vehicle with Robotic Automation** program seeks to achieve an optimal mix of manned and unmanned technologies in a small well protected, highly deployable combat vehicle.

The **Small UAV Strike Munition** program will develop the technologies for a precision-guided munition, dramatically reduced in size and cost, for application to airborne unmanned systems and for use by dismounted Soldiers and Marines. An inexpensive, low-weight precision-guided munition that is effective against soft targets (vehicles, dismounts, conventional structures) can be utilized where expensive precision-guided weapons (e.g., Hellfire, intended for armored vehicles) are used today.

Following the success of shaftless propulsion technologies demonstrated in the Tango Bravo program, DARPA and the U.S. Navy will design, build, and test a large-scale **Submarine Shaftless Stern Demonstrator** to characterize and mitigate risks associated with ship integration into a next generation submarine propulsion option. The demonstrator will be built to the minimum scale necessary to extrapolate hydrodynamics, powering, and acoustics to full-scale performance.

The goal of the **Super-Fast Submerged Transport** (formerly Underwater Express) program is to explore the application of supercavitation technology to underwater vehicles, enabling high-speed transport of personnel and/or supplies. Supercavitation places the vehicle inside a cavity where vapor replaces water, reducing the drag due to fluid viscosity by orders-of-magnitude and power requirements dramatically. This program will use modeling, simulation, experiments and testing to understand the physical phenomena associated with supercavitation and its application to underwater vehicles.

Combatant divers currently rely on 1940's-era tools (compass and stopwatch) to conduct hydrographic surveys and confirmatory beach reports. The poor accuracy of these methods was a significant risk in combatant dive missions in World War II, and still is today. The purpose of this program is to develop the **Tactical Underwater Navigation System (TUNS)**, a rapid and accurate handheld underwater navigation system using advanced navigation technology for combatant divers suitable for hydrographic surveys and confirmatory beach reports.

The **Tango Bravo** program is exploring design options for a reduced-size submarine with equivalent capability of the VIRGINIA Class submarine. The implicit goal of this program is to reduce platform infrastructure and, ultimately, the cost of future submarine design and production.

The **Unique Propulsion Techniques** program will develop a novel underwater propulsion technology for unmanned underwater vehicles and other underwater platforms that require high maneuverability at low velocities. The objective of the program is to develop a ribbon fin propulsion system, the type of propulsion used by electric eels, and demonstrate the increased low velocity power efficiency and maneuverability of an actual underwater platform.

The goal of the **Unmanned Persistent Parafoil System (UPPS)** program is to develop and integrate the enabling technologies and system capabilities required to demonstrate a vehicle with large payload and long endurance characteristics capable of taking off and landing on the back of a small ship. The UPPS could be deployed rapidly and would provide 48-hours of continuous organic air-support to small ground units or small marine vessels with a 200 pound surveillance and communication package.

The **UUV Power Technologies** program will explore high-risk, high-payoff technologies that would significantly increase the overall mission duration of future unmanned underwater vehicles (UUVs). To meet this objective, this effort is pursuing novel UUV power systems, such as novel fuel cells and structural batteries that have the potential for demonstrating energy densities in the range of 1000–1500 watt-hours per liter.

The **Very High Speed Torpedo Defense** program will develop concepts for U.S. ship defense systems to defeat very high speed (250 knot), rocket-powered, super-cavitating torpedoes currently under development by other nations. Queued by a ship's sonar system, the torpedo can be identified and localized using a large search volume laser-radar tracking system that can be used to compute a firing solution. The torpedo will then be engaged by specially designed high-speed projectiles (also super-cavitating) fired from the ship to neutralize the incoming threat.

The goal of the **Vulture** program is to develop an aircraft capable of remaining on-station, uninterrupted, for over five years to perform intelligence, surveillance, reconnaissance, and communication missions over an area of interest. Vulture would, in effect, be a retaskable, persistent pseudo-satellite capability, in an aircraft package. The program will conclude with a year-long flight demonstration with a fully functional payload.

The **WDM LAN for Aerospace Platforms** program will facilitate building or upgrading military aircraft and other aerospace platforms with a fiber-optical networking infrastructure. This will have many capabilities that are well beyond those of currently used copper-based technology. These new capabilities include: scalability in bandwidth and number of connected devices; immunity to electromagnetic interference (EMI) and cable cross-talk; reduced cable and overall system weight and volume; increased reliability without an associated weight or volume penalty; ease of integration and future upgradeability; and the ability to carry mixed analog and digital signal formats. This will be accomplished by taking full advantage of fiber-optical wavelength-division-multiplexing (WDM) technology and leveraging optoelectronic and photonic integration techniques developed in DARPA photonics components programs.

The **Wideview** program will exploit a technology used successfully by the underwater acoustic community, and convert it to give tactical aerial vehicles the ability to continuously detect, locate, and track battlefield sounds (such as sniper firing) over a 360-degree field of view.

High Level Platform Autonomy with Increased Mission Complexity

The **Broad Ocean Demining** program will develop and demonstrate system capabilities to counter maritime improvised explosive devices (IEDs). The program will also explore innovative distributed systems that can escort ships and allow them to detect, avoid, and if necessary, neutralize these threats while underway. The program's technology development will include surveillance networks that can be rapidly emplaced and affordably monitored, improved detection and neutralization techniques, and robotic systems that can carry out the search and neutralization missions with minimal support from military ships.

The goal of the **Detect UAV** program is to develop techniques to detect, track, and characterize small unmanned air vehicles that are easily built, inexpensive, easy to operate, and offer an asymmetric adversary the ability to reach into well-defended locations and cause potentially large amounts of damage. The program includes signal processing techniques to: (i) detect small air targets in radar, video, acoustic, and passive radio-frequency intercepts; (ii) correlate those data with known objects (e.g., civilian aircraft); (iii) analyze the motion of any uncorrelated data; and (iv) rapidly task narrow-field-of-view sensors to collect more-detailed data.

The **Helicopter ALert and Threat Termination (HALTT)** program will provide Army and Navy/Marine helicopters with a way to detect small arms and RPG attacks, improve their ability to respond, and provide affordable defeat of RPGs or other rockets.

The **Heterogeneous Urban Reconnaissance Team (HURT)** program is developing integrated tactical planning and sensor management systems for heterogeneous collections of unmanned platforms operating in urban environments. HURT controls multiple unmanned air vehicles (UAVs), feeding surveillance data to warfighters with handheld computers. Warfighters can request information, and HURT directs the most suitable UAV to the location. At the same time HURT can control other UAVs, maintaining broad area surveillance.

The Learning Applied to Ground Robots (LAGR) program is developing a new generation of learning perception and control algorithms for autonomous ground vehicles and integrating these learned algorithms with a highly capable robotic ground vehicle. The learning methods developed in this program will be broadly applicable to autonomous ground vehicles in all weight classes and in a wide range of terrains. Algorithms will be created that learn to navigate based on experience and by mimicking human teleoperation. LAGR is expected to develop systems that will provide breakthroughs in complex terrain navigation performance.

The **Learning Locomotion (L2)** program is addressing specific concerns in legged robotic systems. The approach taken here is to learn to interpret sensor data and apply this knowledge to actuator control to improve locomotion and navigation in complex environments. Learning techniques will include (but not be limited to) reinforcement learning and learning from examples. These advancements will open new horizons for unmanned military operations, surveillance and reconnaissance, and dramatically advance the capabilities of autonomous vehicles.

The **Legged Squad Support System (LS3)** program will explore the development of a tetrapod platform scaled to unburden the infantry squad and, hence, unburden the Soldier. LS3 will leverage technical breakthroughs of prior biologically inspired legged platform development efforts to develop system designs to the scale and performance adequate for infantry squad mission applications, focusing on endurance, payload, terrain negotiation, and human-machine interaction capabilities, as well as secondary design considerations, such as acoustic signature.

The **Multi Dimensional Mobility Robot (MDMR)** program is investigating concepts that use serpentine mobility to achieve new ground robot capabilities for search and rescue applications. The MDMR system will navigate complex urban terrain and provide the operator with real time images of its environment in applications that include: overcoming obstacles that are a significant fraction of its length; crossing slippery surfaces; ascending poles; climbing steep slopes; and optically sensing its immediate surroundings.

The **Sea Shield** program will develop an extensible automated battle management capability to provide persistent surveillance and targeting coverage to protect naval battle groups against overwhelming threats. Sea Shield will extend area protection 50-fold using layered and distributed sensing and targeting by developing and implementing air, sea, and subsurface autonomous, collaborative, and self-healing sensor networks. The automated battle management system will enable timely and coordinated decision-making information and situational awareness for the commander.

DARPA conducted the **Urban Challenge** to accelerate development of autonomous ground vehicles capable of navigating in an urban environment and operating safely among other vehicles. In the Urban Challenge, unmanned autonomous vehicles had to obey traffic laws, avoid moving and stationary obstacles, complete U-turns within road boundaries, negotiate busy intersections, enter and exit parking spaces, and find and travel along an alternate route when the primary route is blocked. From a starting field of 35 semifinalists, 11 Urban Challenge finalists successfully and safely completed a National Qualifying Event to compete in the final event on November 3, 2007, in Victorville, California. The top three teams that completed the Urban Challenge's 60 mile course in six hours or less were: (i) Tartan Racing's "Boss" of Pittsburgh, Pennsylvania, turned in the top performance, winning the $2 million cash prize for first-place; (ii) Stanford Racing's "Junior" of Stanford, California, won the $1 million for second place; and (iii) Victor Tango's "Odin" of Blacksburg, Virginia, received $500,000 for finishing third.

The goal of the **Urban Ops Hopper** program is to develop a semi-autonomous hybrid hopping/articulated wheeled robotic platform that could adapt to the urban environment in real-time and provide both surgical lethality and/or intelligence, surveillance, reconnaissance (ISR) to any point of a city, while remaining lightweight, small, and expendable. This hopping robot would be truly multi-functional in that it would negotiate all aspects of the urban battlefield to deliver ISR and/or lethal payloads to non-line-of-sight targets with precision.

Seamless Networking Between Manned and Unmanned Platforms

The **Collaborative Networked Autonomous Vehicles (CNAV)** program will develop autonomous control methods to cause a distributed set of unmanned undersea vehicles to self-organize and distribute tasks through judicious transactions conveyed over a shared communications network. CNAV will provide submerged target detection, localization, and tracking in restrictive littoral waters by creating a field of dozens or hundreds of vehicles that are connected by acoustic wireless communications. The vehicles work collaboratively and autonomously to detect, classify, localize and track target submarines transiting the field.

The goal of the **Collision Avoidance & Dynamic Airspace Control** program is to maximize airspace utilization through dynamic military airspace management. The goal is for the current labor-intensive, human-centric process to be replaced by an automated system that efficiently manages all objects in the airspace, including munitions, manned aircraft, and unmanned air vehicles.

The **Persistent Ocean Surveillance** program combines geolocation techniques, such as the global positioning system, with station-keeping and intra-sensor communication technologies to provide long-term station-keeping ocean environment sensing buoys. These technologies, when applied with state-of-the-art undersea warfare sensors, will result in a floating field of smart sensors capable of observing the undersea environment in an area, including detecting submarines and other undersea vehicles.

DETECTION, CHARACTERIZATION, AND ASSESSMENT OF UNDERGROUND STRUCTURES

Our adversaries are well aware of the U.S. military's sophisticated intelligence, surveillance, and reconnaissance assets, and the global reach of our strike capabilities. In response, they have been building deeply buried underground facilities to hide various activities and protect them from attack.

While large, developed facilities have long been recognized as strategic threats, there is increasing need to find and characterize small underground structures. These include caves that serve as hiding places and tunnels for smuggling weapons and infiltrators across borders. Caves and tunnels provide secret entry into sensitive areas and might even contain prisons, weapons laboratories, or nuclear power plants.

To meet the challenge posed by the proliferation of these facilities, DARPA is developing a variety of sensor technologies and systems – seismic, acoustic, electromagnetic, optical, and chemical – to find, characterize, and conduct post-strike assessments of underground facilities.

The **Airborne Tomography using Active Electromagnetics (ATAEM)** program is developing an active electromagnetic (EM) system for airborne imaging of subsurface structures, such as underground facilities or perimeter-breaching tunnels. The ATAEM system illuminates the ground with electromagnetic energy and interprets resulting distortions of the electric and magnetic fields to detect and characterize surreptitious structures. An integrated system combining active illumination, sensing, and detection processing will be developed and demonstrated on an unattended air system.

The **Cross-Border Tunnel (CBT)** program is developing technologies and systems to detect small tunnels used to breach security perimeters and national borders. The program goal is to develop innovative technologies, inspired by geophysical exploration techniques, that detect and characterize these threat tunnels, while simultaneously satisfying operational considerations such as search rate, site access, and exposure of friendly forces. The CBT program is currently performing collections of seismic and electromagnetic data at a test bed using current state-of-the-art sensors from the geophysical industry.

The **Fast-Scan Cross-Border Tunnel Detection** program will investigate, develop, and transition a tunnel detection system that focuses on a fast linear scan rate, for operationally tractable protection of large controlled areas or national borders. Contrary to invasive imaging methods, the Fast-Scan concept is to provide rapid detection of anomalous subsurface structures consistent with voids. The technical challenges include: (i) identification of optimal detection strategies, source characteristics, and sensor geometries; (ii) rejection of clutter with length scales similar to tunnels or response from non-threat structures (utilities); and (iii) technology migration to a moving platform.

The **Low-Altitude Airborne Sensor System (LAASS) Active EM Payload** program proposes to map out the distribution of wiring and voids of underground facilities and tunnels by adding active electromagnetic imaging to the current LAASS passive electromagnetic design. This capability would provide the Army, USMC and Special Operations Forces critical intelligence on the rudimentary facilities and caves used as operating bases or weapons caches by asymmetric threat forces.

The goal of the **Low-Altitude Airborne Sensor System (LAASS) Gravity Gradient Payload** program is to develop and demonstrate an airborne gravity gradient system, integrated on a suitable (unmanned preferred) air vehicle, to detect and image underground facilities/tunnels by measuring the spatial change in acceleration (gravity gradient) induced by the void which defines the facility/tunnel. This capability would provide the ground forces (U.S. Army, USMC, Special Operations Forces) critical intelligence for the detection and characterization of underground facilities or tunnels that breach controlled areas or borders.

The **Low-Altitude Airborne Sensor System (LAASS)** program is developing an airborne sensor system to find and characterize underground facilities used to shield and protect strategic and tactical activities, including command and control, weapons storage, and manufacture of weapons of mass destruction. By passively capturing emissions associated with underground facility presence and operations, and doing so using airborne sensors (acoustic, electromagnetic, gravity), LAASS can significantly increase our ability to seek out underground facilities and map out their vulnerabilities and backbone structure.

The **Robust Tunnel Mapping and Operations** program will investigate, develop, and transition a single system that jointly maps underground tunnel networks and supports below-ground communications and navigation to meet the operational needs of ground forces conducting urban or counter-UGF operations. The program will explore and identify active sensing strategies that, in the process of mapping the extent of the tunnel network, can simultaneously support internal operations. The technical challenges include: (i) identification of a single phenomenology to meet mapping and operational needs; (ii) development of man-portable sensors for communications and navigation; and (iii) technology integration to a single system.

Building on the successes of technology developed under the Counter Underground Facilities program, the **Strategically Hardened Facility Defeat** program will continue to develop alternative earth-penetrating technologies to defeat strategically hardened targets. Because the size and weight of traditional earth penetrating weapons scale exponentially with the depth of the targeted facility, current warhead penetration depths are, and always will be insufficient to reach many of these targets. Therefore, a strategic capability gap exists, and new approaches to earth penetration and warhead delivery are needed. This program seeks to leverage recent advances in earth-penetrating technologies for full defeat of strategically hardened facilities.

SPACE

The national security community, and the U.S. military in particular, use space systems for weather data, warning, intelligence, communications, and navigation; these systems provide great advantages over potential adversaries. American society as a whole uses space systems for many similar purposes, making them an integral element of the U.S. economy and way of life.

These advantages – and the dependencies that come with them – have not gone unnoticed, and there is no reason to believe they will remain unchallenged or untested. In FY 2002, the Secretary of Defense directed DARPA to begin an aggressive effort to ensure that the U.S. military retains its preeminence in space by maintaining unhindered U.S. access to space and protecting U.S. space capabilities from attack.

There are five elements in DARPA's space strategic thrust:

- **Access and Infrastructure** is developing technology to provide rapid, affordable access to space and efficient on-orbit operations;
- **Situational Awareness** will provide the means for knowing what else is in space and what that "something else" is doing;
- **Space Mission Protection** is developing the methods for protecting U.S. space assets from harm;
- **Space Mission Denial** is working on technologies that will prevent our adversaries from using space to harm the United States or its allies; and
- **Space-Based Support to the Warfighter** is developing space-based reconnaissance, surveillance, communications, and navigation to support military operations down on earth – extending what the United States does so well today.

ACCESS AND INFRASTRUCTURE

The **Blackswift Test Bed** program will develop an extended-duration hypersonic test bed to study tactics for a hypersonic airplane that includes a runway take-off, Mach 6 cruise, and a runway landing. This test bed is an evolution of the reusable Hypersonic Cruise Vehicle developed under the Falcon program. Key technologies to be demonstrated include efficient aerodynamic shaping for high lift-to-drag, lightweight and durable (reusable) high-temperature materials and thermal management techniques including active cooling, autonomous flight control, and turbine-based combined cycle propulsion.

The **Falcon** program is developing and demonstrating hypersonic technologies that will enable prompt global reach missions. This capability is envisioned to entail a reusable hypersonic cruise vehicle (HCV) capable of delivering 12,000 pounds of payload at a distance of 9,000 nautical miles from CONUS in less than two hours. The program will also develop a low-cost, responsive small launch vehicle (SLV) capable of launching small satellites into low earth and sun-synchronous orbits, providing the nation with a new, small payload access to space capability.

The goal of the **Fast Access Spacecraft Testbed (FAST)** program is to demonstrate a suite of critical technologies required to perform rapid orbital repositioning in the geosynchronous belt. The ultimate goal of FAST is to demonstrate technology to enable a high-efficiency, high-power (50-80 kilowatt), fast-transfer, roaming satellite, which would permit on-demand access to any point on the geosynchronous ring or within the high-altitude, super synchronous "graveyard" (where derelict systems are regularly repositioned in order to free up orbital slots within the ring), greatly improving our space situational awareness capabilities.

The goal of the **Front-end Robotics Enabling Near-term Demonstration (FREND)** program is to develop, demonstrate and fly robotic manipulator technologies designed to allow interaction with geosynchronous orbit-based military and commercial spacecraft, extending their service lives and permitting satellite repositioning or retirement. FREND will combine detailed stereo photogrammetric imaging with robotic multi-degree-of-freedom manipulators to autonomously grapple space objects not outfitted with custom interfaces, and offers the potential for spacecraft salvage, repair, rescue, reposition, de-orbit and retirement, and debris removal.

The goal of the **High Delta-V Experiment (HiDVE)** program is to design, develop, and demonstrate a low-mass, low-volume, high delta-V solar thermal propulsion engine suitable for integration with an approximately 15 kilogram nanosatellite host. A HiDVE system will provide small satellites, historically constructed without propulsive capability, with substantial delta-V, thereby affording nanosatellites increased orbital range in terms of both attitude and plane.

The **Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP)** is developing advanced technologies, capabilities, and space environment characterization required to demonstrate – across the continuum from low-Earth orbit to the deep space, super geo-synchronous environment – a suite of advanced, lightweight microsatellite technologies integrated into high-performance microsatellites.

The goal of the **NanoPayload Delivery (NPD)** program is to validate the technical feasibility of ultra-lightweight (1-10 kilograms), rapid-response spacecraft delivery from land, sea, or air-based platforms that could be boosted to low earth orbit (200 kilometer altitude) in a matter of hours following call-up.

The goal of the **System F6** program is to demonstrate a radically new space system composed of a heterogeneous network of formation flying or loosely connected small satellite modules that will, working together, provide at least the same effective mission capability of a large monolithic satellite. System F6 will partition the tasks performed by monolithic spacecraft (power, receivers, control modules, etc.) and assign each task to a dedicated small or microsatellite. This fractionated space system offers the potential for reduced risk, greater flexibility (e.g., simplified on-orbit servicing, reconfigurability to meet changing mission needs), payload isolation, faster deployment of initial capability, and potential for improved survivability.

Situational Awareness

The **Bi-Static Shield** program will utilize existing satellite tracking, telemetry and control (TT&C) radio frequency illumination beams to create an electromagnetic (EM) shield in the immediate satellite vicinity (e.g., within a 30 kilometer radius from a geosynchronous orbit (GEO) satellite). Using the satellite omni antennas to serve as bi-static receivers, reflections from intruder satellites could be detected up to 10 kilometers from GEO spacecraft by extracting the very weak bi-static illumination signals reflected off the intruder satellites. Use of existing satellite TT&C transmit antennas to generate a bi-static EM shield would provide a very important situational awareness capability without the need for additional on-orbit assets around individual satellites.

The **Long View** program is developing an inverse synthetic aperture laser radar that will enable the high-resolution imaging of geostationary satellites when coupled to a large aperture telescope. Long View will develop an optical reference oscillator that is stable over the propagation time to a geostationary satellite and back (about a quarter of a second), and autofocus algorithms that restore image quality that has been degraded due to atmospheric turbulence and optical reference oscillator instability over the imaging time (about 100 seconds).

The goal of the **Space Situational Awareness (SSA) & Counterspace Operations Response Environment (SCORE)** program is to develop and demonstrate an operational framework and responsive defense application to enhance the availability of vulnerable commercial space-based communications resources. SCORE will correlate a wide range of operational support and space system ground user data to rapidly identify threat activities, propose mitigating countermeasures, and verify the effectiveness of selected responses.

The **Space Surveillance Telescope (SST)** program will develop and demonstrate an advanced ground-based optical system to enable detection and tracking of faint objects in space, while providing rapid, wide-area search capability. A major goal of the SST program is to develop the technology for large, curved focal plane array sensors to enable an innovative telescope design that combines high detection sensitivity, short focal length, wide field of view, and rapid step-and-settle to provide orders-of-magnitude improvements in space surveillance. This capability will enable ground-based detection of un-cued objects in deep space for purposes such as asteroid detection and space defense missions.

Space Mission Protection

The **RAD Hard by Design** program is developing, characterizing, and demonstrating microelectronic design technologies to enable fabrication of radiation hardened electronic components using leading-edge, commercial fabrication facilities. The program is pursuing development of design-based technologies that will enable pure commercial fabrication technologies to attain radiation hardened electronics equivalent to those from dedicated foundries.

The effects of High Altitude Nuclear Detonations (HAND) are catastrophic to satellites, generating magnetically trapped charged particles that produce an enhanced radiation environment that would immediately degrade low earth orbiting (LEO) spacecraft capability and result in their destruction within a few weeks. The **Sleight of HAND (SOH)** program is a proof-of-concept demonstration of the technology and techniques to rapidly mitigate the HAND-enhanced trapped radiation within days of a HAND event, before LEO spacecraft capabilities are degraded.

The purpose of the **ULF Wave Study** program is to develop and demonstrate methods for controlling and optimizing signal generation of ultra-low frequency (ULF) waves as well as controlling propagation to develop the potential for use as a communication method. This will lead to a quantitative understanding of the outstanding issues related to ULF generation and global propagation appropriate for transition from research to field implementation. The ULF program will provide necessary understanding of HAARP generated ULF waves that will lead to the development of ULF for applications of significance to military operations.

Space-Based Support to the Warfighter

The goal of the **MEO Synthetic Aperture Radar (MEOSAR)** program is to develop techniques to identify moving targets and extract them from the data prior to imaging to avoid streaking caused by their motions. MEOSAR will develop reliable automated detection of moving targets within SAR imagery using a double thresholding process in interferometric phase and amplitude, a detection technique that can be readily reversed to excise the moving targets from the clutter (image) background. The program will develop improved motion detection and removal algorithms, demonstrate their performance on simulated and airborne data, and develop an architectural concept for a MEOSAR system.

The goal of the **Novel Satellite Communications (NSC)** program is to develop a multi-user satellite communications system that allows ground-based users with handheld radios to communicate with the satellite at high data rates, even when the users are close to multiple jammers and/or located in urban (i.e., severe multi-path) settings. NSC will accomplish this through novel signal processing, communications, and coding techniques.

INCREASING THE TOOTH TO TAIL RATIO

U.S. forces are on a transformation path to operational units that are rapidly deployable, flexible and effective across a range of missions, from combat to stability operations. Deployed forces require a robust and extensive support infrastructure that is growing even larger. The support infrastructure (the "Tail") holds back the ability of the operational units (the "Tooth") to deploy rapidly and be within the decision loop of enemy forces.

As information and communications increase in importance to modern combat and stability operations, more personnel are needed to operate the computers, software applications, and networks that support the front-line forces. New information technology offers an opportunity to increase the existing forces' tooth to tail ratio by reducing the number of personnel required for support operations and making them available for other duties as needed by the Combatant Commanders.

From the personal computer to the Internet and beyond, DARPA has been a key catalyst behind much of the information revolution. Information Technology (IT) is a powerful tool for warfighters because it increases their tooth to tail ratio: IT is a substitute for layers of bureaucracy that would otherwise be needed to process information and handle the routine chores required for many warfighting tasks, while enabling warfighters to do things they never could before.

DARPA is continuing this tradition, focusing on revolutionary new information technologies that will help the U.S. military make better decisions faster and with fewer support personnel.

There are three major themes in this strategic thrust:

- **Cognitive Computing** is reducing manpower by providing information systems that "know what they are doing" and can learn;
- **High Productivity Computing Systems** are speeding up the development and deployment of new weapon systems by more complete and rapid design and testing; and
- **Language Processing** is improving our global operations by providing local knowledge and interaction with the local population by removing language and culture barriers through superb machine language translation, thereby reducing the need for human translators.

COGNITIVE COMPUTING

The goal of the **Accelerated Learning** program is to identify non-invasive interventions that increase the speed of progressing from novice to expert in key military tasks. These may include, but are not limited to, neurophysiologically-driven training regimens, neurally optimized stimuli, and stimulatory/ modulatory interventions.

The ability to make real-time changes to fielded military systems is a concern. The introduction of instructable computing would permit non-programmers to reprogram hardware in real time in the field. The **Bootstrapped Learning** program will develop the core technology for such field-trainable military computing systems. This will directly address the growing need for real-time tactical reprogramming of military hardware and software systems. Bootstrapped Learning is essential for autonomous military systems that will need to understand not only what to do, but why they are doing it, and when it is appropriate to stop.

Finding and integrating the right fragments of information from disparate data sources is a long-standing challenge for heterogeneous, legacy military information systems. The **Data Integration and Exploitation SystEm that Learns (DIESEL)** program will develop a new suite of information integration techniques that can learn to automatically ingest and understand new information systems as they occur, and to semi-automatically map/integrate those new systems into the existing information environment. DIESEL's superior information integration capability will give warfighters the right information they need at the right time, resulting in better and faster decisions.

The **Education Dominance** program will provide the first Digital Tutor to interact with each student individually, thereby optimizing their learning pace and knowledge. Ultimately, the program will demonstrate its superiority against the schoolhouse and their best human tutors in a challenge cup.

The **Foundational Learning Technology** program seeks to develop advanced machine learning techniques that will enable cognitive systems to continuously learn, adapt, and respond to new situations by drawing inferences from past experience and existing information stores, resulting in military systems that are more robust, self-sufficient, and require minimal or no platform-specific customization. The program will develop hybrid learning techniques to create cognitive systems capable of learning military strategy, leveraging large amounts of prior knowledge, incorporating external guidance, and applying prior knowledge in real time to the naturally changing environment – all without programmer intervention.

The **Integrated Learning** program is creating a new computer learning paradigm in which systems learn complex workflows from warfighters, while the warfighters perform their regular duties – a capability that current machine learning technologies do not have. The program is focused on military planning tasks such as air operations center planning and military medical logistics. This learning technology would make it possible to create many different types of military decision support systems that learn by watching experts, rather than relying on hand-encoded knowledge, which is expensive and error-prone.

The **Know What Is to Know Subsystem (KWIKS)** program is developing a support tool that, during the execution of a military operation, autonomously and continually tracks the state of what is known about the environment (and how well), and the forms and priorities of additional collection needs to achieve mission objectives with fewer friendly casualties and lower collateral damage. KWIKS will provide substantially automated assistance to the current (laborious and non-real-time) process of collections planning, which currently includes manual steps such as analysis of external context, enemy and neutral goals and capabilities, and assessment of known threats.

The **Knowledge Representation and Reasoning Technology** program is developing technologies to acquire, integrate, and use high performance reasoning strategies in knowledge-rich domains to provide DoD decision makers with rapid, relevant knowledge from a broad spectrum of sources, such as text, that may be dynamic and/or inconsistent. This research will explore new computational models to enable command and control systems to use conceptual representations to perform visual-spatial reasoning and to assist the commander in understanding and analyzing complex battlefield scenarios.

The cost of handcrafting information within the narrow confines of first order logic or other artificial intelligence (AI) formalisms is prohibitive for many applications. **Machine Reading** addresses these issues by replacing the expert and associated knowledge engineer with un-supervised or self-supervised learning systems, systems that "read" natural text and insert it into AI knowledge bases, i.e., data stores especially encoded to support subsequent machine reasoning.

The **Personalized Assistant that Learns (PAL)** program is developing integrated cognitive systems that act as personalized executive-style assistants for military commanders and decision-makers. PAL is creating a new generation of machine learning technology that will enable information systems to: automatically adjust to new environments and new users; help commanders adapt to new enemy tactics, evolving situations and priorities; accelerate the incorporation of new personnel into command operations; and, make more effective use of resources.

The **Transfer Learning** program is developing technologies that will enable a military system, either autonomous or assisting a human, to function in novel operational scenarios by adapting and applying what it has learned from training scenarios and previous operational experience. The system would act effectively and appropriately in novel situations with little training. In order to acquire, restructure, and apply task and domain knowledge in novel domains, the program uses techniques such as learning by analogy, task chunking, deliberative techniques such as impasse analysis, and constructing modular, hierarchical and dynamically composable knowledge representations.

HIGH PRODUCTIVITY COMPUTING SYSTEMS

The goal of the multi-agency **High-Productivity Computing Systems (HPCS)** program is to develop revolutionary, flexible, and well-balanced computer architectures that will deliver high performance with significantly improved productivity for a broad spectrum of applications. The HPCS technology development plan has three phases that extend to the end of this decade. The three phases are: (I) concept design study; (II) research and development; and (III) system development, resulting in large-scale prototypes. In November 2006, the HPCS program moved into the third and final phase, in which two vendors will complete the designs and technical development of very large (petascale) productive supercomputers, demonstrating prototype systems in 2010-2011. If successful, HPCS will enable nuclear stockpile stewardship, weapons design, cryptanalysis, weather prediction, and other large-scale problems that cannot be addressed productively with today's computers.

LANGUAGE PROCESSING

The **Exploitation Language Technology for GeoINT** (geospatial intelligence) program will build a system to: (i) extract and linguistically confirm terms and labels of geographic significance from graphical, textual and audio sources; and (ii) to associate and verify the extracted information against features extracted from imagery. Both extraction and association will be performed across multiple languages, and the program will develop necessary database and query technology to support rapid access and search.

The **Global Autonomous Language Exploitation (GALE)** program is revolutionizing the exploitation of both speech and text in multiple languages, which is currently slow, labor-intensive, and limited, by providing, in an integrated product, automated translation of foreign speech and text, along with content distillation. GALE will eliminate the need for translation and subject matter experts at every military site where foreign language broadcast media and web-posted content information is obtained, and will enhance open-source intelligence and local/regional situational awareness. Earlier DARPA work in foreign language processing yielded an initial integrated architecture concept for speech transcription and text translation, resulting in near edit-worthy text. Continuing work under GALE will produce a fully mature integrated architecture and dramatically improve translation accuracy by exploiting context and other clues. GALE is addressing unstructured speech such as talk show conversations and chat room communications, and developing timely, succinct reports and alerts for commanders and warfighters.

The **Robust Automatic Translation of Speech (RATS)** program will address noisy and hostile conditions where speech is degraded by distortion, reverberation, and competing conversations. RATS will build upon advances in GALE technology to enhance the capabilities of speech processing to enable Soldiers to hear or read clear English versions of what is being said in their vicinity, despite a noisy environment.

The **Spoken Language Communication and Translation System for Tactical Use (TRANSTAC)** program is developing technologies for robust, spontaneous, real-time two-way translated speech between our warfighters and native speakers. TRANSTAC addresses the issues surrounding the rapid deployment of devices for translating new languages, especially languages and dialects with few translators. The program will support Arabic dialects spoken in Iraq.

BIO-REVOLUTION

DARPA's strategic thrust in the life sciences, called Bio-Revolution, is a comprehensive effort to harness the insights and advances of modern biology to make U.S. warfighters and their equipment safer, more capable, and more effective.

For more than a decade, the United States and many other nations have made enormous investments in the life sciences – so much that it has become commonplace to say that the world is entering a "golden age" of biology. DARPA is mining these new discoveries for concepts and applications that could enhance U.S. national security in revolutionary ways.

DARPA's bio-revolution thrust has four broad elements:

- **Protecting Human Assets** refers to DARPA's work in biological warfare defense (BWD) and combat casualty care. Advances in BWD will protect warfighters not only from biological warfare agents, but also from the infectious diseases they regularly encounter overseas. We are also developing advanced combat casualty care technologies to greatly improve the chances of our wounded surviving battlefield injury.
- **Biology to Enhance Military Systems** is creating new systems with the autonomy and adaptability of living things by developing materials, processes, and devices inspired by living systems. The idea is to let nature be a guide toward better engineering.
- **Maintaining Human Combat Performance** is aimed at maintaining the warfighter's peak physical and cognitive performance once deployed, despite extreme battlefield stresses such as heat and altitude, prolonged physical exertion, and sleep deprivation.
- **Restoring Combat Capabilities after Severe Injury** describes the revolutionary technology DARPA is developing to restore full function after severe injuries. Examples include techniques to accelerate healing, and revolutionary new prostheses for combat amputees.

PROTECTING HUMAN ASSETS

The **Accelerated Manufacturing of Pharmaceuticals** program will create an extremely rapid, flexible, and cost-effective manufacturing system capable of producing three million doses of Good Manufacturing Process-quality vaccines or monoclonal antibodies within 12 weeks. This revolutionary manufacturing platform will have extraordinary flexibility, allowing for the manufacture of vaccines to protect against a wide range of viral, protozoan, fungal, bacterial, and toxin antigens. A key to the program will be using manufacturing facilities that can be rapidly and cheaply established and/or used for other applications when not producing therapeutics.

The goal of the **Blood Pharming** program is to create a donor-less blood supply via the creation of custom automated cell culture systems capable of large-scale blood cell production from progenitor cell sources.

The goal of the **Chip-Scale Micro Gas Analyzer** program is to utilize the latest microelectromechanical systems (MEMS) technologies to implement separation-based analyzers (e.g., gas chromatographs, mass spectrometers, and polychromator-like devices) at the microscale to greatly enhance the selectivity of sensors to specific species. This will enable extremely reliable, remote detection of chemical/biological agents. The use of MEMS technology should also increase analysis speed and allow such complex analyzer systems to operate at extremely low power levels – perhaps low enough for operation as autonomous, wireless sensors.

The **Deep Bleeder Acoustic Coagulation (DBAC)** program will develop an automated system for detecting and stopping internal bleeding. It nominally will consist of a "blanket" or cuff, which, once placed over the injured area, will automatically detect (through acoustic Doppler sensing) and cauterize the internal wound using ultrasonics.

The **Extreme Chemical Clothing** program will develop a completely new approach to chemical protection based on an impermeable shell and a vapor layer with microfluidic materials and peristaltic flow to maintain core temperature during intermittent bursts of combat activity. Blending characteristics of a thermos and a heat pipe, Extreme Clothing will enable extended operation in desert, arctic, and high-altitude environments by independently controlling evaporative heat transfer and external shell temperature as core bioheat generation fluctuates.

The **Feedback Regulated Automatic Molecular Release (FRAMR)** program is developing biodegradable self-regulating drug delivery systems that will enable feedback-regulated release in response to biomarker(s) correlated with drug efficacy and/or toxicity. These systems will enable Soldier self-care through drug delivery methods that guarantee, in the combat environment, a therapeutic dose while eliminating the possibility of overdose.

The **Femtosecond Adaptive Spectroscopy Techniques for Remote Agent Detection (FASTREAD)** program will demonstrate the capability to detect biological agents at standoff distances. The keys to this new capability are advances in femtosecond lasers, coupled with coherent nonlinear optical spectroscopy, laser pulse shaping techniques, and adaptive optics used with strategies that optimize the return signal. The final goal of this effort will be to demonstrate sensitivities down to 10 agent-containing-particles per liter of atmosphere.

The goal of the **Hyperadsorptive Atmospheric Sampling Technology (HAST)** program is to develop systems that permit exhaustive, accurate, and economical collection of atmospheric trace constituents for chemical mapping of urban and military environments. The system will demonstrate materials, packaging, and extraction technologies that sample atmospheric impurities whose concentration ranges from 20 parts per trillion to 200 parts per million by volume from 100 liter-atmospheres of gas in less than five minutes.

The objective of the **Long Term Storage of Blood Products** program is to extend the shelf life of human blood products through natural means to provide medical operations in theater a safe, storable, and stable supply of blood and hemostatic agents. Plans include the transition of a human platelet product with a shelf life of two years at room temperature.

The goal of the **Military Medical Imaging** program is to provide a formidable arsenal of diagnostic tools for warfighter performance and care by developing medical imaging capabilities to support military missions and operation. The program will miniaturize and enhance the capabilities and speed of CAT scanners and will develop non-invasive imaging modalities for use by medics.

Today's chemical sensors are unable to combine sensitivity (parts-per-trillion) and selectivity (unambiguous identification of molecular species) with low false alarm rate. The **Mission-Adaptable Chemical Sensors (MACS)** program will develop a sensor based upon rotational spectroscopy of gases that will have superior capability in all categories, with the goal of achieving the highest possible sensitivity (parts-per-trillion) for unambiguous detection of all chemical species. MACS will focus on size reduction and simplicity of function to achieve portability and simultaneous detection of hundreds of species.

The **Nightingale** program will design, develop, integrate and demonstrate the enabling technologies and system capabilities required to perform fully autonomous, just-in-time medical response and evacuation using an autonomous, airborne, man-rated platform. The Nightingale system will integrate advanced life support capabilities into a small unmanned (or optionally piloted) air vehicle that can serve as a low-cost, high-availability air ambulance deployed forward alongside troops in contact

The goal of the **PACMAN-V** program is to make an artificial phagmosome, or "destructive vacuole," which can be directed by surface ligands to destroy viruses, protozoa, or bacteria.

Skin, wound, and catheter infections are a major cause of morbidity and mortality following battlefield trauma. The goal of the **Plasma Self Sterilization Medical Devices** program is to develop self-sterilizing medical devices to reduce post-trauma and post-treatment systemic infection in combat medical care. The current focus includes experiments to determine the effectiveness of plasmas against a variety of microbes, as well as to identify the principal mechanism of action for plasma affects.

The **Predicting Health and Disease (PHD)** program will develop methods to assess whether an individual will develop a disease before the onset of symptoms. While current methods diagnose and treat after an individual reports to a physician, the goal of the PHD program is to use frequent surveillance to detect, intervene, and eliminate disease before symptoms emerge, with the vision of maintaining warfighter medical readiness. PHD will develop the technology for a field-portable, point-of-care health assessment system that is able to handle large throughput (100 or more analyses) in short time spans (less than 3-hour turnaround) at low cost. This will require a multidisciplinary approach to diagnostics that includes, at a minimum, innovative data analytic methodologies coupled with traditional and nontraditional medical diagnostics.

Predicting Pathogen Emergence is a multidisciplinary program that will deploy metagenomics, population immunity, and commensal (non-pathogenic) colonization as tools to prevent the emergence of new human diseases such as Marburg, severe acute respiratory syndrome, and avian influenza.

The **Preventing Violent Explosive Neurological Trauma (PREVENT)** program is aimed at protecting our warfighters from traumatic brain injury resulting from explosions, such as those from improvised explosive devices. The goal of the early phases of this effort is to identify the physical and biological mechanisms that cause this injury. These results will be used to develop medical treatments and protective countermeasures that directly address the cause of injury.

The **Radiation Biodosimetry (RaBiD)** program is developing technologies for rapid, high-throughput, portable and low-cost biodosimeters to determine the radiation dose to individuals after acute radiation exposure. This technology will rapidly identify individuals who have been exposed to high-dose radiation in order to accurately assess radiation exposure levels.

The **Rapid Vaccine Assessment** program is developing an interactive and functional *in vitro* human immune system using tissue engineering. This "immune system" will be able to test the efficacy of vaccines against threat agents that, at the present time, can only be tested in animal models, thus significantly decreasing the time needed and increasing the probability of success for biological warfare vaccine development.

There are no simple, automated respiratory support devices that are suitable for the combat medic. Breathing emergencies on the battlefield either go untreated or require the full attention of combat medics, leaving them unavailable to help other casualties. The **SAVe: Portable Ventilator** program developed an automated "Ambu bag" usable in theatre by the combat medic that is simple to operate, safe, rugged, and inexpensive. Since last year, the SAVe ventilator has been deployed with combat medics, and is saving lives today. Because of its compact size, ease of use, and cost, a modification of the SAVe is being developed for civilian emergencies, such as pandemics.

The **Self-Decontaminating Surfaces** program will explore, identify, and develop creative new material technologies for the ultimate purpose of providing a surface treatment that is biocidal and exhibits self-cleaning/renewal behavior. The approach will involve innovative ways to incorporate biocides into various surface treatments that will be used with mechanisms of self-cleaning that explore the use of hierarchical surface morphology.

The **Sensor Tape** program will develop and demonstrate a low-cost one-time-use low-power band-aid sized adhesive-applied blast dosimeter that records accumulative blast effects for integration into combat medical care.

The **Standoff Triage** program will develop remote life signs detection technologies to assess the medical condition of individuals on the battlefield, at ranges of 10-100 meters, prior to sending in medics under fire. This program will develop remote optical, infrared, and radio frequency techniques to monitor key life signs, such as respiration and heart rate, to determine the timing and magnitude of a potential medical response. The technologies will be evaluated for handheld operations by medics on the ground, and on airborne platforms conducting post-conflict battlefield surveillance.

The objective of the **Surviving Blood Loss** program is to delay the onset hemorrhagic shock due to blood loss by reducing cellular oxygen demand. This will require developing a fundamental understanding of the mechanisms of oxygen use in cells, as well as the degradation mechanisms caused by lack of oxygen and how to reduce them.

The **Threat Agent Cloud Tactical Intercept and Countermeasure (TACTIC)** program will develop and demonstrate the capability to: (i) rapidly detect, classify, and identify an airborne chemical warfare agent/biological warfare agent battlefield threat at standoff distances; and (ii) use countermeasures to neutralize and/or precipitate the threat before it reaches the intended target. Upon successful completion of the preliminary design and critical design reviews, a prototype system will be built to demonstrate an effective classification/identification and countermeasure system capability in open-air tests.

The **Transportable Magnetic Resonance Imaging (MRI)** program is developing an MRI system capable of field deployment to in-theater combat support hospitals for diagnosis and assessment of traumatic brain injuries to front-line Soldiers, Sailors, and Airmen. The program will demonstrate a MRI system that weighs less than 800 pounds and has a footprint of less than 10 square feet. The goal is for the system to have a field of view 25 centimeters by 25 centimeters by 25 centimeters, with 1.5 millimeter by 1.5 millimeter by 1.5 millimeter volumetric pixel dimensions, and that effectively produces two-dimensional axial images in 45 seconds or less (per 1.5 millimeter slice).

The vision of the **Trauma Pod** program is to develop a rapidly deployable system permitting a remote physician to perform critical acute stabilization and/or surgical procedures in a teleoperative mode on wounded Soldiers in the battlefield who might otherwise die from loss or airway, hemorrhage, or other acute injuries, such as a tension pneumothorax, before they can be transported to a combat hospital. The system would be used when the timely deployment of proper medical personnel is not possible or too risky, and the patient cannot be evacuated quickly enough to an appropriate medical facility. The program has demonstrated, for the first time, the conduct of a surgical procedure on a human phantom using only a telerobotic surgeon and robotic surgical assistants.

The goal of the **Virtual Autopsy** program is to develop a new concept in post-mortem examination to compliment current procedures by increasing both the accuracy and speed of performing autopsies. This will make autopsy information available more rapidly, while being less invasive. It will also provide information that will lead to a better understanding of wartime injuries and, thus, the development of improved protective equipment.

The **Wound Stasis Spray** program will create a nanofiber-based sprayable wound treatment that provides: (i) immediate prevention of blood loss; (ii) antimicrobial activity; and (iii) control of local tissue responses including pain and inflammation. The end product will be a spray device that maintains therapeutic stability under military operating conditions, carries enough product to treat cubic square feet, and is operable with one hand.

Biology to Enhance Military Systems

Accelerated Learning: Operational Systems will demonstrate "novice to expert" quantitative tracking and acceleration in specific operational tasks of interest on military populations, aligned with current service partner goals. The program will develop both task-specific and task-independent methods and strategies for learning acceleration applicable across multiple domains.

The **Biodemilitarization of Munitions** program will develop a system for rapid, safe, and effective inactivation of explosive munitions stockpiles in-place, greatly reducing the raw materials available for constructing, for example, improvised explosive devices. The program will develop chemical and biological technologies and control processes to rapidly perforate munition casings and alter the explosive fill. The perforation and explosive alteration technologies will be integrated into a fieldable system and tested against munitions stockpiles.

The **Biological Sensory Structure Emulation (BioSenSE)** program is designed around the concept of understanding biological sensory structures through advanced characterization, and emulating or transferring this knowledge to the creation of superior synthetic sensors. This program will focus on vibration/flow sensing and thermal sensing, with the goal of producing man-made sensors with the extreme capabilities found in the biological world.

The goal of the **Biologically Inspired Sensor Arrays** program is to mimic biological approaches to develop smaller scale arrays suitable for small unmanned air vehicles. The program will explore multipath interactions, frequency/temporal/spatial relationships, and the corresponding advanced space-time-frequency signal processing algorithms to develop highly sensitive directional capabilities.

The **Cognitive Technology Threat Warning System (CT2WS)** program is developing prototype Soldier-portable digital imaging threat queuing systems capable of effective detection ranges of one to ten kilometers against dismounts and vehicles, while simultaneously surveying a 120-degree or greater field-of-view. The program will harness the brain's natural capacity to rapidly detect threats (human-in-the-loop) with hardware and software implementations of neuromimetic processing similar to that carried out by the human visual system to create a cognitive system that quickly finds threats in the environment – with a low number of false positives – giving our warfighters more time to make tactical decisions within the operating environment.

The **Enabling Stress Resistance** program will create a comprehensive, quantitative description of the impact stress has on the brain, including neurophysiological, cognitive and behavioral measures. This includes understanding stress resilience, effects of intense physical exercise on the brain, repeated stress exposure, maladaptive stress response, control over stress, corticosterone stress response, and genetic identification of novel target genes related to the stress response and profile.

The **Nastic Materials** program will develop new materials that distribute the strain and power capability of hydraulic actuation throughout an active material. This will result in a material that is truly *adaptive*, i.e., a material that can change shape with essentially infinite degrees of freedom, producing large-scale structural shape changes.

The **Neovision2/Neovision** program is pursuing an integrated approach to understanding the object recognition pathway in the brain. This fundamental biological research will use methods intentionally geared toward computational and modeling approaches that are amenable to hardware- and software-based implementations. If successful, this effort would propel the field of visual neuroscience forward, while laying the groundwork for synthetic visual systems with drastically improved speed and fidelity.

The goal of the **Neurotechnology for Intelligence Analysts (NIA)** program is to understand how early neural signals can be used to determine when the brain has seen a particular image of interest, and to develop approaches to non-invasively measure these signals. Successful development of a neurobiologically-based image triage system would increase the speed and accuracy of image analysis in a context where the number of acquired images is expected to rise significantly.

The **Powerswim** program is using the highly efficient way sea animals swim to design a new swimming device. Ordinary swim fins push through the water and are about 10 percent efficient. The Powerswim program is developing a device that uses fin lift for propulsion – it basically "flies" through the water – with an efficiency of 80 percent. This could double the speed and range of U.S. Navy SEALS, allowing them to arrive on-shore much faster and much less fatigued.

The **RealNose** program will create an exquisitely sensitive, but flexible olfactory system built from, and inspired by, the structure and components of the mammalian olfactory system.

The goal of the **Stealthy Sensors** program is to capitalize on unique capabilities in animal endurance, mobility, and sensing to protect military personnel in high-threat environments. Example applications include using a pigeon's natural homing behavior to redirect trained birds to investigate a remote target, and a multifunctional electronics package for high-performer improvised explosive device detection dogs.

The goal of the **Understanding Long Term Memory** program is to determine the precise biochemical basis for the induction and maintenance of long term memory, focusing on the neuron, not the synapse. The program will develop training and assessment techniques that maximize long term memory.

The **Z-Man** program is developing climbing aids that will enable an individual Soldier to scale vertical walls constructed of typical building materials without the need for ropes or ladders. The inspiration for these climbing aids is the technique by which geckos, spiders, and small animals scale vertical surfaces by using unique biological material systems that enable controllable adhesion using van der Waals forces, or by hooking surface asperities. This program seeks to build synthetic versions of those material systems and then use them in a novel climbing aid optimized for use by humans.

MAINTAINING HUMAN COMBAT PERFORMANCE

The **Molecular Targets of Stress** program will determine the precise biochemical mechanism that leads to adverse consequences associated with physical and/or mental stress. Whether physical or mental, stress leads to the production of adrenaline and similar hormones that affect diverse cells in similar ways. By precisely identifying the biochemical changes inside the cell, the program will identify targets for new countermeasures. Impacts of the program could span from muscle fatigue to post traumatic stress disorder.

The goal of the **Peak Soldier Performance** program is to develop novel strategies that exploit and control the mechanisms of energy production, metabolism, and use during short periods of deployment requiring high levels of physical demand. The ultimate goal is to deploy the warfighter at peak physical condition and maintain that level of performance throughout the mission, providing the warfighter with the ability for prolonged activity without the loss of strength, endurance, or mental acuity during mission critical periods.

Restoring Combat Capabilities after Severe Injury

The **Cell Prosthetics** program will develop therapeutics for diverse forms of battlefield injury by focusing on the cell as a target for therapeutics. Specific technologies to embed enzymes or custom drug portals in the cell membrane will be investigated. The program offers the potential for universal cellular grafts that can be utilized for repair and restoration.

The **Closed-Loop Bone Osteogenesis** program will develop an implantable device useful for stimulating bone growth in cases of traumatic injury and lengthening of remnant limbs after amputation. The "smart implant" will facilitate modification of treatment parameters based on feedback (mechanical and biological) from the regenerate site.

The **Cranial Facial Reconstruction (FACE)** program will co-develop a high-fidelity wound imaging and modeling system with advanced tissue engineering focused on correction of cranio-facial trauma. The developed set of tools would allow *in silico* surgical planning/training and produce patient-specific facial tissue ready for surgical implantation.

The goal of the **Human-Assisted Neural Devices (HAND)** program is to develop the scientific foundation for understanding the language of the brain for application to a variety of emerging DoD challenges, including improving performance on the battlefield and returning active duty military to their units. This will require an understanding of neuroscience, significant computational efforts, and new material design and implementation. Key advances expected from this research include the ability to improve decision making in a variety of DoD applications, including imagery analysis. This program will also provide an understanding of how the brain adapts as it learns, which can be translated into improved training approaches that allow transition from novice to expert in military tasks, e.g., marksmanship, with minimum effort and time.

The **Restorative Encoding Memory Integrated Neural Device (REMIND)** program will restore memory function to warfighters who have suffered a traumatic brain injury (TBI). These methods could be applied to the broader TBI patient population, as well as to those who have suffered from stroke.

The rate and quality of wound healing is a critical factor in recovering from battlefield injury, including loss of limb and burns. By developing an understanding of the behavior of cells as they recover from injury, the goal of the **Restorative Injury Repair/Phase II** program is to reduce healing times by 50 percent, while significantly reducing the scar tissue that leads to serious future complications.

The goal of the **Revolutionizing Prosthetics** program is to radically improve the state of the art for upper limb prosthetics, moving them from crude devices with minimal capabilities to fully integrated, fully functional limb replacements that are directly controlled by the brain, just like natural limbs. Current prosthetic technology generally provides only gross motor functions with very crude approaches to control, which makes it difficult for wounded soldiers to return to military service. The program is combining the talents of scientists from diverse areas (including medicine, neuroscience, orthopedics, engineering, materials science, control and information theory, mathematics, power, manufacturing, rehabilitation, psychology and training) to radically improve the ability of combat amputees to return to normal function.

Core Technologies

The eight DARPA strategic thrusts described above are strongly driven by national security threats and opportunities. However, a major portion of DARPA's research emphasizes areas largely independent of current strategic circumstances. These core technologies are the investments in fundamentally new technologies, particularly at the component level, that historically have been the technological feedstocks for new systems creating quantum leaps in U.S. military capabilities.

In fact, these technologies often form enabling chains. Advanced materials have enabled new generations of microelectronics, which, in turn, have enabled new generations of information technology, the key technology for network-centric operations. DARPA's support of these foundations naturally flows into its strategic thrusts with a fair amount of productive overlap. For example, some of the work under the Bio-Revolution thrust is closely related to the materials work, and the information technology work is being reshaped by the Increasing the Tooth to Tail thrust.

Quantum Science and Technology

Until recently, quantum effects in many electronic devices did not have overriding significance. However, with shrinking device sizes, quantum effects not only have to be taken into account but can dominate how devices perform. DARPA is conducting research aimed at technology built around exploiting quantum effects to achieve revolutionary new capabilities.

The **Cognitively Augmented Design for Quantum Technology (CAD-QT)** program is developing learning-based optimization tools to enable the design of radically new electronic, optical, and optoelectronic devices that exploit effects at the quantum level. This is in contrast to traditional microelectronic/photonic device design, which utilizes quantum effects only at the scale where the numbers of carriers or photons is large enough to apply statistical averages. CAD-QT is developing quantum models and advanced search and optimization algorithms to create an intelligent search engine to guide the designer through the complex trade spaces of quantum device design.

The **Guided BEC** (Bose-Einstein Condensate) program is developing improved navigation technology for aircraft (including unmanned air vehicles) and naval vessels by demonstrating Bose-Einstein Condensate-based atom interferometers as a way to precisely measure device rotation. Both magnetic and optically formed waveguides will be used to demonstrate rotation sensitivity. This program will also focus on improving BEC lifetime and atom flux, which will allow devices to reach compelling sensitivity levels and enable atom interferometer-based inertial measurement units that offer two orders-of-magnitude improvement over current navigation systems.

The **Hyperspectral Radiographic Sources (HRS)** program will develop a set of interoperable modules to convert ultra-short, ultra-intense laser pulses into high-brightness beams of either secondary photons (vacuum ultraviolet light, x-rays, etc.) or particles (protons, electrons, neutrons, or positrons). By interfacing with a common laser source, a single table-top apparatus will form a system by which one would duplicate many of the capabilities of several different National-Laboratory-scale facilities.

The goal of the **Nanoscaled Architecture for Coherent Hyper-Optic Sources (NACHOS)** program is to produce nanoscaled lasers with all three dimensions shorter than the wavelength of the light they produce. Nanoscaled lasers potentially offer a wide range of applications, including close integration with electronics, on-chip light sources, and single photon sources.

The **Quantum Entanglement Science and Technology (QuEST)** program is creating new quantum information science technologies, focusing on loss of information due to quantum decoherence, limited communication distance due to signal attenuation, protocols, and larger numbers of quantum bits (Qubits) and their entanglement. Key among the program's challenges is integrating improved single- and entangled-photon and electron sources and detectors into quantum computation and communication networks. Defense applications include highly secure communications, algorithms for optimization in logistics, highly precise measurements of time and position on the earth and in space, and new image and signal processing methods for target tracking.

The **Quantum Information Science (QIS)** program will explore all facets of the research necessary to create new technologies based on quantum information science. The goal of the program is to demonstrate the potentially significant advantages of quantum mechanical effects in communication and computing. Expected applications include: new, improved forms of highly secure communication; faster algorithms for optimization in logistics and wargaming; highly precise measurements of time and position on the earth and in space; and new image and signal processing methods for target tracking.

The **Quantum Sensors** program is developing approaches to exploit non-classical effects called entanglement to improve the resolution and range of military sensors. Quantum sensors will retain the generally better propagation characteristics of long wavelength light, while achieving the better spatial resolution of short wavelength radiation. Whereas conventional, classical sensors rely on light with shorter wavelengths (e.g., blue light) to produce sharp images, quantum sensors will be able to use a non-classical effect called "entanglement" to retain high resolution as the wavelength increases. Two broad classes of sensor are under consideration: Type I quantum sensors propagate entangled photons to a target and back to a detector, where quantum effects may enhance resolution; Type II quantum sensors propagate classical radiation to the target, and entangled photons are used within the detector to improve resolution. A third class of approach, based on ghost imaging, is also being explored.

The goal of the **Slow Light** program is to develop the fundamental physics and materials to enable the engineering and integration of "slow light" optical components for a broad variety of information processing tasks. Key technical challenges include developing new solid-state materials, detailed study of non-equilibrium effects and other physical limitations of slow light systems, and understanding and exploiting few-photon interactions with slow light systems.

BIO-INFO-MICRO

For the past several years, DARPA has been exploiting and developing the synergies among biology, information technology, and micro-/nanotechnology. Advances in one area often benefit the other two, and DARPA has been active in information technology and microelectronics for many years. Bringing together the science and technology from these three areas produces new insights and new capabilities.

The **Bio-Electronics and Photonics** program will demonstrate new capabilities in biologically derived optical and electronic media and devices. The program will explore highly promising organic and biological materials, such as deoxyribonucleic acid (DNA), proteins, and novel nucleic acid-like materials that have the potential to fundamentally change the way that we develop and process electronics by producing the biological analog of band gap and heterostructure engineering. The program will develop techniques for inclusion of such biological materials in a myriad of electrical devices ranging from diodes to batteries, the primary objective being improved performance (e.g., reduced leakage current and faster switching times in field effect transistors) and lower costs.

The **Brain Plasticity for Accelerated Learning** program will conduct basic research to uncover and utilize the innate plasticity in the human brain in order to accelerate learning in the operational environment. This effort will develop specific methods to track, facilitate and accelerate learning in the operational environment through line sensitive electroencephalography and functional magnetic resonance images

The **Control of Protein Conformations** program will enable the modulation of single protein affinity, activity, and selectivity via real-time manipulation of single protein conformation. Real-time control of protein conformation will enable the development of biosensors with tunable properties and/or improved countermeasures for defense against chemical and biological attack.

The **Engineered Bio-Molecular Nano-Devices and Systems** program will develop and demonstrate engineered bio-molecular, nanoscale devices that enable real-time observation and analysis of bio-molecular signals, enabling single-molecule sensitivity with the simultaneous exploitation of the temporal domain (i.e., stochastic sensing). Arrays of such devices will enable an order-of-magnitude (10- to 10-times) reduction in the time required to analyze and identify known and unknown (engineered) molecules.

The goal of the **Fundamental Laws of Biology** program is to discover the mathematical principles (i.e., fundamental laws) of biology. The first phase has identified fundamental problems in mathematical biology that cross many orders-of-magnitude in spatiotemporal scales. The goal of the current phase is to translate the mathematical language developed in phase one into theories of biological phenomenon that can be used to make and verify predictions.

The goal of the **Hybrid Insect MEMS (HI-MEMS)** program is to create technologies to reliably integrate microsystems payloads on insects. If successful, these payloads would extract power from the insect, control insect locomotion, and also carry DoD-relevant sensors. The technology would use biological entry points in insect development, e.g., metamorphosis, to achieve reliable bio-electro-mechanical interfaces to insect sensors and tissue. One of the program's objectives is to control insect locomotion to within five meters over a distance of 100 meters, have the insect remain at the target, and transmit information from sensors, microphone, and, possibly, a camera.

The **Intelligent Multi-modal Volume Angio Computed Tomography (IM-VAC)** program will create a digital imaging system that is capable of performing a total body scan of a person using the multiple scanning techniques of computed tomography (CT), positron emission tomography (PET), and single positron emission tomography (SPECT) on a single detector. Such a capability will be able to produce a single image that presents both anatomic (CT scan) and functional (PET and SPECT scans) information in a single image.

The goal of the **Non-contact EEG Technologies (NET)** program is to develop a non-contact electroencephalograph system based on new electric field sensor designs. The sensors would have performance characteristics to measure the electric field due to brain activity (0.5-21 hertz (Hz) signal with 500 nanovolt per $Hz^{1/2}$ sensitivity) and be compact enough to mount on a lightweight cap or inside a warfighter's helmet. The signal from the individual sensors would then be collected and sent wirelessly to a unit mounted on the subject for further processing.

The **Plantenna** program is investigating the potential for use of plants as antennae. Applications include: (i) repeaters for low-power interior monitoring devices; (ii) covert cellular communication network; (iii) clandestine radio reception and broadcast; and (iv) spoofing enemy countermeasures.

The goal of the **Protein Design Processes** program is to radically transform the protein design process by developing new mathematical and biochemical approaches to the *in silico* design of proteins with specific functions. This would be extremely important to enhancing the discovery and design processes for therapeutics by determining the structure of a specific protein that binds with a specific pathogen in days, not months.

The **Revolutionizing Electronics with Biological Materials** program aims at two objectives: (i) develop new materials to replace silicon for ultra-dense and miniaturized electronic devices; and (ii) develop liquid-state electronics. Specifically, the program will explore highly promising organic and biological materials, such as deoxyribonucleic acid (DNA), proteins, and novel nucleic acid-like materials that have the potential to fundamentally change the way electronics are developed and processed.

The **Systems of Neuromorphic Adaptive Plastic Scalable Electronics (SyNAPSE)** program will develop a brain-inspired electronic "chip" that mimics the function, capacity, size, and power consumption of a biological cortex. If successful, the program will provide the foundations for functional machines to supplement humans in many of the most demanding situations faced by warfighters today. A specific objective of the program is to process video images for information abstraction (e.g., annotation) and task initiation. The two main technical challenges to achieving this vision are developing an artificial electronic synapse and developing a neural algorithm-architecture that exploits these synapses.

The **Young Faculty Award (YFA)** program will identify rising research stars in junior faculty positions in academia and expose them to DoD needs and DARPA's program development process. The long-term goal is to develop the next generation of academic scientists in key disciplines (e.g., microsystems, mathematics, and neuroscience) who will focus a significant portion of their career on DoD and national security issues.

MATHEMATICS

DARPA's mathematics program develops new mathematical tools for a broad continuum of DoD missions. The program is rooted in the tenet that DoD needs are best addressed by integrated teams of mathematicians and subject matter experts. This enables the rapid exploitation of new mathematical techniques to create novel technologies, as well as translating technological needs into research problems for the mathematics community.

The goal of the **Analog Logic** program is to develop and demonstrate architectures, designs, and development tools for implementing computational functions in analog circuitry to overcome performance limitations inherent in digital designs. This program will apply the technologies to signal processing functions typically performed in digital form, which experience design complexity, high power consumption, thermal loads, limits to computational speeds, loss in dynamic range, and susceptibility to manufacturing variances. The Analog Logic program will build and demonstrate an analog-only signal processing capability with no local oscillator, down-conversion, or analog-to-digital conversion.

The **Computational Duality** program will exploit deep dualities in theoretical mathematics, such as those linking facts between algebra and geometry, number theory and physics, as well as frequency and phase, to derive and develop fast computational algorithms. These computational advances will result in a set of robust tools to enable deeper understanding of multi-scale biological structures, quantum level phenomena, neuroscience, network analysis, fluid flow, and the structure of physically based partial differential equations. These techniques will be fundamental in understanding both stochasticity in nature and computation at scale -- the two major computational challenges facing DoD in the coming century.

The **Discovery and Exploitation of Structure in Algorithms (DESA)** program is aimed at developing mechanisms to provide simultaneous optimality and portability to algorithmic implementations. Current practice entails hand-tuning, by experts, of software kernels for optimal execution on specific hardware platforms. DESA seeks mechanisms to replace this expensive practice with automated mechanisms for optimizing the implementation of crucial classes of algorithmic primitives (e.g., basic operations of signal/image processing, trellis operations, graphics) for computing platforms of disparate characteristics.

The goal of the **Focus Areas in Theoretical Mathematics (FAThM)** program is to develop new mathematical foundations for conformal field theory in physics. It is also pioneering a new approach for conducting focused research collaborations in defense-relevant basic mathematics.

The **Geospatial Representation and Analysis** program will develop mathematical methods that provide efficient representations of geometric objects that, in turn, enable high compression ratios, while preserving end-user precision and accuracy requirements. This will address shortfalls in the ability to represent geometric objects for a number of defense applications, such as digital maps and terrain models.

The **Mathematics of the Brain (MoB)** program will leverage recent advances in neuroscience and mathematics to construct an integrated mathematical model of the brain that is consistent and predictive, rather than merely biologically inspired. Further, MoB will seek to develop a theory that overcomes the difficulties present in traditional approaches, such as artificial intelligence and artificial neural network, to properly model complex human brain processes such as logical reasoning, language, mental computation, and context-dependent mental set.

The principal goal of the **Non-Linear Math for Mixed Signal Microsystems (NLMMSM)** program is to demonstrate a significant linearity enhancement capability based upon a digital signal processing approach, implemented in a high-performance, very large scale integration (VLSI) chip, enabling wideband, high-dynamic range sensor systems to be developed in a cost effective manner. Unlike conventional approaches that struggle to correct nonlinearities, NLMMSM exploits inherent system nonlinearities to achieve unparalleled performance.

The goal of the **Robust Uncertainty Management (RUM)** program is to create a new system-level design paradigm that is able to achieve performance and cost objectives, while managing the uncertainty that is inherent in large, multiscale, highly interconnected systems where dynamics are important. This will enable large systems, such as those routinely found in defense, that are robust by design, fault-tolerant, with guarantees of performance given uncertainty arising from noise and incomplete identification of the state.

The **Sensor Topology for Minimal Planning (SToMP)** program will develop and implement global topological and geometric tools to dramatically reduce the amount of sensing complexity needed to solve problems involving sensor networks, autonomous systems, and configurable sensor platforms. The program will leverage high-dimensional mathematical insights to capitalize on miniaturized, pervasive, and coordinated sensors. These fundamental mathematical and computational tools will have a broad impact across several defense applications as sensor networks, autonomous systems, and configurable sensor platforms reside throughout the military.

The purpose of the **Topological Data Analysis (TDA)** program is to develop the mathematical concepts and techniques necessary to determine the fundamental geometric structures underlying massive data sets, and then develop further tools to exploit that knowledge. This program will produce cross-cutting, easy-to-use algorithms that exhibit and extract hidden properties of massive data sets, and export them to diverse groups of DoD practitioners investigating data sets of military significance.

MATERIALS

The importance of materials technology to Defense systems is critical and long-standing. Many fundamental changes in warfighting capabilities have sprung from new or improved materials. The breadth of this impact is large, ranging from stealth technology, which succeeds partly because materials can be designed with specific responses to electromagnetic radiation, to information technology, which has been enabled by advances in materials for electronic devices.

In keeping with this broad impact, DARPA maintains a robust and evolving materials program. DARPA's approach is to push new materials opportunities and discoveries that might change how the military operates. In the past, DARPA's work in materials has led to such technology revolutions as high-temperature structural materials for aircraft and aircraft engines, and the building blocks for the world's microelectronics industry. The materials work DARPA is supporting today builds on this heritage.

DARPA's current work in materials includes the following areas:

- **Structural Materials and Components** includes low-cost and ultra-lightweight materials designed for structures and to accomplish multiple performance objectives in a single system;
- **Functional Materials** are advanced materials for non-structural applications such as electronics, photonics, magnetics, and sensors; and
- **Smart Materials and Structures** involves materials that can sense and respond to their environment.

Structural Materials and Components

The **Accelerated Insertion of Materials** program is developing computational and experimental approaches to shorten the time it takes for a material to move from research to a defense application. Past efforts have focused on inserting superalloys for turbine disks and composites for aircraft structures. The current thrust is a joint effort with the Office of Naval Research to develop a digital research tool to quantitatively describe and explore three-dimensional microstructural evolution for the design, prediction and control of engineering materials.

The promise of carbon nanotubes has been thwarted by the inability to maintain the order-of-magnitude increase in properties when the nanotubes are made into composites. The **Advanced Structural Fiber** program will demonstrate continuous, cost-effective processing of the nanotubes into fibers that have the same properties as the nanotubes, but are amenable to composite processing, leading directly to a commensurate increase in the strength and other functionality of defense composite structures.

DARPA's **Armor Challenge** is identifying revolutionary and promising new armor systems for military vehicles. The Armor Challenge is aimed primarily at inventors and small organizations that do not have the resources to initiate full-scale armor development programs. New armor concepts are evaluated on a continuous basis to ensure that potentially valuable ideas are not overlooked. Participants are evaluated based on ballistic test results generated at a qualified testing facility during periodic "shoot-offs," as well as cost effectiveness of the armor design. Successful armor designs are considered for follow-on testing or potential armor development programs.

DARPA Titanium Initiative program, now in its second phase, seeks to develop and establish revolutionary industrial production and processing methodologies and capabilities for titanium metal and its alloys. The overall goals of this program are to: (i) establish a U.S.-based, high-volume, low-cost, environmentally benign production capability enabling widespread use of titanium and its alloys; (ii) develop and demonstrate unique, previously unattainable titanium alloys, microstructures, and properties that enable new high-performance applications; and (iii) develop meltless consolidation techniques that will provide low-cost billet, rod, sheet, and plate products that match the properties of traditional wrought titanium mill product. Current efforts are aimed to produce high-quality titanium at target costs of less than four dollars per pound; scale-up of these methods is underway.

The **High Performance, Corrosion Resistant Materials** program will develop a derivative class of high-performance structural amorphous metal coatings for long-term corrosion resistance in saline environments. Efforts are currently focused on demonstrating the efficacy of coatings on 688-class submarines, Naval surface combatants, and the new Littoral Combat Ship.

The **Lightweight Ceramic Armor (LCA)** program will leverage recent breakthroughs in novel ceramic fabrication processes to: (i) optimize the material composition and nanostructure for maximum protection per unit weight and cost; (ii) scale up the fabrication technology to the size of body armor; and (iii) investigate the potential for the development of dramatically improved ballistic armored headgear along these same lines.

The **Nano-Composite Optical Ceramic (NCOC)** program is developing the material and processes to make infrared windows and aerodynamically shaped domes with optical and mechanical capabilities that exceed those of single crystal sapphire for midwave infrared (three-to-five micron) operation. The program will achieve midwave infrared optical transmission comparable to that of spinel, with mechanical properties comparable to those of sapphire, and decrease optical scatter to increase mechanical and thermal shock capabilities to exceed those of sapphire.

The **Naval Advanced Amorphous Coatings** program is developing a derivative class of high-performance structural amorphous metal coatings that provide outstanding corrosion resistance and damage tolerance in difficult marine environments. The program objective is to have these coatings certified for unrestricted use on Naval ships.

The **Optical Lattice Emulators** program is developing an unprecedented capability to emulate computationally intractable, strongly-correlated, many-body condensed matter materials or models for materials for which we have no verifiable theoretical solution or experimental realization. This tool will enable profound changes in our fundamental understanding of advanced materials, such as high-temperature superconductors. In addition, the tool developed under this program will permit the design and investigation of novel material systems.

Existing methods for materials development rely on synthetic methods of either perturbing known materials or substituting atomic constituents in order to achieve desired properties. The goal of the **Predicting Real Optimized Materials (PROM)** program is to develop *ab initio* computational approaches to predict the composition and structure of a material based on the desired properties.

The goal of the **Programmable Matter** program is to develop a new functional form of matter constructed from mesoscale particles that assemble into complex three-dimensional objects upon external command. These objects will exhibit all of the functionality of their conventional counterparts, and ultimately be able to reverse back to the original components.

The **Reactive Structures** program will develop and demonstrate materials/material systems that can serve both as high strength structural materials, i.e., be able to withstand high stresses, and can also be controllably stimulated to produce substantial blast energy. The new reactive structures will replace the inert structural materials currently used in munition cases. This will provide both structural integrity and energy within the same material system and the ability to rapidly release the energy upon demand.

The **Structural Amorphous Metals** program is developing a completely new class of calcium- and aluminum-based alloys. The calcium-based alloy will enable ultralight hybrid structures for space applications with high structural efficiency and thermal management. These structures promise 50 percent reduction in launch weight of specific satellite systems. The aluminum-based alloy will enable much lighter gas turbine fan blades for both advanced military and commercial engines.

The **Synthetic Evolvable Materials** objective of this effort is to design and demonstrate synthetic materials that exhibit responsive and adaptive behavior typical of biological systems. One example is synthetic materials that change their physical, optical, electrical and chemical properties as a result of external stimuli such as applied stress, temperature, and chemical environment.

The **Topologically Controlled Lightweight Armor (TCLA)** program is seeking to develop new armor material and/or system designs that exploit the concept of topological arrangements of multiple materials to achieve ballistic performance beyond what can be achieved through material chemical or compositional changes alone. The goals of this program are to cut vehicle armor weight by two-thirds, while cutting costs by 50 percent when compared to rolled homogeneous armor currently in use.

Functional Materials

The goal of the **Diatoms-Based Nano Structures** program is to develop the capability of mass producing and assembling customized nanoelectromechanical systems and biomimetic components for myriad applications. Microorganisms, such as fungi, diatoms, and bacteria, provide an untapped platform to produce unique, three-dimensional structures. By leveraging diatoms' self-assembly properties, while controlling their material properties, this program could discover ways to inexpensively mass-manufacture unprecedented designs of everyday microwave components.

Effective, current reverse osmosis desalination technologies consume large amounts of energy and require frequent maintenance. The **Materials with Novel Transport Properties** program will develop revolutionary technologies that greatly reduce the energy consumption and maintenance of desalination systems, while at the same time supporting high rates of desalination. Specifically, the goals of this program are to demonstrate a prototype seawater desalination system that produces 75 gallons per hour of potable water from seawater, while achieving two orders-of-magnitude reduction in size and weight, and one order-of-magnitude reduction in power, compared to existing systems.

The Multifunctional Surface Systems collection of programs will, in general, demonstrate atomic control and morphopological structures on surfaces that enable superior performance of state-of-the-art materials and processes. The **Multifunctional Surface Sytems: Carbon Nanotube (CNT) Cold Cathodes** program focuses on carbon nanotubes, which have been shown to generate field emission currents of nearly 40 milliamperes per square centimeter. Large current density will allow for emitting surfaces to be small and ultimately reduce the required propellant weight budget in satellite systems.

The Multifunctional Surface Systems collection of programs will, in general, demonstrate atomic control and morphopological structures on surfaces that enable superior performance of state-of-the-art materials and processes. The goal of the **Multifunctional Surface Systems: Low Temperature Colossal Supersaturation (LTCSS)** program is to provide efficient, low temperature, extreme surface chemical modification of the crystal lattice and will provide increased fatigue resistance, hardness, and corrosion resistance in stainless steel alloys without any reduction in bulk fracture toughness. The LTCSS surface treatment processes for stainless steel metal components will enable new mission critical weapons, vehicle systems, and space components.

The Multifunctional Surface Systems collection of programs will, in general, demonstrate atomic control and morphopological structures on surfaces that enable superior performance of state-of-the-art materials and processes. The goal of the **Multifunctional Surface Systems: Pulse Thermal Processing (PTP)** program is to provide an enabling capability to control diffusion-based processes of thin films and material surfaces on the nanometer scale. PTP will enable new micro-electric devices and thin film batteries to significantly increase platform performance and usable service life.

The Multifunctional Surface Systems collection of programs will, in general, demonstrate atomic control and morphopological structures on surfaces that enable superior performance of state-of-the-art materials and processes. The goal of the **Multifunctional Surface Systems: Surface Control for Superhydrophobics** program is to obtain non-wettable surfaces through nanoscaled topology. New methods will be developed that have more control and reproducibility over long ranges than currently available.

The Multifunctional Surface Systems collection of programs will, in general, demonstrate atomic control and morphopological structures on surfaces that enable superior performance of state-of-the-art materials and processes. The goal of the **Multifunctional Surface Systems: Surface Wave Communication and Power Transmission (SWCPT)** program is to guide surface waves around a free surface without leaking power to free space, thereby eliminating the need for complicated communication buses and saving wiring harness weight in military platforms. SWCPT will enable rectenna, temperature sensing, pressure sensing, damage detection, communications, and power transmission to be contained on vehicle surface.

The **Negative Index Materials** program is developing and demonstrating novel microwave negative refractive index materials that will enable novel antenna and radar designs with reduced size and improved bandwidth and efficiency. The program is also extending the frequency of operation and/or operational bandwidth of "negative index" or "left-handed" materials to demonstrate novel radio frequency and optical applications.

The **Smart Gills** program will use novel approaches in materials science to create a system for underwater missions that: (i) eliminates the need to carry a primary oxygen supply; (ii) safely eliminates carbon dioxide from the breathing gas stream; (iii) incorporates the latest in technology for monitoring the physiological safety of users and minimizing decompression sickness risk; (iv) increases stealth by eliminating macroscopic gas bubble ejections; and (v) is equal to or less difficult to carry, maintain, and operate than current closed-circuit underwater breathing devices. The Smart Gills system will ensure that the supply of oxygen and removal of carbon dioxide do not limit underwater mission duration.

Smart Materials and Structures

The **Chemical Communications** program seeks to develop self-powered chemical systems that can encode an input a message, convert the message to a modulated optical signal, and transmit it repetitively to a receiver via a small replicator device, with the form factor of a personal digital assistant or cell phone. The replicator device will enable warfighters to generate disposable optical transmitters in real-time, each with a user-specified message, that can be powered by batteries, solar cells, or similar means.

POWER AND ENERGY

Portable sources of electric power are critical to today's military. Developing portable, efficient, and compact power supplies has important ramifications for increasing our military reach, decreasing our logistics burden, and improving the overall efficiency of our warfighting forces – especially for distributed and net-centric operations.

The **Anomalous Effects in Metal Deuterides** program seeks to investigate and replicate, if possible, recent reports of excess heat production and transmutation in palladium metal foils that have been loaded with deuterium (metal deuterides). In particular, this program is addressing two questions in the field of low energy nuclear reactions/low energy nuclear fusion: (i) the reproducible and controllable demonstration of excess thermal energy (in quantities that exceed the "break even" point); and (ii) the correlation of quantitative excess thermal energy with nuclear byproducts.

The goal of the **At Sea Fueling Station** program is to develop the capability to harvest methane hydrates from Continental Shelves, using unmanned drilling and energy recovery vehicles, and produce hydrocarbon fuels for use by maritime and expeditionary forces – without requiring a conventional logistics ship and underway replenishment (UNREP). If successful, this program will provide the enabling technology for providing hydrocarbon fuel production feedstocks for at-sea maritime fuel production, and reduce the need for long-distance logistic fuel transport for maritime based expeditionary forces.

The **BioFuels** program is exploring longer term, higher risk approaches to obtaining and using energy. A pathway to affordable self-sustainable agriculture-sourced production of an alternative to petroleum-derived JP-8 that will meet all DoD needs will be investigated, as well as the development of man- and vehicle-portable technologies to produce substantial quantities of JP-8 and other useful liquid fuels from indigenously available or harvestable resources near desired locations worldwide.

The **Broad Spectrum Feedstock BioFuels** program will dramatically expand the production potential for Bio-JP-8 to a broad range of feedstocks, including cellulosic and algal materials. The Broad Spectrum Feedstock BioFuels program will build on the BioFuels program and extend the feedstock potential to a set of much broader, diverse, and plentiful sources – sufficient to affordably address the entire DoD consumption within a sustainable commercial framework.

The **Direct Thermal to Electric Conversion (DTEC)** program seeks revolutionary advancements in the state-of-the-art in DTEC technologies that would significantly reduce the gap between achievable conversion efficiencies and ideal thermal cycle conversion efficiencies. This technology is key to developing high-efficiency, solid-state electric generators that could convert thermal energy to electricity for future electric and hybrid electric military platforms.

The **Flexible Fuel Power Sources** program will develop small fuel cells that are fuel-flexible, i.e., operable at useful efficiencies from almost any indigenously available liquid fuel – from vodka to JP-8. The key technical innovation required for this type of smaller fuel-flexible power cell technology is the ability to derive power by breaking carbon-carbon bonds at low temperature via innovative catalysis. Recent breakthroughs in the development of alkaline fuel cells strongly suggest the potential for this capability. The resulting capability will provide the Soldier in the field with the capability to derive power from any indigenous fuels with no adjustment to the power generator itself.

The goal of **Improved Anodes for Lithium Batteries** is to explore a variety of mixed-oxide materials as anodes, which can replace the presently-used graphite in today's lithium ion batteries. Detailed physical and electrochemical studies on the novel anodes will result in optimum compositions and techniques. The program will demonstrate the proof-of-concept that lithium salts can participate in the "conversion" reactions, analogous to the oxides and mixed-oxides of metals to give rise to Li-recyclability and high capacity.

The **Integrated High Energy Density Capacitors (IHEDC)** program will develop high power, high temperature capacitors (one kilovolt, greater than 200 C, losses below 0.001 percent) using environmentally safe materials to reduce the weight and volume. This will provide reliable, compact capacitors tightly integrated with active power electronic components to enable prognostics, adaptability, and therefore "smart" capacitors. The ability to integrate active and passive power electronic components will open the design space for high power electrical systems.

The goal of the **Micro Isotope Micro-Power Sources (MIPS)** program is to demonstrate safe, affordable micro isotope power sources able to outperform conventional batteries in terms of energy and/or power density, and provide long-lasting milliwatt-level power for an array of military applications, such as unattended sensors, perimeter defense, detection of weapons of mass destruction, and environmental protection.

Compact portable power sources capable of generating power in the range of a few hundred milliwatts to one watt are critical to providing power for untethered sensors and other chip-scale microsystems. The **Micro Power Generation** program will replace today's technologies that rely on primary and rechargeable batteries (which severely limit mission endurance and capability) by extending microelectronic machine technology to develop micro-power generators based on mechanical actuation and thermal-electric power generation.

The **Micro Power Sources** program is exploring innovative approaches to enable revolutionary advances in small primary or secondary energy storage devices. New battery architectures, the use of new materials and their corresponding chemistries, and the incorporation of energy harvesting to maintain energy densities in substantially smaller volumes will result in new capabilities. These devices are envisioned as the prime power source for very small sensors, robotic devices, and electronic systems.

The goal of the **Micropower Engine** program is to significantly improve the cost, weight, and overall capability of man-portable power systems by developing a small power system built around a fuel-breathing, hydrocarbon-fueled, recuperated, expander-cycle micro-scale turbine engine – which could be substituted for a standard battery in military man-portable power applications. The proposed engine in this program is "fuel-breathing" rather than "air-breathing," using liquid hydrocarbon fuel, rather than air, as the working fluid of its thermodynamic cycle, thus enabling compression at much lower rotational speeds.

The **Mobile Integrated Sustainable Energy Recovery (MISER)** program is developing technologies that can process military waste into logistics fuels for both fuel cells and military generators. The technology focuses on methods, such as super-critical water, that dissolve waste into gaseous-phase hydrocarbons.

The goal of the **Nanostructured Materials for Power** program is to improve battery energy density, the energy product of magnets, and the efficiency of current thermoelectric devices by developing primary and secondary batteries from the "ground up" (nanoscale electro-chemical sources) and nanostructured thermoelectric materials that will achieve 30% or greater thermal-to-electric conversion efficiencies (thermoelectrics). Once deployed, this higher energy and power will significantly reduce the weight and volume burden of power devices. This will greatly reduce the logistics trail, provide higher torque for permanent magnet motors, and revolutionize the method of providing refrigeration in the field.

The **Next Generation Fuel Cell Chemistries** program is investigating three primary areas – electrochemical sources, thermoelectronics, and permanent magnets – focusing in each area on nanoscale development to achieve revolutionary improvements in battery materials and chemistries, achieve 30 percent or greater thermal to electric conversion efficiencies, and provide magnets with energy products twice that of currently available magnets.

The **Pyrofusion** program is building on the demonstration of a compact deuterium-deuterium (D-D) neutron source where the temperature change of a lithium tantalate pyroelectric crystal is used to produce a change in polarization. The resulting voltages are sufficient to power an electrostatic D-D fusion reaction. Applications for this technology include compact portable neutron sources for analysis and detection of highly enriched uranium, compact x-ray sources for medical field use, and compact scanning probe electron microscopes.

The **Radioisotope Micro-Power Sources (RIMS)** program will develop the technologies and system concepts required to safely produce electrical power from radioisotope materials for portable and mobile applications, using materials that can provide passive power generation. The goal is to provide electrical power to macro-scale systems such as munitions, unattended sensors, weapon systems, radio frequency identification tags, and other applications requiring relatively low (up to tens of milliwatts) average power.

The **Robust Portable Power** program is further optimizing and ruggedizing fuel cell and Stirling engine generators for specific military applications. Twenty to thirty watt Soldier power applications include laser designators, mine sweepers, chemical detectors, heavy thermal weapons sights, and toughbooks. Soldier power applications in the 150 watt range include providing power for robots and unmanned air vehicles, e.g., PackBot, Raven, and Puma.

As the Services move to increasing reliance on electric systems for propulsion and weapons, the need for compact, efficient power systems is becoming critical. The **Superconducting Hybrid Power Electronics (SuperHyPE)** program will develop the low-alternating-current-loss, high-critical-current-density, second-generation superconducting tape and very high breakdown field cryogenic capacitors that, together, promise to make cryogenic power conversion a reality.

The **Surface Wave Energy Harvesting** program will develop and demonstrate unique generator technologies to extract and convert energy from ocean wave and other object motions. The successful development of new, very low friction electrical generators that convert ocean wave power to electrical energy will enable new concepts of operations for unmanned and manned vehicles, unattended sensors, communications, weapons, and other maritime devices. Tactical and oceanographic surveillance systems requiring extended life operations will also benefit from these renewable and scalable energy sources.

The goal of the **Very High Efficiency Solar Cell (VHESC)** program is to develop solar cells that demonstrate at least 50 percent efficiency in an affordable, manufacturable photovoltaic device that provides Soldiers with portable power for electronic devices, while dramatically reducing the complex logistics associated with delivering batteries to troops in the field and improving mission endurance and individual Soldier agility.

MICROSYSTEMS

DARPA is shrinking ever-more-complex systems into chip-scale packages, integrating microelectronics, photonics, and microelectromechanical systems (MEMS) into "systems-on-a-chip" that have new capabilities. It is at the intersection of these three core hardware technologies of the information age that some of the greatest challenges and opportunities for DoD arise. Examples include integrating MEMS with radio frequency electronics and photonics; integrating photonics with digital and analog circuits; and integrating radio frequency and digital electronics to create mixed signal circuits. The model for this integration is the spectacular reduction in transistor circuit size under Moore's Law: electronics that once occupied entire racks now fit onto a single chip containing millions of transistors.

DARPA's current work in microsystems includes the following areas:

- **Microelectronics** – manipulate electrons in digital, analog, and mixed signal circuits for sensing, processing, and communications;
- **Photonics** – generate, detect, and modulate photons for imaging, communications, and sensing;
- **Microelectromechanical Systems (MEMS)** – exploit the processing tools and materials from semiconductor technology to build electro-mechanical structures at the micro- and nano-scale; and
- **Combined Systems-on-a-Chip** – integrate microelectronics, photonics, and MEMS technologies into systems on a single chip.

Microelectronics

The **Advanced Microsystems Technology** program will explore a range of advanced microsystem concepts well beyond existing technologies, focusing on technologies that exploit three-dimensional structures, new materials for Geiger mode detectors, advance patterning, and extreme scaling in silicon devices.

The **Airplane-on-a-Chip (AOC) - Chip Scale Avionics** program seeks to exploit continued advances in integrated microsystems technology to remake the stovepipe/legacy avionics architecture present in modern aircraft. The fundamental goal of the program is to deliver an avionics system approaching one cubic centimeter in volume and dissipating tens of milliwatts of power, compared with tens of cubic centimeters (best case) and tens of watts of power in contemporary systems. It is expected that such advances will revolutionize airframe design and capability by delivering more functionality at lower power in a smaller volume, enabling distributed avionics for enhanced survivability and increase autonomous operation.

The **Analog-to-Information Receiver Development (A-to-I)** program will develop ultra-wideband digital radio frequency receivers based on analog-to-information converter (AIC) technology. AICs loosen the traditionally rigid tradeoff of frequency coverage against dynamic range in digital receiver applications using a family of novel mathematical algorithms and representations known as compressive sampling. AIC-based designs will increase receiver dynamic range and frequency band of regard, while reducing power consumption and size. AIC-designs will also reduce or eliminate the need for post-sensing digital compression, reducing data glut and minimizing bandwidth for transmission downlinks and/or data storage.

The **Carbon Electronics for RF Applications (CERA)** (formerly Co-integration of Carbon-Based RF (Radio Frequency) Electronics with Silicon Technology (CrEST)) program seeks to develop metal oxide silicon field effect transistors based on the planar carbon monolayer (graphene) system, which has most of the desirable properties of carbon nanotubes, but is found in a planar geometry that is much more compatible with standard complementary metal-oxide semiconductor (CMOS) processing. Graphene field effect transistor devices are envisioned to be an enhancement of, not a replacement for silicon CMOS for critical radio frequency or mixed signal circuit elements. So a primary goal of this program is to demonstrate integration of graphene devices into standard silicon CMOS processing.

The **Chip-Scale Direct Sampling Receiver (CSDSR)** program aims to realize true software-defined radio front-ends that feed radio frequency input signals directly to analog-to-digital converters (ADC's), allowing the rest of the radio to be realized digitally and completely reconfigurable via software. The key to making this possible is the use of technologies capable of isolating channels (not bands, but channels with less than 0.05 percent bandwidth) directly after the antenna, removing all out-of-channel interferers before they arrive at the low noise amplifier (LNA)/ADC input. The CSDSR program would ultimately make possible universal receivers capable of operating under conceivably any communication standard by merely reconfiguring themselves.

The goal of the **Chip-Scale High Energy Atomic Beams** program is to pursue chip-scale high-energy atomic beam technology by developing high-efficiency radio frequency accelerators, either linear or circular, that can achieve energies of protons and other ions up to a few million electron volts. Chip-scale integration offers precise, micro actuators and high electric field generation at modest power levels, which would enable several orders-of-magnitude decreases in the volume needed to accelerate the ions. Furthermore, thermal isolation techniques will enable high-efficiency beam to power converters, perhaps making chip-scale self-sustained fusion possible.

The **Chip-to-Chip Optical Interconnects (C2OI)** program is developing optical technology for chip-to-chip interconnects at the board and backplane level to help close the performance gap between on-chip and between-chip interconnection technology. The goal is to mitigate data throughput bottlenecks affecting military-critical sensor signal processing systems.

The goal of the **Compound Semiconductor Materials On Silicon (COSMOS)** program is to develop new methods for tightly integrating compound semiconductor technologies within silicon CMOS circuits in order to achieve unprecedented circuit performance levels. COSMOS will focus on a strategy seeking to optimize performance, size, and cost that will involve sub-circuit integration in which III-V materials devices are placed onto a processed CMOS wafer.

The **Computational Imaging (CI)** program seeks to develop new imaging constructs that exploit the full information content (intensity, phase, and frequency) at the detection plane to perform real-time image processing in the analog domain. This imagery will be combined with advanced digital image processing algorithms to leverage the unique image plane information for more rapid image analysis and target identification.

The goal of the **Contiguous Multi-Mega-pixel Infrared Imaging Arrays** program is to develop large arrays for persistent surveillance, with the objective of developing technology for multi-megapixel arrays with integral signal and image processing. Since contiguous coverage over large areas is essential, approaches will be developed to construct extremely large array assemblies from smaller arrays without loss of lines at the intersection between arrays. A new array architecture will be designed to integrate electronic overhead functions in a three-dimensional structure directly underneath the active pixel array to: (i) leverage and extend emerging three-dimensional signal processing technology; and (ii) establish a technology base for large contiguous array assembles not possible with current infrared arrays.

Low light level imaging has proven its value by providing the individual warfighter with the tactical advantage to see first in crucial night imaging scenarios. With widespread use of low light level technology, a new paradigm in low light level imaging is necessary to maintain these distinct advantages and provide new capability beyond current imaging technology. The **Day/Night Adaptive Imager** program will incorporate noiseless detection and processing of individual photon events to leverage the benefits of solid state imaging and take advantage of three-dimensional signal processing architecture at the detector. By detecting an image formed from individual photon events without the addition of excess noise, the image can be processed and manipulated to provide the user image information not possible with current sensors.

The **Design-space Exploration and Synthesis Technology for Integrating Nontraditional Microsystems at Yield (DESTINY)** program will introduce a rational methodology for the co-design of mixed-signal systems. These systems are widely employed in military radar, communications, SIGINT and ELINT electronics. By simplifying the design process through automated tools, DESTINY will enable complete system optimization at an unprecedented level. This will result in new mixed-signal electronic systems that have greater capability and improved reliability, while reducing size, weight, power, and system cost. Furthermore, DESTINY will shorten the design cycle, increase the manufacturing yield, and reduce support burdens for mixed-signal electronics.

The goal of the **Electromagnetic Pulse Tolerant Microwave Receiver Front End (EMPIRE)** program is to create a wide bandwidth, tunable radio frequency (RF) front-end technology that is immune to electromagnetic pulse attack. This program will seek an entirely new approach to RF front-end technology, in which all metal and front-end electronic circuitry are eliminated. Of particular interest will be an all-dielectric, electronics-free radio frequency front-end with sensitivity and dynamic range consistent with today's wireless communication and radar systems. By eliminating the metallic antenna, a secondary goal is to significantly reduce detectable radar cross section.

Modern military platforms require increased dynamic range receivers for both radar and electronic warfare antenna systems. The goal of the **Feedback-Linearized Microwave Amplifiers (FLARE)** program is to develop radio frequency amplifiers with a revolutionary increase in dynamic range receivers through the use of linear negative feedback.

The overall goal of the **Focus Center Research Program (FCRP)** – a collaborative effort between the Department of Defense and industry – is to sustain the unprecedented, uninterrupted performance improvement in information processing power over the past four decades. There are five such focus centers at U.S. institutions of higher education: the

Gigascale Science Research Center, Circuits and Systems Center, Interconnect Focus Center, Materials, Structures and Devices, and Functionally Engineered Nano-Architectonics. The focus centers help promote radical innovation in semiconductor technology.

The **Gratings of Regular Arrays and Trim Exposures (GRATE)** program will develop revolutionary one-dimensional circuit design methodologies, combined with interference grating-based lithography methods, to enable cost-effective low-volume nanofabrication for DoD applications. Military electronics capabilities are currently limited by the high cost of nanofabrication. The GRATE program seeks to provide a solution to cost-effective, low-volume patterning requirements found in military application-specific integrated circuit chips.

The goal of the **High Power Wide Band Gap Semiconductor Electronics Technology** program is to develop components and electronic integration technologies for high-power, high-frequency microsystem applications based on wide band gap semiconductors.

The objective of the **High Resolution Short Wave Infrared/High Density Infrared Retina (Brownout Vision)** program is to cultivate emerging material growth and deposition technology having the potential to produce extremely high-resolution, high-density, short wave detector arrays. The program will pursue material growth approaches that include infrared quantum dots, molecular beam epitaxy, and epitaxial growth onto selected areas of the silicon readout. The growth techniques must be optimized to produce films with high optical absorption, and uniform film characteristics consistent with deposition over large areas.

The goal of the **High-Frequency Integrated Vacuum Electronics (Hi-FIVE)** program is to demonstrate microfabricated, integrated vacuum tubes operating at 220 gigahertz (GHz) with a minimum of 50 watts of output power and five GHz bandwidth. The Hi-FIVE program figure of merit will be the power-bandwidth product, and the goal is to achieve 500 power-bandwidth (W-GHz). The ultimate goal is to develop a micro-fabricated, high-bandwidth, high-power "upper" millimeter-wave (220 GHz) amplifier consisting of a solid-state millimeter-wave monolithic integrated circuit driver, an integrated cathode, compression optics, micromachined interaction structure, and beam collector.

The goal of the **Ideal Radio-Frequency Mixer (IRM)** program is to develop ultra-high-linearity electronic mixers to support the needs of wideband high-dynamic-range receivers. To fully realize the capabilities of the ultra-high-linearity, low-noise amplifiers (LNAs) and ultra-high-dynamic-range analog-to-digital converters (ADCs) currently being developed under other DARPA programs, the dynamic range requirements through the receiver chain will need to be larger – and the mixer is critical part of the receiver (located between the LNA and the ADC). This project will focus on developing the necessary technologies for a mixer without an additional power penalty.

The **J-Band Advanced Digital Receiver (JADR)** program will exploit the pioneering architectural breakthroughs of the Advanced Digital Receiver program to create the next generation of analog-to-digital converters in low-power (four watt) silicon germanium (SiGe) chip/complementary metal-oxide-semiconductor decoder chip integrated into a compact flip-chip package. JADR will extend Advanced Digital Receiver's impact into the J-band (10 to 20 gigahertz) by aggressive integration into scalable SiGe technology.

The **Low Power Micro Cryogenic Cooler** program will attain superior performance in micro-scale devices (e.g., low noise amplifiers, infrared detectors, radio frequency front-ends, and superconducting circuits) by cooling selected portions to cryogenic temperatures. The key approach that should allow orders-of-magnitude power savings is to selectively cool only the needed volume/device via microelectromechanical systems-enabled isolation technologies.

The **Maskless Direct-Write Nanolithography for Defense Applications** program will develop a maskless, direct-write lithography tool that will address both the DoD's need for affordable, high-performance, low-volume integrated circuits and the commercial market's need for highly customized, application-specific integrated circuits. This program will also provide a cost-effective manufacturing technology for low-volume nanoelectromechanical systems and nanophotonics initiatives within the DoD. Maskless lithography tools, installed in the Trusted Foundry and in commercial foundries, would enable incorporation of state-of-the-art semiconductor devices in new military systems, and allow for the cost-effective upgrade of legacy military systems.

The goal of the **Microantenna Array Technology & Applications (MIATA)** program is to develop low-cost arrays that can simultaneously sense both millimeterwave and infrared scenes, along with compact millimeterwave designator sources for passive and active imaging applications in the spectral region from W-band (94 gigahertz) to the long-wave infrared optical region. The military utility of this technology includes conventional passive imaging with compact devices at elevated temperatures, passive or active ballistic imaging through extreme weather and obscurants, polarization discrimination of man-made objects, rapid electronic spectral tuning for clutter discrimination, and ultrawideband response. It may also include synthetic apertures, phased arrays, true-time, and steered receiver beams.

The **Microsensors for Imaging (MISI)** program is developing technology for extremely small, lightweight cameras sensitive in the short wave infrared for a wide range of applications. MISI is initially focusing on two important areas: micro air vehicles, and a head-mounted system. The camera components comprise a micro-system, including optics, focal plane array and electronics, with display, energy source and illuminator included as the head-mounted system with a weight goal of 350 grams. The weight goal for the micro air vehicle application is ten grams.

The goal of the **Miniature, Room Temperature, Ultra-sensitive Magnetic Sensor (MRUMS)** program is to develop a micron-scale, room temperature magnetic sensor with detection sensitivity at least comparable to that of a superconducting quantum interference device. The device would also require low power and be produced with standard microfabrication processes.

The goal of the **Nano-Electro-Mechanical Computers (NEMS)** program is to integrate nanoscale mechanical switches and gain elements integrated intimately with complementary metal-oxide semiconductor switches. One mechanical switch per transistor would enable the transistor to operate at near-zero leakage powers, enabling pico- or femtowatt standby operation. Using mechanical power supplies and mechanical vibrating clocks could enable electronics that are less susceptible to electromagnetic pulse attacks, and enabling nanomechanical elements in direct band gap materials would circumvent problems of gate oxide stability, allowing fast logic with optics functionality.

The **Novel Topological Materials and Nanoelectronics** program will produce topological arrangements of molecular ensembles and reduce the number of physical circuit elements required in nanostructured electronics. This will significantly reduce the cost, mass, and power required for self-assembled nanoelectronic systems. The developed methods will also be crucial in improving the defect tolerance and robustness of self-assembled nanostructure construction.

Nanotechnology research in optics will develop the ability to create structures of the same scale as incident light wavelengths and, therefore, can interact with and affect the incident light. The goal of the **Optical Antenna Based on Nanowires** program is to create nanometer-scale structures that act as optical antenna arrays that can respond coherently to electromagnetic fields at optical wavelengths. A system based on this technology would potentially be smaller, lighter in weight, and able to move from the sub-optimal method of intensity-only measurements into the information-rich domain of complex imaging.

The goal of the **Processing Algorithms with Co-design of Electronics (PACE)** program is to provide the DoD with an architecture and algorithm co-design capability for graph-structured signal processing. Graph algorithms are the key to post-detection signal processing, helping to "connect the dots" in a huge variety of emerging challenges such as change detection in massive data transactions or forensic and predictive analyses of activities from video data over wide areas and extended times. Solutions available today that might meet these mission requirements are limited by prohibitively long and costly manual design times. PACE seeks to enable the co-design of the next generation of embedded signal processing algorithms and architectures capable of processing large sparse matrix data structures associated with graph-structured signal processing algorithms, providing signal processing capabilities not possible today, while achieving dramatically reduced design time and cost.

Frequency-hopping radios greatly interfere with co-located ultra-sensitive receivers, a situation that will get worse as the "hoppers" proliferate – even interfering within the receive channels of one another. The **Semiconductor-Tuned HTS Filters for Ultra-Sensitive RF Receivers (SURF)** program would increase the tuning speed of high-temperature superconducting filters from about a second, using current mechanical methods, to the microsecond speeds required for systems such as the Joint Tactical

Information Distribution System. In addition to interference-rejection at microsecond speeds, these filters would make it possible to perform wide spectral searches with unprecedented frequency resolution, enabling detection of very weak signatures characteristic of threat systems.

Current, commercial graphics processor units (GPUs, e.g., hardware and software of the type currently used for fast geometry computations in hand-held electronic games such as Nintendo's GAME BOY®) offer several advantages over more traditional embedded processors, including enhanced memory access bandwidth, hardware-accelerated floating-point vector geometry functions, low power consumption, and open source programming language support. The **Space, Time Adaptive Processing (STAP) Boy** program will research, develop, and demonstrate miniature, low-power, low-cost, teraflop-level signal processing solutions derived from commercial GPUs to allow the DoD to exploit the continuing phenomenal growth in both performance and programmability of GPUs.

The goal of the **Steep-subthreshold-slope Transistors for Electronics with Extremely-low Power (STEEP)** program is to develop field emission (tunneling)-based metal oxide silicon field effect transistors. Such devices would lower supply voltages by a factor of five, which would result in a 25-fold savings in active power and a standby power savings of at least a factor of one-hundred. Prototype circuits will be developed showing such power savings with little to no impact on performance. These field emission devices will be integrated into standard silicon complementary metal oxide semiconductor (CMOS)-based processing methods, and potentially offer significant CMOS power reduction with no performance penalty.

The goal of the **Structured ASIC Design (StASD)** program is to provide the performance advantages of a customized application specific integrated circuit, but without the high overhead costs of programmable or fine-grain reprogrammable devices. The program will develop highly novel, customizable ASICs that will dramatically enhance DoD applications in terms of cost, time to design, and performance.

The **Surface Enhanced Raman Scattering (SERS) - Science and Technology** program seeks to identify and overcome the key scientific and technical challenges necessary for replacing existing chemical and biological warfare agent sensors with SERS-based sensing approaches. SERS nanoparticles have considerable potential for both chemical and biochemical sensing due to: (i) their potentially large spectral enhancement factors; (ii) the nature of spectral fingerprints that can be expected to yield low false alarm rates; and (iii) the capability for detecting targeted molecules at useful standoff ranges. The program will focus on the fundamental technical challenges facing potential sensor performance, including sensitivity, selectivity, and enhancement factors.

The **Thermal Ground Plane (TGP)** program will develop new approaches to removing local hot-spots that limit the performance of high-speed signal processing electronics, radar imaging systems, optoelectronic devices, and other systems characterized by above-ambient thermal issues. This program will complement the Low Power Micro Cryogenic Coolers program by addressing the performance-critical issue of excessive heat removal. The program will consider both monolithic and heterogeneous thermal management approaches based on a variety of thermal materials and heat removal methods. Examples include: self-powered liquid spray cooling, integral copper heat pipes, microfluidic channels, and diamond interposer layers.

The **Three-dimensional integration (3DIC)** program will develop a new generation of computer-aided design tools together with fabrication techniques to design integrated three-dimensional electronic circuits. The program will focus on: (i) methodologies to place and route three-dimensional circuits; (ii) analyzing and assessing coupled electrical and thermal performance of electronic circuits; and (iii) tools for the synthesis and coupled optimization of parameters such as integration density, cross-talk, interconnect latency, and thermal management. The program seeks to develop a robust three-dimensional circuit technology through the development of advanced process capabilities, and the design tools needed to fully exploit a true three-dimensional technology for producing high-performance digital circuits.

The **Three-Dimensional Microelectromagnetic Radio Frequency Systems (3-D MERFS)** program is building upon technology developed under the Vertically Interconnected Sensor Array program to develop complete millimeter wave (MMW) active arrays on a single wafer, or a very small number of wafers. The program will exploit new technologies being developed commercially that allow gallium arsenide active components to be placed on silicon wafers, and advances in indium phosphide and silicon germanium that may allow an entire MMW electronically scanned array to become very highly integrated on a sandwich of wafers, which would make them very cheap, compact, lightweight, and reliable. If successful, 3-D MERFS would enable development of new, six-inch (or less) diameter MMW electronically steerable arrays for seekers, communication arrays for point-to-point communications, and sensors for smart munitions, robotics, and small remotely piloted vehicles.

The **THz Transistors (TT)** program will develop the technologies for terahertz (THz) transistors by following recently-established scaling laws for indium phosphide (InP) heterojunction bipolar transistors. This program will focus on developing transistors with cutoff frequency significantly greater than one THz. The program will also address the novel research areas of testing, calibration, and modeling of THz transistors and circuits.

The **Trust in Integrated Circuits (TRUST)** program will enhance the trustworthiness of IC's regardless of where they are manufactured. The TRUST program will focus on: (i) developing new tools and techniques for determining if untrusted design tools have added additional functionality not defined in the original specification; (ii) developing new tools and techniques to rapidly reverse-engineer integrated circuits to determine if there has been any modifications of the IC at the untrusted foundry; and (iii) developing a new class of verification tools to secure the design and loading process of field programmable gate arrays.

The goal of the **Ultra-Low Power Subthreshold Electronics (UPSE)** program is to develop technology for circuit operation at the physical limits of power supply voltages in order to achieve over a ten-fold reduction in energy consumption for integrated circuits. UPSE seeks to develop a circuit technology that will allow operation of devices in the subthreshold regime (less than or equal to 0.3 volts), in contrast to the typical superthreshold regime (approximately one volt). UPSE avoids the need for specialized custom device fabrication by emphasizing use of standard commercial complementary metal-oxide-semiconductor technology. The program will build a demonstration sensor or communication integrated circuit of significant military interest showing compelling low-power performance and new mission capabilities.

The **Vertically Interconnected Sensor Arrays (VISA)** program will develop and demonstrate vertically interconnected, focal plane array readout technology capable of more than 20 bits of dynamic range – over an order-of-magnitude higher than current state of the art – enabling significant advances in the functionality of infrared systems. Vertical interconnections between the detectors and the readouts that avoid first going through row-column multiplexers will allow for high frame rates concurrent with high-resolution images. The program will expand architectures for three-dimensional focal plane arrays, where multiple levels of signal processing are integrated into each pixel in the array, to include multiple processing layers, higher density vias (small openings in an insulating oxide layer that enable electrical connections, e.g., between layers) at the pixel, and coverage of a broad spectral band from the visible to the infrared. This increased on-chip processing power will enable new capability for smart sensors, such as high-speed imaging, on-chip threat discrimination, and anti-jamming. Defense applications include mid/long wavelength target acquisition systems for air and ground; smart missile seekers; anti-jamming; and imaging through high-intensity sources.

The goal of the **WIFI-EYEPOD** program is to transform the dismounted Soldier into a semi-autonomous direct-current-to-ten-gigahertz sensor/communications/signals intelligence platform using a personal digital assistant modified with a broadband multifunctional radio frequency (RF) sensor plugged into its universal serial bus port. Combined with DARPA's STAP-BOY program or even a standard laptop, the RF EYEPOD enhancement will enable real-time local processing for extremely time-sensitive and perishable data requiring immediate processing and response. The WIFI-EYEPOD RF sensor may be used to control and or hunt near-field communications networks, allowing the Soldier to virtually see enemy combatants communicating and setting up attacks, hiding behind walls, and in buildings mixed with non-combatants.

Photonics

The goal of the **Adaptive Photonic Phased Locked Elements (APPLE)** program is to demonstrate a fully scalable and modular architecture of phased sub-apertures capable of producing an arbitrarily large optical aperture that can be rapidly and non-mechanically steered over a wide field of regard with high precision.

The objective of the **Advanced Photonic Switch (APS)** program is to develop on-chip, photonic switching devices which are fabricated in a CMOS-compatible process and which maximize switching speed while simultaneously minimize device power dissipation, transmission losses, area, and sensitivity to ambient temperature variations. The photonic switches developed in this program will be spectrally broadband, capable of simultaneously switching multiple, high bit-rate wavelength channels, and scalable to complex, multiple-input and multiple-output port switches.

The **Advanced Precision Optical Oscillator (APROPOS)** program will enhance the performance of radars in detecting slow moving targets, electronic warfare systems in identifying specific emitters, and communications systems in weak signal detection and clutter suppression at increased standoff ranges. The program will leverage advances in materials and lasers to develop new, precision, microwave-stable local oscillators with extremely low phase noise (up to 50 decibels better than the current state of the art) at small offsets from microwave carrier frequencies.

The **Deep Ultraviolet Avalanche Photodetectors (DUVAP)** program seeks to develop high-sensitivity, compact ultraviolet detectors – specifically, avalanche photodiodes that can detect single photons. These ultraviolet detectors will dramatically improve the performance and reduce the size and weight of the biological warning detectors developed in the DUVAP program, and will increase the range and data rate of covert ultraviolet communications systems.

The goal of the **Efficient Mid-Wave Infrared Lasers (EMIL)** program is to develop efficient, solid-state coherent sources to cover the atmospheric transmission bands in the mid-wave infrared (three-to-five micron) at 10 watts power with wall plug efficiencies of at least 10 percent, since infrared countermeasure (IRCM) systems, in particular, depend on intense sources at these bands. EMIL lasers promise to require enormously less volume (100–1000 times) and power (factor of 10), while providing superior pulse format (continuous wave operation). These lasers will enable new architectures and approaches that will permit IRCM systems to be deployed on platforms (e.g., rotorcraft) that are highly vulnerable to man-portable air defense systems and other threats, but for which current IRCM systems are prohibitive or are inadequate.

The **Electronic & Photonic Integrated Circuits on Silicon (EPIC)** program will develop two critical alternative photonic technologies based on silicon substrates. The first addresses active photonic components, based on silicon, that do not rely on generating light within the material. The second will address optical transistor action, or switching, in silicon. Taken together, these two capabilities will create a new paradigm in which silicon will provide a platform for monolithic integration of photonic and electronic functions.

The goal of the **Frequency Domain Analog Optical Signal Processor** program is to develop an analog signal processor capable of processing the equivalent of one teraflop per watt in the frequency domain. This program will require the development of large photonic integrated circuit-based filter arrays and associated photonic components, which are many times more complex than the current state of the art.

The goal of the **Integrated Photonic Delay (iPhoD)** program is to develop a chip-scale, integrated photonic platform with "fiber-like" losses for optical buffering and high-resolution, multi-tap microwave and millimeter-wave frequency processing applications.

The goal of the **Linear Photonic RF Front End Technology (PHOR-FRONT)** program is to develop photonic transmitter modules that can adapt their frequency response and dynamic range characteristics to mate with the full spectrum of narrow-band and broadband microwave transmission applications covering the two megahertz - 20 gigahertz range. These field-programmable, real-time adaptive photonic interface modules will find application in high dynamic range communications, radar, and electronic warfare antennas.

The **Omni-Directional Flash & Launch Detection, Positioning, Classification and Observation System (MEGA)** program will develop a low-cost, omni-directional, staring infrared sensor that provides circumferential imagery of its surroundings. The MEGA sensor and algorithms will be used to detect weapon discharges in its field of regard, locate and classify them, and convey the information to other units or systems connected to it.

To provide an unprecedented level of performance for optical systems and enable numerous high-level applications, including sub-diffraction-limited imaging and ultra-wide band optical communications, the **Optical Arbitrary Waveform Generation (OAWG)** program seeks to demonstrate a compact, robust, practical, stable octave-spanning optical oscillator integrated with an encoder/decoder capable of addressing individual frequency components with an update rate equal to the mode-locked repetition rate.

The **Parametric Optical Processes and Systems (POPS)** program aims to direct terabits per second optical switching to move ultra-short optical bits in time and wavelength to accomplish "wavelength grooming," in which data packets are captured and manipulated. POPS will develop disruptive manufacturing processes to reduce the cost and delivery time for future DoD systems.

The goal of the **Photonic Analog Signal Processing Engines with Reconfigurability (PhASER)** program is the creation of new photonic integrated circuit (PIC) elements and associated programmable filter array concepts that will enable high-throughput, low-power signal processors. The program is focused on the development of novel "unit cells," which may be used as building blocks to synthesize arbitrarily complex filters within a PIC platform for ultra-high-bandwidth signal processing applications.

The goal of the **Photonic Bandwidth Compression for Instantaneous Wideband A/D Conversion** (formerly Ultra-WideBand Analog-to-Digital (A/D) Conversion (UWB-ADC)) program is to develop revolutionary technologies to enable analog-to-digital converters (ADCs) with high-resolution and large instantaneous bandwidth, while maintaining power consumption that is commensurate with user community requirements. Such ADCs would have a dramatic impact on signals intelligence capabilities, and would alleviate the current ADC bottleneck in high-capacity digital radio frequency communications links by enabling more spectrally-efficient wideband waveforms.

The goal of the **Semiconductor AlGaN Injection Lasers (SAIL)** program is to demonstrate lasers based on heterostructures of aluminum gallium nitride with ultraviolet emission in the wavelength range of 340 to 270 nanometers. Potential applications of SAIL devices include stand-off biodefense, such as point detection of aerosolized bio agents.

The **Supermolecular Photonics Engineering (MORPH)** program will develop novel organic molecules and polymers with much higher electro-optic (EO) activity than can be achieved with traditional materials by exploiting new theoretical paradigms. These new materials will be demonstrated in high-performance EO modulators with drive voltage less than one volt, and 100 gigahertz bandwidth. In a related thrust area, new third-order optical non-linear materials will be developed and exploited for sensor protection against laser threats in the near infrared region.

Secure, high-capacity, free-space communications is essential for the transformational communications architecture to be realized. The goal of the **Technology for Agile Coherent Optical Transmission & Signal Processing (TACOTA)** program is to develop optoelectronic component technologies that enable increased physical layer security in optical transmission systems through the synergistic use of coherent optical technologies and high-speed electronics. Both digital and analog transmission will be considered.

The goal of the **Ultraperformance Nanophotonic Intrachip Communication (UNIC)** program is to demonstrate nanophotonic technology for (i) access to on-chip ultradense systems, and (ii) input/output to/from a chip containing such ultradense systems. UNIC technology could be applied to development of ever faster and more complex processing such as real-time pattern matching, target recognition, image processing and terahertz-class command-and-control networks.

The **University Photonic Research (UPR) Centers** program is dedicated to coupling university-based engineering research centers of excellence with industry to conduct research leading to advanced optoelectronic components critical to providing warfighters comprehensive awareness and precision.

The goal of the **University Photonics Research (UPR) II** program is to use university-based teams of interdisciplinary researchers to develop photonic intelligent microsystems that lead to new paradigms for higher performance, lower energy requirements, greater environmental stability, and adaptive behavior. These university-based research projects will be coupled with industrial participants to transition the intermediate results of long term research into products.

Recent innovations in solid state imaging devices can contribute to a new class of sensors that can create an image with only a few photons per pixel, exceeding the performance of current low-light-level imagers. The **Visible/Short Wave Infrared - Photon Counting** program will apply these innovations to develop imaging over a broad spectral band at extremely low levels of ambient illumination, enabling a unique capability for remote sensing, unattended sensors, and payloads for autonomous ground and air platforms.

Microelectromechanical Systems (MEMS)

The goal of the **Analog Spectral Processors (ASP)** program is to leverage microelectromechanical capabilities to make precision radio frequency (RF) components and to perform low-insertion-loss/heterogeneous component integration. ASP will demonstrate integrated analog spectral processors that greatly reduce the dynamic range and bandwidth requirement on analog-to-digital converters and other front-end components. The resulting dramatic reduction in size, weight, and power of RF systems will help make advanced RF capabilities available to the individual warfighter.

The **Harsh Environment Robust Micromechanical Technology (HERMIT)** program is developing micromechanical devices that can operate under harsh conditions (e.g., large temperature excursions, large power throughputs, high g-forces, and corrosive substances), while maintaining unprecedented performance, stability, and lifetimes. Applications of interest include micromechanical radio frequency switches, vibrating resonator reference tanks, gyroscopes, and accelerometers.

Recent breakthroughs in three-dimensional fabrication, including work on DARPA's Three-Dimensional Microelectromagnetic Radio Frequency Systems (3-D MERFS) program, and development of photo-patternable glasses, patternable ceramics, and other technologies, have now opened up new possibilities. The **Magnetic MEMS** program will explore the potential of using new fabrication technologies to capture magnetic phenomenology and effect miniaturization, and improved performance for a range of critical military systems.

The **MEMS Exchange** program seeks to provide flexible access to complex microelectromechanical systems (MEMS) fabrication technology in a wide variety of materials and to a broad multi-disciplinary user base via the MEMS Exchange service. A major goal of the effort is to ensure self-sustained operation of MEMS Exchange after the end of the program by adding several process modules to the existing repertoire and increasing the number of processes run per year to raise revenues to the point of self-sufficiency.

The goal of the **Micropumps** program is to provide improvements in microscale pumping capabilities and performance (of the order of 10^{-6} torr and less than one cubic centimeter in volume) to facilitate and greatly enhance operation of a variety of microsystems for DoD applications. Pumping is crucial for distributing fluids through a microsystem and for providing a vacuum for various technologies (including micro mass spectrometers, nanoscale detectors, radio frequency resonators, and a variety of other nanoelectromechanical devices). However, many microsystems still employ off-chip pumping because available microscale pumps do not meet application requirements, and, in many cases, are the limiting factor in developing an integrated, low-power, micro total analysis system or electronic device.

The goal of the **N/MEMS Science and Focus Centers** program is to support an enhanced fundamental understanding of a number of important technical issues critical to the continuing advance of nanoelectromechanical systems (NEMS) and microelectromechanical systems (MEMS) technologies and their transition into military systems.

The long development time for nanoelectromechanical system (NEMS) and microelectromechanical systems (MEMS) components is often due to the many number of iterations needed to make devices, which involve multiple physics domains. The goal of the **NanoCAD** program is to reduce the time to market for MEMS and NEMS components by, for example, developing: (i) natural graphic modeling techniques to take mechanical and electrical concepts and turn them into process flows; and (ii) reduced variable models that connect the nanoscale physics (e.g., contact physics, thermal and electrical conduction) to micro-scale to macroscale physics on a PC workstation.

The goal of **Non-Linear Dynamics** is to identify unique and unexpected benefits that can emerge from the nonlinearities and other unusual dynamics seen in nanoelectromechanical systems. Nanomechanical sensors, resonators, oscillators and other devices are presently fabricated to operate solely in their linear domain, but exploiting the nonlinear responses of these devices can lead to improved performance in multiple applications, including: sensing, telecommunications, signal processing, and data storage.

Combined Systems-on-a-Chip

The goal of the **COmpact Ultra-stable Gyro for Absolute Reference (COUGAR)** program is to develop a compact, ultra-stable gyro for absolute reference applications by combining the performance potential of the resonant fiber optic gyro with bandgap optical fiber, ultra-stable compact lasers, phase conjugate elements, and silicon optical benches. The COUGAR gyro will have a practical and typical size (approximately four inch diameter) featuring bias stability and sensitivity (or angle random walk), which is more than 100 times better than state-of-the-art gyroscopes.

The **Microsystem Integrated Navigation Technology (MINT)** (formerly Chip-Scale Atomic Sensors) program is developing technology for precision inertial navigation coupled with micro navigation aiding sensors. MINT will develop universally reconfigurable microsensors (e.g., for magnetic fields, temperature, pressure) with unmatched resolution and sensitivity. These devices will use the latest in microelectromechanical systems and photonic technologies to harness perturbations in atomic transitions as the sensing and measuring mechanisms for various parameters.

The **Microtechnologies for Air-Cooled Exchangers (MACE) Heat Sink Enhancement** program will explore emerging concepts for enhancement of the performance of heat rejection systems for the DoD. Specific program goals include the reduction of the thermal resistance by a factor of four and reducing the power consumption of the cooling system by a factor of three. Successful projects will apply MACE technologies to a customer-specified application.

The **Navigation-Grade MEMS Inertial Measurement Unit (IMU)** program will develop micro-scale accelerometers and gyros with navigation-grade performance that use only milliwatts of power. The program will transcend traditional single mass-spring methods for navigation sensing and will explore alternative approaches, such as multiple, interconnected mass-spring systems, micro-levitated spinning structures, micro-optical readout mechanisms, atomic interferometric readout mechanisms, and fluidic contortions.

The **Precision Opto-Mechanics - Mechanical Properties of Light** program will develop new optomechanical devices that utilize enhanced optical gradient forces within resonant nano-optical cavities for all-optical actuation and sensing. Potential applications for this technology include optically controlled nano-mechanical resonators and optically tunable filters. Radio frequency (RF) filters and reference oscillators based on on-chip resonators offer a solution to the increasing count of RF components needed in miniaturized wireless systems.

The goal of the **Short-range Wide-field-of-regard Extremely-agile Electronically-steered Photonic Emitter and Receiver (SWEEPER)** program is to develop chip-scale dense waveguide modular technology to achieve true embedded phased array control for beams of approximately 10 watts average power, less than 0.1 degree instantaneous field of view, greater than 45 degree total field of view, and frame rates of greater than 100 hertz in packages that are "chip-scale." This performance would represent a three orders-of-magnitude increase in speed, while also achieving a greater than two order-of-magnitude reduction in size. Moreover, the integrated phase control will provide the unprecedented ability to rapidly change the number of simultaneous beams, beam profile, and power-per-beam, thus opening up whole new directions in operational capability.

The **Submillimeter Wave Imaging Focal Plane Array (FPA) Technology (SWIFT)** program will develop revolutionary component and integration technologies to enable exploitation of the submillimeter region of the spectrum. A specific program goal is developing a new class of sensors capable of low-power, video-rate, background and diffraction-limited submillimeter imaging.

The **Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST)** program will develop super-scaled indium phosphide heterojunction bipolar transistor technology for a 10-fold increase in transistor integration for complex mixed-signal circuits. The program has established the core transistor and circuit technology to enable demonstration of critical, small-scale circuit building blocks suitable for complex mixed signal circuits operating three times faster than current technology, at one-tenth the power. TFAST is now extending the technology to the demonstration of complex mixed signal circuits, with an emphasis on direct digital synthesizers for frequency agile transmitters.

The **Transparent Displays** program will develop and refine technologies for the next generation of displays that are transparent, low-power, lightweight, and high-speed by leveraging new developments in electrically switchable Bragg gratings, silicon based micro-lasers, solid state laser de-speckling technology, and embedded nanoscale optics. The new displays would replace existing displays in a host of applications such as canopy-, windshield-, and window-integrated displays, and new lightweight avionics displays. The technology will enable innovative approaches to information sharing, such as integrated helmet display visors, bringing the digital battle space to the individual warfighter.

INFORMATION TECHNOLOGY

Information Technology is one of DARPA's most important, long-standing core technology foundations. DARPA's information technology programs are building on both traditional and revolutionary computing environments to provide the kind of secure, robust, efficient, and versatile computing foundation that our network-centric future requires. DARPA is creating radical new computing capabilities to make the commander and the warfighter more effective in the field.

DARPA's work in information technology is closely intertwined with the strategic thrust "Increasing the Tooth to Tail Ratio." It is a core technology that supports an even broader set of problems and opportunities.

The **Application Communities** program is developing technologies to protect DoD information systems that use commercial software against cyber attack and system failure by developing collaboration-based defenses that detect, respond, and heal with little or no human assistance. This capability will bring intelligent security adaptation to widely-deployed DoD systems and make security properties and status more apparent to decision-makers, thus increasing the speed and confidence with which military systems can be securely and dynamically reconfigured, particularly under stressful conditions.

The **Computer Exploitation and Human Collaboration** program supports research in broad areas of computational science having the potential for revolutionary advances in performance and other metrics. The goal of the research is to yield significant advances in networking, software, hardware and computational systems that would allow warfighters and commanders to interact in a natural way with computers, enable a new generation of collaboration methods and information acquisition, and provide seamless exchange of information.

The **Computer Science Study Group (CSSG)** program supports emerging ideas from the computer science academic community to address DoD's need for innovative computer and information science technologies. CSSG introduces a generation of junior researchers to the needs and priorities of the DoD, and enables the transition of those ideas and applications by promoting joint university, industry, and government projects.

The **Digital Network Archive (DNA)** program is pursuing a network-based approach to information storage and management that will enable a network-based repository to hold all digital information. DNA provides a mechanism for the virtual (i.e., logical, not physical) centralization of all enterprise information, making it possible for the warfighter to take full advantage of all available pertinent information in a rapid and flexible manner.

Ensuring dramatic advances in processing performance is critical as the amount and type of raw data needing to be turned into actionable information rapidly escalates. Future COTS processors are ill-suited for developing military requirements because they are increasingly less productive for military applications, are power-hungry, and limit the performance available to the warfighter. To support escalating processing needs both at the embedded and supercomputer level, completely new architectures at the processor/memory/data movement and system level are needed to enable extreme computing. The **Extreme Computing** program will enable ExaScale computing systems in the post-2010 timeframe, with processing that will exceed one quintillion (10^{18}) operations (floating point, fixed point or data movement) per second.

The future of DoD research depends on the continuing engagement of high school-age students in science- and technology-related fields. The **High School Science Study Group/CS Futures** program, an offshoot of the Computer Science Study Group program, will fund efforts to identify the computer science interests of local high school students. The professors will then work with the students on advanced-level research ideas.

Memes are information (or ideas) which propagate, persist, and influence individual and social behavior for good or ill. The **Information PIP (Propagation, Impact, Persistence)** program will establish an underlying science and understanding of information propagation (infectious ideas, memes) to identify ideas/memes as distinguishable entities and be able to predict their effects. The longer-term goal is to develop a comprehensive theory of memetics and to make new discoveries concerning the human brain, cognition, and social networks.

The **Information Theory for Mobile Ad Hoc Networks (ITMANET)** program is exploring the fundamental science of interconnected systems to provide powerful mathematical tools for understanding the intrinsic properties and complexities of large-scale networks and other distributed systems. Research is focused on the development of an overarching "Information Theory for Wireless Mobile Ad Hoc Networks" to enable the next generation of DoD's wireless networks and provide insight concerning the acquisition and deployment of nearer-term systems.

Today, production-quality compilers are developed at significant cost for a defined class of systems – regardless of the actual system resources available to and/or needed by an application. The **Software Producibility** program will reduce the cost, time, and expertise required to build large complex software systems by developing new techniques for rapidly developing adaptive software that can be easily changed to conform to new software design and development tools, can readily comply with new requirements, and can readjust dynamically to environmental perturbation. A combination of fundamental software analysis and tool assistance can enable software developers to function effectively at the expert level in multi-framework environments but without the excessive investments of time required by current techniques.

MANUFACTURING SCIENCE AND TECHNOLOGY

The DoD requires a continuous supply of critical, defense-specific materiel and systems. To ensure reliable, robust, and cost-effective access to these items, manufacturing technologies that can meet DoD's needs must be available in the DoD industrial base.

The **Advanced Flexible Manufacturing** program funds for the Robert C. Byrd Institute for Advanced Flexible Manufacturing at Marshall University and the Defense Techlink Rural Technology Transfer Project. The Byrd Institute provides both a teaching facility and initiatives to local area industries to utilize computer-integrated manufacturing technologies and managerial techniques to improve manufacturing productivity and competitiveness. Training emphasizes technologies to significantly reduce unit production and life cycle costs and to improve product quality.

The **Disruptive Manufacturing Technologies (DMT)** program is focused on reducing the fabrication time and cost of materials and/or components. Particular emphasis include self-curing composites for aircraft applications, direct digital manufacturing of technologies, and replacing traveling wave tube amplifiers with lower cost solid-state components.

The goal of the **Novel Technologies for Optoelectronics Materials Manufacturing (NTOMM)** program is to reduce the cost of imaging and emissive device fabrication to one to 10 percent of current costs by developing and demonstrating new technologies for Group II-VI (e.g., cadmium selenide) and III-V (e.g., gallium nitride) materials and device manufacturing. Cost reductions of this size would dramatically expand the uses for devices such as large area infrared imaging systems, non-planar devices and systems, and thin film and flexible devices and systems.

The **Tip-Based Nanofabrication (TBN)** program will develop methods for precise, repeatable, manufacturing at the nanoscale, using atomic force microscope tips as tools. Confinement of extreme conditions (temperatures, fluxes, fields & forces) to the region within a few microns of the tip will enable heterogeneous integration of normally incompatible materials.

LASERS

Lasers have been important to the DoD for over 40 years. They have multiple military uses, from sensing to communication to electronic warfare to target designation. And since the technology was first demonstrated, DoD has maintained a steady interest in developing, evaluating, and deploying lasers for a wide range of speed-of-light weapon applications. DARPA has been involved in lasers and laser technology development for the DoD since the early 1960s, and continues its work today in this crucial area.

The goal of the **Aero-Adaptive/Aero-Optic Beam Control (ABC)** program is to improve the performance of high-energy lasers on tactical aircraft against targets in the aft field of regard. This program will optimize flow control strategies for pointing angles in the aft field of regard, and will explore the ability of the flow control system to be synchronized with the adaptive optics.

The **Air Laser** program is investigating the potential for an efficient high energy laser (HEL) concept that combines the advantages of chemical and solid state lasers while minimizing the disadvantages. The initial concept used cryogenic solid-state laser Raman pumping of cryogens, and achieved the one kilowatt output Phase 1 goals. The current concept will investigate the potential of a Discharge Excited Catalytic Oxygen Iodine Laser (DECOIL) to make maximum use of air in the laser device. The DECOIL device is an alternative to the well known chemical oxygen iodine laser (COIL) developed in 1977 and scaled to megawatt levels. DECOIL offers the potential of an open or closed cycle, electrically powered system with minimal stored consumables, no toxic, complex, and massive chemical storage and handling, and all the advantages of COIL such as excellent beam quality, operation in an atmospheric window, and high power operation.

The **Architecture for Diode High Energy Laser Systems (ADHELS)** program will develop all-solid-state laser diode drivers with integrated fault mode protection that will decrease the size and weight of these laser systems by a factor of four by allowing the laser diode array to operate at elevated temperature, increase the diode array lifetime tenfold, and decrease lifecycle costs fivefold. The goal is to attain these improvements for diode laser arrays operating in the infrared, visible, and ultraviolet regions of the spectrum.

The goal of the **Coherently Combined High-Power Single-Mode Emitters (COCHISE)** program is to develop new, breakthrough technologies to improve diode bar lifetime and beam quality, and, ultimately, lead to coherent combination of individual emitters in laser diode bars and arrays. Coherent combination of laser diode arrays would provide high-power laser architectures that are up to three times more efficient than existing diode-pumped solid-state laser technology, while improving beam quality and increasing far-field, on-axis intensity.

The goal of the **GORGON - High Power Mid-IR Laser** program is to develop and integrate advanced laser and detector technologies to provide proactive infrared countermeasure capabilities for a variety of airborne platforms as required by the Multi-function Electro-optical Defense of U.S. Aircraft (MEDUSA) program.

The goal of the **High Energy Liquid Laser Area Defense System (HELLADS)** program is to develop a high-energy laser weapon system (~150 kilowatt) with an order-of-magnitude reduction in weight compared to existing laser systems. With a weight goal of less than five kilograms per kilowatt, HELLADS will enable high-energy lasers to be integrated onto tactical aircraft and will significantly increase engagement ranges compared to ground-based systems.

The goal of the **Revolution in Fiber Lasers (RIFL)** program is to develop multi-kilowatt, single-mode, narrow linewidth fiber laser amplifiers using diffraction-limited diode pump arrays to achieve the requisite power and coherence for future multi-kilowatt directed energy architectures.

The goal of the **Super High Efficiency Diode Sources (SHEDS)** program is to develop laser diodes that are 80 percent efficient in converting electrical power to optical power. These will be used to optically pump ytterbium and neodymium solid state lasers operating near 1060 nanometers for high-power laser systems. Such high-efficiency laser pumps for these solid state lasers will lead to dramatic reductions in the size and weight of 100 kilowatt-class diode pumped solid state lasers.

The goal of the **Ultra Fast Lasers with Response > 100 GHz** program is to develop ultra-fast lasers with modulation response greater than 100 gigahertz (GHz) resonance frequency. The capability to engineer the resonance frequency and to design monolithically integrated laser structures with a tailored radio frequency response would lead to more efficient, higher power, millimeter-wave optoelectronic sources with the resonance frequency scaleable to the terahertz regime.

The **UltraBeam** program involves conversion of femtosecond-duration ultraviolet laser light pulses to x-rays, and the study of intense x-ray pulse propagation in various media.

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The goal of the **Visible InGaN Injection Lasers (VIGIL)** program is to demonstrate green (500 nanometers) injection lasers operating continuous wave at room temperature with power output up to one watt, wallplug efficiency of 30 percent, and stable output during a time period longer than 1,000 hours. These lasers will be fabricated with a yield of 20 percent. VIGIL lasers will enable applications requiring a close match between the light source and the peak response wavelength of the human eye. Other applications include taking advantage of the minimum absorption of sea water in the blue-green spectral region and miniaturized displays.

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* Some programs described in this Fact File do not appear explicitly in the Descriptive Summaries, but are activities within items formally referenced in the Descriptive Summaries. Therefore, we have listed both Project Titles and the Descriptive Summary References.

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Intrinsically Assured MANETs	5	Dynamic Quarantine of Computer-based Worms	0602303E	IT-03
Iron Curtain	19	Crosshairs	0602702E	TT-04
J-Band Advanced Digital Receiver (JADR)	54	J-Band Advanced Digital Receiver (JADR)	0602716E	ELT-01
Joint Air/Ground Operations: Unified, Adaptive Replanning (JAGUAR)	13	Joint Air/Ground Operations: Unified, Adaptive Replanning (JAGUAR)	0603760E	CCC-01
Joint Mission Rehearsal	13	Network Command	0603766E	NET-01
Know What Is to Know Subsystem (KWIKS)	34	Advanced Ground Tactical Battle Manager	0603760E	CCC-01
Knowledge Representation and Reasoning Technology	34	Knowledge Representation and Reasoning Technology	0602304E	COG-02
Laminar Flow Flight Demonstration	24	Laminar Flow Flight Demonstration	0602702E	TT-07
Large Area Coverage Search-while-Track and Engage (LACOSTE)	8	Advanced Airborne Optical Sensing	0603767E	SEN-02
Laser Geospatial Referencing (LGR)	8	Soldier-borne Sensor Technology	0603767E	SEN-02
Lasers Through Clouds	9	Ground Targeting Sensors	0603767E	SEN-02
Learning Applied to Ground Robots (LAGR)	27	Robust Robotics	0602304E	COG-02
Learning Locomotion (L2)	27	Robust Robotics	0602304E	COG-02
Legged Squad Support System (LS3)	27	Legged Squad Support System (LS3)	0603766E	NET-01

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Lightweight Ceramic Armor (LCA)	47	Lightweight Ceramic Armor (LCA)	0602702E	TT-04
Lightweight High Efficiency Aircraft Power Generation	24	Lightweight High Efficiency Aircraft Power Generation	0602702E	TT-07
Linear Photonic RF Front End Technology (PHOR-FRONT)	58	Linear Photonic RF Front End Technology (PHOR-FRONT)	0602716E	ELT-01
Local Area Network droid (LANdroid)	1	Cognitive Networking	0602304E	COG-03
Long Term Storage of Blood Products	37	Tactical Biomedical Technologies	0602715E	MBT-02
Long View	31	Long View	0603287E	SPC-01
Low Power Micro Cryogenic Cooler	54	Low Power Micro Cryogenic Coolers	0603739E	MT-12
Low-Altitude Airborne Sensor System (LAASS)	29	Low-Altitude Airborne Sensor System (LAASS)	0603767E	SEN-01
Low-Altitude Airborne Sensor System (LAASS) Active EM Payload	29	Low-Altitude Airborne Sensor System (LAASS)	0603767E	SEN-01
Low-Altitude Airborne Sensor System (LAASS) Gravity Gradient Payload	29	Low-Altitude Airborne Sensor System (LAASS)	0603767E	SEN-01
Machine Reading	34	Knowledge Representation and Reasoning Technology	0602304E	COG-02
Magnetic MEMS	60	Magnetic MEMS	0603739E	MT-12
Magneto Hydrodynamic Explosive Munition (MAHEM)	18	Magneto Hydrodynamic Explosive Munition (MAHEM)	0602702E	TT-04
Malicious Network Mitigation	5	Defensive Autonomous Systems	0602303E	IT-03
Maneuver and Control on the Urban Battlefield	19	Maneuver and Control on the Urban Battlefield	0602702E	TT-04
Maskless Direct-Write Nanolithography for Defense Applications	54	Maskless Direct-Write Nanolithography for Defense Applications	0603739E	MT-15
Materials with Novel Transport Properties	48	Engineered Bio-Molecular Nano-Devices and Systems	0601101E	MS-01
Mathematics of the Brain (MoB)	45	Human Assisted Neural Devices	0601101E	BLS-01
MEMS Exchange	60	MEMS Exchange	0603739E	MT-12
MEO Synthetic Aperture Radar (MEOSAR)	32	MEO Synthetic Aperture Radar (MEOSAR)	0603287E	SPC-01
Micro Isotope Micro-Power Sources (MIPS)	50	Micro Isotope Micro-Power Sources (MIPS)	0602716E	ELT-01
Micro Power Generation	50	Micro Power Generation	0603739E	MT-12
Micro Power Sources	50	Alternate Power Sources	0602715E	MBT-01
Microantenna Array Technology & Applications (MIATA)	55	Microantenna Array Technology & Applications (MIATA)	0603739E	MT-15
Micro-Beam Clock	5	Micro-Beam Clocks	0603739E	MT-12

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Micropower Engine	50	Micropower Engine	0602702E	TT-04
Micropumps	60	Micropumps	0603739E	MT-12
Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP)	31	Microsatellite Demonstration Science and Technology Experiment Program (MiDSTEP)	0603287E	SPC-01
Microsensors for Imaging (MISI)	55	Microsensors for Imaging (MISI)	0603739E	MT-15
Microsystem Integrated Navigation Technology (MINT)	61	Microsystem Integrated Navigation Technology (MINT)	0603739E	MT-12
Microtechnologies for Air-Cooled Exchangers (MACE) Heat Sink Enhancement	61	Microtechnologies for Air-Cooled Exchangers (MACE) Heat Sink Enhancement	0603739E	MT-12
Military Medical Imaging	37	Military Medical Imaging	0602715E	MBT-02
Miniature, Room Temperature, Ultra-sensitive Magnetic Sensor (MRUMS)	55	Miniature, Room Temperature, Ultra-sensitive Magnetic Sensor (MRUMS)	0603739E	MT-15
Mission-Adaptable Chemical Sensors (MACS)	37	Mission-Adaptable Chemical Sensors (MACS)	0602383E	BW-01
Mobile Integrated Sustainable Energy Recovery (MISER)	50	Alternate Power Sources	0602715E	MBT-01
Mobile Networked Multiple-Input/Multiple-Output (MIMO) (MNM)	21	Mobile Networked Multiple-Input/Multiple-Output (MIMO) (MNM)	0603760E	CCC-02
Molecular Targets of Stress	40	Maintaining Combat Performance	0602715E	MBT-02
Multi Dimensional Mobility Robot (MDMR)	27	Multi Dimensional Mobility Robot (MDMR)	0603766E	NET-01
Multifunction Electro-Optics for Defense of U.S. Aircraft (MEDUSA)	9	Multifunctional Electro-Optics for Defense of U.S. Aircraft (MEDUSA)	0603768E	GT-01
Multifunctional Surface Systems: Carbon Nanotube (CNT) Cold Cathodes	48	Multifunctional Materials and Structures	0602715E	MBT-01
Multifunctional Surface Systems: Low Temperature Colossal Supersaturation (LTCSS)	48	Multifunctional Materials and Structures	0602715E	MBT-01
Multifunctional Surface Systems: Pulse Thermal Processing (PTP)	48	Multifunctional Materials and Structures	0602715E	MBT-01
Multifunctional Surface Systems: Surface Control for Superhydrophobics	48	Multifunctional Materials and Structures	0602715E	MBT-01

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Multifunctional Surface Systems: Surface Wave Communication and Power Transmission (SWCPT)	48	Multifunctional Materials and Structures	0602715E	MBT-01
Multilingual Automatic Document Classification, Analysis and Translation (MADCAT)	21	Multilingual Automatic Document Classification, Analysis and Translation	0602303E	IT-04
Multi-Modal Missile	24	Multi-Modal Missile	0603286E 0603764E	AIR-01 LNW-01
Multipath Exploitation Radar (MER)	9	Multipath Exploitation Radar (MER)	0603766E	NET-01
Multispectral Adaptive Networked Tactical Imaging System (MANTIS)	15	Urban Commander	0603760E	CCC-01
N/MEMS Science and Focus Centers	60	N/MEMS Science and Focus Centers	0601101E	ES-01
NanoCAD	60	NanoCAD	0603739E	MT-12
Nano-Composite Optical Ceramic (NCOC)	47	Nanoscale/Biomolecular and MetaMaterials	0601101E	MS-01
Nano-Electro-Mechanical Computers (NEMS)	55	Nano-Electro-Mechanical Computers (NEMS)	0603739E	MT-12
Nano-Flapping Air Vehicles	25	Nano-Flapping Air Vehicles	0602702E	TT-07
NanoPayload Delivery (NPD)	31	NanoPayload Delivery (NPD)	0603287E	SPC-01
Nanoscaled Architecture for Coherent Hyper-Optic Sources (NACHOS)	42	Nanoscaled Architecture for Coherent Hyper-Optic Sources (NACHOS)	0601101E	ES-01
Nanostructured Materials for Power	50	Multifunctional Materials and Structures	0602715E	MBT-01
Nastic Materials	40	Materials for Initiation and Actuation	0602715E	MBT-01
National Cyber Range (NCR)	5	Cyber Security Initiative	0305103E	CYB-01
Naval Advanced Amorphous Coatings	47	Structural Materials and Coatings	0602715E	MBT-01
Navigation-Grade MEMS Inertial Measurement Unit (IMU)	61	Navigation-Grade MEMS Inertial Measurement Unit (IMU)	0603768E	GT-01
Negative Index Materials	48	Functional Materials and Devices	0602715E	MBT-01
Neovision2/Neovision	40	Neovision2 Nanostructure in Biology	0602715E 0601101E	MBT-02 BLS-01
NetTrack	12	Advanced Radar Sensor Technology	0603767E	SEN-02
Network-Centric Situation Assessment	13	Network Command	0603766E	NET-01
Networked Bionic Sensors for Language/Speaker Detection	9	Networked Bionic Sensors for Language/Speaker Detection	0603760E	CCC-02

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Networked Embedded Systems Technology (NEST)	16	Networked Embedded Systems Technology (NEST)	0602702E	TT-13
Networking in Extreme Environments (NetEx)	22	Networking Extreme Environments (NetEx)	0602702E	TT-04
Neurotechnology for Intelligence Analysts (NIA)	40	Neuroscience Technologies	0602715E	MBT-02
Next Generation (XG)	2	Next Generation (XG)	0603760E	CCC-02
Next Generation Core Optical Networks (CORONET)	3	Next Generation Core Optical Networks (CORONET)	0602303E	IT-03
Next Generation Fuel Cell Chemistries	50	Novel Power Sources	0602715E	MBT-01
Next Generation RF Antenna System	9	Advanced Radar Sensor Technology	0603767E	SEN-02
Next Generation Routing and Addressing	22	Next Generation Routing and Addressing	0603760E	CCC-02
Nightingale	37	Nightingale	0602702E	TT-07
Non-contact EEG Technologies (NET)	44	Non-contact EEG Technologies (NET)	0602716E	ELT-01
Non-Linear Dynamics	60	Micromechanical Amplifiers	0603739E	MT-12
Non-Linear Math for Mixed Signal Microsystems (NLMMSM)	45	Non-Linear Math for Mixed Signal Microsystems	0602716E	ELT-01
Novel Satellite Communications (NSC)	32	Novel Satellite Communications (NSC)	0603287E	SPC-01
Novel Technologies for Optoelectronics Materials Manufacturing (NTOMM)	63	Novel Technologies for Optoelectronics Materials Manufacturing (NTOMM)	0602716E	ELT-01
Novel Topological Materials and Nanoelectronics	55	Engineered Bio-Molecular Nano-Devices and Systems	0601101E	MS-01
Oblique Flying Wing (OFW)	25	Oblique Flying Wing (OFW)	0603286E	AIR-01
Omni-Directional Flash & Launch Detection, Positioning, Classification and Observation System (MEGA)	58	Soldier-borne Sensor Technology	0603767E	SEN-02
Optical & Radio Frequency Combined Link Experiment (ORCLE)	3	Optical & RF Combined Link Experiment (ORCLE)	0603760E	CCC-02
Optical Antenna Based on Nanowires	55	Optical Antenna Based on Nanowires	0602716E	ELT-01
Optical Arbitrary Waveform Generation (OAWG)	58	Optical Arbitrary Waveform Generation (OAWG)	0602716E	ELT-01
Optical Lattice Emulators	47	Atomic Scale Materials and Devices	0601101E	MS-01
PACMAN-V	37	Unconventional Therapeutics	0602383E	BW-01
Parametric Optical Processes and Systems (POPS)	59	Parametric Optical Processes and Systems (POPS)	0602716E	ELT-01

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Peak Soldier Performance	40	Maintaining Combat Performance	0602715E	MBT-02
Persistent Ocean Surveillance	28	Persistent Ocean Surveillance (includes Surface Wave Harvesting)	0603766E	NET-02
Persistent Operational Surface Surveillance and Engagement (POSSE)	16	Persistent Exploitation	0603767E	SEN-02
Personalized Assistant that Learns (PAL)	34	Personalized Assistant that Learns (PAL)	0602304E	COG-02
Photonic Analog Signal Processing Engines with Reconfigurability (PhASER)	59	Photonic Analog Signal Processing Engines with Reconfigurability (PhASER)	0602716E	ELT-01
Photonic Bandwidth Compression for Instantaneous Wideband A/D Conversion	59	Photonic Bandwidth Compression for Instantaneous Wideband A/D Conversion	0602716E	ELT-01
Plantenna	44	Bioinspired Sensors	0602715E	MBT-02
Plasma Self Sterilization Medical Devices	37	Biological Interfaces	0602715E	MBT-02
Polar Bear	9	Ground Targeting Sensors	0603767E	SEN-02
Polarized Rotation Modulation (PZRM) Communications	2	Polarized Rotation Modulation (PZRM) Communications	0603760E	CCC-02
Polymer Ice (Traction Control for Mobility Assurance)	19	Non-Lethal Alternatives for Urban Operations	0603764E	LNW-01
Powerswim	40	BioRobotics and BioMechanics	0602715E	MBT-02
Precision Inertial Navigation Systems (PINS)	25	Precision Inertial Navigation Systems (PINS)	0603768E	GT-01
Precision Opto-Mechanics - Mechanical Properties of Light	61	Precision Opto-Mechanics - Mechanical Properties of Light	0602716E	ELT-01
Predicting Health and Disease (PHD)	37	Advanced Diagnostics	0602383E	BW-01
Predicting Pathogen Emergence	37	Unconventional Therapeutics	0602383E	BW-01
Predicting Real Optimized Materials (PROM)	47	Nanoscale/Biomolecular and MetaMaterials	0601101E	MS-01
Predictive Analysis for Naval Deployment Activities (PANDA)	13	Predictive Analysis for Naval Deployment Activities (PANDA)	0603760E	CCC-01
Predictive Battlespace Awareness	13	Predictive Battlespace Awareness	0603760E	CCC-01
Preventing Violent Explosive Neurological Trauma (PREVENT)	38	Bio Interfaces	0601101E	BLS-01

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Processing Algorithms with Co-design of Electronics (PACE)	55	Processing Algorithms with Co-design of Electronics (PACE)	0602716E	ELT-01
Prognosis	25	Prognosis	0602715E	MBT-01
Programmable Matter	47	Programmable Matter	0601101E	CCS-02
Protein Design Processes	44	Nanostructure in Biology	0601101E	BLS-01
Pyrofusion	51	Alternate Power Sources	0602715E	MBT-01
Quantum Entanglement Science and Technology (QuEST)	42	Quantum Entanglement Science and Technology (QuEST)	0601101E	ES-01
Quantum Information Science (QIS)	42	Quantum Information Science (QIS)	0602716E	ELT-01
Quantum Key Distribution over Wide-Area Fiber Optic Networks	5	Quantum Key Distribution over Wide-Area Fiber Optic Networks	0602303E	IT-03
Quantum Sensors	42	Quantum Sensors	0602716E	ELT-01
Quarantine Toxic UAV Payloads	19	Quarantine Toxic UAV Payloads	0603766E	NET-01
Quint Networking Technology (QNT)	3	Network Centric Sensing and Engagement	0603767E	SEN-02
RAD Hard by Design	32	RAD Hard by Design	0603287E	SPC-01
Radar Scope	16	Visibuilding	0603767E	SEN-01
Radiation Biodosimetry (RaBiD)	38	Advanced Diagnostics	0602383E	BW-01
Radioisotope Micro-Power Sources (RIMS)	51	Radio Isotope Micro-Power Sources (RIMS)	0602716E	ELT-01
Rapid Eye	9	Rapid Eye	0603286E	AIR-01
Rapid Vaccine Assessment	38	Unconventional Therapeutics	0602383E	BW-01
Reactive Structures	47	Materials for Initiation and Actuation	0602715E	MBT-01
RealNose	40	Bioinspired Sensors	0602715E	MBT-02
Real-time Adversarial Intelligence and Decision-making (RAID)	13	Advanced Ground Tactical Battle Manager	0603760E	CCC-01
RealWorld	21	RealWorld	0602702E	TT-06
Recognize Improvised Explosive Devices and Report (RIEDAR)	20	Recognize Improvised Explosive Devices and Report (RIEDAR)	0602702E	TT-04
Remote Detection of Suspicious Vehicles (RDSV)	9	Precision Urban Combat Systems (PUCS)	0603766E	NET-01
Rescue Transponder (RT)	16	Rescue Transponder (RT)	0603767E	SEN-01
Restorative Encoding Memory Integrated Neural Device (REMIND)	41	Human Assisted Neural Devices	0601101E	BLS-01
Restorative Injury Repair/Phase II	41	Biological Adaptation, Assembly and Manufacturing Tactical Biomedical Technologies	0601101E 0602715E	BLS-01 MBT-02

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Retro-directive Ultra-Fast Acquisition Sensor (RUFAS)	10	Retro-directive Ultra-Fast Acquisition Sensor (RUFAS)	0603760E	CCC-02
Reversible Barriers (ReBar)	20	Reconfigurable Structures	0602715E	MBT-01
Revolution in Fiber Lasers (RIFL)	64	Revolution in Fiber Lasers (RIFL)	0602702E	TT-06
Revolutionizing Electronics with Biological Materials	44	Engineered Bio-Molecular Nano-Devices and Systems	0601101E	MS-01
Revolutionizing Prosthetics	41	Revolutionizing Prosthetics	0602715E	MBT-02
River Eye	12	River Eye	0603766E	NET-02
Riverine Crawler Underwater Vehicle	25	Riverine Crawler Underwater Vehicle	0602702E	TT-03
Robust Automatic Translation of Speech (RATS)	35	Robust Automatic Translation of Speech (RATS)	0602303E	IT-04
Robust Portable Power	51	Novel Power Sources	0602715E	MBT-01
Robust Surface and Sub-Surface Navigation (RSN/SSN)	25	Robust Surface and Sub-Surface Navigation (RSN/SSN)	0603768E	GT-01
Robust Tunnel Mapping and Operations	30	Robust Tunnel Mapping and Operations	0603767E	SEN-01
Robust Uncertainty Management (RUM)	45	High Performance Algorithm Development	0602702E	TT-06
Rocket Propelled Grenade (RPG) Pre-launch Detection and Cueing	20	Rocket Propelled Grenade (RPG) Pre-launch Detection and Cueing	0602702E	TT-04
Rootkit Detection	5	Rootkit Detection	0602303E	IT-03
RPGNets	20	RPGNets	0602702E	TT-04
SandBlaster	25	Ground Targeting Sensors	0603767E	SEN-02
SAVe: Portable Ventilator	38	Tactical Biomedical Technologies	0602715E	MBT-02
Scalable MMW Architectures for Reconfigurable Transceivers (SMART)	10	Scalable MMW Architectures for Reconfigurable Transceivers (SMART)	0603760E	CCC-02
Scalable Network Monitoring (SNM)	6	Trustworthy Systems	0602303E	IT-03
Scalable Precision Strike (SPS)	18	Guided Projectiles	0602702E	TT-04
Sea Shield	28	Sea Shield	0603766E	NET-02
Seismic/Acoustic Vibration Imaging (SAVI)	15	Seismic/Acoustic Vibration Imaging (SAVI)	0603766E	NET-01
Self-Decontaminating Surfaces	38	External Protection	0602383E	BW-01
Self-Regenerative Systems (SRS)	6	Security-Aware Systems	0602303E	IT-03
Semiconductor AlGaN Injection Lasers (SAIL)	59	Semiconductor AlGaN Injection Lasers (SAIL)	0601101E	ES-01

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Semiconductor-Tuned HTS Filters for Ultra-Sensitive RF Receivers (SURF)	55	Semiconductor-Tuned HTS Filters for Ultra-Sensitive RF Receivers (SURF)	0602716E	ELT-01
Sensing and Exploitation of Urban Movers (SE-UM)	10	Advanced Radar Sensor Technology	0603767E	SEN-02
Sensor Tape	38	Soldier-borne Sensor Technology	0603767E	SEN-02
Sensor Topology for Minimal Planning (SToMP)	45	Integrated Sensing and Processing	0602702E	TT-06
Short Wave Infrared through Fog (SWIF) and Clouds	10	Ground Targeting Sensors	0603767E	SEN-02
Short-range Wide-field-of-regard Extremely-agile Electronically-steered Photonic Emitter and Receiver (SWEEPER)	61	SWEEPER	0602716E	ELT-01
Situation-Aware Protocols in Edge Network Technologies (SAPIENT)	6	Cognitive Networking	0602304E	COG-03
Sleight of HAND (SOH)	32	Sleight of HAND (SOH)	0603287E	SPC-01
Slow Light	43	Functional Materials and Devices	0602715E	MBT-01
Small Combat Vehicle with Robotic Automation	25	Small Combat Vehicle with Robotic Automation	0602702E	TT-04
Small UAV Strike Munition	25	Small UAV Strike Munition	0603286E	AIR-01
Smart Dust Sensor Networks Applied to Urban Area Operations	15	Precision Urban Combat Systems (PUCS)	0603766E	NET-01
Smart Gills	49	Functional Materials and Devices	0602715E	MBT-01
Software Producibility	63	Software Producibility	0602303E	IT-02
Sonic Projector	20	Sonic Projector	0602702E	TT-06
Space Situational Awareness (SSA) & Counterspace Operations Response Environment (SCORE)	32	Space Situational Awareness & Counterspace Operations Response Environment	0603287E	SPC-01
Space Surveillance Telescope (SST)	32	Space Surveillance Telescope (SST)	0603287E	SPC-01
Space, Time Adaptive Processing (STAP) Boy	56	Space, Time Adaptive Processing (STAP) Boy	0603739E	MT-15
Spatially Processed Image Detection and Ranging (SPIDAR)	10	Advanced Airborne Optical Sensing	0603767E	SEN-02
Speckle Exploitation for Enhanced Reconnaissance (SEER)	10	Speckle Exploitation for Enhanced Reconnaissance (SEER)	0603767E	SEN-01

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Spoken Language Communication and Translation System for Tactical Use (TRANSTAC)	35	Spoken Language Communication and Translation System for Tactical Use	0602303E	IT-04
Spread Spectrum Networking	6	Spread Spectrum Networking	0602303E	IT-03
Standoff Precision ID in 3-D (SPI 3-D)	10	Advanced Airborne Optical Sensing	0603767E	SEN-02
Stand-off Solid Penetrating Imaging	20	Stand-off Solid Penetrating Imaging	0603739E	MT-15
Standoff Triage	38	Standoff Triage	0603767E	SEN-01
Stealthy Sensors	40	Bioderived Materials	0602715E	MBT-02
Stealthy, Persistent, Perch and Stare (SP2S)	15	Stealthy, Persistent, Perch and Stare (SP2S)	0603286E	AIR-01
Steep-subthreshold-slope Transistors for Electronics with Extremely-low Power (STEEP)	56	Steep-subthreshold-slope Transistors for Electronics with Extremely-low Power	0602716E	ELT-01
Strategic Communication Assessment and Analysis System (SCAAS)	4	Strategic Communication Assessment and Analysis System (SCAAS)	0602702E	TT-13
Strategically Hardened Facility Defeat	30	Strategically Hardened Facility Defeat	0603767E	SEN-01
Structural Amorphous Metals	47	Structural Materials and Coatings	0602715E	MBT-01
Structured ASIC Design (StASD)	56	Structured ASIC Design (StASD)	0602716E	ELT-01
Submarine Shaftless Stern Demonstrator	26	Tango Bravo	0603766E	NET-02
Submillimeter Wave Imaging Focal Plane Array (FPA) Technology (SWIFT)	61	Submillimeter Wave Imaging Focal Plane Array (FPA) Technology (SWIFT)	0602716E	ELT-01
Super High Efficiency Diode Sources (SHEDS)	64	Super High Efficiency Diode Sources (SHEDS)	0602702E	TT-06
Superconducting Hybrid Power Electronics (SuperHyPE)	51	Power Components	0602715E	MBT-01
Super-Fast Submerged Transport	26	Super-Fast Submerged Transport	0602702E	TT-03
Supermolecular Photonics Engineering (MORPH)	59	Molecular Photonics (MORPH)	0601101E	ES-01
Super-Resolution Vision System (SRVS)	18	Ground Targeting Sensors	0603767E	SEN-02
Surface Enhanced Raman Scattering (SERS) - Science and Technology	56	Surface Enhanced Raman Scattering (SERS) - Science and Technology	0601101E	MS-01
Surface Wave Energy Harvesting	51	Persistent Ocean Surveillance (includes Surface Wave Harvesting)	0603766E	NET-02

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Surveillance and Threat Neutralization in Urban Environments	20	Surveillance and Threat Neutralization in Urban Environments	0603767E	SEN-01
Surviving Blood Loss	38	Tactical Biomedical Technologies	0602715E	MBT-02
Synthetic Aperture Ladar for Tactical Imaging (SALTI)	11	Synthetic Aperture Ladar for Tactical Imaging (SALTI)	0603767E	SEN-02
Synthetic Evolvable Materials	47	Reconfigurable Structures	0602715E	MBT-01
System F6	31	System F6	0603287E	SPC-01
System for Planning Information Operations and Nonkinetic Effectiveness (SPINE)	6	System for Planning Information Operations and Nonkinetic Effectiveness (SPINE)	0602303E	IT-03
Systems of Neuromorphic Adaptive Plastic Scalable Electronics (SyNAPSE)	44	Systems of Neuromorphic Adaptive Plastic Scalable Electronics (SyNAPSE)	0602716E	ELT-01
Tactical Combined Fiber-Optical & Free-Space Edge Network	3	Tactical Combined Fiber-Optical & Free-Space Edge Network	0603760E	CCC-02
Tactical Sensor Network Technologies (TSNT)	12	Target Identification Technology	0603767E	SEN-02
Tactical Underwater Navigation System (TUNS)	26	Precision Inertial Navigation Systems (PINS)	0603768E	GT-01
Tango Bravo	26	Tango Bravo	0603766E	NET-02
Technology for Agile Coherent Optical Transmission & Signal Processing (TACOTA)	59	Technology for Agile Coherent Optical Transmission & Signal Processing (TACOTA)	0602716E	ELT-01
Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST)	61	Technology for Frequency Agile Digitally Synthesized Transmitters (TFAST)	0602716E	ELT-01
Terahertz Imaging Focal-Plane Technology (TIFT)	16	Terahertz Imaging Focal-Plane Technology (TIFT)	0602716E	ELT-01
Thermal Ground Plane (TGP)	56	Thermal Ground Plane (TGP)	0603739E	MT-12
Threat Agent Cloud Tactical Intercept and Countermeasure (TACTIC)	38	Threat Agent Cloud Tactical Intercept Countermeasure (TACTIC)	0602383E	BW-01
Three-dimensional integration (3DIC)	56	Design Tools for 3-Dimensional Electronic Circuit Integration	0602716E	ELT-01
Three-Dimensional Microelectromagnetic Radio Frequency Systems (3-D MERFS)	56	3-D Microelectromagnetic RF Systems (3-D MERFS)	0602716E	ELT-01
THz Transistors (TT)	57	THz Transistors (TT)	0602716E	ELT-01

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Time Reversal Methods	12	High Performance Algorithm Development	0602702E	TT-06
Tip-Based Nanofabrication (TBN)	63	Tip-Based Nanofabrication (TBN)	0601101E	ES-01
Topological Data Analysis (TDA)	45	High Performance Algorithm Development	0602702E	TT-06
Topologically Controlled Lightweight Armor (TCLA)	47	Materials for Force Protection	0602715E	MBT-01
Training Superiority	21	Training Superiority	0602702E	TT-06
Transfer Learning	34	Foundational Learning Technology	0602304E	COG-02
Transmission, Switching and Applications for Next-Generation Core Optical Networks	4	Next Generation Core Optical Networks (CORONET)	0602303E	IT-03
Transparent Displays	61	Transparent Displays	0602716E	ELT-01
Transportable Magnetic Resonance Imaging (MRI)	38	Tactical Biomedical Technologies	0602715E	MBT-02
Trauma Pod	39	Trauma Pod	0602715E	MBT-02
Trust in Integrated Circuits (TRUST)	57	Trusted, Uncompromised Semiconductor Technology (TrUST)	0602716E	ELT-01
Trustworthy Systems	6	Trustworthy Systems	0602303E	IT-03
ULF Wave Study	32	Sleight of HAND (SOH)	0603287E	SPC-01
Ultra Fast Lasers with Response > 100 GHz	64	Ultra Fast Lasers With Response > 100 GHz	0602716E	ELT-01
UltraBeam	64	UltraBeam	0602716E	ELT-01
Ultra-Low Power Subthreshold Electronics (UPSE)	57	Ultra-Low Power Subthreshold Electronics (UPSE)	0602716E	ELT-01
Ultraperformance Nanophotonic Intrachip Communication (UNIC)	59	Ultradense Nanophotonic Intrachip Communication (UNIC)	0603739E	MT-15
ULTRA-VIS	22	Urban Commander	0603760E	CCC-01
Ultra-Wide Band Multi-Function Photonic Transmit and Receive (ULTRA T/R) Modules	11	Ultra-Wide Band Technology	0603739E	MT-15
Understanding Long Term Memory	40	Neuroscience Technologies	0602715E	MBT-02
Unique Propulsion Techniques	26	Unique Propulsion Techniques	0602702E	TT-03
Unique Signature Detection	17	Novel Sensors for Force Protection	0602702E	TT-04
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Unmanned Persistent Parafoil System (UPPS)	26	Unmanned Persistent Parafoil System (UPPS)	0602702E	TT-07
Urban Challenge	28	Information Sciences Cognitive Computing Future Combat Systems	0601101E 0602304E 0603764E	CCS-02 COG-02 LNW-03
Urban Ops Hopper	28	Urban Ops Hopper	0603766E	NET-01
Urban Photonic Sandtable Display (UPSD)	12	Home Field	0602702E	TT-13
Urban Reasoning and Geospatial Exploitation Technology (URGENT)	16	Federated Object-level Exploitation (FOX)	0603766E	NET-01
UUV Power Technologies	26	Long Duration Power Concepts	0602715E	MBT-01
Vehicle and Dismount Exploitation Radar (VADER)	11	Advanced Radar Sensor Technology	0603767E	SEN-02
Vertically Interconnected Sensor Arrays (VISA)	57	Vertically Integrated Sensor Arrays (VISA)	0603739E	MT-15
Very High Efficiency Solar Cell (VHESC)	51	Very High Efficiency Solar Cell (VHESC)	0602715E	MBT-01
Very High Speed Torpedo Defense	26	Very High Speed Torpedo Defense	0602702E	TT-13
Video Verification and Identification (VIVID)	17	Pattern Analysis Technology	0603767E	SEN-02
Virtual Autopsy	39	Military Medical Imaging	0602715E	MBT-02
Visible InGan Injection Lasers (VIGIL)	65	Visible InGan Injection Lasers (VIGIL)	0602716E	ELT-01
Visible/Short Wave Infrared - Photon Counting	59	Visible/Short Wave IR - Photon Counting	0603739E	MT-15
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Visualizing the Info Ops Common Operating Picture (VIOCOP)	3	Visualizing the Info Ops Common Operating Picture (VIOCOP)	0602702E	TT-13
VPN for ad hoc Networks	2	VPN for ADHOC Networks	0603760E	CCC-02
Vulture	26	Vulture	0603286E	AIR-01
WDM LAN for Aerospace Platforms	26	Fiber-Optical Network for Aerospace Platforms	0603760E	CCC-02
Wide Area Network (WAN) Monitoring	6	Wide Area Network (WAN) Monitoring	0602303E	IT-03
Wide Band Gap Semiconductor Electronics for RF Applications (WBGS-RF)	11	High Frequency Wide Band Gap Semiconductor Electronics Technology	0602716E	ELT-01
Wideview	27	Wideview	0602702E	TT-03
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Wireless Network after Next (WNaN)	2	Wireless Network after Next (WNaN)	0603760E	CCC-02
Wound Stasis Spray	39	Tactical Biomedical Technologies	0602715E	MBT-02
Young Faculty Award (YFA)	44	Young Faculty Award	0601101E	CCS-02

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