Office of Naval Research
ONR
Science & Technology

Code 35

Naval Air Warfare and Weapons

The Office of Naval Research (ONR) serves as the Department of the Navy's science and technology (S&T) solutions provider for Navy and Marine Corps needs. Our mission, defined by law, is to "plan, foster and encourage scientific research in recognition of its paramount importance as related to the maintenance of future naval power and the preservation of national security," and to "manage the Navy's basic and applied research, and advanced technology development to foster transition from science and technology to higher levels of research, development, test and evaluation."

The Naval Air Warfare and Weapons (Code 35) department supports Navy and Marine Corps needs, fostering basic, applied and advanced research in support of the Sea-Based Aviation National Naval Responsibility as well as directed energy, electromagnetic launch and high-speed conventional air and surface weapons.

This booklet highlights an assortment of the program areas being investigated within Code 35. These broad areas incorporate discoveries and inventions made across government laboratories, universities and industry. The following pages will give some insight into how these investigations interrelate scientific advancements with military objectives. If you have any questions or would like more information on any individual effort, ONR program officer contact information is provided.

Thank you for your interest in helping define the future of Naval Air Warfare and Weapons.

Dr. Thomas J. Beutner
Department Head
Naval Air Warfare and Weapons (Code 35)

DOING BUSINESS WITH CODE 35 PAGE 45

Naval Air Warfare and Weapons

The Office of Naval Research (ONR) (www.onr.navy.mil) was established as an Echelon 1 command with the Chief of Naval Research (CNR) reporting to the Secretary of the Navy to sponsor scientific research efforts that will enable the future operational concepts of the Navy and the Marine Corps.

As the Department of the Navy's science and technology provider, ONR identifies S&T solutions to address Navy and Marine Corps needs. Since its establishment in 1946, ONR continues to be the first place that senior naval leadership turn to for addressing emerging technology issues and challenges.

ONR manages the diverse naval S&T portfolio to:

- Address enduring naval needs and ensure every dollar contributes maximum impact
- Maintain investments and intellectual capital in areas unique to the Navy and Marine Corps
- Promote a culture of open innovation across the naval services
- Encourage new researchers and stimulate competitive research with technically proficient program officers and efficient business processes
- Seek partnerships with academia and industry that complement or enhance S&T outputs
- Encourage informed risk-taking and learn from failure
- Provide pathways for transitioning S&T outputs, including interactions between the S&T community and potential technology users in early stages
- Identify and leverage global technological advances
- Counter technological surprise
- Hedge against uncertainty.

Within ONR there are six codes, or departments, responsible for meeting emergent warfighter needs:

Code 30: Expeditionary Maneuver Warfare and Combating Terrorism
Code 31: Command, Control, Communications, Intelligence, Surveillance and Reconnaissance (C4ISR)
Code 32: Ocean Battlespace Sensing
Code 33: Surface Warfare and Weapons
Code 34: Warfighter Performance
Code 35: Naval Air Warfare and Weapons

This booklet focuses on Code 35, Naval Air Warfare and Weapons. Code 35 is responsible to the CNR to provide overall leadership and management of the Department of the Navy's S&T program in assigned areas to include emerging

technologies and demonstration opportunities in autonomous air systems, directed energy, surface- and air-launched weapons, and sea-based rotary and fixed-wing aviation.

Within these areas, Code 35 investment is further broken down by the maturation level of the area being investigated. There are three basic categories of funding within the code:

Discovery and Invention (D&I) consists of basic research (Budget Activity (BA) 6.1) and early applied research (BA 6.2). This is the seed corn that explores undiscovered technologies for future application. The D&I portfolio by design has a broad focus with a long time span from five to 20 years needed to mature discoveries. Its programs are selected based on potential naval relevance and technology opportunity. D&I investments are the essential foundation required for advanced technology and leverage other service, governmental, department, industry, international and general research community investments.

Leap Ahead Innovations include Innovative Naval Prototypes (INP). These are technology investments that are potentially game-changing or disruptive in nature. INPs achieve a level of technology suitable for transition in four to eight years. Leap Ahead funding comes from both applied research (BA 6.2) and advanced technology development (BA 6.3).

Acquisition Enablers (AE) include Future Naval Capabilities (FNC)–component technologies that deliver in a three- to five-year time horizon. The FNCs mature technology into requirements-driven, transition-oriented products in the late stages of applied research (BA 6.2) and advanced technology development (BA 6.3). FNCs provide enabling capabilities to fill gaps in the Office of the Chief of Naval Operations and Marine Corps Combat Development Command requirements analyses identified in the Navy and Marine Corps strategies.

The following pages detail the individual investment areas. Each page lists the Code 35 program officer responsible for executing developments within that area. You are encouraged to contact us to get involved and help to ensure that our warfighter is never in a fair fight.

RESEARCH

HUMAN/UNMANNED
SYSTEM COLLABORATION

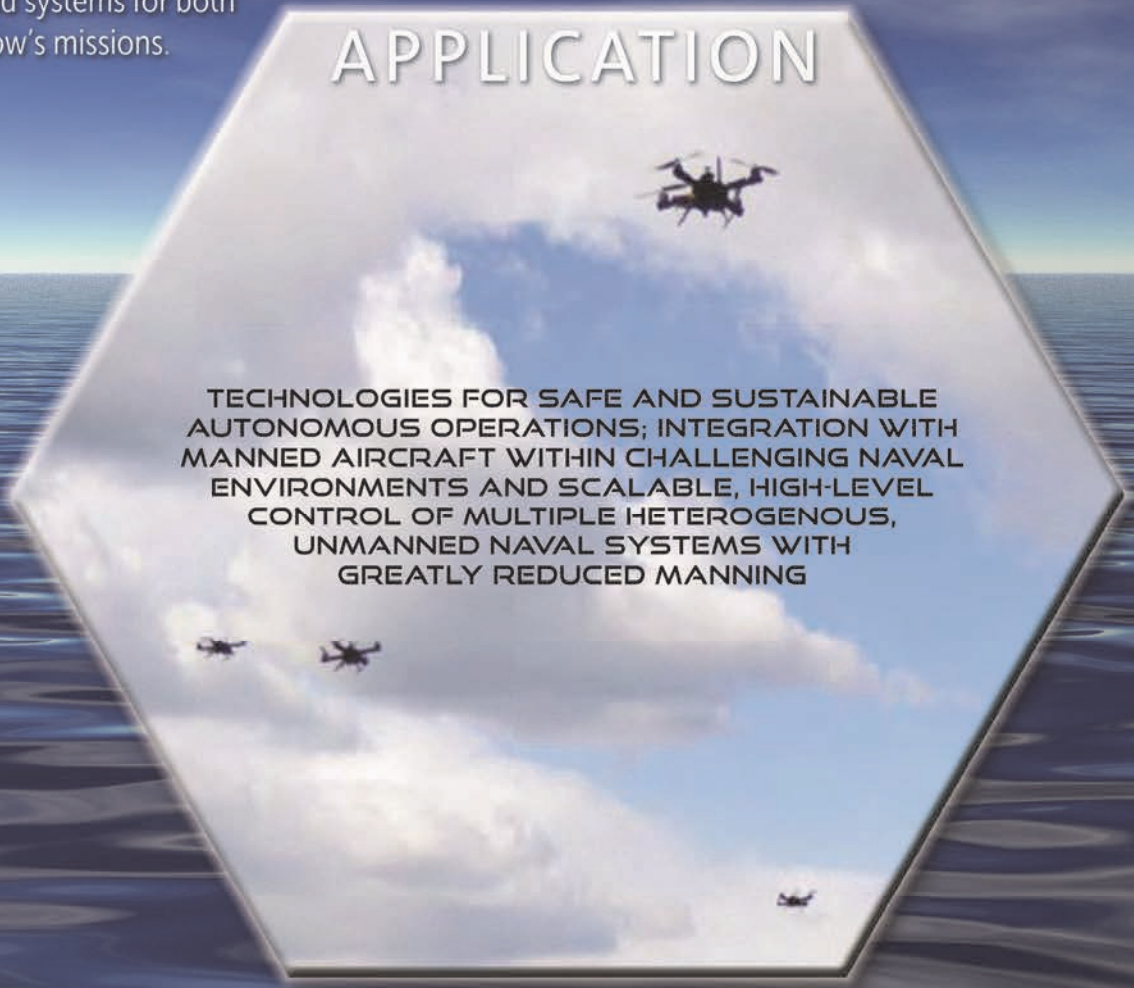
PERCEPTION &
INTELLIGENT CONTROL

SCALABLE & ROBUST
DISTRIBUTED COLLABORATION

INTELLIGENCE ENABLERS
& ARCHITECTURES

Multidisciplinary, cross-department research that supports the broad range of naval domains and systems for both today's and tomorrow's missions.

APPLICATION



TECHNOLOGIES FOR SAFE AND SUSTAINABLE AUTONOMOUS OPERATIONS; INTEGRATION WITH MANNED AIRCRAFT WITHIN CHALLENGING NAVAL ENVIRONMENTS AND SCALABLE, HIGH-LEVEL CONTROL OF MULTIPLE HETEROGENOUS, UNMANNED NAVAL SYSTEMS WITH GREATLY REDUCED MANNING

AUTONOMOUS SYSTEMS

DEMONSTRATION

MARINE CORPS BASE QUANTICO, Virginia (Feb. 25, 2014) Lance Cpl. Cody Barss uses a handheld tablet to request resupply during an Office of Naval Research demonstration of the Autonomous Aerial Cargo/Utility System (AACUS), which gives helicopters the capability for unmanned flight. AACUS consists of software and sensors that can be applied to a variety of rotary-wing aircraft and will provide the U.S. Marine Corps with the ability to rapidly support forces on the front lines, as an alternative to convoys, manned aircraft or air drops in all weather and possibly hostile conditions, with minimal training required by the requestor. (U.S. Navy photo by John F. Williams/Released)

Office of Naval Research
ONR
Science & Technology

Autonomous Aerial Cargo/Utility System (AACUS)

AT A GLANCE

WHAT IS IT?

The AACUS program explores advanced autonomous capabilities for reliable resupply/retrograde and, in the long term, casualty evacuation by an unmanned air vehicle under adverse conditions. Key features of AACUS include a vehicle autonomously avoiding obstacles while finding and landing at an unprepared landing site in dynamic conditions, with goal-directed supervisory control by a field operator with no special training.

WHAT WILL IT ACCOMPLISH?

- Due to an open architecture approach for global management of mission planning data, AACUS technologies will be platform agnostic and transferable to both new and legacy cargo unmanned aerial systems (CUASs).
- AACUS-enabled CUASs will rapidly respond to requests for support in all weather conditions, launch from sea and land, fly in high/hot environments and autonomously detect and negotiate precision landing sites in potentially hostile settings.
- Such missions could require significant obstacle and threat avoidance with aggressive maneuvering in the descent-to-land phase.

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AACUS is an Office of Naval Research Innovative Naval Prototype (INP) program. The need for AACUS stems primarily from Marine Corps requirements for "an alternate means to provide time-sensitive logistics support to greatly dispersed locations. Cargo UASs can provide a solution to move tailored ammunition, supplies, fuel/water or weapons packages in adverse weather from the sea or ashore over harsh terrain as required (24/7)." *Universal Needs Statement (UNS) for the Cargo UAS*

While vertical takeoff and landing (VTOL) systems have significant advantages over other means of resupply and evacuation, including avoidance of improvised explosive devices and greater speed over trucks, manned VTOL aircraft are often limited by weather, hostile conditions and manning constraints, which are mitigated when using unmanned aerial vehicles.

Recent progress has been made in Cargo Unmanned Aerial System (CUAS) autonomous cargo drops and deliveries; however, such advances rely upon the presence of prepared, obstacle-free landing sites as well as trained CUAS operators with some level of control over flight parameters.

AACUS represents a substantial leap over both present-day operations, as well as other near-term CUAS development programs, as it is focused on autonomous obstacle avoidance and unprepared landing site selection with precision landing capabilities including contingency management until the point of landing. AACUS includes a goal-based supervisory control component such that any field personnel can request and negotiate a desired landing site. Moreover, this system will communicate with ground personnel for seamless and safe loading and unloading.

Another unique aspect of AACUS is its portability–this system will be VTOL platform agnostic with an associated open architecture framework allowing it to be used across different air vehicle platforms.

This INP builds on several previous and current small business technology transfer efforts including:

Research Challenges and Opportunities:

- N10A-T039: Autonomous Landing at Unprepared Sites for a Cargo Unmanned Air System
- N111-070: Scalable Warfighter Interface to Support High-level Interactions with an Autonomous Cargo and Casualty Evacuation Unmanned Air System at Remote, Unprepared Sites
- A07-032: Multi-Agent Based Small Unit Effects Planning and Collaborative Engagement with Unmanned Systems

Science of Autonomy

AT A GLANCE

WHAT IS IT?

Addresses critical multidisciplinary autonomy challenges that cut across different ONR departments and warfighting areas/domains, including air, sea, undersea and ground.

HOW DOES IT WORK?

- Focused on four interrelated areas:
  1. Human Collaboration with Autonomous Systems
  2. Perception and Intelligent Decision-Making
  3. Scalable Distributed Collaboration
  4. Intelligent Architectures
- Develops collaborations between researchers in different autonomous system domains that have traditionally been somewhat separated (air, sea, undersea, ground), control theory, computational intelligence, human factors, biology, economics, cognitive science/psychology and neuroscience

WHAT WILL IT ACCOMPLISH?

Autonomous operations in many naval domains, for many mission types and on multiple platforms that can:

1. Operate as part of a hybrid force with manned systems and platforms
2. Maintain survivability through decentralized assets/redundancy
3. Reduce the need to place personnel and high-value assets in high-threat areas
4. Reduce manning and comms requirements
5. Expand the operational envelope of naval forces, provide force multiplication or replace existing capability with a less expensive alternatives.

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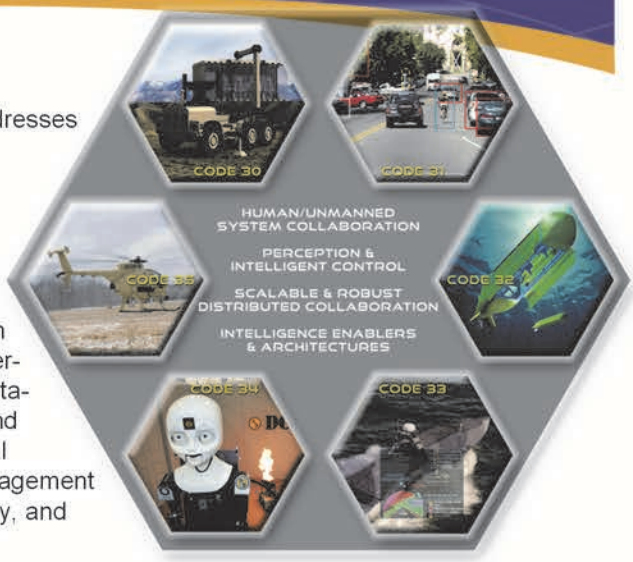
Other ONR participants: Behzad Kamgar-Parsi, Jason Stack, Dan Deitz, Terri Paluszkiewicz, Bob Brizzolara, Tom McKenna, Paul Bello

The Science of Autonomy effort addresses critical multidisciplinary research challenges that cut across different Office of Naval Research (ONR) departments and warfighting areas/domains. This involves different autonomous system domains that have traditionally been somewhat separated (air, sea, undersea, ground), control theory, computational intelligence, human factors and related fields such as biology/animal behavior/cognition, economics/management theory, cognitive science/psychology, and neuroscience.



The research is focused on making progress on a set of autonomy technical challenges that were identified in a series of ONR/Naval Research Laboratory workshops. The challenges are in the four interrelated areas of Human Collaboration with Autonomous Systems, Perception and Intelligent Decision-Making, Scalable Distributed Collaboration and Intelligent Architectures. These challenges need to be addressed relative to critical aspects of the naval domain, including: (1) Operations in spatially and temporally variable and uncertain environments with limiting manning, communications and other resources; (2) users with a wide range of skills and experience including getting unmanned system services to support small tactical units; (3) diverse environments encompassing air, sea surface, undersea and ground systems and hybrid concepts in between; (4) platforms with highly limited and intermittent communications; (5) complex missions with heterogeneous platforms and sensors including significant differences in physical and sensing capabilities; (6) rapid and dynamic responses to user needs and changes in the operating space; and (7) the need for automation to explain its capabilities to the user and reliably execute the required tasks in the required time.

Examples of multidisciplinary research include: (1) a control engineer working with a neuroscientist to develop spatial understanding approaches for autonomous systems that fit human semantic models and could be used to create unmanned aerial vehicle "wingmen" for dismounted Marines; (2) biologists and engineers using models of social interactions in animal groups that allow individuals to access higher-order computational abilities at the collective level and make good decisions despite uncertainty; and (3) biologists, psychologists, and engineers applying behavioral and cognitive models of predator-prey relationships to engineered systems for intelligence, surveillance of reconnaissance of large, complex areas by heterogeneous unmanned systems.

Research Challenges and Opportunities:

- Scalable, self-organizing, survivable, organizational structure/hierarchy of heterogeneous unmanned vehicles appropriate to naval mission domains
- Autonomous learning, reasoning and decision-making in unstructured, dynamic and uncertain environments
- Human interaction/collaboration including understanding intent and actions of human team members, adversaries and bystanders
- Organic perception/understanding to support decision-making, reasoning and actions in a complex, dynamic world

Unmanned Air System Autonomy

AT A GLANCE

WHAT IS IT?

Basic and applied research in autonomous control and collaborative control, with a focus on key challenges of naval air systems and heterogeneous naval teams that include air systems.

HOW DOES IT WORK?

- Safe shipboard and airspace operations integrated with manned aircraft for Naval missions
- Control of large numbers of heterogeneous unmanned systems in complex airspaces
- Sustainable operations in challenging weather and environmental conditions
- New tactical roles for unmanned air systems such as riverine, under the canopy in heavy foliage, casualty evacuation and as a wingman for dismounted marines
- Shared and distributed control to get unmanned air system services to the tactical edge

WHAT WILL IT ACCOMPLISH?

- Control large numbers of unmanned systems that can be deployed in great numbers
- Allow safe and sustainable operations more like manned aircraft on Naval missions and in challenging environments/weather conditions
- Reduce manning for unmanned system operations
- Support a wide range of users including small ships, Marine Corp/SOF small units, maritime patrol aircraft, submarines, etc.
- Increase autonomous system services out to the tactical edge

POINT OF CONTACT:

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Research in intelligent autonomy focuses on technologies for safe, reliable and scalable control of heterogeneous unmanned naval systems based on high-level mission tasking. This includes collaborative and shared use of unmanned systems by a variety of types of operators and users of unmanned system services. An important part of this is to allow unmanned air systems to be operated in a way more compatible to manned aircraft (i.e., without special restrictions or procedures) in naval mission and environments.

Applied research efforts focus on airspace management, ground/shipboard operations, supervisory control of teams of heterogeneous unmanned systems, optimizing shared use of multiple unmanned system resources by multiple requestors collaborating among themselves and with multiple operators, and allowing small unit users to rapidly input mission tasking based on high-level intelligence requirements only.

Key research areas include:

- Safe shipboard and airspace operations integrated with manned aircraft for naval missions. This includes development of an integrated system that supports the human need for "big picture" situational awareness for flight deck control and launch operations, as well as local interaction between unmanned vehicles and deck handlers. It also includes the development of replanning and execution tools for airspace and mission management of a family of unmanned systems.
- New tactical roles for unmanned air systems such as riverine, under the canopy in heavy foliage, casualty evacuation and as a wingman for dismounted marines. This includes basic research in perception-based control in complex environments and applied research to support flying in complex riverine areas under the canopy by utilizing vision-based navigation and path planning and non-GPS landing at unprepared sites in complex environments (weather, obstacles, slopes, terrain, etc.).
- Sustainable operations in challenging weather and environmental conditions including harvesting atmospheric energy and flight in challenging weather.
- Control of large numbers of heterogeneous unmanned systems in complex airspaces including supporting the human operator in managing complex multi-vehicle operations.
- Shared and distributed control to get unmanned air system services to the tactical edge.

Research Challenges and Opportunities:

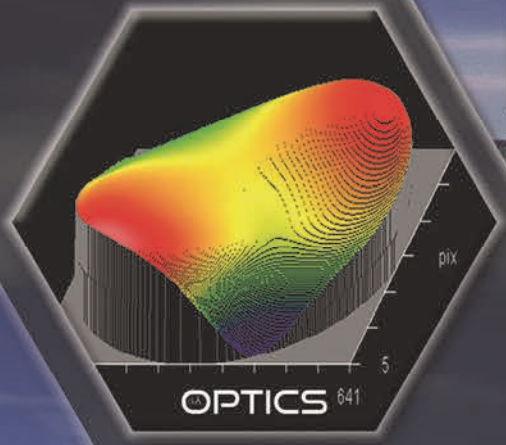
- Biologically inspired, perception-based control for safe operation around complex, unknown and unstructured terrain and humans
- Adaptive and robust multi-unmanned vehicle collaboration approaches for operations over complex areas and in-time critical applications
- Human interaction and collaboration approaches for managing large numbers of unmanned vehicles
- Analytic tools for analysis/verification and validation that allow for prediction of complex autonomy approaches under realistic assumptions

QUANTICO, Virginia (Feb. 25, 2014) An MH-6 Little Bird helicopter equipped with the Autonomous Aerial Cargo/Utility System (AACUS) technology lifts off during an Office of Naval Research demonstration held at Marine Corps Base Quantico. AACUS consists of a sensor and software package that when integrated into rotary-wing aircraft enables autonomous, unmanned flight, allowing the Marine Corps to rapidly resupply forces on the front lines as an alternative to dangerous convoys, manned aircraft or air drops in all weather conditions. (U.S. Navy photo by John F. Williams/Released)

RESEARCH

BEAM CONTROL

ATMOSPHERIC PROPAGATION



OPTICS

"Advances in high- and low-energy lasers and high-power radio frequency technologies enable a new class of weapons – directed energy weapons (DEWs) – that could be highly effective in the future battlespace. We will capitalize on these advances by providing our Sailors and Marines robust DEWs and countermeasures to complement our legacy and future kinetic and electronic warfare weapon systems, thereby dramatically improving the effectiveness of our naval forces against a diverse range of 21st Century threats."

– A Directed Energy Vision for U.S. Naval Forces

APPLICATION

COUNTER DIRECTED ENERGY

AVIATION PLATFORMS

SHIP DEFENSE

DIRECTED ENERGY

DEMONSTRATION

San Diego (Aug. 4, 2012) The Laser Weapon System (LaWS) striking a remote-controlled target aircraft, right. The LaWS technology demonstrator is built by ONR and Naval Sea Systems Command from commercial fiber solid state lasers, utilizing combination methods developed at the Naval Research Laboratory. The Office of Naval Research's SSL portfolio includes LaWS development and upgrades providing a quick-reaction capability for the fleet with an affordable SSL weapon prototype. This capability provides Navy ships a method for Sailors to easily defeat small boat threats and aerial targets without using bullets and was deployed on the USS *Ponce* in 2014. (U.S. Navy photo/Released)

Code 35

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Counter-Directed Energy Weapons (CDEW)

AT A GLANCE

WHAT IS IT?

ONR's CDEW Program explores innovative research and solutions aimed at delivering a new means for adapting to, defending against and negating the effects of hostile high-energy lasers (HEL), high-power radio frequency (HPRF) and other directed energy weapons in the maritime domain.

HOW DOES IT WORK?

- Lasers and radio frequency weapons transmit energy through the electromagnetic spectrum. Laser irradiation deposits energy onto a target, causing it to heat up, melt or burn. Radio frequency illumination can cause electronic circuit disruptions or failures.
- Investigate methods to detect laser and radio frequency energy in order to dissipate, defocus or reflect the energy, resulting in reduced damage to the target.
- The end goal is to mitigate or neutralize the damaging effects of directed energy weapon systems used against U.S. naval forces.

WHAT WILL IT ACCOMPLISH?

The CDEW Program will investigate the fundamental intersection between directed energy, materials, optics and physics through both basic and applied research.

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The C-DEW Program was initiated in response to the rapid development of high-energy laser (HEL) and high-power radio frequency (HPRF) threats. Directed-energy weapons (DEWs), for the purposes here, are considered to be from sources that utilize means other than kinetic energy to deliver energy to damage or disable a target. The advancement in the technologies of DEWs, in particular HELs and HPRF, and their proliferation in many nations, has raised the urgency of developing techniques and technology for defense of United States naval assets.

The Office of Naval Research is pursuing basic and applied research with potential airborne, surface and ground applications that would provide operational effectiveness against various known and projected DEW systems. In the coming years, efforts will continue to broaden the scope of CDEW research topics and understanding. The basic research tenet of CDEW strives to understand how energy transmission and conversion inefficiencies can be exploited as a countering technique. This is accomplished through a combined emphasis on advanced instrumentation, modeling and simulation as well as experimentation within a threat-driven domain.

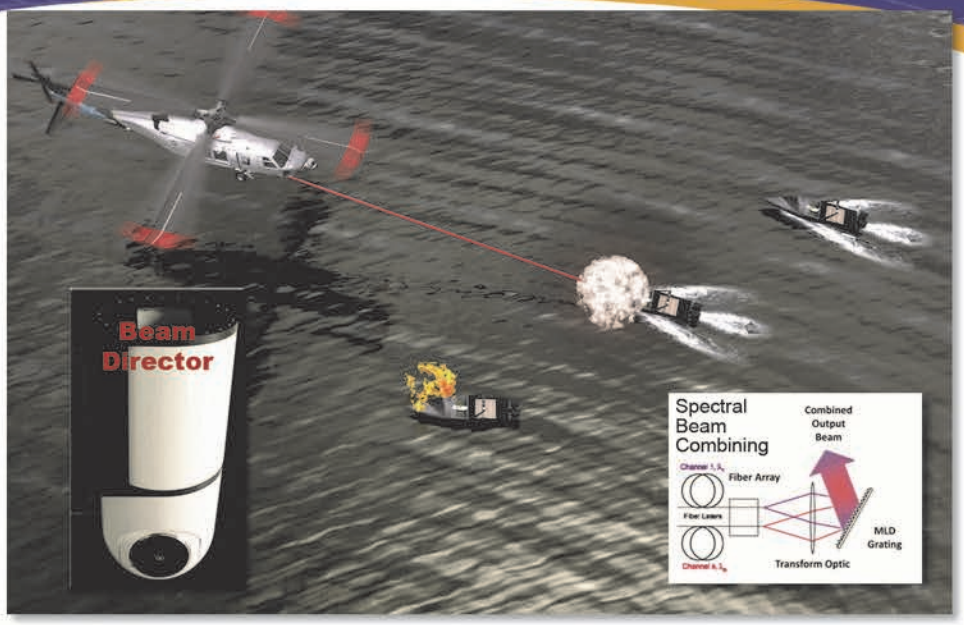
Efforts have begun to examine innovative technologies, techniques and tactics. This research examines both material and nonmaterial solutions and their implications when related to the nullification of various directed energy weapon systems. Current studies include the modeling of effects and experimentation on materials and systems, as well as total systems integration with existing naval platforms.

Some aspects of the CDEW research have potential civilian applications, such as laser eye protection, laser beam detection and electromagnetic interference (EMI) hardening.

Research Challenges and Opportunities:

- Increased survival from HEL attack—HEL protection
- Counter-HEL—detection of threat lasers—laser source geo-location
- Increased survival from HPRF attack—HPRF Protection
- Counter HPRF—novel methods to detect/characterize HPRF attack

High Energy Fiber Laser System (HEFL)



AT A GLANCE

WHAT IS IT?

A prototype High-Energy Laser Weapon System (HELWS) consisting of five subsystems: (1) spectral beam combining (SBC) fiber laser; (2) beam director; (3) thermal management; (4) energy storage and power distribution; and (5) integrating structure

HOW DOES IT WORK?

The high-power laser beam is created by combing many low-power fiber lasers using an SBC grating. It then passes through the beam director, which optimizes the beam shape and uses gimbaled optics to track and hold the beam on target. Laser light is absorbed by the target, damaging it by rapid heating and ablation of material.

WHAT WILL IT ACCOMPLISH?

Provide a flight-worthy, state-of-the-art HELWS prototype with the size, weight and power scaled to support an airborne demonstration. Target damage depends on the laser power, beam director aperture, beam quality, target range and laser dwell time on the target.

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The HEFL demonstrator is working to advance subsystem-level technologies for directed-energy weapons that will complement existing kinetic weapons. The concept of employment for a High-Energy Laser Weapon System (HELWS) operating from an airborne platform includes an offensive capability in target-rich environments (e.g., barrage, swarm and stream raids) and a self-protect capability (e.g., hard-kill of man-portable air defense systems and similar threats). The concept also increases mission kills per sortie (at a relatively low cost by using aviation fuel converted to high-energy laser power) against low-end asymmetric threats and frees the limited load-out of advanced kinetic weapons to strike high-end threats.

HEFL's scalable, modular approach to an airborne laser weapon demonstration is an outgrowth of the Navy's Small Business Innovative Research projects in lasers, beam control, thermal management and prime power. The laser architecture—spectral beam combining—is inherently scalable by varying the number of lower-power laser modules combined to form a single high-power laser beam. The beam director design collects, shapes and directs the laser to the selected aimpoint while compensating for the target/platform motion and atmospheric conditions. The thermal management design consists of a water/glycol-based system that will maintain the laser's 55° C operating temperature.

In 2015, the Navy will receive the SBC laser, beam director, thermal management and parts of the energy storage and power distribution subsystems. The subsystems will be installed in the high-energy weapon facility for further testing, integration and evaluation.

Research Challenges and Opportunities:

- Ruggedized, high-temperature, fiber-laser modules and SBC grating
- Lightweight, rechargeable, high-energy storage that meets flight safety criteria
- Adaptive optics to reduce power loss due to atmospheric transmission
- Low-cost, flight-worthy integrating structure

Solid State Laser Technology Maturation Program (SSL-TM)

AT A GLANCE

WHAT IS IT?

Initiated in 2012, the ONR SSL-TM Program will develop and mature high-energy laser technologies into a prototypical weapon system for use and installation on the Navy's surface combatants.

HOW DOES IT WORK?

- LASER means "**L**ight **A**mplification by **S**timulated **E**mission of **R**adiation." SSLs utilize specific solid chemicals that, when combined with a light source (often LEDs), amplify and focus light at long range.
- For a laser weapon system, the resulting light and heat transmitted to a target causes the failure of structures. SSLs are typically categorized into one of two classes—slab-type or fiber-type.
- Slab lasers use centimeter-sized prismatic or rectangular geometries, whereas fiber lasers are thin rods about the diameter of a human hair and many meters long.
- In either type, an SSL weapon utilizes a ship's electricity to power the laser, and then the resulting light is directed by mirrors through an external, aimable beam director, where a complex optic system focuses the laser light onto targets.

WHAT WILL IT ACCOMPLISH?

- The SSL-TM Program's goal is to produce a prototypical weapon system for use on surface Navy combatants. Lasers have the capability for speed-of-light engagements, with very precise, real-time targeting and battle-damage assessments.
- Lasers can provide measured weapon effects, matched with extremely deep magazine capacities to defend against multiple, simultaneous arriving threats potentially posed against Naval surface forces: armed, unarmed intelligence, surveillance and reconnaissance or lethal unmanned aerial vehicles; light aircraft; small boats; asymmetric surface targets; or small diameter rockets and missiles.
- The prototypes will examine the utility for precision discrimination of targets, and enhancement in aiming of existing guns and missiles.

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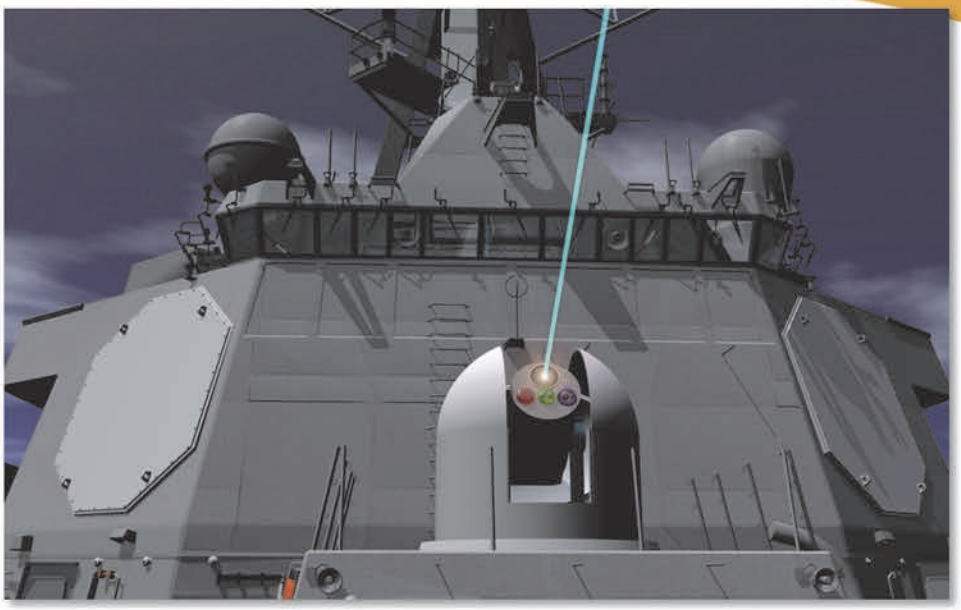


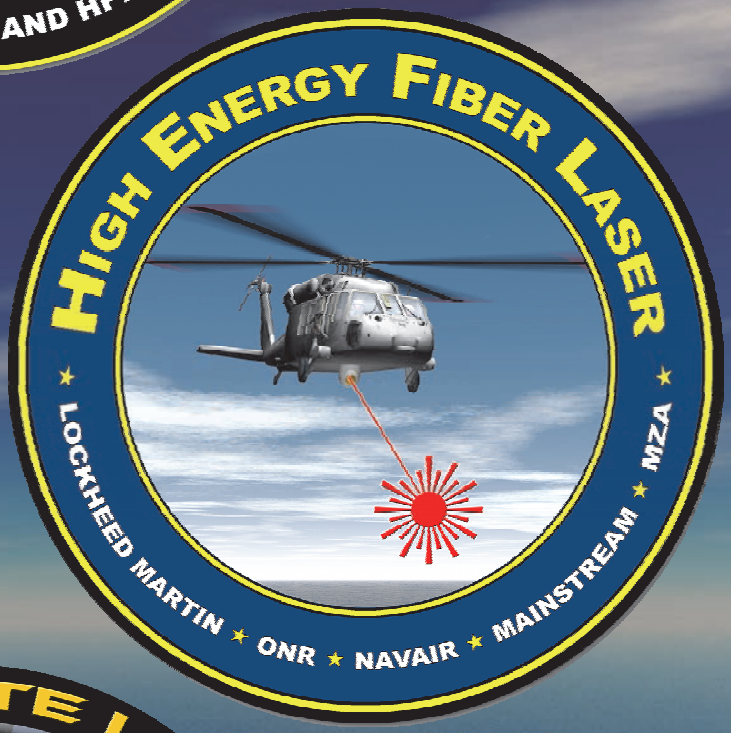
The Department of Defense (DoD) began funding research in high-energy lasers soon after the invention of the laser in 1960, when it was thought that they might (if scalable to high power) have tremendous impact on how wars were fought. In 1973, a new chemical laser technology, based on deuterium fluoride (DF), was determined to be scalable to high power at mid-infrared wavelengths which propagate far better in the atmosphere than other frequencies. The Navy and the Advanced Research Projects Agency then jointly built a multi-hundred kilowatt-class laser, from which the Navy leveraged this technology to produce the nation's first megawatt-class high-energy laser weapon test bed. The Mid-InfraRed Advanced Chemical Laser and the SeaLite Beam Director were installed and integrated at White Sands Missile Range in the mid-1980s and used for experiments by DoD. While performance of these MW-class lasers was highly promising with many targets successfully engaged, the logistics and safety issues of hazardous chemicals in a shipboard environment severely hampered further development or implementation on the Navy's surface combatants.

Solid State Laser (SSL) technology with weapons-level effects has been maturing rapidly, and recent advancements by the scientific and commercial sectors have begun to show that a potential application on surface combatants is possible. In particular, the ONR Maritime Laser Demonstration (MLD) for the first time in 2011 took a laser to sea and successfully conducted a mission scenario against a representative threat small boat, while underway. Further, support for a continuation of competitive programs like LaWS (Laser Weapon System - NSWC Dahlgren), the MLD (Northrop Grumman) and MK 38 TLS (Tactical Laser System, Boeing/BAE) continues to garner interest and generate discussion. The start of the SSL-TM Program has been strongly encouraged by Navy leadership to enhance expertise and develop programmatic focus. A key goal of SSL-TM is to align the science and technology program thresholds and objectives with future research and development/acquisition planning processes and requirements, meeting current budgetary constraints. The goal of the SSL-TM Program is to produce multiple demonstration-level events with prototypical quality systems in a competitive environment.

Research Challenges and Opportunities:

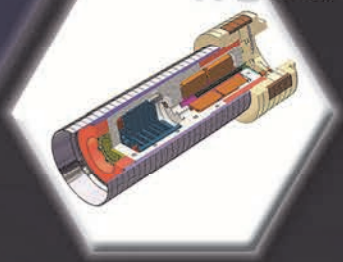
- Atmospheric propagation of high-energy laser in a maritime environment
- Ruggedized, high-energy, density-tolerant, optical path components
- Compact, high-efficiency laser generation technology

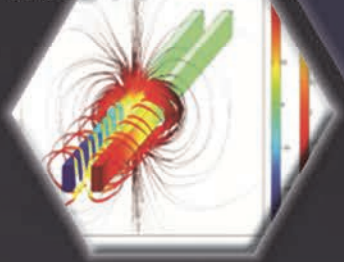
COUNTER-DIRECTED ENERGY WEAPONS
PROTECTION AGAINST HEL AND HPM TECHNOLOGY


HIGH ENERGY FIBER LASER
LOCKHEED MARTIN ★ ONR ★ NAVAIR ★ MAINSTREAM ★ MZA

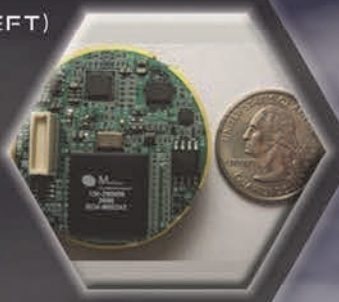
SOLID STATE LASER
DETER • DISRUPT • DAMAGE • DISABLE • DESTROY

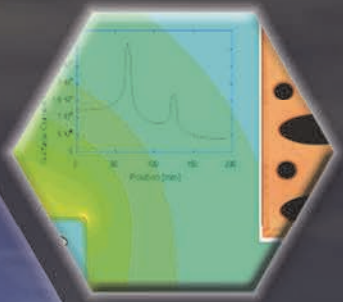
RESEARCH





(CLOCKWISE FROM UPPER-LEFT)
HIGH-G ELECTRONICS
MODELING & SIMULATION
PACKAGING
PULSED POWER
THERMAL & COOLING
ADVANCED MATERIALS





The Electromagnetic Railgun is a long-range, high-energy system that uses electricity rather than gun powder or rocket motors to allow hypervelocity launch of projectiles. Railgun projectiles are able to strike at greater than 110 nautical miles in approximately four minutes with potential for multi-mission applications.

APPLICATION

SHIP DEFENSE

ANTI-SURFACE WARFARE

NAVAL SURFACE FIRE SUPPORT

ELECTROMAGNETIC & HYPERSONIC WEAPONS

DEMONSTRATION

WASHINGTON (March 13, 2014) An artist rendering shows the Office of Naval Research-funded electromagnetic railgun installed aboard the joint high-speed vessel USNS *Millinocket* (JHSV 3). The railgun is a long-range weapon that launches projectiles using electricity instead of chemical propellants and is currently undergoing testing at Naval Sea Systems Command, Dahlgren Division. (U.S. Navy photo illustration/Released)

Code 35

Office of Naval Research
ONR
Science & Technology

Electromagnetic Railgun

AT A GLANCE

WHAT IS IT?

The EM Railgun launcher is a long-range weapon that fires projectiles using electricity instead of chemical propellants. Magnetic fields created by high electrical currents accelerate a sliding metal conductor, or armature, between two rails to launch projectiles at 4,500 mph.

HOW DOES IT WORK?

- Electricity generated by the ship is stored over several seconds in the pulsed power system.
- Next, an electric pulse is sent to the railgun, creating an electromagnetic force accelerating the projectile up to Mach 6.
- Using its extreme speed on impact, the kinetic energy warhead eliminates the hazards of high explosives in the ship and unexploded ordnance on the battlefield.

WHAT WILL IT ACCOMPLISH?

- With its increased velocity and extended range, the EM Railgun will give Sailors a multi-mission capability, allowing them to conduct precise naval surface fire support or land strikes; ship defense; and surface warfare to deter enemy vessels.
- Navy planners are targeting a 100+ nautical mile initial capability.
- A variety of new and existing naval platforms are being studied for integration of a future tactical railgun system.

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The Department of the Navy's science and technology corporate board chartered the Innovative Naval Prototype (INP) construct to foster game-changing and disruptive technologies ahead of the normal requirements process.

The Electromagnetic Railgun INP was initiated in 2005. The goal during Phase I, a proof-of-concept demonstration at 32 mega-joule muzzle energy, has been achieved. A future weapon system at this energy level would be capable of launching a 100+ nautical mile projectile. This launch energy has the advantage of being able to stress many components to evaluate full-scale mechanical and electromagnetic forces.

Phase I was focused on the development of launcher technology with adequate service life, development of reliable pulsed power technology and component risk reduction for the projectile.

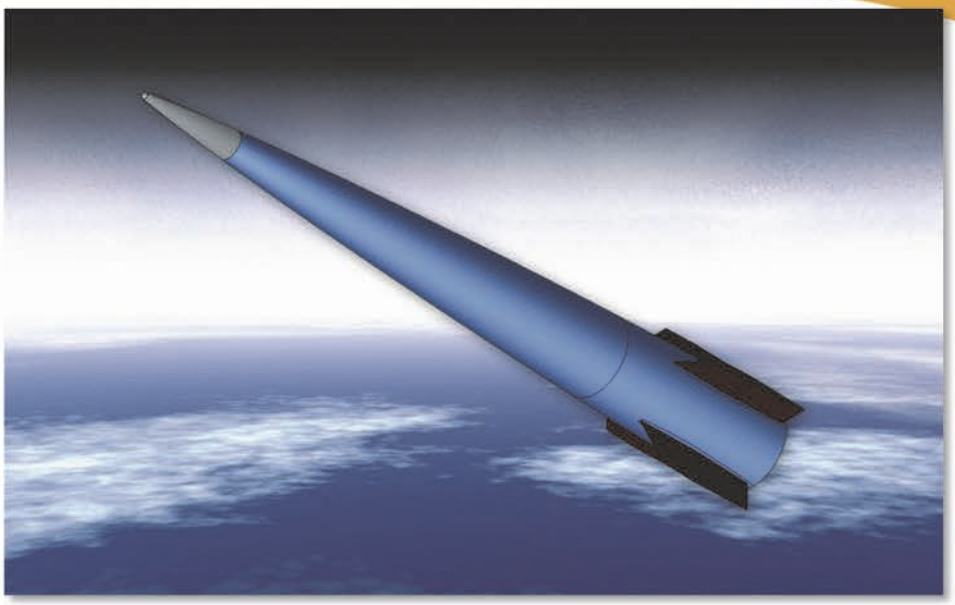
Phase II, which started in 2012, will advance the technology for transition to an acquisition program. Phase II technology efforts will concentrate on demonstrating a rep-rate fire capability. Thermal management techniques required for sustained firing rates will be developed for both the launcher system and the pulsed power system.

The railgun is a true warfighter game changer. Wide-area coverage, exceptionally quick response and very deep magazines will extend the reach and lethality of ships armed with this technology.

Research Challenges and Opportunities:

- Advanced thermal management techniques for long slender metal rail structures
- Extended service life for materials and components in harsh environment
- High-strength, dielectric, structural materials
- High-speed, high-current metal-on-metal sliding electrical contact
- System interfaces between high-power loads and platform power distribution
- Compact pulsed power systems and power electronics
- High-conductivity, high-strength, low-density conductors
- Repetitive rate switches and control technologies
- Aerothermal protection systems for flight vehicles
- High-acceleration tolerant electronic components and structural materials

Hyper Velocity Projectile (HVP)



AT A GLANCE

WHAT IS IT?

The HVP is a next-generation, common, low-drag, guided projectile capable of completing multiple missions from different gun systems.

HOW DOES IT WORK?

The HVP is configurable for various mission roles and gun systems through the use of multiple Integrated Launch Package (ILP) components coupled with a modular, common airframe.

WHAT WILL IT ACCOMPLISH?

With its increased velocity, precision and extended range, the HVP will provide the Navy with the capability to address a variety of current and future threats in the mission areas of naval surface fire support, ship defense and anti-surface warfare using current and future gun systems.

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The Hyper Velocity Projectile (HVP) is a next-generation, common, low-drag, guided projectile capable of completing multiple missions from various gun systems such as the Navy 5-inch, 155-mm and future railguns. Types of missions performed will depend on gun system and platform. The program goal is to address mission requirements in the areas of naval surface fire support, cruise missile defense, anti-surface warfare and other future naval mission areas. Mission performance will vary depending upon gun system, launcher or ship. HVP's low-drag, aerodynamic design enables high velocity, maneuverability and decreased time-to-target. These attributes, coupled with accurate guidance electronics, provide low-cost mission effectiveness against current threats and the ability to adapt to air and surface threats of the future.

The high-velocity, compact design relieves the need for a rocket motor to extend gun range. Firing smaller, more accurate rounds improves danger-close/collateral damage requirements and provides potential for deeper magazines and improved shipboard safety. Responsive wide-area coverage can be achieved using an HVP from both conventional gun systems and future railgun systems.

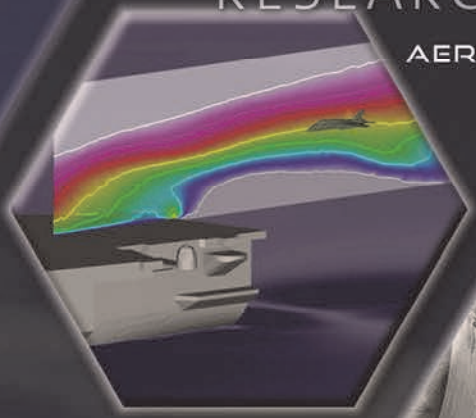
The modular design will allow an HVP to be configured for multiple gun systems and to address different missions. The HVP is being designed to provide lethality and performance enhancements to current and future gun systems. An HVP for multiple systems will allow for future technology growth while reducing development, production and total ownership costs.

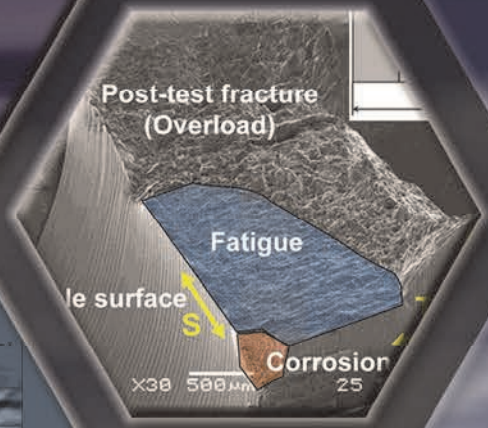
Research Challenges and Opportunities:

- High acceleration-tolerant electronic components
- Lightweight, high-strength structural composites
- Miniature, high-density electronic components
- Safe, high-energy propellants compatible with shipboard operations
- Aerothermal protection systems for flight vehicles

RESEARCH

AERODYNAMICS





MATERIALS

JET NOISE

The maritime environment is both unique and complex, and naval operations are inherently dangerous under even the most benign of circumstances. As a result, the Navy places great emphasis on maintaining vigorous S&T investments in research areas critically important to maintaining superiority of Naval aviation. Sea-based aviation addresses science and technology in multiple disciplines including aeromechanics, guidance navigation and control, structures, materials, jet noise reduction and propulsion.

APPLICATION

(CLOCKWISE FROM UPPER-LEFT)
AERODYNAMICS
FLIGHT CONTROL
STRUCTURES
MATERIALS
JET NOISE REDUCTION
PROPULSION

SEA-BASED AVIATION

DEMONSTRATION

IWO TO, Japan (May 14, 2013) An F/A-18E Super Hornet from the Dambusters of Strike Fighter Squadron (VFA) 195 assigned to Carrier Air Wing (CVW) 5 practices a touch-and-go landing during field carrier landing practice (FCLP) at Iwo To, Japan. Magic Carpet, or Maritime Augmented Guidance with Integrated Controls for Carrier Approach and Recovery Precision Enabling Technologies, could sharply reduce the number of FCLPs needed to keep pilots qualified for carrier ops. (U.S. Navy photo courtesy of Mass Communication Specialist Trevor Walsh)

Code 35

Office of Naval Research
ONR
Science & Technology

Sea-Based Aviation National Naval Responsibility (SBA NNR)

AT A GLANCE

WHAT IS IT?

- Many research areas—uniquely important to the Department of the Navy—are not addressed by research investments from the other military services.
- The Office of Naval Research (ONR) must ensure continuing U.S. leadership in these vitally important scientific and technical disciplines.

HOW DOES IT WORK?

ONR identifies certain technical areas as National Naval Responsibilities (NNR). ONR looks at various scientific fields and assesses:

- The scope of naval responsibility
- Funding and funding trends
- The scope, degree, stability and trend of non-naval funding
- The scientific and technological performer base in academia, government and industry
- The scientific and technological infrastructure
- The scientific and technological knowledge base, including graduate and post-doctoral programs
- The prospects of integration with and transition to engineering development and acquisition programs.

WHAT WILL IT ACCOMPLISH?

- Above all, SBA NNR seeks to keep the fields healthy by giving them stability.
- It keeps key areas of basic and applied research strong, and it balances theoretical, empirical and field work to sustain a research infrastructure.

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The Office of Naval Research established Sea-Based Aviation SBA NNR in 2011. NNRs are established to maintain the health, currency and technical superiority of areas critical to naval operations. In addition, the focused investments in these areas ensure a pipeline of students trained in areas of naval importance.

SBA includes the operation of aircraft to, from and on sea-based platforms.

The technical challenges of SBA have been broadly categorized under the following areas:

- Structures and materials
- Propulsion
- Propulsion integration
- Ship interfaces and operations
- Avionics/electronics
- Air refueling
- Aerodynamics
- Guidance, navigation and control (GNC)
- Design tools
- Unmanned aerial vehicle launch and recovery; autonomy, high-tempo operations

The maritime role of the naval aircraft is complex, demanding and unique. Operation aboard a ship has a dominant influence on the design of the aircraft. The dynamic interface between aircraft and ship requires a high degree of precision maneuvering to land on the moving ship deck in adverse weather and wind. The materials must resist a highly corrosive environment. The structure and configuration must be large enough to perform the mission and then have the ability to fold into a small footprint to be stored into small hangars, leaving enough room for critical maintenance. The air vehicle must be multi-mission capable for a diverse set of tasks.

Research Challenges and Opportunities:

- Air vehicle technology
- Airframe structures and materials
- Propulsion

Sea-Based Aviation National Naval Responsibility Structures and Materials

AT A GLANCE

WHAT IS IT?

Design, materials selection, fabrication, inspection and maintenance related to air-vehicle structures. Airframe Structures and Materials Science and Technology addresses durability, structural life, sustainment, ready-for-tasking effectiveness and affordability. Most airframe technology challenges are not platform or design specific; they are fully represented in both current new-build and planned next-generation platform designs.

HOW DOES IT WORK?

Core investments include basic and applied research funding, with proposals developed for Future Naval Capabilities and other advanced technology development options. Work is supported by naval aviation experts at the Naval Air Systems Command, Naval Air Warfare Center laboratories and the Naval Research Laboratory. Close coordination with the Air Force Research Laboratory, the Army Aviation Command and the Defense Advanced Research Projects Agency helps ensure that, in addition to Navy and Marine Corps unique technology needs, the investments of other services and agencies are leveraged and integrated.

WHAT WILL IT ACCOMPLISH?

Advanced airframe technology will address the following needs and environments of Navy and Marine Corps aviation in:

- Understanding and predicting the impact of material property degradation
- Developing advanced shipboard inspection, maintenance and repair methods
- Airframe structural life prognosis and sustainment
- Integrated materials selection and design analysis
- High-mechanical loads and lightweight structural requirements for shipboard launch and recovery.

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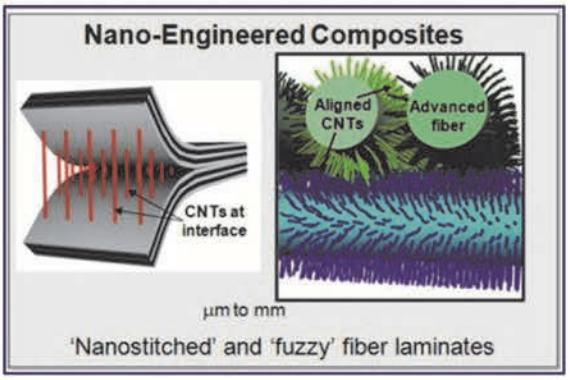
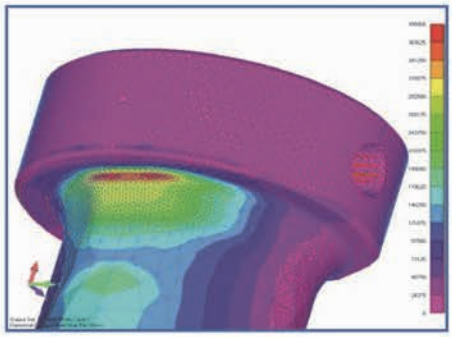
High-Loading, Lightweight Structural Materials



Structural Failure Modes



Naval aviation is in the forefront of the Navy power projection mission. Sea-Based Aviation poses structural and material challenges that are substantially different from land-based aviation requirements. A robust program that sustains a focused aircraft S&T activity underpinning research, design, production and sustainment is critical to the health of naval aviation.

Under the ONR Sea-Based Aviation National Naval Responsibility, the Structures and Materials program will enable more robust aircraft design; reduce maintenance and sustainment impacts due to design decisions driven by weight or environmental factors; improve the fidelity of materials selection impact analysis and tradeoff decisions; and enable reduced weight without reducing durability. The Structures and Materials program covers technical areas such as multi-material risk and reliability, integrated structural and material degradation design analysis, remaining life prediction, multi-scale fatigue and fracture prediction, optimized airframe materials selection, multi-functional materials research, advanced structural concepts and modeling complex load and degradation interactions.

Basic and applied research programs are being conducted in the areas of advanced concepts, durable aircraft development, structural analytics and prognosis, advanced material design, composites and composite repair and material coatings.

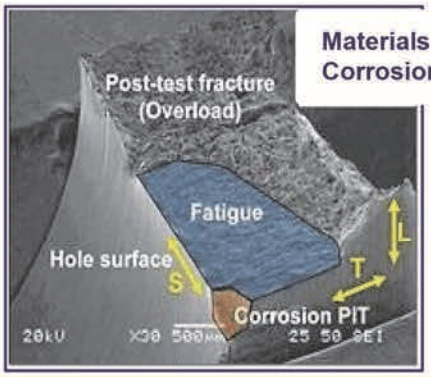
Research Challenges and Opportunities:

- Structural failure mode characterization
- High-loading, lightweight structural materials
- Advanced structural concepts
- Materials degradation/corrosion
- Structural protection and maintenance

Structural Protection/Maintenance

Advanced Structural Concepts

Materials Degradation/ Corrosion



Naval Air Warfare

Autonomous Systems • Directed Energy • Electromagnetic

and Weapons (Code 35)

c & Hypersonic Weapons • Sea-Based Aviation • Sea Strike

Sea-Based Aviation National Naval Responsibility – Air Vehicle Technology

AT A GLANCE

WHAT IS IT?

Aircraft technology includes fixed-wing, rotary wing, and vertical/short takeoff and landing (V/STOL) vehicle technologies; ship/aircraft dynamic interface; air vehicle management and control; aerodynamics; aeromechanics; subsystems; and modeling, simulation and analysis tools.

HOW DOES IT WORK?

Core investments include:

- Advanced, efficient computational fluid dynamics techniques for modeling aerodynamics problems of naval importance such as ship superstructure airwake, coupled ship/aircraft aerodynamics and aircraft maneuvering in ship airwakes
- Wind tunnel and in-situ testing of ships in support of ship/aircraft dynamic interface studies
- Technology development, computational modeling and wind tunnel test of advanced V/STOL concepts
- Analytical and experimental investigations of rotorcraft handling qualities, including identification of favorable vehicle response types for operation in turbulent ship airwakes and control systems for carefree, near-ship maneuvering

WHAT WILL IT ACCOMPLISH?

Air vehicle technology will contribute to Navy and Marine Corps aircraft with enhanced performance, maneuverability, and survivability; reduced operating and support cost; and suited to the particular needs and environments of Navy and Marine Corps missions.

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The Navy and Marine Corps rely on fixed-wing, rotary-wing and vertical/short takeoff and landing (V/STOL) aircraft to perform and support a wide variety of missions, such as close air support, air defense, logistics, expeditionary operations, anti-submarine and anti-mine warfare, and search and rescue. The unique requirement to operate from ships at night and in bad weather and high sea states leads to a number of S&T challenges. Shipboard landings require precise relative navigation and ability to maneuver in highly turbulent ship airwakes and to land on pitching and rolling decks in high sea states. Shipboard operations also require unique designs to accommodate limited space and safe operations and support in densely packed areas. The Marine Corps depends on fast, agile air vehicles to execute its Ship-to-Objective Maneuver and distributed operations. These challenges require focused core investments, as well as close coordination and integration with other services and agencies that have substantial investments in air vehicle technologies.

The Air Vehicle Discovery and Invention (D&I) program invests in basic and applied research in both fixed- and rotary wing vehicles. Emphasis is placed on naval-relevant issues requiring focused Navy investment. An ongoing program in ship airwake prediction has yielded advanced methods and in-house naval expertise and has greatly enhanced the fidelity of piloted simulations of shipboard landings. Continued D&I focus in this area targets high-fidelity, fully-coupled ship/aircraft airwake models operating in real-time for implementation in piloted simulations and ship and aircraft design studies. Another research topic area considers rotorcraft aeromechanics, with projects currently in multicyclic blade control for vibration reduction, hub drag prediction, and flow control. For fiscal year 2014-15, focus has shifted toward research task areas identified under the recently designated Sea-Based Aviation National Naval Responsibility.

Research Challenges and Opportunities:

- Computationally efficient analytical tools for ship/aircraft dynamic interface simulation
- Advanced control systems for carefree shipboard landings in challenging operating conditions
- Automated shipboard landings and deck operations
- Efficient, high-speed V/STOL concepts for sea-based operations
- Flow control for improved air vehicle aerodynamics
- Innovative experimental methods for ship airwake measurement

Sea-Based Aviation National Naval Responsibility – Propulsion

AT A GLANCE

WHAT IS IT?

The Sea-based Aviation National Naval Responsibility (SBA NNR) Propulsion focus area is a long-term basic and applied research initiative having an objective to maintain the health, currency and technical superiority of Sea-Based Aviation science and technology (S&T) in propulsion-related technology areas.

HOW DOES IT WORK?

With academia, industry and naval aviation laboratories as its source of expertise, the SBA NNR Propulsion focus area will solicit the most innovative and technically sound research topics to fulfill its objective, then develop them through basic and applied research efforts leading to future S&T transitions for naval aviation.

WHAT WILL IT ACCOMPLISH?

The SBA NNR Propulsion focus area will provide the advanced propulsion, power and thermal management technologies supporting future naval aviation needs. In addition, it will support the technology infrastructure necessary to maintain technology superiority while serving as a pipeline of future scientists and engineers.

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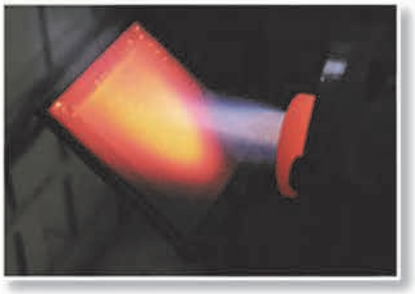
The Office of Naval Research established the Sea-Based Aviation National Naval Responsibility (SBA NNR) research initiative in April 2011 to maintain the health, currency and technical superiority of Sea-Based Aviation science and technology. Three focus areas of the SBA NNR have been identified—aircraft research, structures and propulsion—which address important challenges facing naval aviation and provide opportunities for basic and applied research efforts to address them.

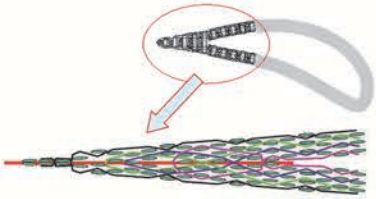
Propulsion systems touch on every aspect of air vehicle operations and are the primary source of vehicle performance capability. On the other hand, turbine propulsion systems typically are the primary fleet readiness driver and are the largest cost driver in operational systems, since they require extensive development and maintenance/support. With the large effect on performance, readiness and cost comes the greatest opportunity for improvements due to advanced technology.

The Propulsion focus area of the SBA NNR will provide innovative research and technology in five sub-areas of propulsion cycles, subsystems and integration; turbomachinery and drive systems with enhanced maintainability; jet-noise reduction; hot-section materials and coatings; and small unmanned aerial vehicle propulsion. Along with the other focus areas under the SBA NNR, the Propulsion focus area will support the infrastructure necessary to maintain superiority while serving as a pipeline of future scientists and engineers.

Research Challenges and Opportunities:

- Innovative fundamental and subsystem technologies for increasing power and thermal management capability
- Advanced thermodynamic cycles beyond the Brayton cycle–principles, tools and feasibility studies
- Jet noise analytical tools–source models, measurements, predictions, reductions
- Multi-stream noise reduction database and component technology maturation
- Active jet noise control components/testing to achieve beyond -10 decibels reduction
- Durable thermal/environmental barrier coatings for harsh environments
- Ceramic matrix composites for naval-unique operating conditions, materials/manufacturing/joining
- Turbine rotordynamics modeling tools capturing transient/complex loading
- Diagnostics for bearing/lubrication system degradation detection
- Diagnostics- and logic-based tools for "virtual inspection" capability
- Pressure augmentation approaches for increased specific power
- Enhanced integration technologies for carrier suitability
- Repair technologies for foreign object damage-susceptible components
- Small unmanned air system propulsion weight reduction





Complex-Shaped Woven 3-D CMC Structure

Advanced Topcoat System (ATS)

AT A GLANCE

WHAT IS IT?

A primer/topcoat system that provides reduced toxicity to enable shipboard maintenance of aviation and amphibious platforms with high-performance structural protection

HOW DOES IT WORK?

- New topcoat resin chemistry to address maintenance operation restrictions associated with toxic isocyanate materials
- Novel metal-rich primers for improved protection of dissimilar material interfaces; weight reduction versus current zinc-rich pigments

WHAT WILL IT ACCOMPLISH?

Enhanced corrosion protection

- 25 percent reduction in corrosion and coating maintenance costs for naval aviation
- 35 percent reduction in maintenance cost for Marine Corps ground vehicles

Provide improved functional performance and reduced toxicity

- Reduce health and environmental issues by elimination of toxic isocyanates
- Increase exterior color stability, gloss retention, flexibility and erosion resistance for aviation vehicles
- Increase retention of chemical warfare agent resistance, and mar/impact resistance for ground vehicles
- Reduce flammability by increasing flash point to 140°F; volatile organic compounds to 100 g/L

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The ATS Future Naval Capability product is developing protective coating systems with substantially improved corrosion inhibition and reduced environmental, safety and health (ESOH) impacts for Navy and Marine Corps aviation weapon systems and Marine Corps ground and amphibious weapon systems. To achieve this, the ATS program is developing and integrating two technologies: a state-of-the-art topcoat system for aviation (AV) and ground and amphibious vehicles (GV). Performance advancements are focused on increased corrosion performance and optimizing coating deposition, adhesion and chemical agent resistance (GV).

The ATS products are responding to higher performance corrosion requirements with reduced ESOH impact as expressed by the fleet. In addition to substantially reducing the impact of corrosion, the ATS products will reduce the use of volatile organic compounds (VOCs) and hazardous air pollutants (HAPs), as well as reduce flammability. All of these improvements will improve the quality of the workplace for maintenance personnel.

By improving coating system performance, ATS will ensure that the Navy and Marine Corps reduce the impact of maintenance activities worldwide while employing state-of-the-art protection schemes, which enhance survivability over extended maintenance intervals. The ATS products enable increased Sailor/Marine operational health and safety and eliminate restrictions on corrosion prevention and control maintenance that leads to additional costs and reduced readiness; improved durability and survivability delivers increased A_0.

Key Technologies:

Non-isocyanate topcoats, with chemical-agent-resistant coating option for the Marine Corps; lower VOCs, HAPs and flammability (AV and GV)—to address ship-board maintenance capability gap

Aluminum-rich primer with capability for use on aluminum and steel; lower VOCs, HAPs and flammability; larger range of applied thickness (AV and GV)—to address improved galvanic corrosion protection gap

Research Challenges and Opportunities:

- Topcoat – novel, isocyanate-free polymers/catalysts
- Single- (1K) and two-component (2K) formulations
- Primer—novel galvanic protection pigments/inhibitors

Aircraft Structural Parts via Direct Digital Manufacturing (DDM)

AT A GLANCE

WHAT IS IT?

Innovative research programs that provide the technologies to rapidly manufacture one-off or low-volume aircraft structural metallic components from alloy powders using high-energy DDM technology

HOW DOES IT WORK?

The DDM structure-property-processing relationships are complex and not well understood. During DDM processing, layers are melted, solidified and re-melted repeatedly as the part is fabricated; there are repeated solid state transformations (e.g., $\beta \rightarrow \alpha + \beta$, $\alpha + \beta \rightarrow \beta$).
This effort will look to develop:

- Physics-based processing algorithms for defect (micro-porosity, surface quality, etc.) control; dimensionless quantities controlling defects/quality must be linked to process controls
- Technologies required for intelligent process, sensing and control system to ensure consistent part micro-structure and porosity
- A heuristic accelerated certification technology moving from simple to complex geometries and non-structural to fatigue-critical parts to enable rapid certification

WHAT WILL IT ACCOMPLISH?

When fully implemented, DDM repair or manufacture of metallic components could significantly reduce the lead time and cost to acquire high value components.

- 35-45 percent lower part cost
- Two to seven weeks versus 8-28 months to acquire out of production parts
- Conserves strategic material, lowers energy consumption and significantly reduces the needed logistic footprint
- Enables the design/manufacture of far more structurally efficient future weapon systems

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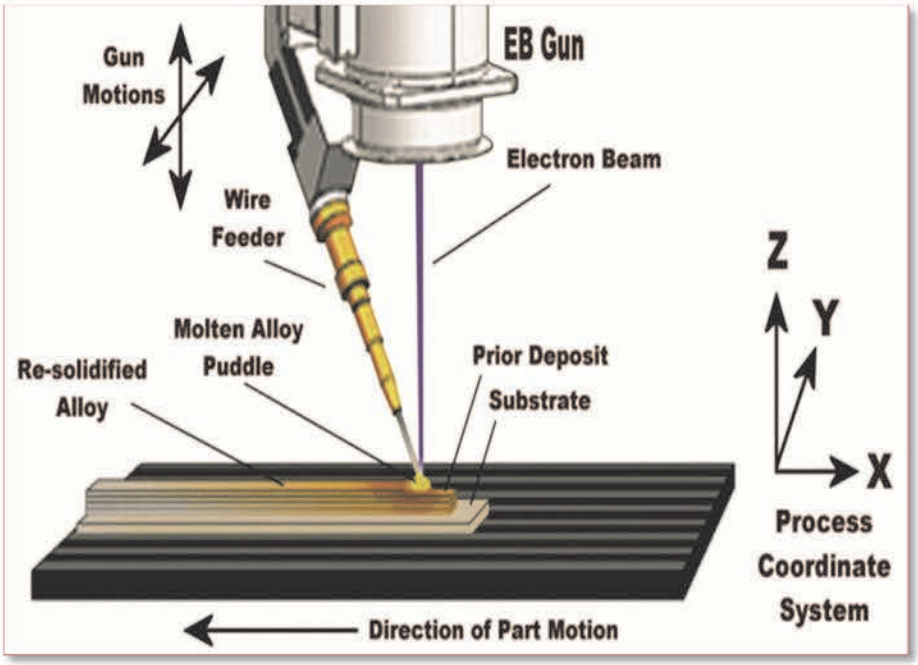

Increasingly the Navy's inventory of aircraft is being extended in service beyond the design life. As a result, components that were never expected to be repaired or replaced are failing. With no replacements available in the supply system, long lead times develop for the repair or manufacture of the replacement items. During such times, the aircraft are grounded, directly impacting warfighter readiness levels.

When fully implemented, the DDM repair or manufacture of metallic components could significantly reduce the lead time required to acquire high-value components. It is estimated that lead time for an F-35 candidate part could be reduced, for example, as much as 75 percent. Further cost savings are anticipated because DDM eliminates the need for tools and dies, reduces the need for machining and increases material utilization.

In order to control the DDM solidification process and solid-state transformations, which ultimately control properties, the thermal properties of the melt pool and the thermal profiles through the part/test bed must be known.

Research Challenges and Opportunities:

- Develop empirically derived process maps and predictive algorithms for accelerating qualification and certification
- Develop new sensor algorithms to measure melt pool temperature in 3-D; currently limited to planar capability
- Develop new sensor algorithms to measure through-thickness part temperature; no systems currently exist
- Develop algorithms to access internal part thermal profiles
- Understand the effect of beam power, size, raster rate
- Develop models that relate the effect of part geometry and beam repeat rate

Dynamically Reconfigurable Data Architectures for Aircraft Data Analysis and Anomaly Detection

AT A GLANCE

WHAT IS IT?

The Dynamically Reconfigurable Data Architectures Small Business Innovative Research program enables rapid, large-scale engineering analysis of aircraft parametric and other sensor data. It is a high-performance time series database with an intuitive graphical user interface and open architecture programming interfaces.

HOW DOES IT WORK?

Dynamically Reconfigurable Data Architectures provides an effective way to organize and compress time series data, allowing storage of terabytes of data while improving data load and query speeds.
Test results have demonstrated a 20 times database size reduction and 200-times increase in query speed when compared with the leading databases.

WHAT WILL IT ACCOMPLISH?

Data collection and management of operational aircraft data is a critical enabler of effective condition-based maintenance (CBM). This effort enables the aerospace user community to rapidly analyze flight data resulting in improved CBM, operational availability and asset life. Accessibility of fleet-wide parametric data is a critical enabler for effective engineering analysis.

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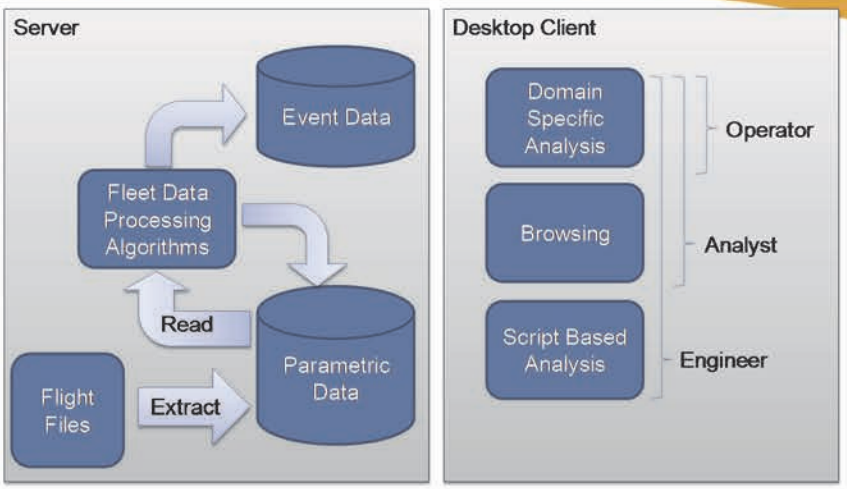

Department of Defense Instruction 4151.22 directs the application of condition-based maintenance (CBM) to optimize material availability and costs, maintain mission capability and improve asset health management. Effective application of CBM requires:

- Engineering analysis of fleet-scale parametric data
- Continuous validation and improvement of engineering algorithms

Dynamically Reconfigurable Data Architectures moves beyond the state of the art to meet these requirements. As condition-based algorithms are developed, historical data is needed to validate their performance. Performing comparative analyses across flights, aircraft and squadrons can help identify indicators that can form the basis of new predictive algorithms.

Existing relational database solutions have significant performance limitations when working with condition-monitoring data. The differences in performance between the relational databases and the capability to dynamically reconfigure data architectures is the difference between an operator waiting hours or days for results and waiting seconds or minutes for many common tasks. Performance and data size are issues with a relational database. The characteristics of many of the condition-monitoring signals lend themselves well to compression but relational databases aren't easily compressed and queried simultaneously.

Research Challenges and Opportunities:

- The challenge and opportunity is to be able to conduct rapid fleet-wide engineering analysis of flight data.

Helicopter Active RPG Protection (HARP)

AT A GLANCE

WHAT IS IT?

The HARP Future Naval Capability will develop and demonstrate a prototype hard kill countermeasure system for defeating rocket-propelled grenades (RPGs) that target helicopters.

HOW DOES IT WORK?

Making maximum use of the existing Aircraft Survivability Equipment suite, HARP will launch, track and guide a unique expendable to intercept and defeat RPGs.

WHAT WILL IT ACCOMPLISH?

Current countermeasure techniques have no effectiveness against RPGs, which do not process seeker information for guidance. HARP will provide a hard-kill countermeasure solution to fill the material capability gap against this historically deadly family of weapons.

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The HARP Future Naval Capability product will deliver helicopter survivability capability against the threat of unguided munitions, specifically rocket-propelled grenades (RPGs). While the capabilities offered by HARP are applicable to a broad range of Navy and Marine Corps aircraft, the initial transition will focus on helicopters. These aircraft, due to their flight profiles, are particularly vulnerable to low-tech, unguided munitions.

HARP will provide a hard-kill RPG countermeasure system that will permit intercept and defeat of multiple incoming RPGs at a safe range from the helicopter. Cueing from existing or planned Aircraft Survivability Equipment sensors will trigger HARP's tracking and guidance sensors to command hard-kill countermeasures to intercept single or multiple RPGs.

The Science and Technology issues that will be addressed in HARP include: the trade between warhead size and lethality and safety of own aircraft, other rotor-craft in the vicinity and blue forces on the ground; the trade between having a short reaction time but maintaining high-accuracy spatial targeting; and the trade between performance, cost and keeping a small footprint on the aircraft.

Research Challenges and Opportunities:

- Hard-kill interceptor countermeasure
- Interceptor-launcher-aircraft interfaces
- Tracker/intercept fire control

Integrated Hybrid Structural Management System (IHSMS)

AT A GLANCE

WHAT IS IT?

The IHSMS Future Naval Capability program will provide integrated global and local structural health monitoring technologies and advanced modeling capabilities that can be transitioned to Navy and Marine Corps rotorcraft.

HOW DOES IT WORK?

This effort will develop and demonstrate a network of small, wired and wireless, energy-harvesting sensors distributed throughout a helicopter's metal and composite structure. The system will gather and report strain, vibration, temperature and environmental data to a central processor for monitoring loads and environmental degradation to determine aircraft structural life and health.

WHAT WILL IT ACCOMPLISH?

Substantial cost savings and safety, readiness and operations enhancement:

- Extended parts flight-hour life and reduced maintenance through direct usage monitoring
- Enhanced safety and reduced reactive maintenance through early damage detection
- Enhanced safety and operational capabilities through preflight and real-time in-flight knowledge of weight and center of gravity
- More comprehensive understanding of failure modes of the vehicle
- Potential for real time flight control corrective action input in case of overstress or battle damage encounters

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The IHSMS Future Naval Capability product will deliver robust management decision tools to enable a shift away from the current deterministic, fixed-flight-hour-based maintenance practice to one based on the management of risk and reliability over an entire rotorcraft fleet. These capabilities are a key enabling technology for the implementation of the condition-based maintenance plus (CBM+) approach to rotorcraft structures. The CH-53K is the platform chosen to transition the IHSMS technologies to the fleet.

Integrated, high-quality information enables adjustment of component retirement time and expansion of maintenance removal criteria. With IHSMS maintenance criteria can be updated based on factual data thereby reducing direct maintenance and spare part replenishment costs. IHSMS will enable integrated health monitoring of composite aircraft structures, including blades and airframes. In addition, it will calculate weight and center of gravity information needed to speed loading operations and enhance safety. It will facilitate accommodation of aircraft growth and mission changes with minimal design changes. And because helicopters are subject to some of the most severe operating conditions and present a worst-case scenario, the technologies developed in IHSMS should be adaptable to many other air, land, sea and undersea platforms.

The IHSMS development process includes the development of sensors, system architecture, and data processing units; laboratory integration and verification testing; and ground and flight validation testing to achieve a Technology Readiness Level of 6.

Research Challenges and Opportunities:

- Very small, robust, wireless, energy harvesting strain sensors
- Methods of sensor integration into metal and composite structure
- Architecture, algorithms and data processing to use local and global data for structural fatigue life determination and health management

Jet Noise Reduction (JNR)

AT A GLANCE

WHAT IS IT?

Through long-term research, the JNR project aims to understand the physics of jet noise produced by high-performance military aircraft, identify materiel/non-materiel solutions to reduce noise and develop and transition technologies in support of the warfighter and the civilian community, especially nearby military bases conducting flight operations.

HOW DOES IT WORK?

Guided by a government-wide panel of science and technology experts, the JNR project:

- Supports the development of theoretical noise models, prediction tools, noise control strategies, diagnostic tools, and enhanced-source localization and propagation techniques
- Proposes American National Standards Institute noise measurement standards for military aircraft.

WHAT WILL IT ACCOMPLISH?

- Improves the physical understanding of noise sources in supersonic jet exhausts from high-performance military aircraft
- Provides critical insight for the development of effective noise control strategies and associated noise reduction potential
- Provides fundamental tools to guide the design of future, optimized, noise-control systems
- Guides noise measurement requirements for naval aviation systems

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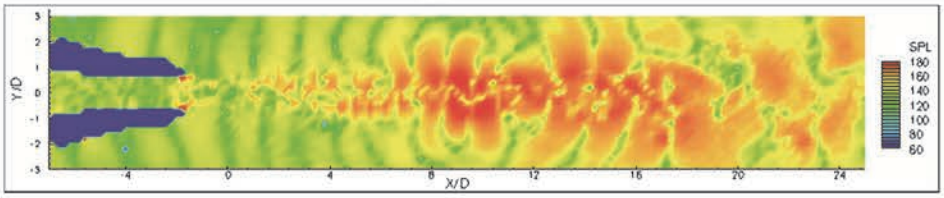

The JNR project is part of the Office of Naval Research's Noise-Induced Hearing Loss Program. As a result of the health and environmental impacts of noise on multiple services within the Department of Defense and the interest in noise among many agencies within the government, the Navy convened a panel of government-wide noise experts in 2010 to guide the JNR project. The JNR Science and Technology (S&T) Panel includes members from the Navy, Air Force, NASA and the FAA and features jet noise researchers, aircraft program representatives and technology experts. Two main tasks have been given high priority: developing a physics-based understanding of jet noise and developing a standard facilitating high-quality, supersonic, jet-noise measurements.

A basic research effort focusing on the development of tools for the active control of hot, supersonic jets was initiated in 2011. It supports the development of theoretical noise models, prediction tools, noise control strategies, diagnostic tools and enhanced source localization and propagation techniques. Additionally, work continues on developing noise-measurement standards for military aircraft.

The JNR project supports the development of fundamental tools that will enable the optimized design of noise-control systems for legacy, emerging and future tactical aircraft. Members of the JNR S&T Panel work across the community to identify technology transition opportunities and provide guidance on improved approaches for low-noise designs. The project examines noise mitigation approaches at all levels of technology maturity, both computationally and experimentally, and encourages research into new areas of noise control through theoretical development and experimental validation.

Research Challenges and Opportunities:

- Effective noise-source models for noise produced by large-scale, jet structures in hot, supersonic jets
- Efficient and reliable time-resolved noise prediction tools
- Validation data for theoretical and computational models
- Effective active-control strategies for exhaust noise

Sea-Based Automated Launch and Recovery System

AT A GLANCE

WHAT IS IT?

The Sea-Based Automated Launch and Recovery System includes technologies needed to provide precision relative navigation and guidance to an aircraft to perform an automated or reduced pilot workload landing on an air-capable ship.

HOW DOES IT WORK?

- Projects will determine the adequacy of various sensor systems and hybrid sensor fused systems to provide precision ship-relative navigation guidance to unmanned or manned aircraft flight control systems and displays, under conditions of degraded weather, high deck motion and electromagnetic interference.
- Both aircraft carrier and small deck ship installations are included with applicability to fixed-wing and rotary-wing aircraft.
- Advanced flight control laws will be developed under another program, Aircraft Technology, to use precision ship-relative navigation inputs and guide the aircraft to a precision approach and landing.

WHAT WILL IT ACCOMPLISH?

- Enable highly reliable, full envelope sea-based unmanned aerial system operations
- Enable manned aircraft reduced workload and/or automated launch and recovery
  - Increased safety, efficiency, expanded operating envelope
  - Training and currency flight cost reductions
  - Reduced structural landing loads; savings in maintenance, extended fatigue life

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The Navy and Marine Corps will increasingly need to operate highly capable unmanned air vehicles (UAVs) from ships at sea. The MQ-8B Fire Scout is the first naval UAV of this type operating from small-deck ships, using the UAV Common Automatic Recovery System radar-based recovery system to provide precision ship-relative navigation (PS-RN) for its fully automated landings. The Unmanned Combat Air System Demonstration program demonstrated the capability for an advanced UAV (represented by the X-47 demonstration aircraft) to operate from aircraft carriers, using a GPS-based PS-RN system for its automated launch and recovery capability. Analyses of and experience with both of these PS-RN approaches indicate that backup or alternative system options are desirable to ensure that highly reliable UAV operations can be conducted under demanding at-sea conditions.

In addition to enabling UAV operations, PS-RN systems can provide navigation and guidance to manned aircraft, both fixed-wing and rotary-wing. In this case, the sensor-based PS-RN guidance could be provided to the pilot on the Head-Up Display, Helmet-Mounted Display or Multi-function Display. PS-RN capability could greatly assist pilots in landing aircraft in conditions of restricted visibility. Ultimately, this capability could be used to fully automate manned aircraft launches and recoveries, with pilots acting as a system monitor with takeover capability. Potential benefits include reduced training requirements, expanded operating envelopes, greater efficiency in degraded conditions, reduced structural loads on landing and enhanced safety. PS-RN capability also could enable automation of aircraft carrier air traffic control (ATC). Potential benefits include reduced fuel consumption, increased efficiency, increased safety and reduced ATC manning.

Research Challenges and Opportunities:

- Non-GPS PS-RN systems performance in:
  - Degraded weather
  - High deck motion
  - Electromagnetic interference/multipath/jamming
  - Alternate missions (e.g., landings ashore, landings on non-surveyed ships, etc.)
- Ship reference displays and aircraft cockpit displays for manned aircraft
- Automated aircraft carrier air traffic control

Ship-launched Electronic Warfare Extended Endurance Decoy (SEWEED)

AT A GLANCE

WHAT IS IT?

SEWEED is a quick-reaction, long-acting air vehicle platform that can carry an electronic warfare (EW) payload for ship self-defense.

HOW DOES IT WORK?

Concept of operations:

- Incoming threat detected
- SEWEED decoy rocket launched from ship
- SEWEED reconfigures to helicopter configuration and takes station
- Ship EW systems control decoy position and tactics
- Each SEWEED could address multiple threats in field of view
- Decoys remain aloft for extended protection

WHAT WILL IT ACCOMPLISH?

- Provide a critical enabler for defense of any naval ship against anti-ship cruise missiles

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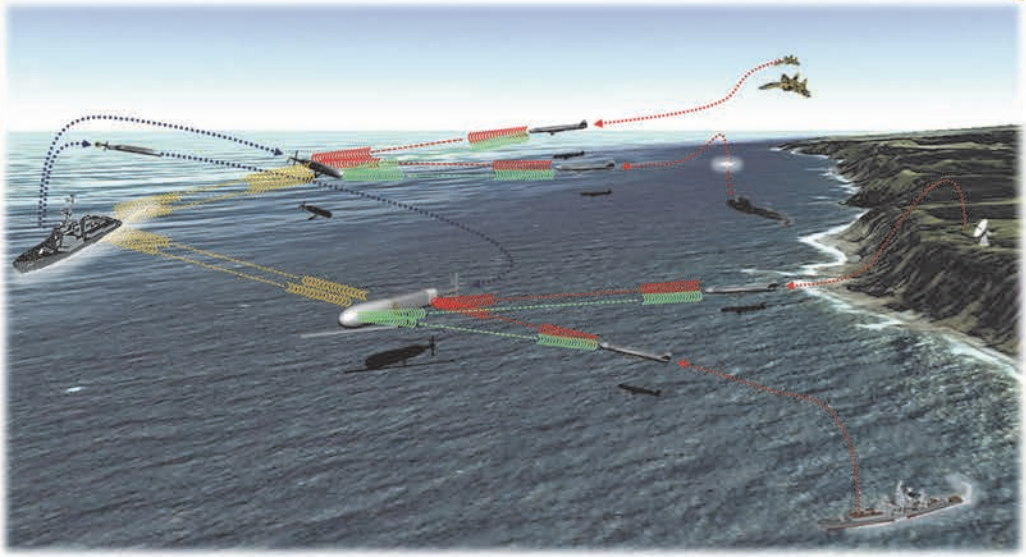

Navy ships are subject to missile attacks that may be short notice and grouped to overwhelm defenses. Defenses include hard-kill, onboard and offboard electronic warfare (EW); all three combined are needed to be most effective. Current offboard (decoy) platforms have limitations in availability, duration of operation or performance. The PEO IWS-2 Advanced Offboard EW program is the Navy initiative that is planning, developing and fielding major capability improvements in this area.

The SEWEED Future Naval Capability program seeks to develop a rotary-wing platform that combines quick reaction with long endurance and serves as an EW payload platform. The EW payload itself is not part of the SEWEED program, but integration provisions are.

SEWEED technologies are drawn from years of experience at the Naval Research Laboratory (NRL) in designing and demonstrating ship-launched decoys. Industry will be asked to further develop and integrate these technologies as appropriate into a design that can be demonstrated to Technology Readiness Level 6 by 2019, and subsequently developed into an operational system.

SEWEED is intended to be stored in and launched from a specially designed launch system, which will be located in the EW area of a naval ship. Alternatively, it could be made compatible with the vertical launch system.

Research Challenges and Opportunities:

- An industry provider will be contracted to develop and demonstrate a design based on the NRL concept and technology.
  - Industry engagement (Request for Information) is the first step in fiscal year 2015
  - Proposals will be requested in early fiscal year 2016

Tern

Artist's Concept

AT A GLANCE

WHAT IS IT?

- Tern is a joint Defense Advanced Research Projects Agency-Navy program to develop and demonstrate vertical take-off and landing (VTOL) air vehicle technologies for long-endurance presence from small-deck, air-capable naval ships.

HOW DOES IT WORK?

- Complex, aerodynamics-enabled high-lift-to-drag-tail-sitter VTOL configurations with large folding wings, hybrid helicopter-aircraft controls, efficient and/or hybrid propulsion and reconfigurable mission packages
- Autonomous launch, landing and mission
- Co-exist with manned H-60s on DDG-51 and LCS-2

WHAT WILL IT ACCOMPLISH?

- Tern will enable a long-endurance air vehicle with a 500-pound payload at a 600 NM mission radius to operate from a DDG-51 or LCS-2.
- Tern will provide situational awareness beyond that achievable with ship-based radars for missions such as intelligence, surveillance and reconnaissance, mine warfare, surface warfare and strike.

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The Tern program will develop and demonstrate technologies for a new class of medium-size aircraft operating from DDG- and LCS-class ships. This vision capability will significantly enhance Navy intelligence, surveillance and reconnaissance (ISR)/strike capabilities by providing a fixed-wing, long-range/endurance solution operable from short deck ships to provide flexible ISR/strike coverage for a global fleet. For ISR missions, the vision system design goal is to provide a persistent orbit at 600 nautical miles or more radius with 500 pounds or more of payload, using aircraft operable from small-deck ships. The vision system must be capable of executing autonomous launch and recovery with minimal manning requirements. Compatibility with small-deck ship operations is an important attribute of the vision vehicle. This includes hangar compatibility, ability to transit from hangar to flight deck, and ability to conduct maintenance and provide supporting logistics in space-constrained, personnel-limited ship environments.

Tern will push beyond limitations of current vertical take-off and landing (VTOL) aircraft design. Current technology VTOLs are inefficient cruise vehicles and have limited flight endurance as a result. The transition from VTOL mode to horizontal airplane flight requires control at large angles of attack, which adds significant additional aerodynamic and controls design challenges. Furthermore, the combination of large wing and vehicle compactness present significant control challenges for precision landing at significant sea states. Onboard power must provide high-thrust operation for takeoff or landing operation and very efficient low-throttle operation to provide long endurance at cruise.

The Tern program builds upon prior investments and technology developments in automated launch and recovery, autonomous flight control and VTOL configurations. In 2018, Tern will culminate in full-scale launch, recovery and flight testing of a demonstrator vehicle that will be consistent with a tactical vehicle in size, mass, aerodynamics, propulsion and autonomous controls. Although not a production prototype, the vehicle will demonstrate the salient characteristics required to evaluate future applications of this new class of aircraft as an innovative solution to current and future Navy mission requirements.

Research Challenges and Opportunities:

- VTOL aircraft design
- Autonomous launch and recovery with minimal manning
- Wing in propeller slipstream unsteady aerodynamics and high angle of attack rotor design and performance
- Engine and electrical power technologies to provide high thrust for VTOL operation and efficient low-throttle operation to provide long endurance at cruise

Variable Cycle Advanced Technology (VCAT)

AT A GLANCE

WHAT IS IT?

The VCAT will identify and mature critical, relevant variable/adaptive cycle turbine propulsion technology for future carrier-based tactical aircraft (TACAIR)/intelligence, surveillance and reconnaissance systems, resulting in dramatic performance and capability improvements.

HOW DOES IT WORK?

- The VCAT is working with industry experts to conduct systems analyses and Navy-unique/important turbine engine technology development options for future naval aviation platform capability desires.
- These efforts are leveraging the Air Force's adaptive versatile engine technology variable; adaptive cycle engine Science and Technology (S&T) demonstration effort; and other versatile affordable advanced turbine engine efforts. VCAT is a part of an overall integrated propulsion, power and thermal management system requiring further S&T maturation.

WHAT WILL IT ACCOMPLISH?

- Advancements in propulsion system technology are essential to meet desired warfighter goals for future carrier-based TACAIR/ISR systems.
- Enhanced energy security for naval aviation and the nation has been, and will continue to be, an important part of the VCAT Program's vision for the future.

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The VCAT program is a partnership effort between ONR and the Department of the Navy's Task Force Energy initiative to realize the potential benefits of recent advancements in variable/adaptive cycle turbine engine technology. Advancements in propulsion system technology are essential to meet desired warfighter needs for future carrier-based tactical aircraft (TACAIR)/ intelligence, surveillance and reconnaissance (ISR) systems. This program was conceived to provide the anticipated enhanced mission capability, energy security and jet noise-reduction requirements expected of future TACAIR/ISR systems.

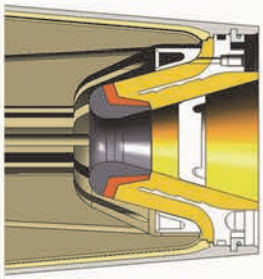
In close coordination with NAVAIR and the overall Naval Aviation Enterprise, the VCAT program objectives are to identify and mature critical, relevant variable/adaptive cycle turbine engine technologies for future carrier-based naval aviation systems. Many promising component technologies, their performance benefits and their development plans have been identified as part of systems analysis efforts that began in fiscal year 2011. Some of those component technologies have been selected for maturation efforts. The U.S. original equipment manufacturers for military fighter turbine engines began technology development efforts in fiscal year 2012, and the plan is to continue through to a Technology Readiness Level 5 maturity.

Projected VCAT engine technology benefits for future carrier-based aviation systems are showing dramatic capability improvements in range and loiter capability for selected conceptual platforms/ missions. The benefits are primarily due to improved thermal and propulsive efficiencies from advanced material/component technologies as well as from the variable/adaptive engine features. Aligned with TFE goals for reducing fuel consumption, results showing reduced specific fuel consumption also offer the potential for significant reductions in both annual fuel costs and logistics tail (i.e., less demand for deployed fuel and tanker aircraft support).

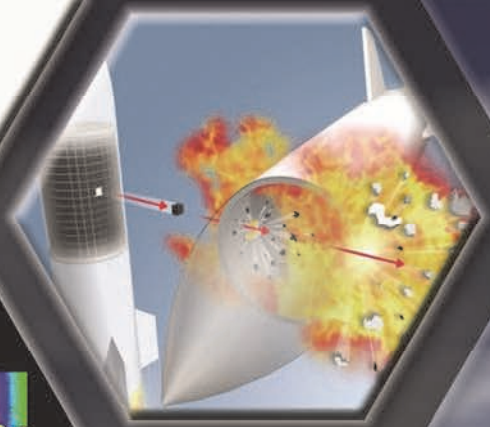
Research Challenges and Opportunities:

- Aerodynamic and mechanical sizing of variable/adaptive engine technologies for naval aviation applications
- Naval aviation-unique challenges:
  - Catapult/trap loads
  - Low-speed thrust response for approach, wave-off and bolter
  - Environmental and corrosion resistance in a marine environment
  - Takeoff water/steam ingestion
  - Carrier-based electromagnetic environmental effects
  - Carrier susceptibility to jet exhaust impingement
  - Dimension and weight constraints to meet aircraft/ship integration requirements
  - Onboard maintainability and supportability

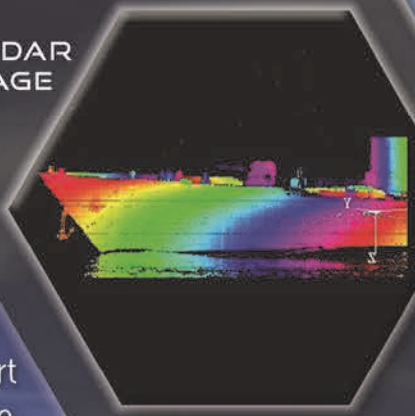
RESEARCH



LOW EROSION NOZZLE



HIGH DENSITY REACTIVE MATERIALS



3D LIDAR IMAGE

Projecting decisive combat power has been critical to every commander who ever went into battle, and this will remain true in decades ahead. Sea Strike operations are how the 21st-century Navy will exert direct, decisive, and sustained influence in joint campaigns. They will involve the dynamic application of persistent intelligence, surveillance, and reconnaissance; time-sensitive strike; ship-to-objective maneuver; information operations; and covert strike to deliver devastating power and accuracy in future campaigns.

APPLICATION

(CLOCKWISE FROM UPPER-LEFT)

ADVANCED ENERGETICS

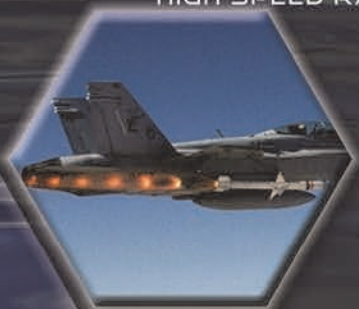
LASER IMAGING & DESIGNATION SYSTEM

AUTOMATIC TARGET RECOGNITION

LONG RANGE ANTI-SHIP MISSILE

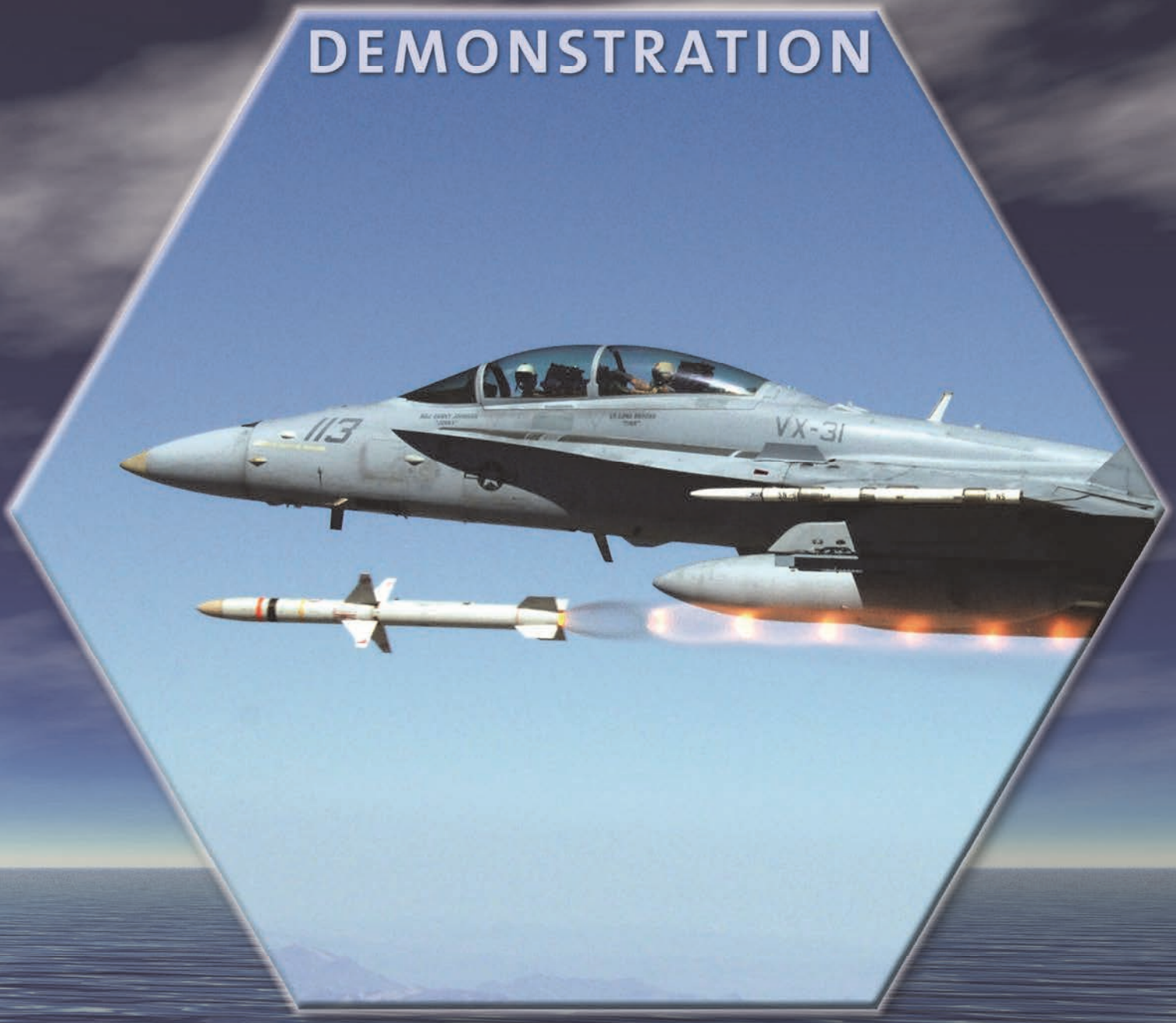
ADVANCED ROCKET MOTOR

HIGH SPEED RADOME DESIGN



SEA STRIKE

DEMONSTRATION



An AGM-88E Advanced Anti-Radiation Guided Missile is fired from a VX-31 F/A-18F Super Hornet over the Naval Air Warfare Center Weapons Division China Lake land range during the missile's operational assessment.

Code 35

Office of Naval Research
ONR
Science & Technology

Combat Safe Insensitive Munitions (CSIM)

AT A GLANCE

WHAT IS IT?

Insensitive munitions (IM) compliance is a requirement for all weapons in the fleet. Yet over 80 percent of the Department of Defense's munitions inventory is still non-compliant. CSIM technology will enable reduced sensitivity ordnance items for all fleet weapon systems.

HOW DOES IT WORK?

- With an expanded understanding of energetic materials initiation, combustion and detonation processes, coupled with knowledge about the types and quantities of crystal defects that exist in energetic materials, weapons designers will be able to develop improved compositions with improved insensitivity characteristics.
- Incorporating these physical inputs into advanced microscopic to mesoscopic modeling efforts will provide a rapid and accurate assessment of new compositions and formulations for advanced weapons system use and reduce IM test time and costs.
- Understanding the first principles is the basis for the development of more accurate large-scale simulations, thus reducing the number of dangerous and expensive tests necessary to qualify new munitions.

WHAT WILL IT ACCOMPLISH?

Mission requirements impose conflicting demands for weapon systems. The warfighter wants significant enhancements in delivery energy in compact volumes and also wants the weapon to be resistant to catastrophic failure in extremely stressful environments, including transportation, loading or storage on land or sea.

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The need for IM compliance

The Navy has grave concerns over conventional munitions and propellant systems, since all munitions are stored on maritime platforms. The accident that occurred on USS *Forrestal* exemplifies why it is critical that conventional munitions display maximum insensitivity when stowed, handled, carried or otherwise exposed to friendly forces and environments but have sufficient energy/lethality to perform mission expectations reliably. This balance between sensitivity and performance is at the focal point of the CSIM program.

USS Forrestal, July 29, 1967

A secondary factor imposed upon Navy and Marine platforms reflects ordnance performance and load-outs. To deliver the greatest lethality weapons, the highest performance munitions/energetic compositions are required. To assist the Navy in meeting this requirement, the advanced energetic materials program is exploring new ways of thinking about delivery of energy on target and ways to enhance performance while increasing or improving IM characteristics.

This program will establish the computational and synthetic chemistry foundations required to target the next generation of energetic ingredients capable of resisting inadvertent thermal and shock loading conditions based on the following derived synthesis hypotheses:

- Increase inter and intra molecular hydrogen bonding
- Delocalize electron density in nitro groups
- Utilize coulombic attractions to stabilize the ground-state structure
- Reduce the number of nitro groups
- Avoid high acidity
- Maximize crystal packing planarity

The implementation of CSIMs will:

- Enable compliance with insensitive munitions mandates
- Substantially enhance ship survivability in case of an accident or attack by eliminating the risk of sympathetic detonation
- Reduce the logistical and operational overburden currently imposed in order to satisfy load, stow, handle and launch non-compliant munitions, thus improving efficiency and reducing cost, with concomitant improvements in pace of operations and potential reduction in manning requirements

Research Challenges and Opportunities:

- Establish the connectivity between molecular structure, crystal morphology prediction and synthesis chemistry to provide IM-compliant energetic ingredients shock and thermal sensitivity
- Focus modeling and simulation to predict stable crystal structures/crystal morphology
- Establish methodologies to model, measure and predict molecular and crystal energetic material response to external shock and thermal modeling
- Validate design criteria for molecular stability as a function of insensitivity

Counter Air Defense (CAD) Improvements

AT A GLANCE

WHAT IS IT?
The CAD Improvements Future Naval Capability (FNC) will increase the kinematic performance of the AGM-88E Advanced Anti-Radiation Guided Missile (AARGM), enabling a significant extension in range capabilities.

HOW DOES IT WORK?
The CAD FNC will achieve this through a combination of propulsion technologies that include state-of-the-art propellants, highly loaded grain design and low-erosion nozzles.

WHAT WILL IT ACCOMPLISH?
By improving the kinematic performance of existing anti-radiation, air-to-ground weapon systems like the AARGM, CAD will ensure that U.S. forces maintain operational superiority over anti-access/area-denial capabilities of any peer competitor.

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The CAD Improvements Future Naval Capability (FNC) product is developing a missile propulsion system with substantially improved kinematic capabilities for the AGM-88E Advanced Anti-Radiation Guided Missile (AARGM). To achieve this, CAD is developing and integrating three technologies: State-of-the- art (SOTA) high-energy propellants, highly loaded grain and low-erosion nozzles. The kinematic performance enhancements are focused on increasing the motor's total impulse and optimizing its thrust profile in order to provide extended range.

Many of the technologies being matured in this FNC are the fruits of ONR investment in a joint-service propulsion program known as integrated high payoff rocket propulsion technology. SOTA propellant formulations from both industry and government will be considered on the basis of increased total impulse power achieved across the spectrum of operational environments. Highly loaded grain technologies will be investigated to enable the "end-burning" of the solid propellant, which will allow for higher volumetric loading of propellant within the rocket motor. Low erosion materials for the nozzle design are needed to endure the greater erosive forces, temperatures and pressures yielded by the high energy propellant and longer duration burn time.

The CAD Improvements product is responding to higher kinematic and range performance requirements for AARGM as expressed by the fleet. In addition to substantially extending the missile's range, the highly loaded grain/end-burning design will provide an improvement to the missile's insensitive munitions characteristics.

The product is primarily focused on transition to the AGM-88E AARGM. In addition, it could serve as a solid rocket motor technology demonstrator for use in any potential future missile system development effort.

Research Challenges and Opportunities:
- Advanced grain design for improved kinematic performance
- Incorporating the grain design technology into production missile systems

Energetic Materials (EM)

AT A GLANCE

WHAT IS IT?

- Research to provide higher performance ordnance with acceptable insensitivity characteristics; includes explosives and propellants
- Focused on understanding of molecular design, synthesis, spectroscopic characterization and process research and development issues associated with energetic ingredient preparation

HOW DOES IT WORK?

- Understanding of EM initiation, combustion and detonation processes coupled with knowledge about types and quantities of crystal defects in EM
- Understanding first principles is the basis of more accurate large-scale simulations, reducing the number of tests necessary to qualify new munitions

WHAT WILL IT ACCOMPLISH?

- Military strike and logistics payoffs applicable across all ordnance systems
- Process refinement and scale-up activities providing consistent, reproducible and well-characterized materials to reduce acquisition cost
- Enable enhanced survivability, reduced operational and logistic burdens, improved operational tempo with respect to load out and sortie rates and reduced EM initiation sensitivity by external stimuli
- Combined kinetic and chemical energy in a weapon system with greatly enhanced lethality

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EM weapon systems can be a game changer by increasing warfighters' lethality and area of dominance. Catastrophic damage improves battlefield damage assessment and reduces sorties. Equally powerful but smaller weapons optimize internal carry and facilitate higher weapon load-outs. Future new ordnance must be adaptable in size to fit a family of delivery systems, contain sufficient energy to defeat the target and be affordable.

The vast majority of ordinance systems use energetic materials to some degree. Energetic materials are used safely in actuators, demolition charges, aircrew escape, missile deployment applications, starter cartridges, gas generators and airbags. EM research, development and manufacturing technology encompass a broad science and engineering spectrum: basic molecular chemistry, detonation physics, combustion processes, pyrotechnic mapping, material science, lethality effects, process chemistry and engineering, and manufacturing technology.

Another EM thrust is related to advanced blast and propellant compositions which rely on ammonium perchlorate (AP) to assist combustion and detonation characteristics. Current AP systems have reached their engineered maximum efficiency, mandating the requirement for new ingredients to continue performance and sensitivity property advances.

Payoffs:

- Ten-times increase in performance
- Insensitive munitions-compliant
- Prolonged storage life (40–50 years)
- Safe handling
- Flexibility in size and weight
- Maximize energy on target compared to traditional weapons, resulting in enhanced lethality and improved weapon effectiveness

Research Challenges and Opportunities:

- New approaches to novel materials that maximize molecular design, synthesis efficiencies and predicted stabilities and achieve performance goals
- Develop a new class of ingredients that can surpass the oxygen content of AP
- Develop macroscopic mechanical and chemical models and an understanding of molecule dynamics and strength/reactivity correlations
- Consistent processing and performance results; process research and development (commonly referred to as "scale-up"); areas of concern are safety and remote operations, critical thermal management, batch-to-batch reproducibility, standardized process for the chemistry and conditions and product quality and purity

High Energy Dense Oxidizers (HEDO)

AT A GLANCE

WHAT IS IT?

The HEDO program is a research effort investigating next-generation energetic materials and concepts that will enable substantially higher-performing ordnance with acceptable insensitivity standards.

HOW DOES IT WORK?

- Technical efforts are directed toward molecular design, exploratory synthesis, investigation of physical and chemical properties and relationships, synthesis efficiencies and process research and development of advanced energetic ingredients.
- When inserted into ordnance/ propulsion systems, these new ingredients will increase system performance 10-fold while meeting insensitivity compliance objectives.

WHAT WILL IT ACCOMPLISH?

- The development of new oxidizer ingredients will yield enormous program payoffs across Navy ordnance systems, such as torpedoes, warheads and strategic and tactical missile propellants.
- Process refinement and scale-up activities will provide consistent and reproducible materials for formulation applications.

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Advanced blast and propellant composition rely on ammonium perchlorate (AP) to assist combustion and detonation. Current AP systems have reached their engineered maximum efficiency, mandating the requirement for new ingredients to continue performance and sensitivity property advances.

The Office of Naval Research Advanced Reactive and Energetic Materials Program seeks to develop next-generation energetic materials (e.g., explosives, propellants and reactive materials) and technologies to enable substantially higher performance ordnance.

New ordnance must be affordable, adaptive in size to fit a family of delivery systems and able to contain sufficient energy to defeat the target. Science and technology must provide ordnance formulation flexibility to meet specific future naval mission requirements; comply with safety and environmental regulations; and achieve significant enhancements in delivery energy in compact volumes, while being resistant to catastrophic failure in extremely stressful environments, such as handling aboard carriers and long-term storage.

Future mission requirements impose challenging and conflicting demands for weapon systems, but advancing HEDOs ultimately will translate into greater national security as the Navy conducts its global mission.

Quantified payoffs include:

- Ten-fold increase in system performance
- Insensitive munitions-compliant, resistant to catastrophic failures
- Prolonged storage life (40–50 years)
- Safe handling onboard ships
- Flexibility in the size and weight of weapon systems

Research Challenges and Opportunities:

- Develop a fundamental understanding of new molecule designs for HEDO synthesis with: ingredient density of 2 grams per cubic centimeter, oxygen content greater than AP, melting point greater than 150° Celsius with a minimum number of synthesis steps
- Develop ingredients with sensitivities no worse than RMX (Research Department explosive)/HMX (or octogen), low hydrogen and carbon content and high oxygen and nitrogen content

High Speed Components (HSC)

AT A GLANCE

WHAT IS IT?
The HSC Future Naval Capability (FNC) is a development effort that will maximize the operational performance of the RIM-162 Evolved SEASPARROW Missile (ESSM) Block 2, while offering new, cost-effective manufacturing and production methods.

HOW DOES IT WORK?
The HSC FNC will achieve this through a combination of materials selection, design configuration and production methods, which will deliver both increased performance characteristics and cost savings.

WHAT WILL IT ACCOMPLISH?
HSC will enable ESSM Block 2 to ensure maximum sensor performance while keeping pace with expected kinematic requirements.

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The HSC Future Naval Capability (FNC) product is a technology development effort intended to enable performance enhancements of the planned RIM-162 Evolved SEASPARROW Missile (ESSM) Block 2 weapon system, and possibly future high-speed and time-sensitive strike weapons. This effort will deliver a more robust, less-expensive radome capable of withstanding increased thermal and structural loads, while increasing uniformity and consistency of electrical properties throughout the entire dome. Development will focus on improving manufacturing and production techniques to provide superior electrical and structural performance characteristics, while achieving high-production yields at reasonable unit cost.

The HSC effort will investigate materials, designs and fabrication processes to develop a radome capable of mitigating thermal and structural loads experienced during extended periods of high-speed operations, minimizing surface degradation due to high-speed water impact and maintaining acceptable electrical properties. Initial work focused on formulating a material or combination of materials that would have suitable electrical, thermal and structural properties for meeting increased weapon system kinematic performance and flight duration requirements. Later work has focused on developing manufacturing tools and processes for fabricating radomes in the requisite form factor. The radomes are homogeneous within themselves, and there is repeatable performance from one radome to the next.

The HSC product is responding to higher kinematic and range performance requirements for ESSM Block 2 as expressed by the fleet. This product is part of a system-wide approach to extend the missile's range, while also decreasing time of flight to target at that achieved maximum range. Potential benefits derived from HSC over current radomes would be enabling ESSM Block 2 to withstand increased thermal shock and structural loads associated with the improved airframe kinematics, while maintaining suitable electrical properties for enabling accurate weapon guidance to the target.

The product is primarily focused on transition during the early Engineering and Manufacturing Development phase of Block 2; however, the materials, design concepts and processes investigated during this FNC effort have applicability to other missile radomes as well.

Research Challenges and Opportunities:
- Development of a repeatable, low-cost radome fabrication and manufacturing approach using new processes for either new or existing materials

Laser Imaging and Designation System (LIDS)

AT A GLANCE

WHAT IS IT?

The LIDS is a fleet experimentation effort that will demonstrate a prototype system for use in detecting, tracking and identifying small boat targets.

HOW DOES IT WORK?

- LIDS will leverage earlier Future Naval Capability efforts to integrate visible, infrared and laser radar (LADAR) within a single sensor turret.
- LIDS will also evaluate automatic target recognition (ATR) algorithms for processing and analysis of the sensor data.

WHAT WILL IT ACCOMPLISH?

By incorporating the LADAR to generate high-quality 3-D imaging, and coupling that with ATR, LIDS can provide increased maritime target identification capabilities in both clear and adverse weather. Additionally, the increased probability of accurate, automated target identification could reduce false alarm rates and sensor operator workload.

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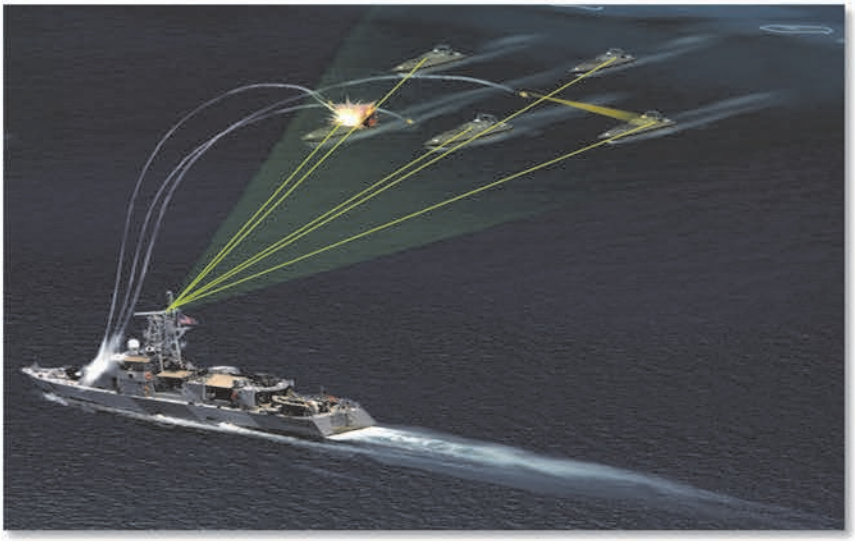

The LIDS is a fleet experimentation effort to evaluate and demonstrate ship-board ability to detect, track and identify small boat targets as might appear in a swarming boat or inshore fast-attack scenario where the sensor-equipped ship is threatened. The LIDS effort will also demonstrate the ability to geo-locate and identify targets for weapons engagement.

LIDS is the follow-on to the Multi-Mode Sensor Seeker (MMSS) Future Naval Capability (FNC), which was completed in 2013. The MMSS effort developed an eye-safe imaging laser radar (LADAR) sensor to be integrated with high-definition visible and mid-wave infrared (MWIR) imaging sensors into a BRITE Star II® baseline turret. The resulting multi-mode sensor subsystem was then integrated with an automatic target recognition (ATR) subsystem, implemented in commercial off-the-shelf hardware, aboard a manned test-bed helicopter for demonstration of product viability. The combining of LADAR with the upgraded sensors enabled generation of high-quality 3-D images that fed ATR algorithms, which in turn enabled processing aboard the sensor platform.

Installed aboard the Atlas test ship, the objectives of the LIDS experiment are to: (1) Demonstrate that LIDS technologies work as designed and advertised; (2) evaluate LIDS as a shipboard ID and targeting sensor; and (3) piggy back on a live-fire Griffin missile test by serving as its targeting sensor.

Pending a successful outcome of this experimentation effort, there exists the possibility of LIDS installation and integration on all Cyclone Patrol Craft-class ships. Furthermore, successful performance could lead to the potential consideration of LIDS integration on larger classes of warship like Littoral Combat Ships.

Research Challenges and Opportunities:

- Integration of multiple advanced sensors utilizing common optical components
- Advanced ATR capabilities that accurately identify maritime targets at increased stand-off ranges
- High-sensitivity LADAR detector arrays

Strike Accelerator

AT A GLANCE

WHAT IS IT?

The Strike Accelerator Future Naval Capability will accelerate the kill chain and enable rapid target identification and multiple-target engagement for the F/A-18E/F/G.

HOW DOES IT WORK?

- Radar and infrared data on shipping are processed and classified or identified by an Aided Target Recognition System.
- The high-confidence output is quickly passed to the aircrew who make the final target determination and engagement decision.

WHAT WILL IT ACCOMPLISH?

- Speeds up target prosecution by reducing the data search and decision-making that the aircrew must complete to execute combat identification and multi-target track.
- This will allow the targeting of precision weapons against multiple stationary or moving targets by a single platform in a single pass in a crowded littoral environment.

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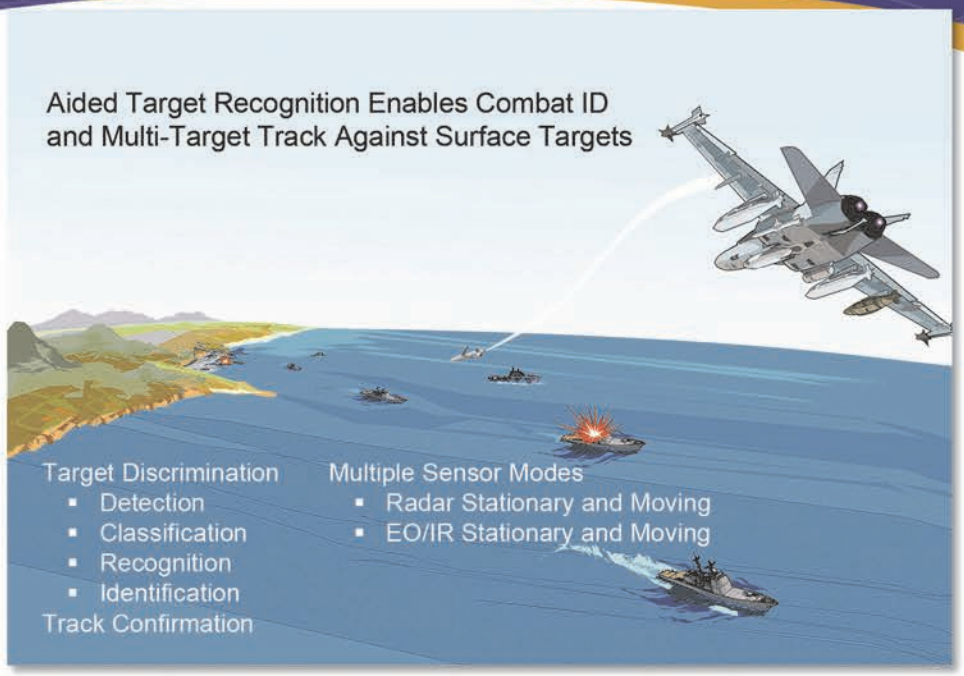

The Strike Accelerator Future Naval Capability (FNC) product will develop and mature an Aided Target Recognition (AiTR) system to provide F/A-18 aircrews with a high decision rate and high classification/recognition/identification confidence against adversary surface combatants. When complete, this capability will automatically recognize and identify ships in port and ships at sea, even in a cluttered littoral environment. By reducing manual data search and target decision time by a factor of 10 to 100, Strike Accelerator will shorten key links in the kill chain—thus enabling traversal of kill chain in minutes and supporting combat identification and multi-moving target track aboard the F/A-18 E/F and EA-18G aircraft. Strike Accelerator will enable the Hornet platform to engage multiple desired points of impact per pass with precision weapons.

Stationary and moving maritime target data are provided to Strike Accelerator by the F/A-18's Active Electronically Scanned Array Radar and Advanced Targeting Forward Looking Infrared optics pod. Strike Accelerator's advanced AiTR algorithms and multi-look, adaptive, and hierarchical architecture will process the raw data inputs and produce outputs at four levels of fidelity for the pilot/aircrew. At the lowest fidelity level—target detection—targets are distinguished from non-targets in the sensor data. Target discrimination outputs then increase in fidelity from classification to recognition and finally to the highest fidelity level of identification. Target discrimination output decisions are passed on to the aircrew as reliable processed information for use in determining the need for further action.

Strike Accelerator's adaptive discrimination will respond to the mission environment by tuning the AiTR system parameters. Multi-look discrimination will fuse the target decisions from multiple sensor images into a single decision. The multiple looks may come from the same sensor at different times or from different on-board sensors/modes or potentially from networked off-board sensors.

Research Challenges and Opportunities:

- Automated high-accuracy radar and optical target detection, classification, recognition and identification
- Hierarchical target discrimination
- Adaptive target discrimination

System Mission Optimized Kinematic Enhancement (SMOKE)

AT A GLANCE

WHAT IS IT?
The SMOKE Future Naval Capability will increase the kinematic performance and lethality of an advanced short-range air-to-air missile, enabling extended range and decreased time to target.

HOW DOES IT WORK?
The SMOKE FNC will achieve this through a combination of propulsion technologies that include a two-pulse, end-burning rocket motor and multi-function integrated energetic safety device.

WHAT WILL IT ACCOMPLISH?
By improving the kinematic performance of emerging air-to-air weapon systems over existing capabilities, SMOKE will ensure the warfighter maintains the tactical edge in air-to-air engagements against any peer competitor.

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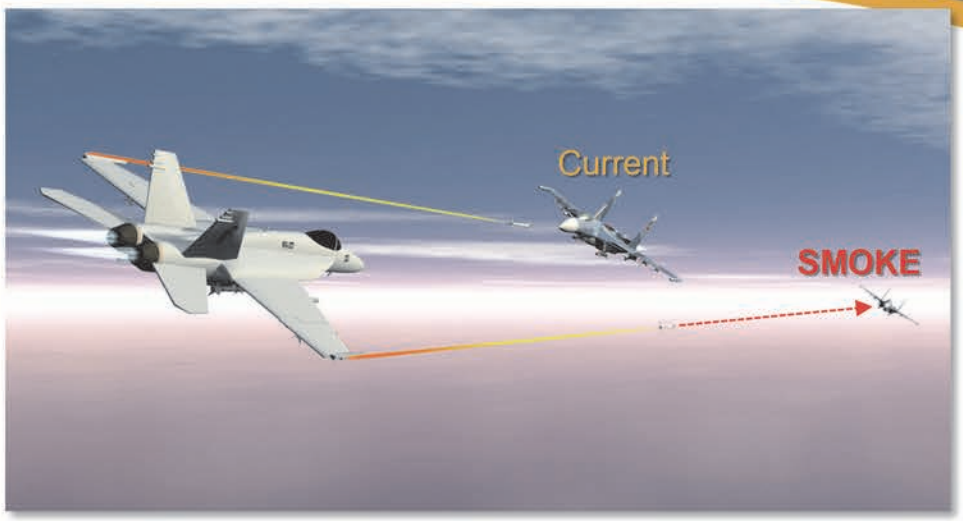

The SMOKE Future Naval Capability (FNC) product is developing missile propulsion and related subsystems for the improved kinematic performance and lethality of future advanced air-to-air missiles. To achieve this, the FNC is developing and integrating two advanced technologies: two-pulse, end-burning rocket motor and multi-function integrated energetic safety device (IESD). The kinematic and lethality performance enhancements are focused on improving the "no-escape range" and "time-to-target."

Many of the technologies being matured in this FNC are the fruits of ONR investment in a joint-service propulsion program known as Integrated High Payoff Rocket Propulsion Technology. The SMOKE propulsion effort will center on the development of a two-pulse, end-burning rocket motor to provide a significant increase in packaged total energy. Thrust output will be provided in two discrete pulses for optimization of kinematic performance throughout the expanded weapons engagement zone. Also, initiation of both rocket motor pulses along with the warhead's safe-arm-device, will be combined into a single mechanism—the multi-function IESD—again freeing up volume for the incorporation of additional propellant.

The SMOKE product is responding to higher kinematic performance and lethality requirements for advanced air-to-air weaponry as expressed by the fleet and will provide the potential to achieve warfighter-defined tactical advantage for threats beyond 2020. This product will extend no-escape range, while decreasing time of flight to target at a significant range for air-to-air engagements. Additional benefits derived from the two-pulse, end-burn design and IESD will be improvement in insensitive munitions response.

Research Challenges and Opportunities:
- Two-pulse highly loaded grain concept configuration with two-pulse survivable thrust vector control
- Distributed and command transmission fuze initiation methods

Doing Business With Code 35

Whether you are looking for solicitations, submitting a proposal or managing your contract or grant, the Acquisitions Department at ONR (http://www.onr.navy.mil/Contracts-Grants.aspx) provides business advice, award execution, award administration, policy development and e-business solutions to ONR's provider network.

For **more information**, please visit www.onr.navy.mil. On this site, you will find links to program opportunities, including:

- **Broad Agency Announcements (BAAs):** A BAA announces an agency's research interests, including criteria for selecting proposals and soliciting the participation of all offerors capable of satisfying the government's needs.
- **Requests for Information (RFIs):** An RFI is used when a government agency does not presently intend to award a contract but wants to obtain price, delivery, other market information or capabilities for planning purposes. Responses to these notices are not offers and cannot be accepted by the government to form a binding contract.
- **Requests for Proposals (RFPs):** An RFP is used in negotiated acquisitions to communicate government requirements to prospective contractors and to solicit proposals.
- **Requests for Quotes (RFQs):** An RFQ is a solicitation that provides, in exacting detail, a list or description of all relevant parameters of the requirement. RFQs are best suited to commercial products and services.
- **Special Notices:** These notices provide information about Industry Days, other events and other information that, while not captured in one of the other funding announcements, may be relevant to a given opportunity.
- **Multiple-Award Task Order Contracts (MATOCs):** MATOCs were previously used by ONR for acquiring support services. ONR now uses SeaPort-e for acquiring support services.
- **SeaPort-e:** This portal is the Navy's electronic platform for acquiring support services in 22 functional areas, including engineering, financial management and program management.

Please read and follow precisely the instructions for submitting paperwork. Forms must be completed, and formats outlined in the instructions must be followed or the paperwork will be returned. Should you have any questions, please reach out to the contact cited in the instructions.

For more information, please contact

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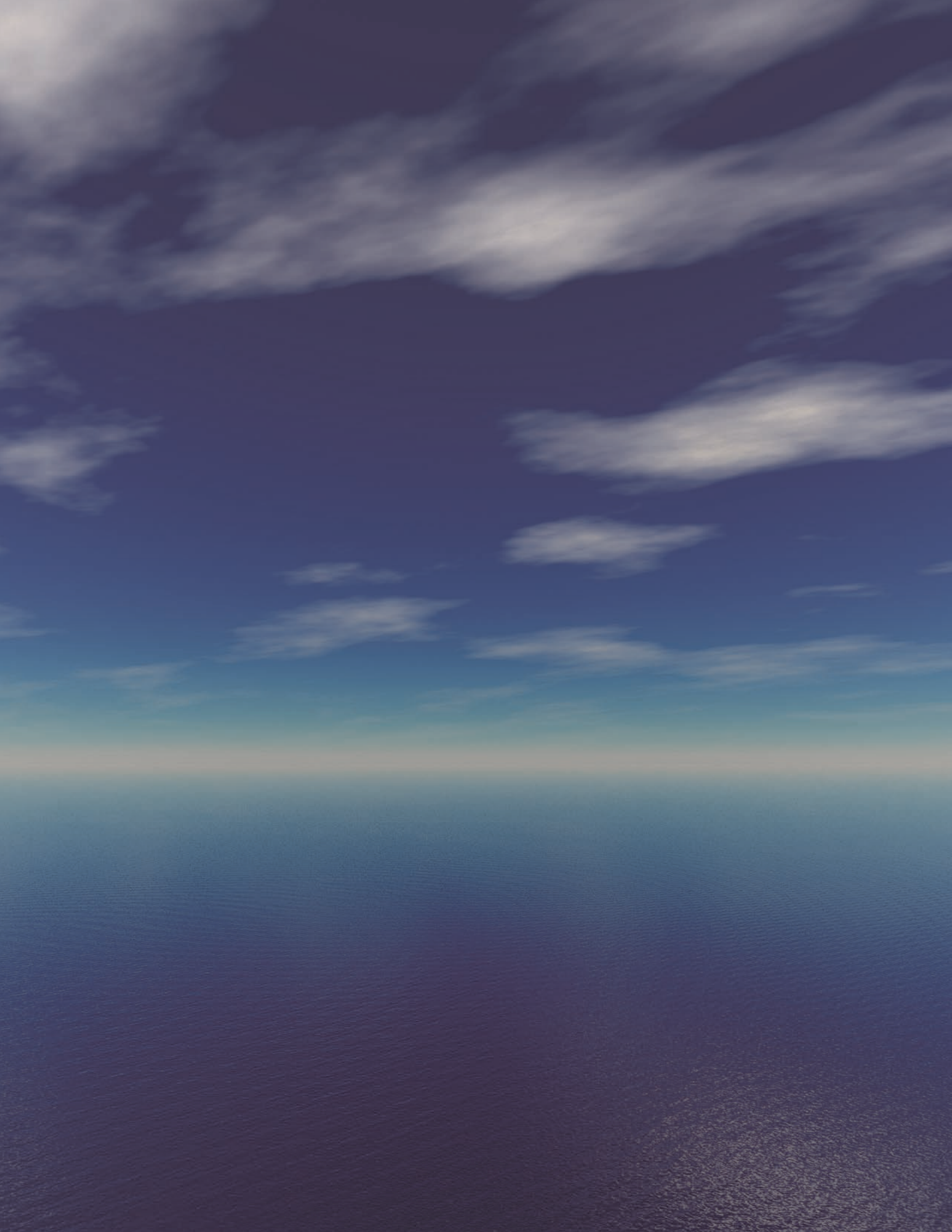
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