Code 35

Naval Air Warfare and Weapons

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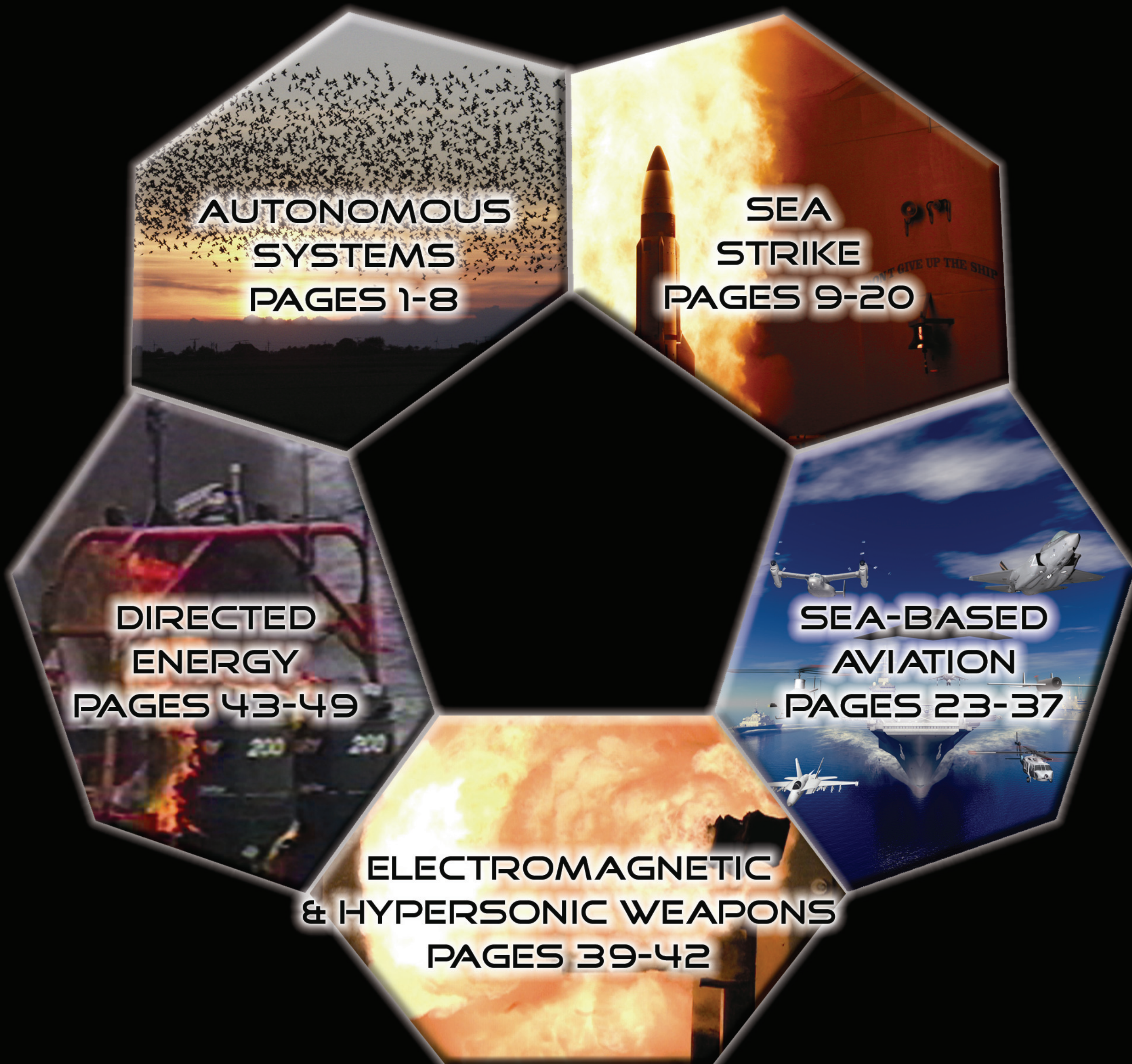
OFFICE OF NAVAL RESEARCH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The Office of Naval Research (ONR) serves as the Department of the Navy's science and technology provider; ONR provides S&T solutions for Navy and Marine Corps needs. Our mission, defined by law, is to "plan, foster, and encourage 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 the 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, the ONR program officer contact information is provided.

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

Michael B. Deitchman
Deputy Chief of Naval Research
Naval Air Warfare and Weapons (Code 35)

INTRODUCTION

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 S&T 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 turns to for addressing emerging technology issues and challenges.

ONR therefore 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, and
- Hedge against uncertainty.

Within ONR there are six Codes 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 Chief of Naval Research to provide overall leadership and management of the DoN'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, sea-based rotary and fixed-wing aviation.

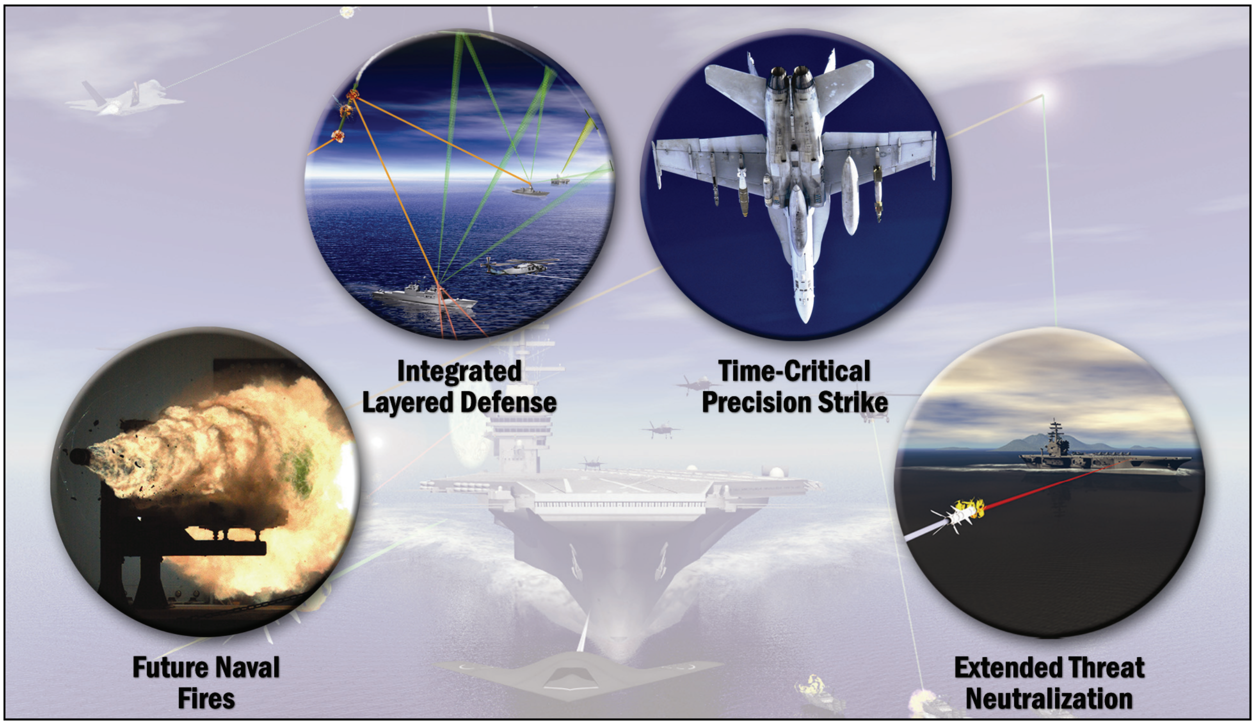
Within these areas, Code 35 investment is further broken down by the maturation level of the area being investigated. There are three basic categories of funding within the Code:

Discovery and Invention 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 5 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 4 to 8 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 3 to 5 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 OPNAV and MCCDC requirements analyses identified in the Navy and Marine Corps strategies.

The following pages detail the individual investment areas. Each page has 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.



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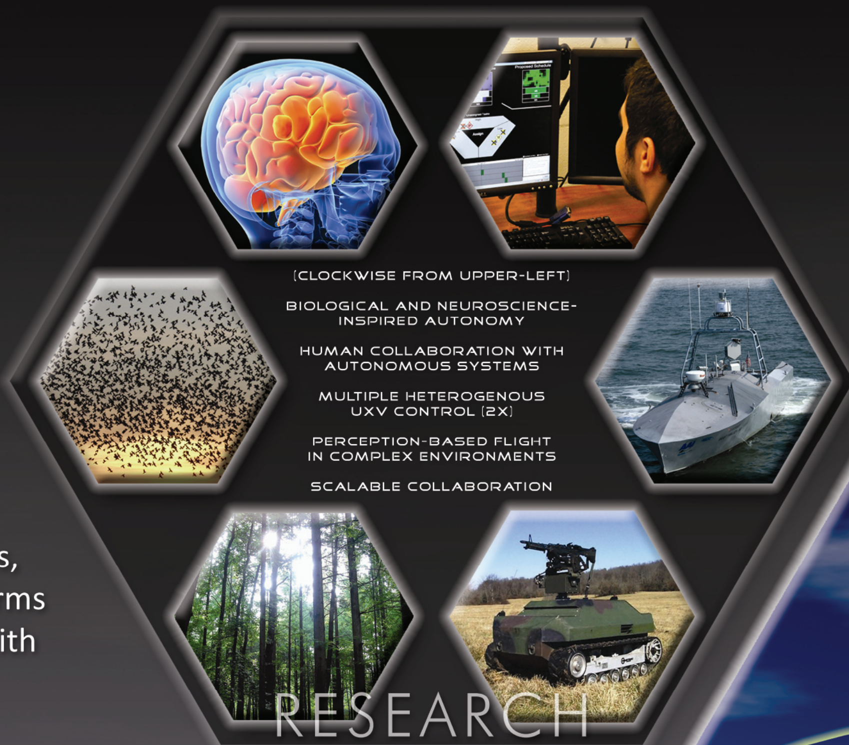
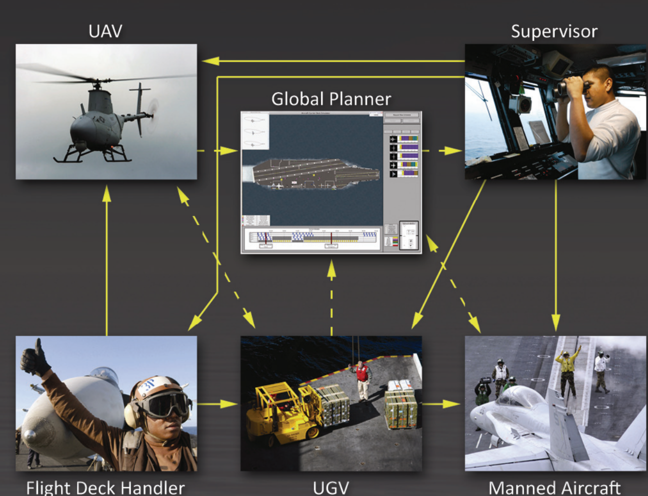


Autonomous operations in many naval domains, for many mission types, and on multiple platforms that can (1) Operate as part of a hybrid force with manned systems and platforms; (2) Maintain survivability through decentralized assets/ redundancy; (3) Reduce the need to place personnel and high-value assets in high-threat areas; (4) Reduce manning and communications requirements; and (5) Expand the operational envelope of Naval forces, provide force multiplication, or replace existing capabilities with less expensive alternatives.



Shipboard Operations

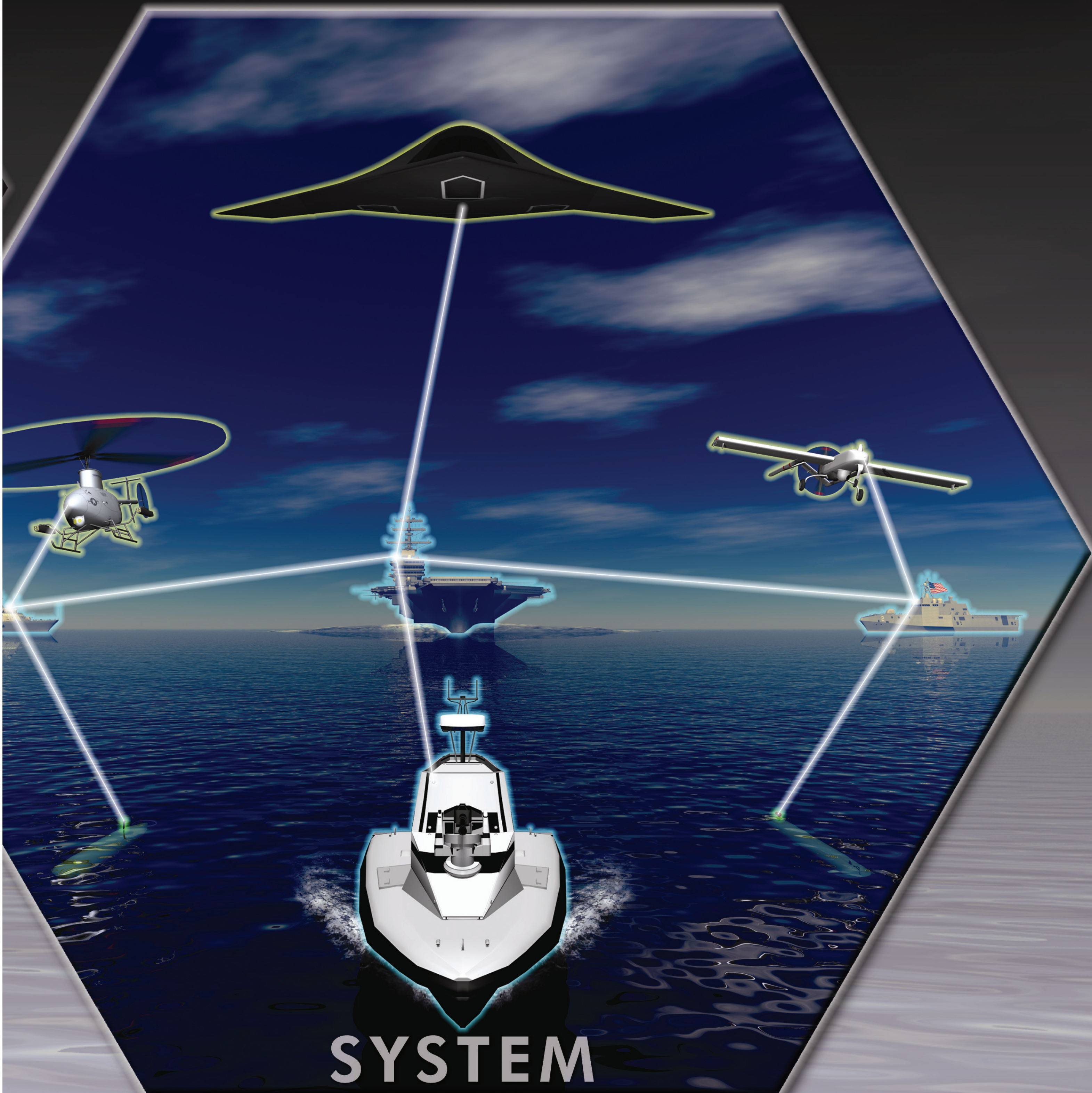
TECHNOLOGIES FOR SAFE AND SUSTAINABLE AUTONOMOUS OPERATIONS; INTEGRATION WITH MANNED AIRCRAFT WITHIN CHALLENGING NAVAL ENVIRONMENTS AND SCALABLE, HIGH-LEVEL CONTROL OF MULTIPLE HETEROGENEOUS, UNMANNED NAVAL SYSTEMS WITH GREATLY REDUCED MANNING.

APPLICATION

E S E A R C H

Code 35

Naval Air Warfare and Weapons



Revolutionary Research . . . Relevant Results

The Adaptive Expert System for the Autonomous Detection of Aviation Mishap Leading Indicators

ONR Program Code 35

At a Glance

What is it?

- The Adaptive Expert System (AES) FNC will provide Naval aviation leadership with an autonomous capability to analyze flight data (1 million+ flight hours/yr) and detect aviation mishap leading indicators in order to reduce the number of human factors related aircraft mishaps through objective intervention.

How does it work?

- AES will develop artificial intelligence algorithms that use neural network and rule-based models for pattern recognition within diverse multidimensional flight datasets.

What will it accomplish?

- Help reduce aviation mishap rates by providing an automated capability for the objective analysis of the myriad flight data collected by Naval aircraft, enabling the identification, trending, and prediction of mishap precursors for which corrective measures can be taken to mitigate risks.

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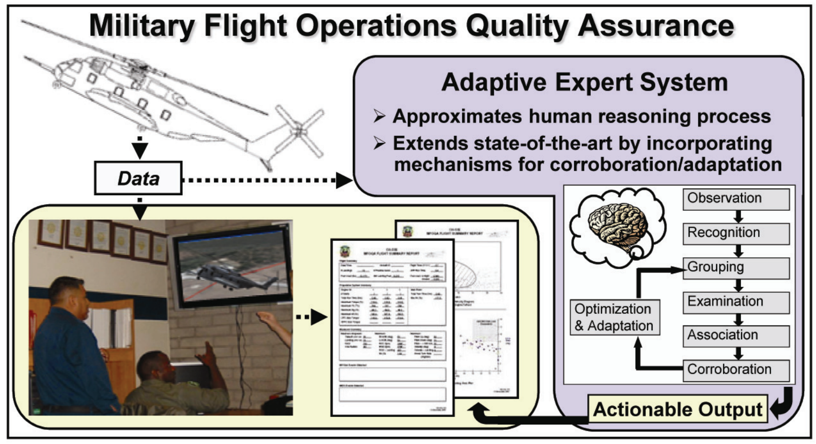
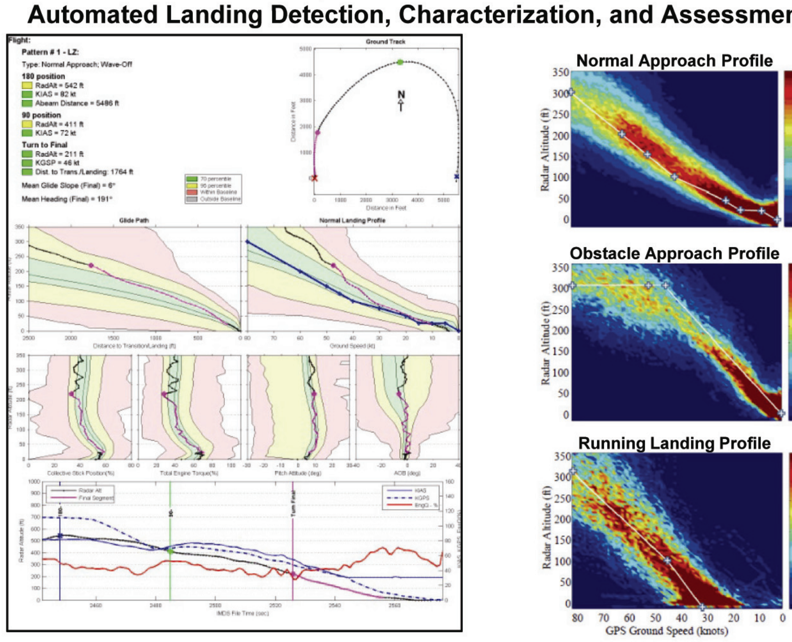


Example AES Functionality:
Automated Landing Detection, Characterization, and Assessment



Manual analyses of the large volume of data from aircraft across the Fleet to effectively detect mishap leading indicators would require an impractical increase in manpower. The Adaptive Expert System (AES) Future Naval Capability (FNC) Product will replicate the human reasoning process with artificial intelligence algorithms that use neural network and/or rule-based models for pattern recognition to identify mishap leading indicators, especially those related to human factors. AES will provide actionable information for risk mitigation to aircrews, squadron leadership, and senior commands, including Commander, Naval Air Forces (CNAF).

Research Challenges and Opportunities:

- Artificial Intelligence/Neural Networks: Extends state-of-the-art by incorporating mechanisms for corroboration/adaptation

ONR Program Code 35

At a Glance

What is it?

- The Autonomous Aerial Cargo/Utility System (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 be 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, be launched 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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The Autonomous Aerial Cargo/Utility System (AACUS) is an Office of Naval Research Innovative Naval Prototype (INP) program with a FY2012 start. The need for AACUS stems primarily from USMC 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 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 more 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 that allows it to be used across different air vehicle platforms.

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

- N10A-T039: Autonomous Landing at Unprepared Sites for a Cargo Unmanned Air System
- N111-070: Scalable Warfighter Interface to Support a 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

Collaborative Anti-Surface Warfare Engagement

ONR Program Code 35

At a Glance

What is it?

- Collaborative Anti-Surface Warfare Engagement (CASE) is an FNC that will apply autonomous group behavior to a salvo of weapons aimed at destroying maritime weapon launch systems. Potential CASE deliverables are broken down into three categories: (1) an off-board, pre-flight, rules based mission planning deliverable, (2) a common architecture and framework for weapon-to-weapon communications, and (3) on-board collaborative logic and algorithms to modify weapon behavior on the fly.

How does it work?

- A salvo of missiles will be launched at an adversary's task group (TG) to destroy their capability to launch weapons at U. S. forces. The adversary TG might have a layered defense capable of destroying many of the incoming missiles. Using CASE technology the missiles would be able to share information about their own positions and the identity, position, and movement of TG ships and their defenses. By acting in concert with each other to prosecute the targets, the incoming missiles could diminish the effectiveness of the layered defenses and increase the probability of survival for each incoming missile.

What will it accomplish?

- CASE will reduce the number of weapons required to successfully engage adversary task groups – at standoff ranges – by increasing the effectiveness and probability of survival for those weapons.

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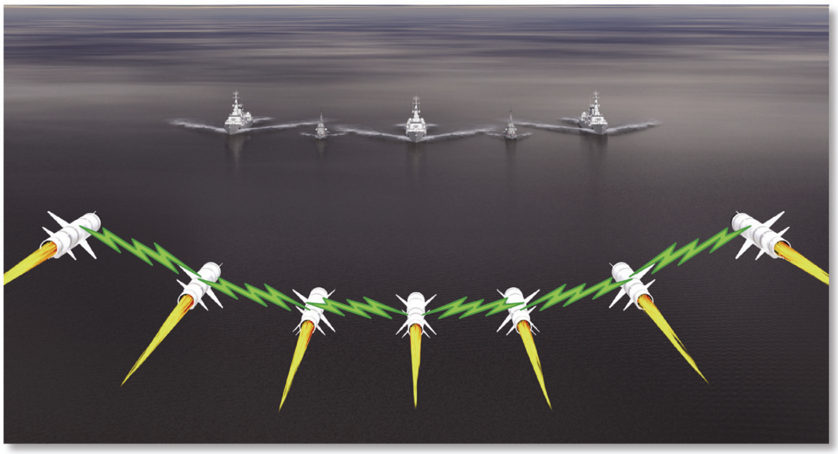

The Collaborative Anti-Surface Warfare Engagement (CASE) Future Naval Capability (FNC) Product will develop shared autonomy among weapons grouped together in a salvo to selectively destroy an adversary's shipboard weapon launch systems. Sophisticated adversaries can expand a range of area denial using surface combatant task groups with advanced air defense and electronic warfare systems. Anticipated adversary improvements in remote sensing and weapons guidance will amplify a potential military anti-access and area-denial (A2/AD) challenge. This A2/AD battlespace drives the need to launch large numbers of weapons from longer stand-off ranges. Weapon salvos implemented with autonomous group behaviors can improve effectiveness against the robust defenses of an adversary's surface combatant task group.

A reduction in the number of weapons needed to engage adversary task groups is one of the goals of CASE. Adversary Task Groups implementing A2/AD strategies are anticipated to have layered defenses to destroy incoming missiles. In order to be successful a large number of missiles must be launched simply to ensure that a few can survive and strike the targets. CASE will use modeling and simulation to generate statistical metrics on the survivability of weapons in a salvo when they autonomously act together in a concerted attack. We will show that by utilizing autonomous group behaviors in the face of a layered defense the probability of missile survivability can be increased. Thus the probability of mission success can be increased, or the same probability of mission success can be achieved with fewer missiles.

CASE will of necessity develop algorithms that enable communications between weapons. Network enabled weapons, which allow in-flight-target updates (called IFTUs) to be received from third party targeters, are on the cusp of being fielded. A successful demonstration of IFTUs transmitted from a third party controller to a network enabled JSOW C-1 recently demonstrated how this capability could enable strikes against moving maritime targets. We propose to take this trend a step further and use existing and/or advanced tactical data links to share information – via J11 messages – among the weapons themselves, when the third party controller is not able to communicate with the weapons.

Research Challenges and Opportunities:

- Identification, modeling and simulation of salvo-level autonomous behaviors that improve weapon survivability
- Extension of the existing J11 message set to encompass weapon-to-weapon communication that enables salvo-level autonomy for both existing and future tactical networks
- Linking captive carry and simulation events to demonstrate a CASE prototype in a relevant environment

Science of Autonomy

ONR Program Code 35

The Science of Autonomy effort addresses critical multi-disciplinary research challenges that cut across different 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/NRL 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 multi-disciplinary 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 UAV "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, (3) biologists, psychologists, and engineers applying behavioral & cognitive models of predator-prey relationships to engineered systems for ISR of large, complex areas by heterogeneous unmanned systems.

Research Challenges and Opportunities:

- Scalable, self-organizing, survivable, organizational structure/hierarchy of heterogeneous UxVs 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

At a Glance

What is it?

- Addresses critical multi-disciplinary 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 of (1) Human Collaboration with Autonomous Systems, (2) Perception and Intelligent Decision-Making, (3) Scalable Distributed Collaboration, and (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, and (5) expand the operational envelope of Naval forces, provide force multiplication, or replace existing capability with a less expensive alternatives.

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Ultra Endurance Unmanned Aerial Vehicle – Heavy Fuel Engine Program –

ONR Program Code 35

At a Glance

What is it?

- The Ultra Endurance Unmanned Aerial Vehicle (UE-UAV) Heavy Fuel Engine (HFE) FNC is developing engine component technologies to help extend the endurance of the air vehicle to at least 12 hours and up to 24 hours.

How does it work?

- This effort will develop detailed finite element models and use performance analysis tools and computational fluid dynamics models to improve scavenging, fuel injection, and mixing.
- Component development and selection focuses on minimizing the engine's weight.
- Testing of prototype hardware will evaluate engine performance and durability.

What will it accomplish?

- The UE-UAV will operate on logistically available fuels, allow for extension of the vehicle endurance capabilities and is suitable for military operational environments.
- In addition to small tactical-sized UAS applications (STUAS), the technology developed and demonstrated will also be suitable for other applications such as portable generators, pumps and other applications the warfighter needs to further reduce the use of volatile fuels in combat environments.

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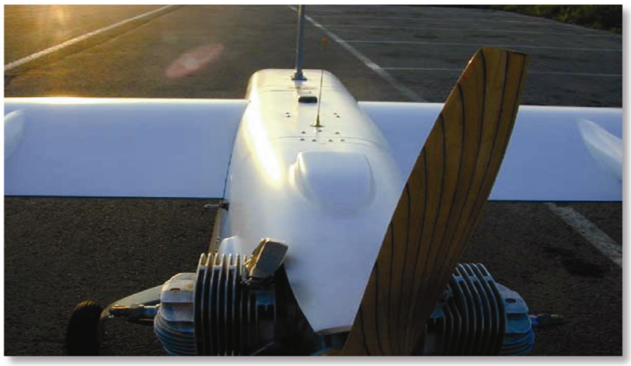
The need for a small tactical UAS heavy fuel engine still exists due to logistics and operational concerns in both maritime and land operations with gasoline. A production small heavy fuel engine will reduce the need for gasoline procurement and storage, allowing the troops to use fuels that are currently available in the logistics system. Heavy-fuels are defined as Diesel, JP-5, and JP-8.

The technology readiness level (TRL) of current state-of-the-art varies considerably from TRL 2 to 5. The Ultra Endurance Unmanned Aerial Vehicle (UE-UAV) Future Naval Capability (FNC) Product recently developed a true small 12 hp diesel engine. It can operate on a broad range of heavy fuels and has a relatively high power-to-weight ratio of 0.75 hp/lb. The time between overhauls is 250 hours, and the engine's life is 500 hours. The applicable Brake Specific Fuel Consumption (BSFC), a measure of its fuel economy, is 0.44 lb/hp-hr. If only achieved individually; power-to-weight ratio, durability, fuel efficiency, or the ability to run on different fuels; would be considered impressive accomplishments, especially considering the use of direct fuel injection within a cylinder bore measuring only ~2 inches. However, the true technical achievement and challenge is to realize all four in the same engine, which is the goal of UE-UAV. Technical areas being addressed include combustion, cycle analysis, and heat management; fuel delivery, atomization, and fuel-air mixing; intake and exhaust systems; power generation systems; mechanical systems; and lastly, controls and engine health management systems.



Research Challenges and Opportunities:

- Efficient combustion with compression ignition in smaller chambers
- Precise miniaturized fuel injection system components
- Design and construction of strong and lightweight smaller engine components (e.g., crankshaft, crankcase)

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 UAS Services to the tactical edge

What will it accomplish?

- Control of large numbers of unmanned systems that can be deployed in great numbers
- Safe and sustainable operations more like manned aircraft on Naval missions and in challenging environments/weather conditions
- Reduced manning for unmanned system operations
- Support a wide range of users from small ships, Marine Corp/SOF small units, maritime patrol aircraft, submarines, etc.
- Increased 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.

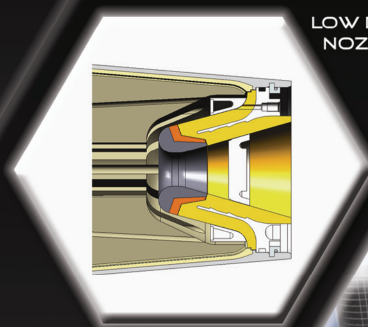
Key research areas include:

- 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" situation awareness for flight deck control and launch operations, as well as local interaction between UVs 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 of 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 UAS 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-UxV collaboration approaches for operations over complex areas and in time-critical applications
- Human interaction and collaboration approaches for managing large numbers of UxVs
- Analytic tools for analysis/V&V that allow for prediction of complex autonomy approaches under realistic assumptions

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.



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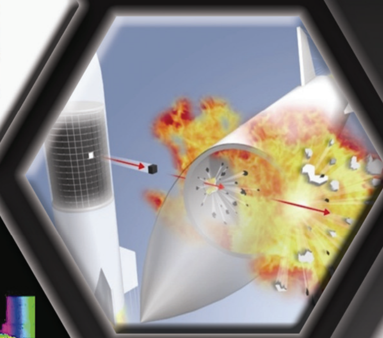
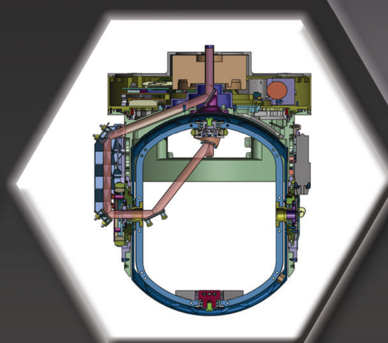
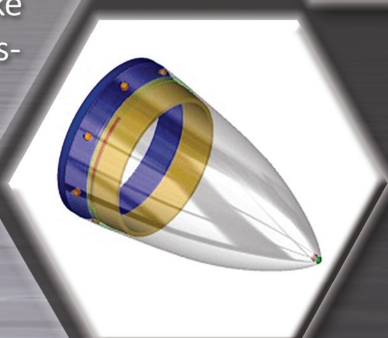


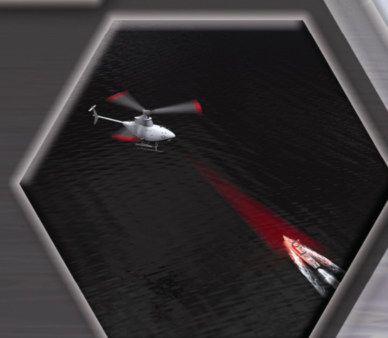
HIGH DENSITY REACTIVE MATERIALS

3D LIDAR IMAGE

RESEARCH







(CLOCKWISE FROM UPPER-LEFT)

ADVANCED ENERGETICS

MULTI-MODE SENSOR SEEKER SCHEMATIC

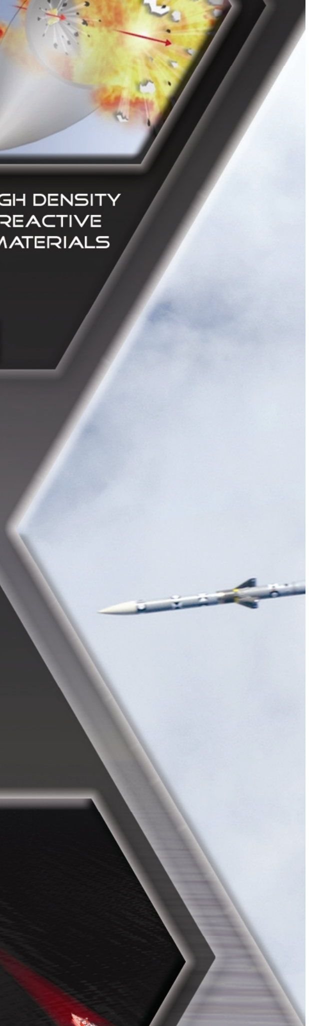
FIRE SCOUT AUTOMATIC TARGET RECOGNITION

LOW-COST MILLIMETER WAVE SENSOR

ADVANCED ROCKET MOTOR

HIGH SPEED RADOME DESIGN

APPLICATION



ESEARCH

Code 35

Naval Air Warfare and Weapons

SYSTEM

Revolutionary Research . . . Relevant Results

Combat Safe Insensitive Munitions (CSIM)

ONR Program Code 35

At a Glance

What is it?

- Insensitive munitions (IM) compliance is a requirement for all weapons in the fleet. Unfortunately, over 80% of the DoD munitions inventory is still non-compliant. CSIM technology will enable reduced sensitivity ordnance items for all classes of fleet weapon systems.

How does it work?

- With an expanded fundamental 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.
- Incorporation of 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 be they during 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. 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.

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 AMRAAM Improvements

ONR Program Code 35

At a Glance

What is it?

- The Counter Air (CA) AMRAAM Improvements FNC will increase the kinematic performance of the AIM-120D medium-range air-to-air missile, thus enabling extended range and decreased time to target.

How does it work?

- The CA FNC will achieve this through a combination of propulsion technologies that include higher energy propellants, highly loaded grain design, composite motor case design, and low erosion nozzles.

What will it accomplish?

- By improving the kinematic performance of existing air-to-air weapon systems like the AIM-120D AMRAAM, CA will ensure the U.S. warfighter maintains the tactical edge in air-to-air engagements against any peer competitor.

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The Counter Air (CA) AMRAAM Improvements Future Naval Capability (FNC) Product is developing a missile propulsion system with substantially improved kinematic capabilities for the AIM-120D Advanced Medium Range Air to Air Missile (AMRAAM). To achieve this, the FNC is developing and integrating four advanced technologies: High Energy Propellants; Highly Loaded Grain; High-Stiffness/Pressure, High Temperature Capable Composite Case; and Low Erosion Nozzles. The kinematic performance enhancements are focused on improving the "no-escape range", "time-to-target", and terminal phase maneuverability.

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 (IHPRPT). Developmental high energy 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" propellant grain, which will allow for higher volumetric loading of propellant within the rocket motor. A lighter weight composite case will be developed to offset the weight delta incurred by the new propellant and grain designs. Lastly, low erosion nozzles are needed to maintain motor efficiencies while enduring greater erosive forces, temperatures, and pressures yielded by the new higher energy propellant and grain designs.

The CA AMRAAM Improvements product is responding to higher kinematic performance requirements for AMRAAM as expressed by the Fleet. These kinematic performance improvements provide the potential to achieve warfighter-defined tactical advantage in the near future. The product will extend the missile's no-escape range, while also decreasing time of flight to target at maximum range and increasing terminal maneuverability for air-to-air engagements. Additional benefits derived from the highly-loaded grain and composite case features are their inherently positive effect on Insensitive Munitions (IM) compliance.

The product is focused on transition to a pre-planned product improvement (P^3I) program for the AIM-120D AMRAAM, but it could also serve as a solid rocket motor technology demonstrator for use in any potential future missile development effort.

Research Challenges and Opportunities:

- Advanced composite case design incorporating increased stiffness and temperature tolerance with minimum thickness
- Advanced propellant formulation and grain design for improved kinematic performance

Counter Air Defense Improvements

ONR Program Code 35

At a Glance

What is it?

- The Counter Air Defense (CAD) Improvements FNC will increase the kinematic performance of the AGM-88B/C/E anti-radiation missiles, thus 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 and HARM, 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 Counter Air Defense (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) and AGM-88B/C High-speed Anti-Radiation Missile (HARM). 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 (IHPRPT). 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 both AARGM and HARM as expressed by the Fleet. In addition to substantially extending the missile's range, the highly-loaded grain/end-burning design will provided an improvement to the missile's Insensitive Munitions (IM) characteristics.

The product is primarily focused on transition to an Engineering Change Proposal (ECP) for 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

Direct Attack Seeker Head (DASH)

ONR Program Code 35

At a Glance

What is it?

- The goal of the Direct Attack Seeker Head (DASH) FNC is to provide an adverse-weather, moving target capability to weapons with a low-cost, dual mode seeker. The DASH seeker intends to add this needed capability to an upgraded Tactical Tomahawk. The modular approach can also potentially support a variety of weapons types such as Zuni rockets, JDAM, etc.

How does it work?

- DASH will combine Millimeter Wave radar with an Imaging Infrared seeker to provide terminal phase guidance to a weapon. DASH will combine all available sensor, navigation, and data-link information into a high quality target solution for use in the weapon target tracker. Using template matching it will correctly confirm the target it was launched against, and establish and maintain track, despite adverse weather conditions.

What will it accomplish?

- Low-cost DASH technology, when coupled with other proposed upgrades, will enable Tomahawk to attack moving and/or relocatable targets in a maritime environment. The mmW radar will facilitate target acquisition in adverse weather and the IIR sensor will enable critical, precise aimpoint selection in the engagement endgame.

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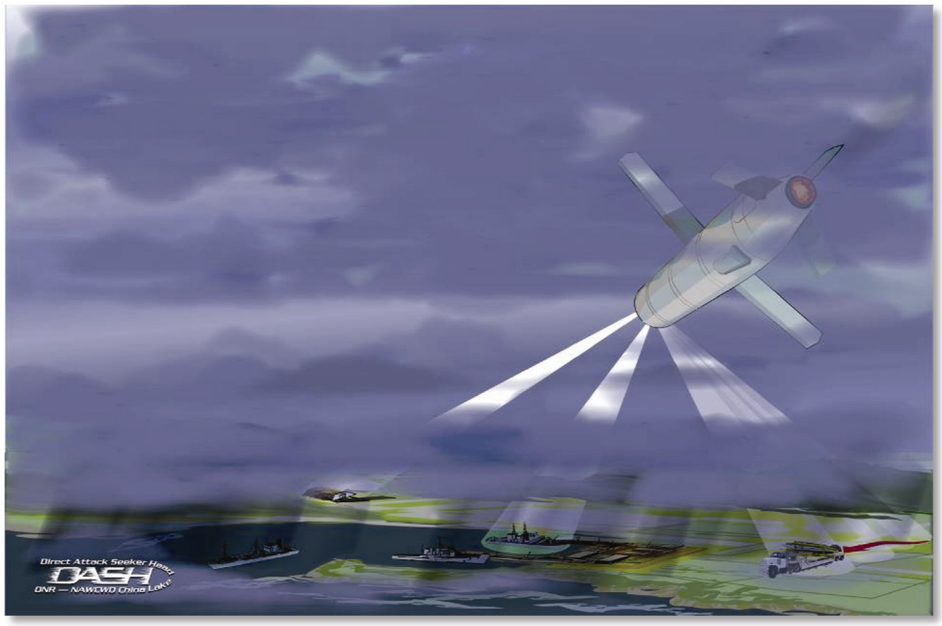

The Direct Attack Seeker Head (DASH) Future Naval Capability (FNC) Product is a low-cost, Imaging Infrared/Millimeter Wave (IIR/mmW) seeker designed to provide terminal guidance to a weapon used against moving or re-locatable (and stationary) targets in adverse weather and varied environments. The key to locating a moving target in adverse weather is the active radar seeker. The IIR seeker comes into play as range closes, providing good angular position to supplement the range information from the radar seeker. The IIR can also refine an aimpoint on the target. Both modes have the ability to support confirmation that the target designated prior to launch is the target being engaged.

The radar was developed with an anticipated low production cost as one of its metrics and the IIR was planned to utilize low-cost, off-the-shelf cameras that rely on uncooled focal plane arrays. The Core Processor has been custom designed for developmental purposes with a complex arrangement of multiple Field-Programmable Gate Arrays and Digital Signal Processors to provide a desired over-capacity. Existing software has been adapted to solve the "single class" classification problem. This is a simple target confirmation approach that keeps seeker cost low.

DASH's modular design approach to system requirements is compatible with the Tomahawk cruise missile and other weapon systems. The dual mode/dual aperture approach provides flexibility in the integration of the seeker. The modular design allows other weapon systems to pull those pieces that are most useful for their applications. For example, the 5-inch diameter radar has cross weapon compatibility, form fit to a MK 80 series fuze-well or suitable for a 5-inch Zuni rocket. The DASH core processor hardware and software design is scalable, providing expansion for additional sensors, as may be needed for a mission customized weapon design solution.

Research Challenges and Opportunities:

- Low-cost radar and IIR seeker components
- Light weight processors with low electrical power demand and rapid data processing capability
- Advanced data fusion algorithms

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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Energetic materials (EM) weapon systems can be a "Game Changer" by increasing the 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 explosives 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:

- 10X increase in performance
- Insensitive Munitions (IM) 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, predicted stabilities and achieve performance goals
- Develop a new class of ingredients that can surpass the oxygen content of AP
- Development of macroscopic mechanical and chemical models; an understanding of molecule dynamics; 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

ONR Program Code 35

At a Glance

What is it?

- The High-Energy Dense Oxidizers (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 ten-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 (ONR) 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 high-energy dense oxidizers 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 g/cc, 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 RDX/HMX, low hydrogen and carbon content, and high oxygen and nitrogen content

High Speed Components

ONR Program Code 35

At a Glance

What is it?

- The High Speed Components (HSC) FNC is a radome development effort that will maximize the operational performance of the AGM-88E Advanced Anti-Radiation Guided Missile, while also 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 AARGM to ensure maximum sensor performance while keeping pace with expected kinematic enhancements.

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The High Speed Components (HSC) Future Naval Capability (FNC) Product is a technology development effort intended to improve the performance of the current AGM-88E Advanced Anti-Radiation Guided Missile (AARGM) strike weapon system and future high speed and time sensitive strike weapons. This effort will deliver a more robust and less expensive radome system. Development will focus on improving high speed performance characteristics with advanced manufacturing processes to produce a superior product at a substantial cost savings.

The HSC effort will investigate materials, designs and fabrication processes in order to develop a radome capable of mitigating thermal and structural loads experienced during extended periods of high speed operations and minimizing surface degradation due to high-speed water impact, while at the same time 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 is focused on developing manufacturing tools and processes for fabricating radomes in the requisite form factor, that the radomes are homogeneous within themselves, and that there is repeatable performance from one radome to the next.

The HSC product is responding to higher kinematic and range performance requirements for AARGM 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 AARGM to withstand increased thermal shock and structural loads associated with advanced airframes and weather encounters, while maintaining suitable electrical properties for enabling accurate weapon guidance to the target.

The product is primarily focused on transition to an Engineering Change Proposal (ECP) to AARGM; 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

Multi-Mode Sensor Seeker

ONR Program Code 35

At a Glance

What is it?

- Multi-Mode Sensor Seeker (MMSS) is a FNC product that will develop and integrate a laser radar (LADAR) sensor with the off-the-shelf BRITE Star II® turret sensor system.

How does it work?

- MMSS will integrate visible, infrared and LADAR within a single sensor turret.
- MMSS will also develop Automatic Target Recognition (ATR) algorithms to process and analyze the sensor data before it is sent to the operator.

What will it accomplish?

- MMSS will demonstrate functionality for target detection, classification and identification against ships, boats, and shore facilities, including ground-based mobile targets.
- A hierarchy of sensor coverage will provide increased stand-off range for Fire Scout and future weapon systems.

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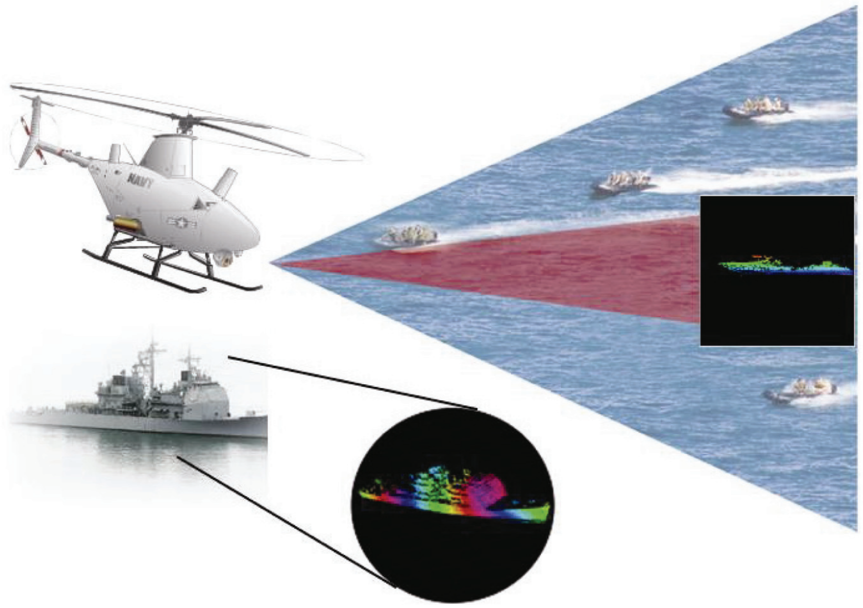

The Multi-Mode Sensor Seeker (MMSS) Future Naval Capability (FNC) Product is developing an eye-safe imaging laser radar (LADAR) sensor to be integrated with high definition (HD) visible and mid-wave infrared (MWIR) imaging sensors into a BRITE Star II® baseline turret. The resulting multi-mode sensor subsystem will be integrated with an Automatic Target Recognition (ATR) subsystem, implemented in commercial off-the-shelf (COTS) hardware, aboard a manned test-bed helicopter for demonstration of product viability. The combining of LADAR with the upgraded EO/IR sensors will enable generation of high-quality three-dimensional (3D) images that will feed ATR algorithms, which in turn will enable processing aboard the sensor platform.

One of the features of this FNC is the adaptation of the turret with a Coudé path, which allows the LADAR and existing laser designator to be taken off gimbal, meaning removed from the turret itself. By utilizing a Coudé path laser beams from both the LADAR transmitter and the designator are generated off gimbal and are transmitted to the turret aperture, thus removing a large heat source from within the turret assembly. Additionally, by removing the lasers from the turret, maintenance and periodic upgrades of the lasers are greatly simplified.

By incorporating the LADAR to generate high-quality 3D imaging, MMSS will provide increased maritime target identification capabilities in both clear and adverse weather. The increased probability of accurate target identification will reduce false alarm rates against friendly or neutral objects. Also, by integrating ATR algorithms with target identification capability and target location data, the workload of the sensor operator will be reduced.

The current transition path of MMSS is to the BRITE Star II® turret, which has been outfitted on several RQ-8A Fire Scout VTUAVs. MMSS is also investigating concepts for its incorporation into the Multi-Spectral Targeting System (MTS-A) system.

Research Challenges and Opportunities:

- Optimization of power generation in erbium-doped yttrium aluminum garnet (Er:YAG) lasers
- Integration of multiple advanced sensors (EO, IR, LADAR) utilizing common optical components
- Advanced ATR capabilities that accurately identify maritime targets at increased stand-off ranges
- High-sensitivity LADAR detector arrays

Sidewinder Mission Optimized Kinematic Enhancement (SMOKE)

ONR Program Code 35

At a Glance

What is it?

- The Sidewinder Mission Optimized Kinematic Enhancement (SMOKE) FNC will increase the kinematic performance and lethality of an advanced short-range air-to-air missile, thus 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 2-pulse end burning rocket motor, high efficiency warhead, 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 U.S. warfighter maintains the tactical edge in air-to-air engagements against any peer competitor.

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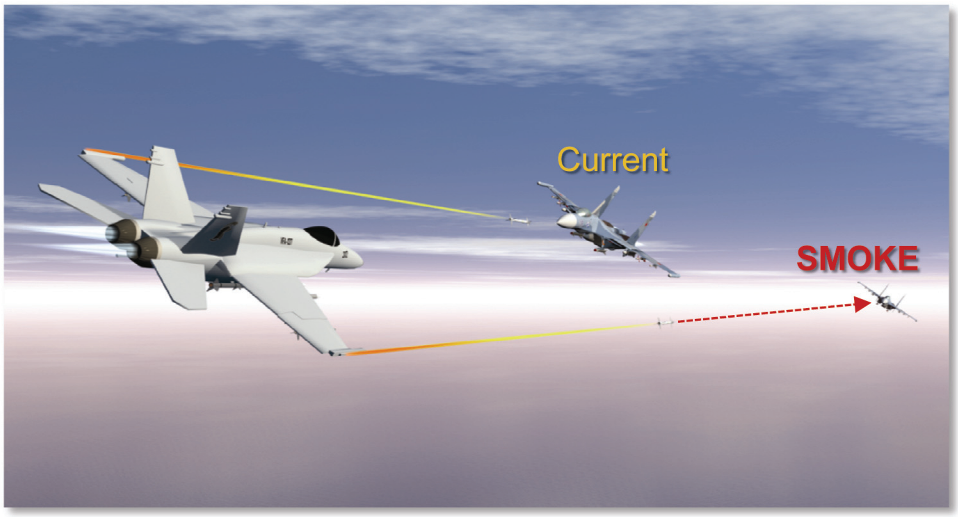

The Sidewinder Mission Optimized Kinematic Enhancement (SMOKE) Future Naval Capability (FNC) Product is developing missile propulsion, warhead and related subsystems for the improved kinematic performance and lethality of future advanced air-to-air missiles. To achieve this, the FNC is developing and integrating three advanced technologies: Two-Pulse End Burning Rocket Motor, High Efficiency Warhead, 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 (IHPRPT). The 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. A high efficiency warhead will be developed to provide reduced volume with equal or greater lethality; the reduced warhead volume will allow for more rocket motor packaging volume. Lastly, 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 also 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, new warhead and IESD will be improvement in Insensitive Munitions (IM) response.

Research Challenges and Opportunities:

- 2-pulse Highly Loaded Grain (HLG) concept configuration with 2-pulse survivable Thrust Vector Control (TVC)
- IM compliant, precision digital detonation warhead
- Distributed and command transmission fuze initiation methods

At a Glance

What is it?

- The Strike Accelerator FNC 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 ID 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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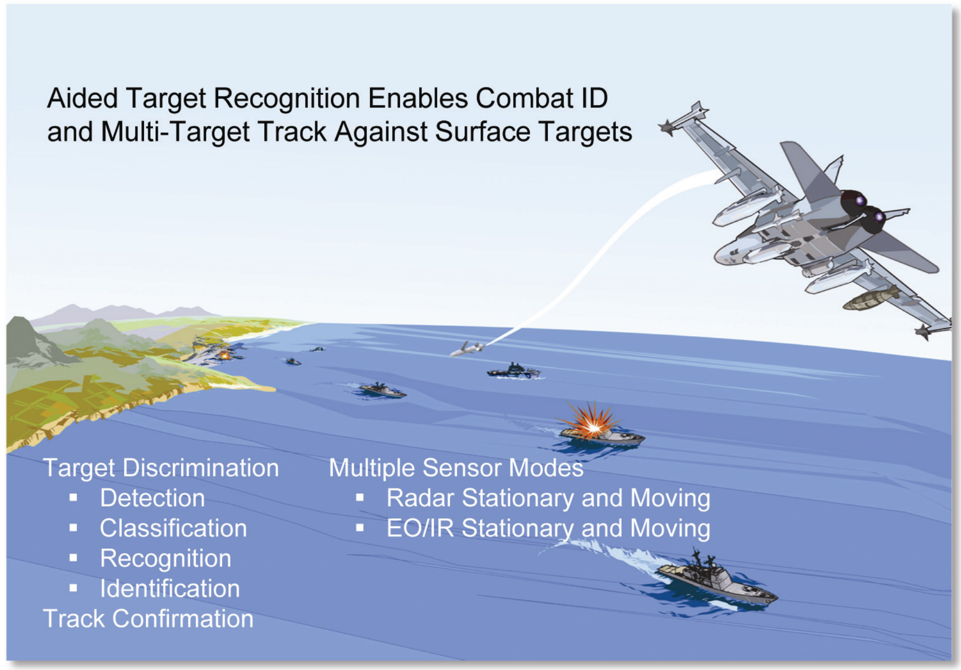


The Strike Accelerator Future Naval Capability (FNC) Product will develop and mature an Aided Target Recognition (AiTR) system to provide F/A-18 aircrews with a high decision rate and high classification/recognition/identification confidence against adversary surface combatants. When complete, this capability 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 ID 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 (AESA) Radar and Advanced Targeting Forward Looking Infrared (ATFLIR) optics pod. Strike Accelerator's advanced AiTR algorithms and multi-look, adaptive, and hierarchical architecture 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.

Should discrimination at all levels fail to pass a quality test, this constitutes a no-decision event and (by design) no information is passed on to the aircrew. 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

ONR
Naval Air Warfare and Weapons Milestones

1940s

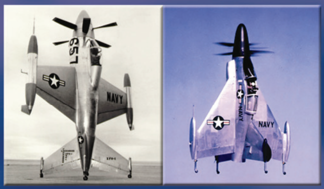
Piasecki HRP Rescuer
Introduction of the Tandem Helicopter

ONR Founded 1946

1950s

Kaman HTK-1K (L)
First Unmanned Helicopter
Bell HSL Model 61 (R)
First All-Weather ASW Helicopter

Hiller YROE-1 Rotorcycle
Single-Seat, Portable Helicopter



Lockheed XFV-1 (L)
Experimental Tailsitter Prototype
Convair XFY-1 Pogo (R)
Experimental Tailsitter Prototype

1960s

Gyrodyne QH-50 DASH
First Operational Unmanned Helicopter

Piasecki VZ-8P SeaGeep
Ducted Rotor, Flying Jeep Prototype

Piasecki 16H-1A Pathfinder II
Experimental High-Speed Helicopter

1970s

McDonnell Douglas/BAE AV-8B
Second Generation Operational V/STOL Aircraft

Canadair/General Dynamics CL-84
U.S. Navy Experimental Tiltwing V/STOL Aircraft

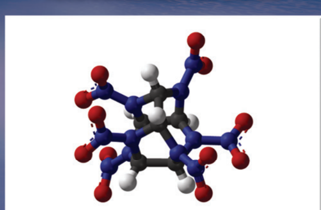
German VAK 191B
Jet V/STOL Strike Fighter

Sikorsky XH-59A
Experimental Compound Co-Axial Rotor with Auxiliary Turbojets

1980s

Bell XV-15
Experimental Tiltrotor
VTOL Aircraft

TARPS
Tactical Airborne
Reconnaissance Pod System



CL-20 First Synthesized
First major breakthrough since
HMX was synthesized in 1930

Bell Boeing V-22 Osprey
First Operational V/STOL
Tiltrotor Transport

1990s

Lockheed Martin X-35B
Multi-Purpose Experimental
Fighter Demonstrator

AIM-9X Sidewinder
Heat-Seeking, Short-Range
Air-to-Air Missile

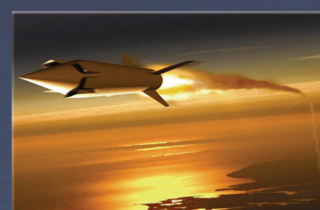
AIM-120 AMRAAM
Advanced Medium-Range
Air-to-Air Missile

Energetic Materials

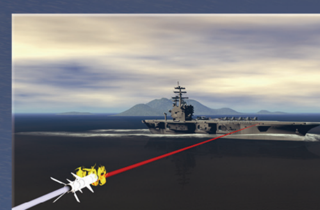
BGM-109 Tomahawk Upgrades
Long-Range, All-Weather, Subsonic
Cruise Missile

2000s

Science of Autonomy



Hypersonic / Supersonic
Airframes



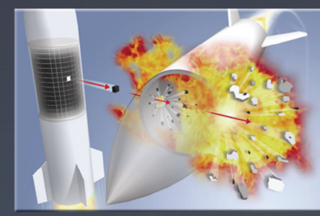
Free Electron Laser

Turbine Engine Technologies

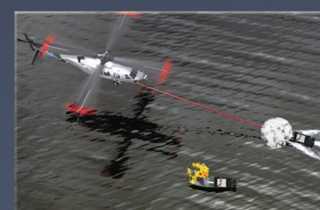
Piasecki X-49A "SpeedHawk"
Experimental High-Speed
Compound Helicopter

2010 & Beyond

World-record setting
33 MJ EMRG Shot



High Density Reactive Materials



High Energy Fiber Laser

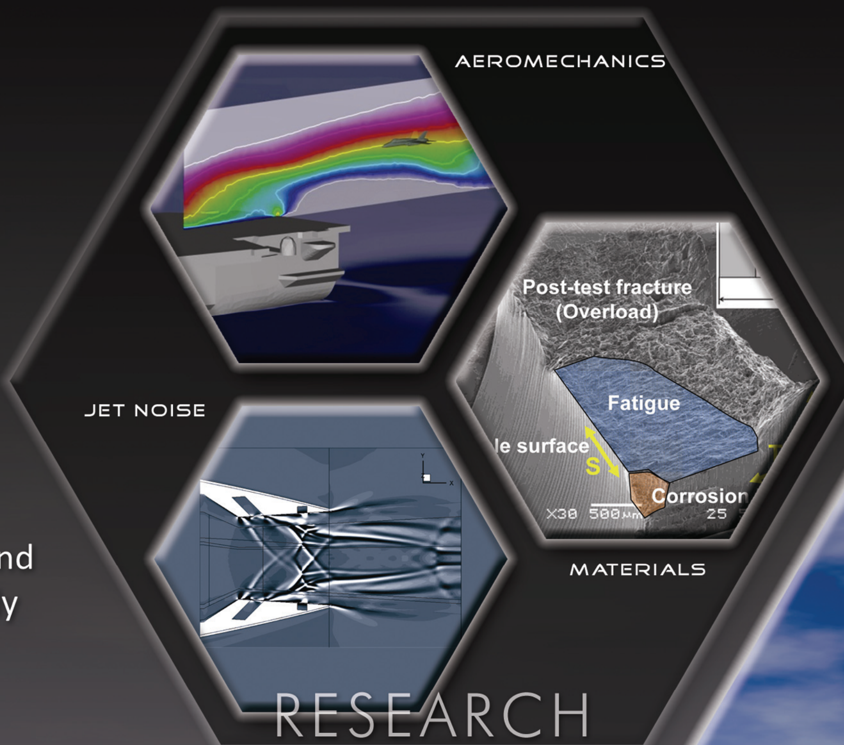
Multi-Mode Sensor Seeker

Maritime Laser Demonstration
April 2011, USS *Paul F. Foster*

Sea-Based Aviation:
A National Naval Responsibility

V A L   R E S E A R C H

O F F I C E   O F   N A V A L   R E



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.

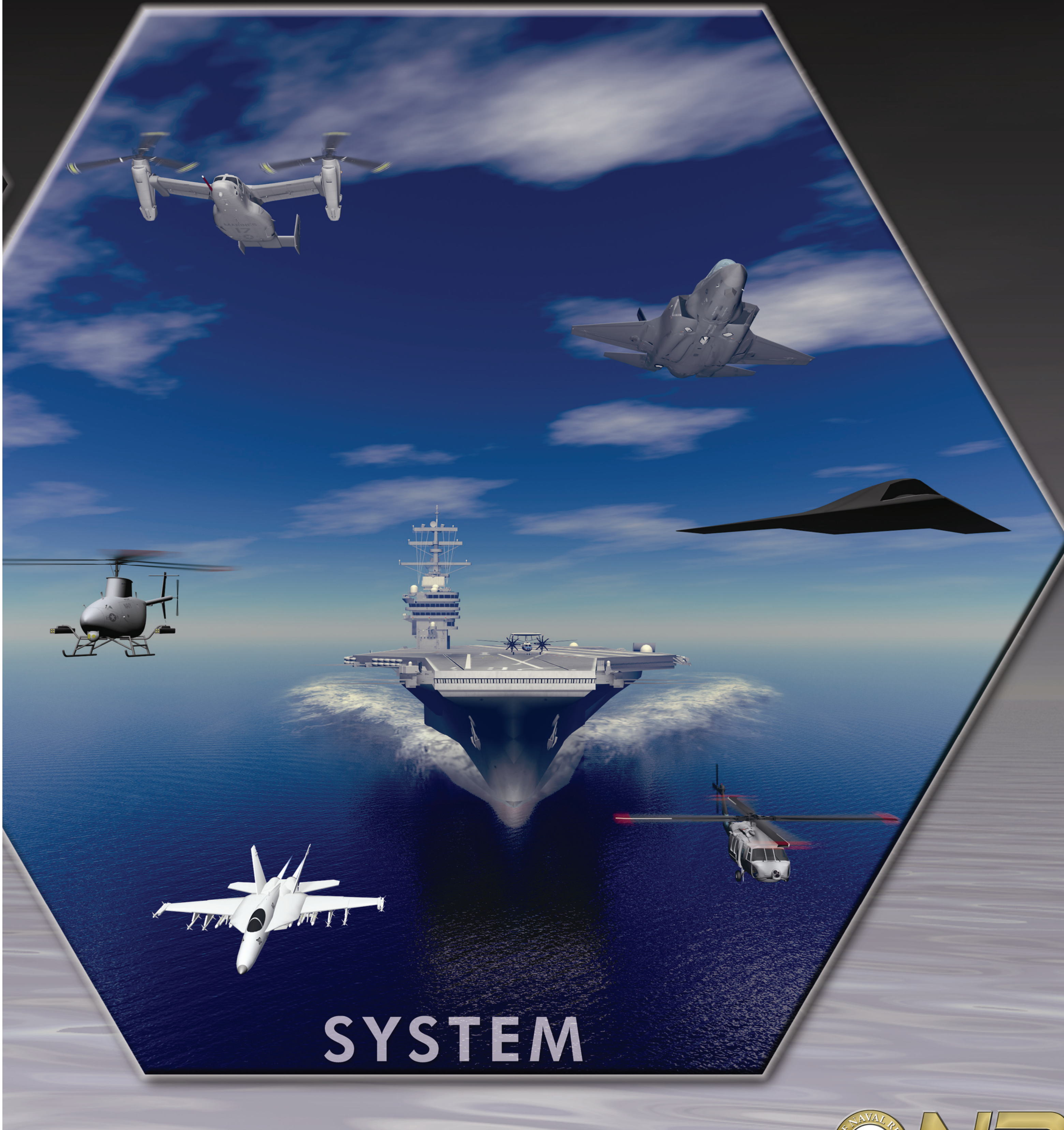
Sea-based aviation addresses science and technology in multiple disciplines including aeromechanics, guidance navigation and control, structures, materials, jet noise reduction and propulsion.

(CLOCKWISE FROM UPPER-LEFT)
AEROMECHANICS
GUIDANCE NAVIGATION & CONTROL
STRUCTURES
MATERIALS
JET NOISE REDUCTION
PROPULSION

E S E A R C H

Code 35

Naval Air Warfare and Weapons



ONR

Revolutionary Research . . . Relevant Results

At a Glance

What is it?

- Many research areas – uniquely important to the DoN – are not addressed by research investments from the other Services.
- On behalf of the Department of the Navy, the Office of Naval Research (ONR) must ensure continuing U.S. leadership in these vitally important scientific and technical disciplines.

How does it work?

- In consultation with experts drawn from the National Academies and elsewhere, ONR identifies National Naval Responsibilities. 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 in the area
  - 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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Sea-Based Aviation (SBA) is the operation of aircraft to, from and on sea-based platforms. SBA, while traditionally thought of in terms of operations from aircraft carriers, can be more broadly associated with many sea-based platforms and concepts to include:

1. Operations from large deck ships (e.g., aircraft carriers, Landing Platform Docks, Landing Helicopter Docks) with substantial deck space for extensive large-scale air operations.
2. Operations from small deck ships (e.g., Guided Missile Destroyers, Littoral Combat Ships, etc.) normally configured to handle only rotary-wing aircraft.
3. Operations from ships without dedicated takeoff/landing platforms for manned aircraft. Such operations include ships that could support Unmanned Aerial Vehicles launched by catapults, launch tubes, etc.
4. Self-deployed, sea-based aircraft concepts (e.g., seaplanes, flying boats, wing-in-ground-effect aircraft, submersible aircraft concepts and other hybrid air/sea concepts).
5. Operations from other sea-based platforms, e.g., submarines, submersible and semi-submersible platforms or unmanned vehicles, mobile offshore base concepts, buoys with air vehicle components and unmanned sea-based platforms.

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

- Structures
- Propulsion
- Propulsion Integration
- Ship Interfaces & Operations
- Avionics/Electronics
- Air Refueling
- Aerodynamics
- Guidance, Navigation & Control (GNC)
- Design Tools
- UAV launch and recovery; autonomy, high tempo operations
- UAV operations from non-aviation ships

The maritime role of the naval aircraft is complex, demanding, and unique. The 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 mission tasks.

Research Challenges and Opportunities (discussed over the next few pages):

- Airframe Structures and Materials
- Air Vehicle Technology
- Propulsion

ONR Program Code 35

At a Glance

What is it?

- Design, materials selection, fabrication, inspection and maintenance related to air-vehicle structures. Airframe materials and structures Science & Technology offers opportunities in 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 directed 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 labs, and the Navy Research Lab. Close coordination with the Air Force Research Laboratory (AFRL), the Army Aviation Command, and the Defense Advanced Research Projects Agency (DARPA) helps to 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 particular 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, and
  - High-mechanical loads/light-weight structural requirements for shipboard launch/recovery.

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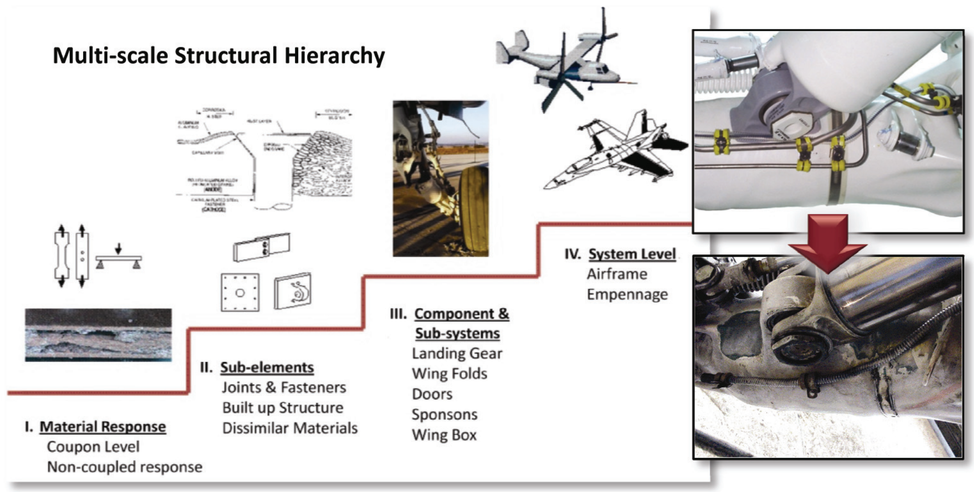


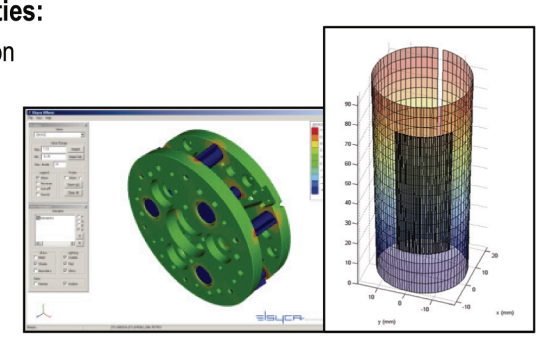
Naval Aviation is in the forefront of the Navy power projection mission, including our ability to successfully meet development, operational performance, readiness, and affordability requirements. There are additional needs for the knowledge, skills and expertise required to support the research, engineering, design, production, acquisition, and sustainment of Naval aircraft. ONR and NAVAIR are addressing these S&T needs in a fully integrated, collaborative approach between the science and technology, the engineering and sustainment, and the acquisition communities, as well as an optimum arrangement for successful, relevant, and efficient technology transitions. Sea-Based Aviation demands structural and materials requirements and challenges that are not the same as land-based aviation requirements. A robust program which sustains a focused aircraft S&T activity is critical to the health of naval aviation.

The ONR Sea-Based Aviation strategy 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 trade-off decisions, and enable reduced weight and/or increased range/payload without reducing durability. The SBA Structure and Material program consists of two thrusts – Advanced Airframes and Durable Aircraft. These two thrusts cover 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 development, and modeling complex load/degradation interactions.

Applied research programs are currently being initiated 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/Light-Weight Structural Materials
- Advanced Structural Concepts
- Materials Degradation/Corrosion
- Structural Protection and Maintenance



Sea-Based Aviation National Naval Responsibility
– Air Vehicle Technology –

ONR Program Code 35

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, sub-systems, and modeling, simulation, and analysis tools.

How does it work?

Core investments include:

- Advanced, efficient Computational Fluid Dynamics (CFD) 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 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 to landings 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 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. During FY 13-14, focus will shift towards research task areas identified under the recently designated Sea-Based Aviation National Naval Responsibility (NNR).

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 –

ONR Program Code 35

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 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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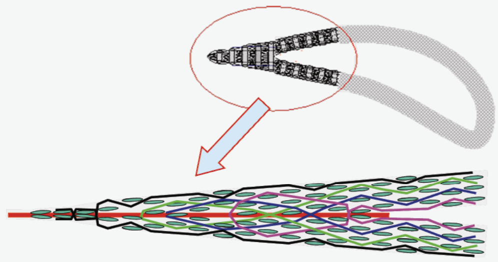
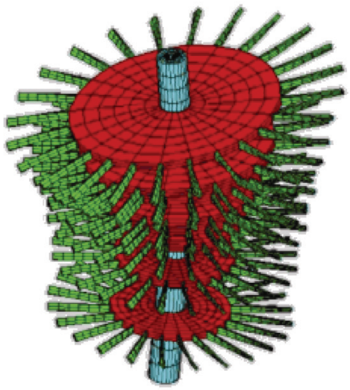


Complex-Shaped Woven 3-D CMC Structures

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



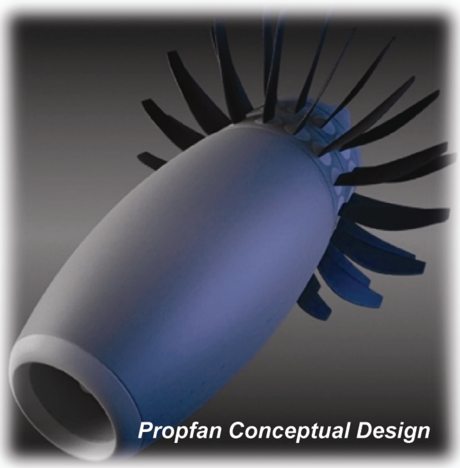
Advanced rotordynamics modeling - primary bend mode -

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 affect 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 1) Energy-Efficient Processes and Subsystems, 2) Turbomachinery and Drive Systems with Enhanced Maintainability, 3) Jet Noise Reduction for TACAIR, 4) Hot-Section Materials and Coatings and 5) Small UAV Propulsion. Along with the other focus areas under the SBA NNR, the Propulsion focus area will also support the infrastructure necessary to maintain technology 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
- Propeller/propfan technologies to reduce noise and provide for high power to weight
- 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 dBA 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
- In-situ repair technologies for FOD-susceptible components
- Small UAS propulsion weight reduction
- Electronic fuel injection system improvements



Propfan Conceptual Design

Advanced Rotor Blade Erosion Protection System

ONR Program Code 35

At a Glance

What is it?

- The Advanced Rotor Blade Erosion Protection System FNC product will develop and deliver an advanced rotor blade leading edge erosion-resistant material system.

How does it work?

- This FNC will conduct the analysis, development, risk reduction and demonstration of advanced rotor blade leading edge erosion-resistant material systems.

- Various materials will undergo sand/rain erosion testing and analysis. Materials will also be evaluated for thermal conductivity, structural characteristics, manufacturability and repairability.

What will it accomplish?

- Increase prop rotor blade mean time between removal as measured by the ability of the protection system to prevent blade removal from sand/rain erosion or damage caused by other environmental effects.

- In addition, the protection system will reduce any maintenance burden by reducing the mean time between repair.

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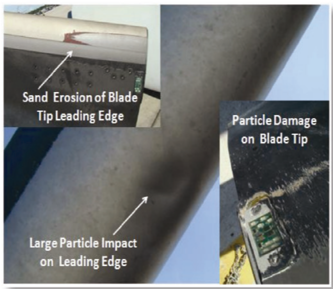
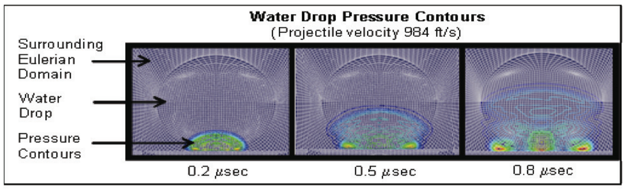
About 71% by weight of the mixture are coarser than 30-mesh. A large number of them are actually larger than 1" in length. These are more like gravels or pebbles with very sharp edges.



Rain: Water hammer pressure/ shock waves



The harsh environments of current operational theaters have significantly increased the impact damage and erosion of prop rotor blades. The erosion degradation of rotor blades and subsequent repair/replacement has become a logistics and maintenance burden for the U.S. Armed Forces when deployed in a desert environment.

Current rotor system blade protection methods (tapes and paints) are largely ineffective and have exhibited widespread rain and sand erosion to substrate within short periods of exposure.

The proposed protection system will be evaluated for its mechanical and thermal properties; its resistance to sand/rain erosion and foreign object damage (FOD) impact; its resistance to solvents, oils, fuel, ultraviolet light, and fungus; as well as its repairability. Final maturation of the leading candidate material solution will include icing-ice protection system analysis, aerodynamic performance (blade dynamic) analysis, material qualification, and subscale whirl/sand-rain testing.

Research Challenges and Opportunities:

- Materials research including hybrid ceramic/polymer-matrix composites; tungsten-carbide -cobalt or -nickel (W-C-Co or W-C-Ni); and hard, flexible metal/ceramic nanocomposites
- Rotorcraft aeromechanics

www.onr.navy.mil

ONR Program Code 35

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 Direct Digital Manufacturing (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 (IPS) to ensure consistent part microstructure and porosity.
- A heuristic Accelerated Certification Technology (ACT) 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% lower part cost
- 2-7 weeks vice 8-28 months to acquire out of production parts
- Conserves strategic material, lowers energy consumption, and significantly reduces the needed logistic foot print
- Enables the design/manufacture of far more structurally efficient future weapon systems

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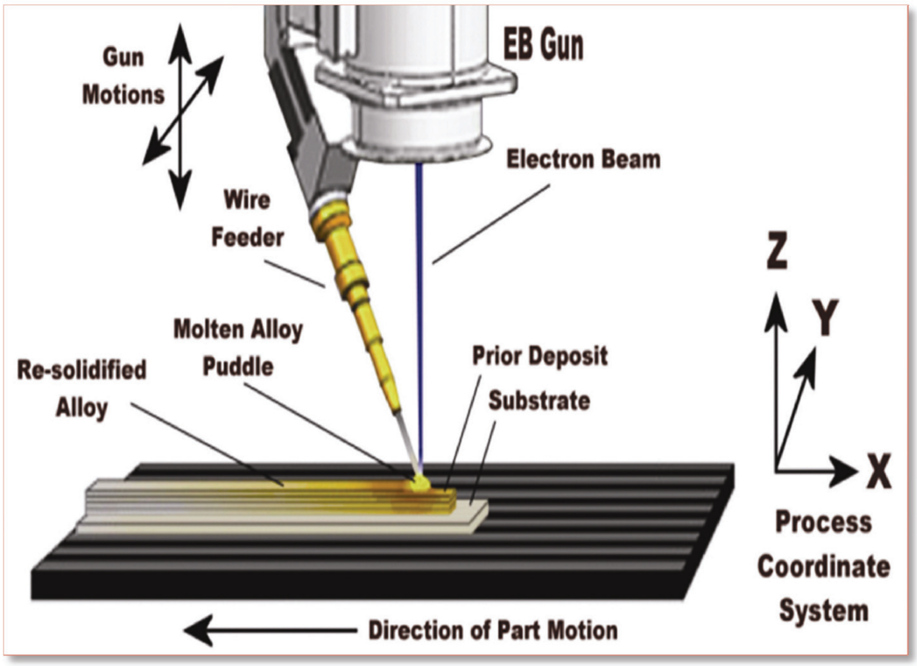

Increasingly the Navy's inventory of aircraft is being extended in service beyond the design life. As a result, components fail that were never expected to be repaired or replaced. With no replacements available in the supply system, long lead times develop for the repair or manufacture of the replacement items. During those 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%. 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 3D; currently limited to planar capability
- Develop new sensor algorithms to measure through-thickness part temperature; no systems 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

ONR Program Code 35

At a Glance

What is it?

- Dynamically Reconfigurable Data Architectures Small Business Innovative Research (SBIR) 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 condition based maintenance, operational availability and asset life. Accessibility of fleet wide parametric data is a critical enabler for effective engineering analysis.

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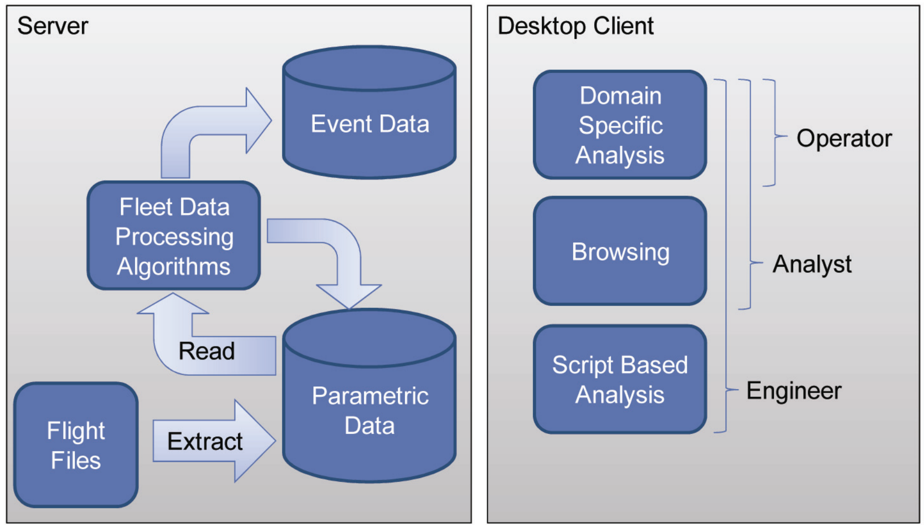

Department of Defense (DoD) Instruction 4151.22 directs the application of CBM+ to optimize material availability and costs, maintain mission capability and improve asset health management. Effective application of CBM+ requires:

- 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 to 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 to them 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 don't lend themselves well to being able to be 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

Integrated Hybrid Structural Management System (IHSMS)

ONR Program Code 35

At a Glance

What is it?

- The IHSMS FNC 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 CG
- 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 Integrated Hybrid Structural Management System (IHSMS) Future Naval Capability (FNC) 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 TRL 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)

ONR Program Code 35

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 the technologies in support of the Warfighter and the Community.

How does it work?

Guided by a Government-wide panel of S&T 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 MIL/ANSI 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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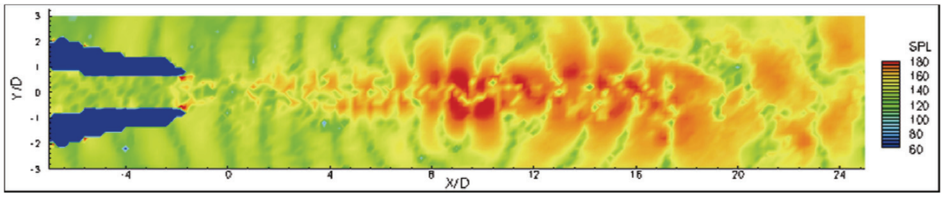

The JNR Project is part of ONR's Noise- Induced Hearing Loss (NIHL) Program. As a result of the health and environmental impacts of noise on multiple services within DoD and the interest in noise for many agencies within the Government, the Navy convened a panel of Government-wide noise experts in 2010 to guide the JNR Project. The JNR S&T Panel consists of members from the Navy, Air Force, NASA and the FAA and includes jet noise researchers, aircraft program representatives, and technology experts. In fiscal year 2010, initial funding was allocated to support the basic program structure and for the two main tasks given high priority; developing a physics-based understanding of jet noise and developing a standard facilitating high-quality, supersonic, jet-noise measurements. In fiscal year 2011, a Basic Research effort focusing on the development of tools for the active control of hot, supersonic jets was initiated. The Basic Research effort 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 Project continues to support 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 continue to work across the community to identify technology transition opportunities and provide guidance on improved approaches for low-noise designs. The Project continues to examine 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

ONR Program Code 35

At a Glance

What is it?

- Laser-Based Helo Landing Aids (LBHLA) will enhance helicopter pilot situational awareness in visually degraded environments (VDE).
- Helicopters are extremely susceptible to brownout in dusty landing zones (LZs), where the pilot can lose sight of the ground or obstructions while hovering.
- LBHLA will provide the pilot with a very accurate, real-time laser generated image of the LZ, plus height-above-ground, drift rate/direction over the ground and relative wind.

How does it work?

- The LBHLA program will utilize a Class 1M eye-safe, dust-penetrating (DUSPEN) Light Detection and Ranging (LIDAR) transceiver to generate true 3D real-time images in and around the landing zone.
- The DUSPEN LIDAR approach is capable of penetrating heavy particulate clouds (e.g., dust, rain, fog, snow) generated by the helicopter rotor downwash during landing, or due to weather, ground vehicles, or concurrent helicopter operations.

What will it accomplish?

- The LBHLA effort will increase the ability of war fighters to conduct vital helicopter operations in visually challenging environments, both day and night.

Point of Contact

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The Laser-Based Helicopter Landing Aids (LBHLA) Future Naval Capability (FNC) Product is one of two technologies within the Helicopter Low-Level Operations (HELO) Enabling Capability that is focusing on solving the problems associated with helicopter brownout. LBHLA was a FY09 FNC new-start program designed to develop the technologies for real-time landing zone (LZ) imaging and obstacle detection. The current phase of the program is focused on system component integration and flight test. The final flight demonstration will provide real-time LZ imagery, thus enabling a pilot to detect obstacles and uneven terrain that would threaten the aircraft while landing in visually degraded environments (VDE). The objective is a system that is compact, lightweight and rugged.

The capability need for the LBHLA program is to provide significantly improved landing capabilities and increased survivability for current and future assault and heavy lift rotary wing aircraft that are deployed from the sea base to operate in austere, forward areas. This program will support and improve the safety and efficiency of landings into unprepared LZs by:

- Mitigating risks associated with landing in unimproved zones with no visual ground reference;
- Allowing aircrew the capacity to land vertically from low altitude hover with zero external visual cues;
- Providing symbology to the pilots to facilitate a safe landing, and to enable precision hover capability for hookup and delivery of sling loads, day or night, in zero visibility conditions; and
- Providing surface feature mapping for added situational awareness, understanding and obstacle detection in dusty LZs or where visual cues are unavailable.

Research Challenges and Opportunities:

The LBHLA program will open opportunities for laser research and technology development in four key areas:

- Non-mechanical laser steering or scanning methods
- Advanced rapid scanning receiver technologies
- Advanced techniques for sensing through dust and other obscurants
- Miniaturized, lightweight and ruggedized laser components

Sea-Based Automated Launch and Recovery System

ONR Program Code 35

At a Glance

What is it?

- 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 PS-RN inputs and guide the aircraft to a precision approach and landing.

What will it accomplish?

- Enable highly reliable, full envelope sea-based UAS 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

Point of Contact

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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 UCARS radar-based recovery system to provide precision ship-relative navigation (PS-RN) for its fully automated landings. The Unmanned Combat Air System Demonstration (UCAS-D) program will in the near future demonstrate 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 in order 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 addition to sensor-based PS-RN systems, guidance could be provided by ship-based displays coupled with pilot displays (e.g., superposition of head-up display symbology over a stabilized ship reference 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. 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 could also 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 Precision Ship-Relative Navigation systems performance in:
  - Degraded weather
  - High deck motion
  - EMI/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

ONR Program Code 35

At a Glance

What is it?

- The Turbine Engine Technology (TET) Enabling Capability (EC), Future Naval Capability comprises two products, Materials and Engines. These products will deliver advanced materials, designs, components and integration technologies for turbine engines leading to improved cost, efficiency, and performance of turbopropulsion for naval aviation.

How does it work?

- Under the Materials Product, applied research and development efforts will be conducted in materials and processes for selected hot-section turbine engine components.
- Under the Engines Product involving engine advanced technology demonstrations, components will be designed using the outputs from the Materials Product as well as other advanced aero/structural concepts developed within the Engines Product, then fabricated, integrated, and tested on demonstrator engines.

What will it accomplish?

- Once tested, these technologies will be ready for incorporation into advanced turbine engines such as those for the F-35 Lightning II.
- The TET EC, by coordinating and integrating the Materials and the Engines Products, will result in significant increases in capability and decreases in operational and sustainment costs which will facilitate attainment of the Navy's performance and affordability goals for the F-35.

Points of Contact

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As military threats and tactics continue to evolve rapidly, operational and sustainment requirements for aircraft and the engines that power them continue to increase as they are called upon to provide America's first response against many traditional and non-traditional threats. Modest improvements in propulsion capability can result in large improvements in system capability and significantly lower cost of ownership. ONR is interested in identifying and maturing advanced integrated propulsion system technologies in support of legacy, emerging and potential future Marine Corps and Navy aviation applications.

The TET Enabling Capability was initiated in FY08. The TET EC's primary metric is reduced cost of operations. However, overall increased capability in terms of performance, reliability and efficiency are of significant interest. The activities contribute directly to joint DoD products and represent the majority of the Department of the Navy's contribution to the Versatile Affordable Advanced Turbine Engine (VAATE) initiative. The efforts are focused primarily on identifying and maturing technologies for engines powering the F-35 Lightning II aircraft. The technologies address challenges unique to F-35 naval variants.

Warfighter Payoff:

The Warfighter Payoff from the TET EC will result ultimately in lower life cycle costs for naval aircraft systems. It will also result in higher engine performance (e.g., thrust-to-weight ratio) which can enable greater sustained aircraft speed and maneuverability, increased operational flexibility (such as for short take-off/vertical landing operations), greater payload capability, and more compact engine installations and vehicle designs. Finally, the TET EC will also reduce the amount of fuel used by turbine engines, which will not only provide for greater reach and/or time-on-station, but also will 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).

Variable Cycle Advanced Technology (VCAT)

ONR Program Code 35

At a Glance

What is it?

- The VCAT Program will identify and mature critical, relevant variable/adaptive cycle turbine propulsion technology for future carrier-based TACAIR/ISR systems resulting in dramatic performance and capability improvements.

How does it work?

- The VCAT Program 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 ADVENT variable/adaptive cycle engine S&T demonstration effort and other VAATE efforts; VCAT is a part of an overall integrated propulsion, power and thermal management system (IPPTMS) 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.

Point of Contact

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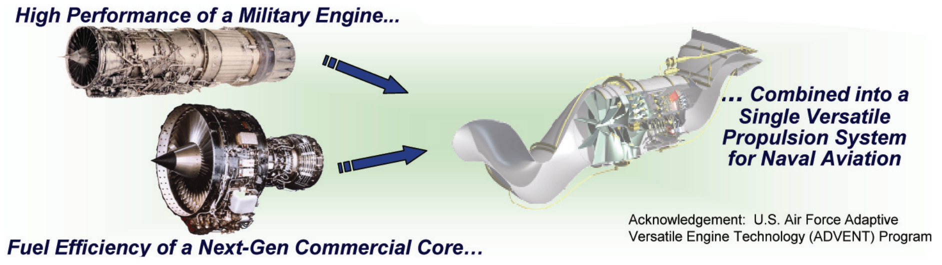


The Variable Cycle Advanced Technology (VCAT) Program is a partnership effort between ONR and the Department of the Navy's Task Force Energy (TFE) initiative to realize the potential benefits of recent advancements in variable/adaptive cycle turbine engine technology. Advancements in propulsion system 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. However, for the Navy to realize that potential capability, marinization/carrier suitability attributes must be addressed. Details of technologies associated with those suitability attributes were defined in a systems analysis effort titled "VCAT Application Studies" beginning in FY11. These studies are being executed with the primary Weapon System Contractors and Original Equipment Manufacturers for military turbine engines. Technology development efforts are to begin in FY12.

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 propulsion-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 (E^3)
  - Carrier susceptibility to jet exhaust impingement
  - Dimension and weight constraints to meet aircraft/ship integration requirements
  - Onboard maintainability and supportability

OFFICE OF NAVAL RESEARCH

S&T

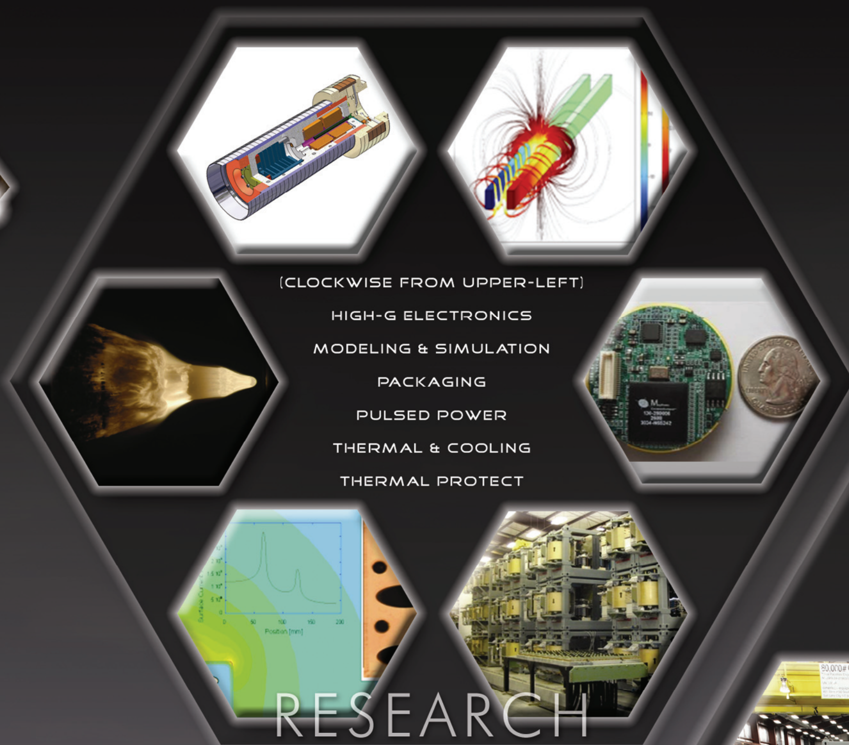
ONR

Revolutionary Research . . . Relevant Results

OFFICE OF NAVAL RE

ELECTROMAGNETIC & HYPERSONIC WEAPONS

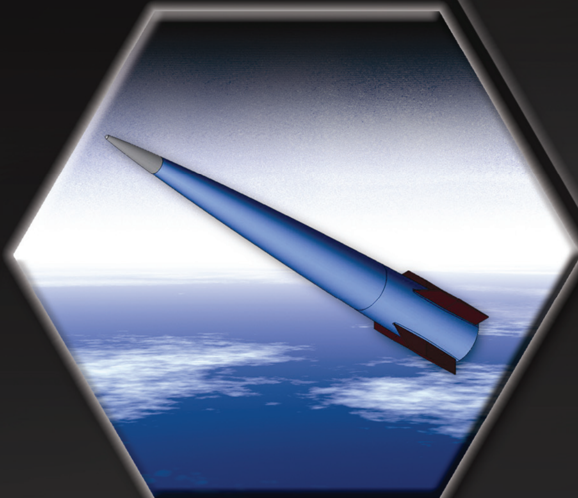
The Electromagnetic Railgun (EMRG) is a long-range, high-energy system that uses electricity rather than gun powder or rocket motors to allow hypervelocity launch of projectiles. Railgun projectiles are able to strike at greater than 200 nautical miles (NM) in approximately 6 minutes with potential for multi-mission applications.



E S E A R C H

Code 35

Naval Air Warfare and Weapons



(CLOCKWISE FROM UPPER-LEFT)

5-INCH Mk 45 LIGHTWEIGHT GUN

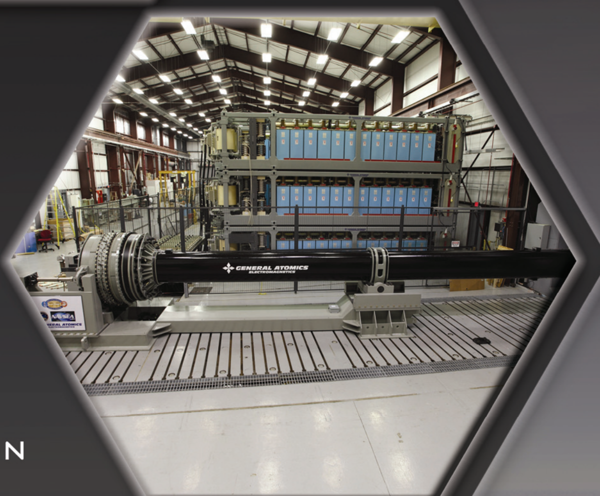
HYPERVELOCITY PROJECTILE

GENERAL ATOMICS RAILGUN

155mm HOWITZER

155mm ADVANCED GUN SYSTEM

BRITISH AEROSPACE ENG. RAILGUN



SYSTEM

Revolutionary Research . . . Relevant Results

Electromagnetic Railgun

ONR Program Code 35

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 to 5,600 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 to Mach 7.5.
- 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 50- to 100-nautical mile initial capability.
- A variety of new and existing naval platforms including the DDG51 are being studied for integration of a future tactical railgun system.

Point of Contact

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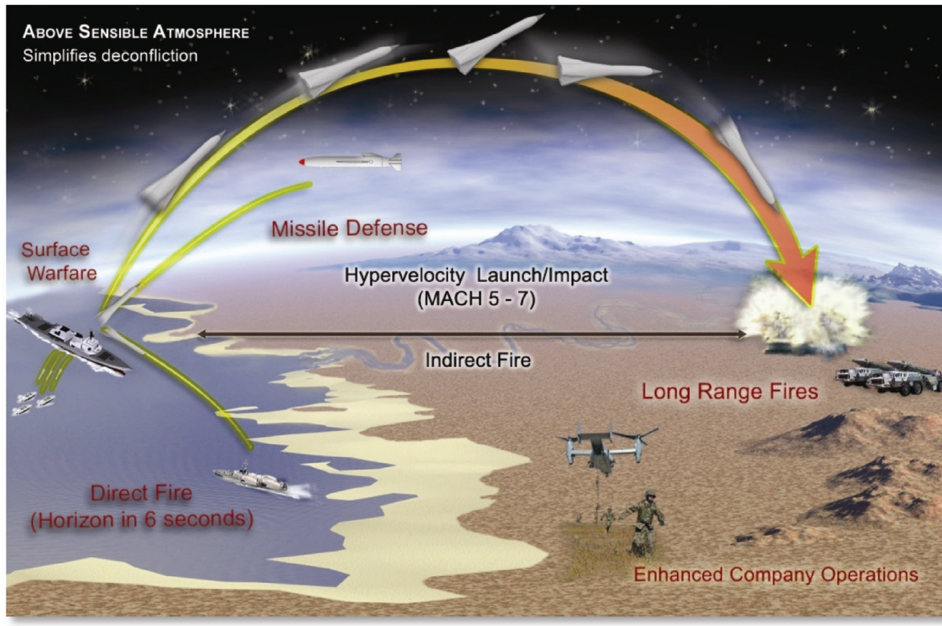

The Department of the Navy's science and technology corporate board chartered the Innovative Naval Prototype (INP) construct to foster game-changing and disruptive technologies ahead of the normal requirements process.

The Electromagnetic Railgun INP was initiated in 2005. The goal during Phase I is 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

Hypervelocity Projectile

ONR Program Code 35

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 Naval threats in the mission areas of naval surface fire support, ship defense, and anti-surface warfare using current and future gun systems.

Point of Contact

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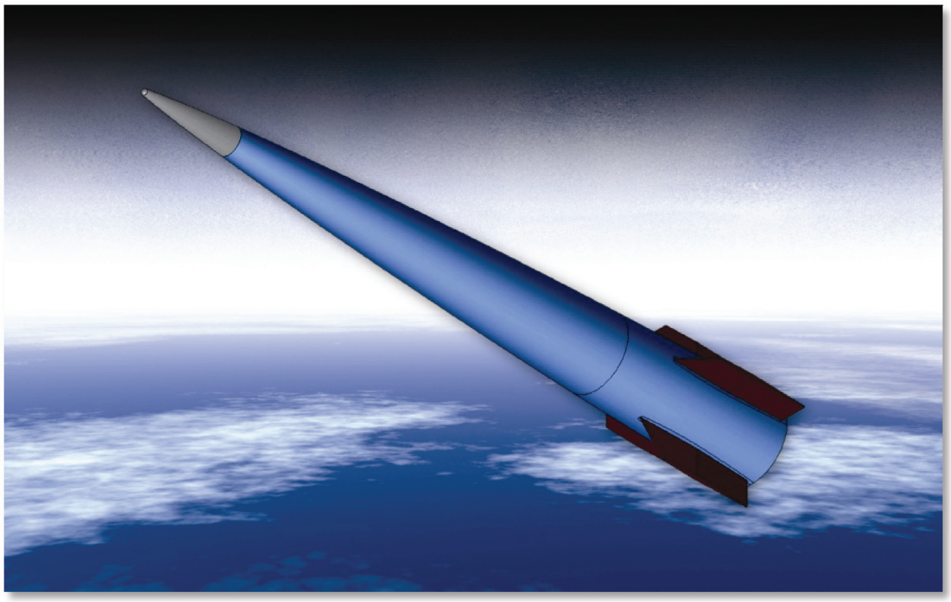

The Hypervelocity Projectile (HVP) is a next generation, common, low drag, guided projectile capable of completing multiple missions for gun systems such as the Navy 5-Inch, 155-mm, and future railguns. Types of missions performed will depend on gun system and platform. The program goal is to address 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 from 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 HVP from conventional gun systems and future railgun systems.

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

Research Challenges & 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

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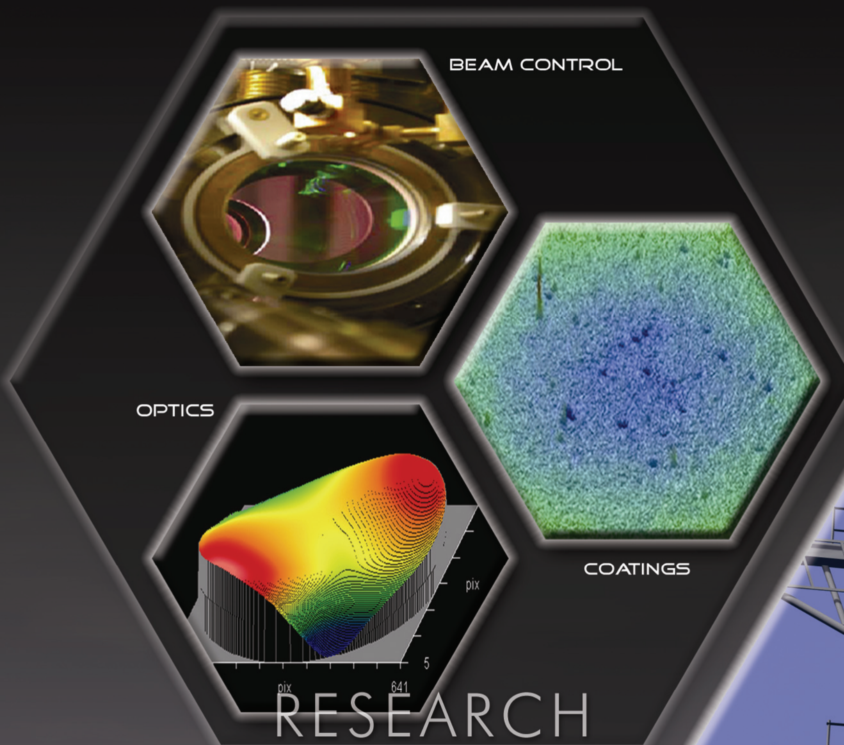


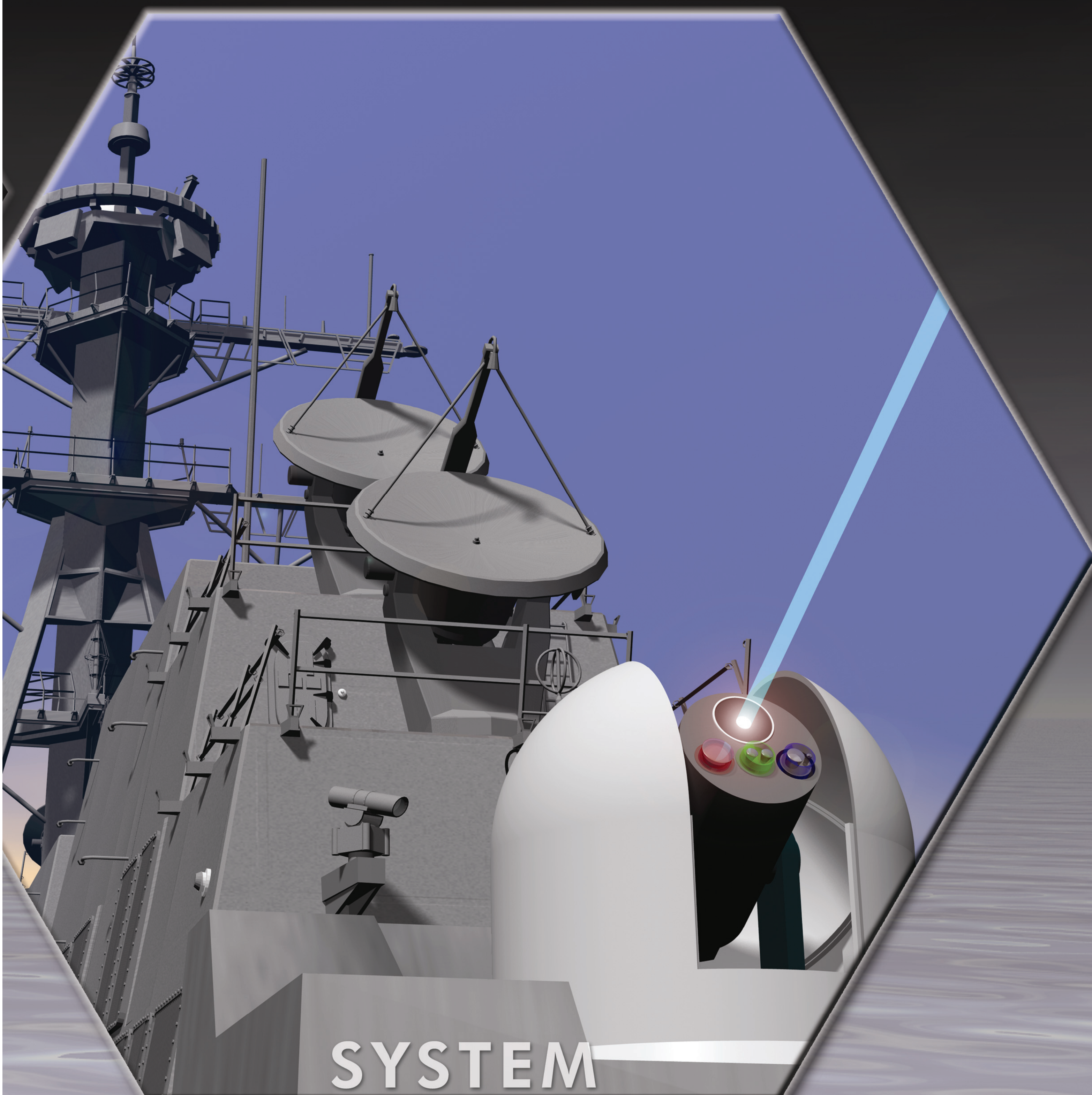
"Advances in high and low energy lasers and high-power radio frequency technologies enable a new class of weapons - directed energy weapons (DEWs) - that could be highly effective in the future battlespace. We will capitalize on these advances by providing our Sailors and Marines robust DEWs and countermeasures 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

ESEARCH

Code 35

Naval Air Warfare and Weapons



ONR

Revolutionary Research . . . Relevant Results

Counter-Directed Energy Weapons

ONR Program Code 35

At a Glance

What is it?

- ONR's Counter-Directed Energy Weapons (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, high-power microwaves, and other directed energy weapons in the maritime domain.

How does it work?

- Lasers and high-power microwaves transmit energy through the electromagnetic spectrum, and the energy being deposited in the illuminated object causes it to heat up, melt, or burn.

- CDEW efforts possess the potential to dissipate, defocus, or reflect energy, resulting in reduced damage to the target.

- This would neutralize the damaging effects of a directed energy weapon when fired against U.S. forces on the battlefield.

What will it accomplish?

- The CDEW Program will investigate the intersection between directed energy, materials, optics, and physics.

Point of Contact

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The Office of Naval Research (ONR), together with the Naval Postgraduate School, the U.S. Naval Academy, the Naval Research Laboratory, and naval air, space and surface warfare centers are investigating basic research topics related to countering the threats that come from directed energy weapons systems, such as high-energy lasers or high-power microwaves.

ONR has started basic research efforts with potential airborne, surface, ground and underwater applications that would provide operational effectiveness against various known and projected weapon systems. In the coming years, efforts will continue to expand in the commercial, university, and academic environments 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.

Funding has already been provided 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 concepts. Current studies include the modeling of effects to address concerns for human safety as well as total systems integration with existing naval platforms.

Specifically, high-energy lasers can be used in maritime operations under various ship-to-ship engagements, but their utility may be limited due to atmospheric conditions. Typical ranges for most lasers are known to have their effectiveness limited due to high-clutter environments and the optical effects of water in the air caused by sea spray. ONR is pursuing a new understanding that will address the complexities of fighting at sea in an already complex naval warfighting construct.

Some aspects of the CDEW research can have potential civilian applications, such as laser eye protection.

Research Challenges and Opportunities:

- Laser and high-power microwave-hardened materials
- Directed energy weapons modeling and simulation
- Atmospheric and turbulence-induced scattering of lasers
- Chaos theory and predictive methods of electronic circuit failure

Free Electron Laser

ONR Program Code 35

At a Glance

What is it?

- The Free Electron Laser (FEL) provides naval platforms with a highly effective and affordable defense capability against surface and air threats, future antiship cruise missiles and swarms of small boats. Utilization of FEL also allows an unlimited magazine with speed-of-light delivery.

How does it work?

- FEL generates high-intensity laser light by utilizing the energy from unbound accelerated high-energy electrons.
- This technology is commonly used in the Department of Energy's particle colliders for basic subatomic research.
- The FEL program is an investment by the Office of Naval Research to transition the accelerator technology from particle colliders to a future ship self-defense weapon system.

What will it accomplish?

- FEL will equip U.S. ships that have high depth-of-fire with speed-of-light delivery, seconds dwell time and a deep magazine for a more powerful means of self-defense. It is a revolutionary weapon that will transform how the Navy fights future battles.

Point of Contact

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The Free Electron Laser (FEL) weapon system will provide U.S. Ships with speed-of-light fire capability for a range of missions and threats, a key element of a future shipboard layered defense.

An Innovative Naval Prototype program for the FEL technology began in 2010. It will demonstrate scalability of the necessary FEL physics and engineering for an eventual megawatt-class device.

This revolutionary technology provides multiple payoffs to the warfighter. The ability to control the frequency of a laser beam allows for operation in the maritime environment. The variability of the beam strength provides graduated lethality with minimum collateral damage and a low cost-per-engagement when compared to the projectile and logistics support costs of conventional explosive munitions. Against low value targets it is an effective alternative to the use of expensive missile systems. The FEL provides speed-of-light and precision engagement of both high speed, sophisticated antiship missiles, as well as swarming, slow speed, unsophisticated small craft.

Research Challenges and Opportunities:

- FEL weapons
- Injectors
- Accelerators
- Amplifier/oscillator designs
- Beam control
- Modeling and simulation
- Scalability

High Energy Fiber Laser System

ONR Program Code 35

At a Glance

What is it?

- The High Energy Spectral Beam Combined Fiber Laser System (HEFL) will deliver a prototype high energy laser weapon system with 25 kW of laser power and the attendant beam director, control, prime power and thermal management subsystems.

How does it work?

- Driven by the telecom industry, rapid advances in the strength and efficiency of electrically powered fiber lasers have occurred.
- Spectral Beam Combining (SBC) brings together the output of many fiber lasers using an optical grating.
- While the SBC laser operates in a narrow band of the short wave infrared, conceptually the process is like a rainbow being combined into a single beam of white light by a grating or prism.
- The SBC high power laser beam then passes through the beam director/control subsystem which modifies the beam to point and hold it on the target aimpoint.
- The target is damaged when the laser light is absorbed by the target, creating rapid heating and ablation of material.
- The damage done to the target depends on the power of the laser, the aperture of the beam director, the quality of the laser beam, the range of the target and the dwell time of the laser beam on the target.

What will it accomplish?

- The HEFL prototype will be demonstrated in a graduation exercise from a helicopter against representative maritime targets.
- The goal is to provide the warfighter with a state-of-the-art, cost effective directed energy capability that complements existing kinetic weapons.

Points of Contact

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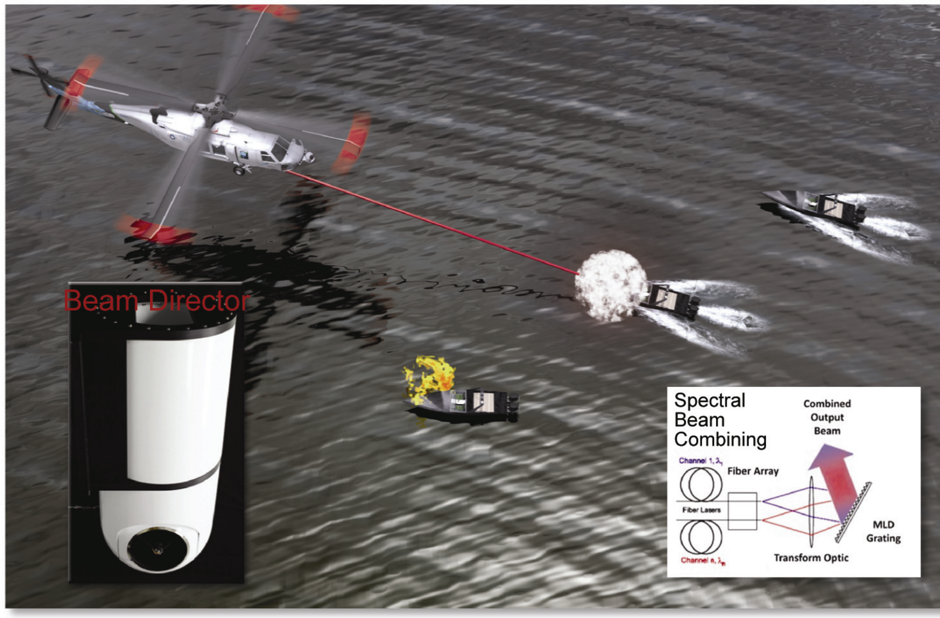

The High Energy Fiber Laser (HEFL) System Future Naval Capability (FNC) Product is working now to provide a directed energy weapon that will complement existing kinetic weapons. The Office of Naval Research, in concert with Resource, Requirements and Acquisition sponsors, are working together to establish the baseline for new program of record, which will deliver an airborne High Energy Laser Weapon System (HELWS) to the Fleet. The Concept of Employment for a HELWS, operating from a rotary wing 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 MANPADS and similar threats). Increased mission kills per sortie (at lower cost by using aviation fuel converted to high energy laser power) against low-end asymmetric threats, frees the limited load-out of advanced kinetic weapons to strike advanced high-end threats.

The HEFL scalable, modular approach to an airborne laser weapon demonstration is an outgrowth of the Navy's Small Business Innovative Research (SBIR) projects in lasers, beam control, thermal management, and prime power. The FNC funding is being applied to further develop the SBIR subsystems and conduct a system level demonstration. The laser architecture – Spectral Beam Combining (SBC) – is inherently scalable by varying the number of lower power laser modules combined together to form a single higher power laser beam. The modules are operating at closely spaced wavelengths and combine with little loss, creating a very bright spatially coherent beam. The beam director design is adaptable to multiple platforms and has been evaluated for rotary wing, fixed-wing, and mobile ground operation.

HEFL will demonstrate the deep magazine that enables a single platform to engage large numbers of adversaries, with precision engagement and speed-of-light delivery of damaging effects at relevant ranges and dwell times. Ultimately, the laser's deep magazine could reduce number of platforms/sorties required for mission success (i.e., lower cost) and potentially reduce the cost of procuring and fielding large numbers of kinetic weapons.

Research Challenges and Opportunities:

- Optical components and coatings for high energy optical train
- Light weight, rechargeable, high energy storage devices
- Adaptive optics to reduce power lost from atmospheric induced beam distortions.

Solid State Laser Technology Maturation Program

ONR Program Code 35

At a Glance

What is it?

- Initiated in 2012, the ONR Solid State Laser Technology Maturation 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" and specifically, Solid State Lasers 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 – either slab-type or fiber-type.
- Slab lasers use small 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, a SSL weapon utilizes 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 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 ISR or lethal UAVs; light aircraft; small boats; asymmetric surface targets; or small diameter rockets and missiles.
- The prototypes will also examine the utility for precision discrimination of targets, and enhancement in aiming of existing guns and missiles.

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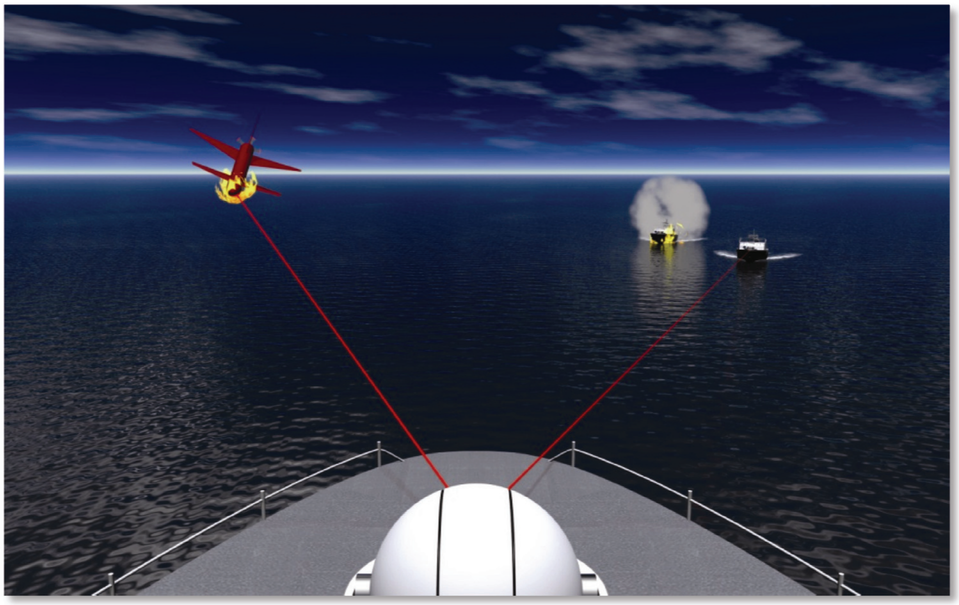

The Department of Defense began funding research in high-energy lasers soon after the invention of the laser in 1960 when it was thought that they might (if scalable to high power) have tremendous impact on how wars were fought. In 1973, a new chemical laser technology, based on deuterium fluoride (DF), 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 ARPA then jointly built a multi-hundred-kW class laser, from which the Navy leveraged this technology to produce the nation's first MW-class HEL weapon test bed. The Mid-InfraRed Advanced Chemical Laser (MIRACL) and the SeaLite Beam Director (SLBD) 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 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 S&T program thresholds and objectives with future R&D/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

Maritime Weapons of Mass Destruction Detection Program

ONR Program Code 35

At a Glance

What is it?

- The Maritime Weapons of Mass Destruction (WMD) Detection Program explores technologies for tracking, detecting, determining intent, intercepting, deciding on operational options, identifying, engaging, and neutralizing WMD in the maritime domain.
- The program provides maritime domain awareness functions related to special nuclear materials (SNMs) from surface or subsurface vessels.

How does it work?

- WMD detection technologies allow a vessel to detect SNMs in an operational mode while on a surveillance mission.
- Detection schemes range in timeframe and may function from above and below the water line.

What will it accomplish?

- The WMD Program goal is to provide solutions that will ensure the safer transport of shipments from foreign ports to the United States without the threat of SNM-based weapons.
- Capable of long-range open ocean transit, these detection systems will oversee at-sea cargo transfers in various sea states and may even permit the high-speed transit of sensor systems between various ports.

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The Office of Naval Research (ONR) is developing technologies for detecting SNMs in a maritime environment. In the past, high-clutter environments and low-resolution detectors have both limited the typical detection range. Development of higher resolution detectors and innovative sensors based on electronic micro- and electromechanical systems could extend the current detection ranges. Additionally, development of higher resolution detectors, innovative sensors, active interrogation systems and approaches for deployment will significantly extend remote standoff detection capabilities.

ONR, the Department of Homeland Security, and the Defense Threat Reduction Agency are working to deliver higher performance systems for naval applications starting in 2011 with a near-term focus on underwater applications. The Naval Research Laboratory, naval warfare centers and others are developing new standoff detection capabilities. The Weapons of Mass Destruction Detection Program will further the design and development of specific longer range detectors that will be tested in large-scale shipboard experiments between 2015 and 2020.

The program consists of multiple technology challenges, all of which are necessary to achieve the long-range counter-WMD vision. Through research partnerships, ONR is formulating multi-mode sensing systems to allow future Navy ships to detect and classify the potential of threats at long ranges, reducing the need for boarding parties and stopping shipping for lengthy searches.

ONR is investigating various active and passive detectors for SNMs as possible sensors and for use in underwater unmanned vehicles. ONR is also studying variable geometry interrogators and airborne sensors to enable detection with little or no need to stop questionable vessels. These systems would require a smaller or minimal crew and maintenance examination from networked shore repair facilities.

The WMD program will deliver to the warfighter an enhanced ability to obtain more accurate sensing of WMD before a warfighter has to set foot on a suspect vessel. This will increase the surveillance capabilities over systems currently available.

Research Challenges and Opportunities:

- Remote standoff detection of special nuclear materials
- Underwater radiation detectors (RSOD/SWM)
- Active interrogation devices
- Modeling and simulation

Revolutionary Research . . . Relevant Results

For more information, please contact

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