
Naval Research Enterprise Addendum to the
NAVAL RESEARCH AND DEVELOPMENT FRAMEWORK
MARITIME SUPERIORITY STARTS HERE

The Naval R&D Framework is a bold call to action: to be first to field decisive capabilities. It identifies key issues to address, as well as three components of the Framework—Align, Allocate and Accelerate—that will guide conversations and efforts across the "discovery to deployment" continuum of naval technology.

Longtime friends, colleagues and partners of the Office of Naval Research (ONR) will notice that the Framework replaces what was previously the "Naval S&T Strategy." This is more than a change of title; it reflects a change in thinking about how all of us in naval science, research and technology development must work together to accelerate capabilities to the Fleet and Force.

Applying the Framework to the Naval Research Enterprise (NRE), which includes ONR, ONR-Global, the Naval Research Laboratory and PMR-51, results in transformations to how we align research to Framework Priorities, allocate our investment portfolios and accelerate decision-making to speed business execution.

Maritime Superiority Starts Here—Naval capabilities begin with discoveries made in science and technology. Talented scientists and engineers in the NRE, and across ONR partners in industry, academia and government labs, draw upon basic research for new knowledge to develop new technologies that ultimately become new capabilities delivered by the acquisition community. We do this well, but must evolve to go beyond traditional boundaries, reducing the time it takes to deliver capabilities into the hands of naval warfighters.

This NRE Addendum to the Naval R&D Framework includes additional detail about how the priorities in the Framework correlate to research subtopics. It further details how each of ONR's six Integrated Research Portfolios (IRPs) address the priorities for their respective naval domain customers. For our partners, the IRPs illuminate research direction and challenges that must be overcome.

When applied to the NRE, the Framework results in:

- Priority-driven, IRPs mapped to core naval functions and domains
- Research business processes with greater agility and flexibility to accelerate technology innovation
- The NRE accepting more risk in truly game-changing technology prospects
- High-velocity learning to speed technology absorption through prototyping, experimentation and demonstration with the warfighter

Supporting our Sailors and Marines is more than just a job—it's a mission, and a challenge we will accept and meet, together.

RADM David J. Hahn, USN
Chief of Naval Research

PRIORITIES

Framework Priority	Objectives	Research Sub Topics	*Future Force Attributes
Augmented Warfighter	• Enhance decision-making speed and quality • Improve human-machine interfaces and teaming • Mitigate tactical-level risk to our people and command, control and communications degradation	Algorithmic phenomenology; autonomy; artificial intelligence; machine reasoning; cognitive science; decision-making; human systems design; human-machine interaction; and training and education	Adaptive, Agile, Autonomous, Connected, Distributable, Interoperable, Lethal, Trained, Fast
Integrated & Distributed Forces	• Enhance dynamic, synchronized actions across forces • Support collaboration spanning geography, domains, platforms and joint partners; leverage satellite and Precision Navigation and Timing advancements • Increase flexibility and reach of the naval force through incorporation of autonomous and disaggregate systems	Autonomous platforms; communications and networks; networked sensors and weapons; positioning, navigation and timing; and coordinated spectrum and signature management	Adaptive, Agile, Autonomous, Connected, Distributable, Interoperable, Scalable, Fast
Operational Endurance	• Enable maneuverability, efficiency, and resiliency for sustained operations by warfighters, systems and platforms (regardless of the threat or operating environment) • Improve platform-level energy storage/ efficiency for propulsion and weapons systems • Develop wide-area and force wide disinformation deception and decoys	Power generation, storage, energy efficiency; survivability, endurance and availability; security/protection; platform affordability; high-performance materials; biomedical; and logistics and sustainment	Adaptive, Agile, Defensible, Distributable, Efficient, Sustainable
Sensing & Sense-Making	• Transform vast data into timely knowledge • Enable persistent awareness and understanding, and optimized operation (regardless of the threat or operating environment) • Integrate artificial intelligence into C4ISR networks scalable to theater wide	Multi-domain and multi-spectral sensors; digital algorithms and data sciences; quantum information sciences; and modeling, simulation and forecasting of the operational environment	Adaptive, Agile, Autonomous, Connected, Distributable, Interoperable, Scalable, Fast
Scalable Lethality	• Enable offensive and defensive actions that are multi-domain, integrated, cost-effective, and kinetic and non-kinetic • Deliver directed energy and low cost, high probability of kill standoff strike	Cyber/algorithmic effects; countermeasures and decoys; counter-weapons, threat neutralization and explosive ordnance disposal; targeting sensors; directed energy and electric weapons; energetics; and lower cost, higher performance weapons	Adaptive, Agile, Autonomous, Connected, Defensible, Distributable, Efficient, Fast, Interoperable, Lethal, Scalable, Sustainable

*Future force attributes derived from OPNAV and HQMC assessments

INTEGRATED RESE

AMPHIBIOUS EXPEDIT

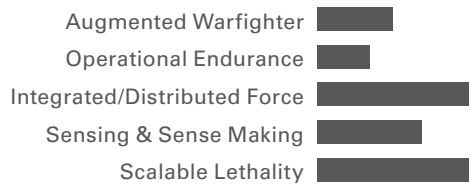
AT A GLANCE

Enables strategically agile and tactically flexible Marine Air Ground Task Forces with naval capability to project power to and from the littorals and conduct operations ashore.

WHY THIS IS IMPORTANT

- The naval expeditionary force will conduct maneuver warfare in increasingly challenging environments and complex terrain
- Technology proliferation is increasing peer- to near-peer adversaries
- Information is increasingly used as a weapon
- Adversaries are gaining electromagnetic and acoustic signatures advantages
- Contested maritime and urban domains

CURRENT SUPPORT OF FRAMEWORK PRIORITIES



DESCRIPTION

Naval expeditionary forces bring unique and powerful capabilities to Combatant Commanders but the evolving environments present challenges compounded by emerging complex hybrid threats.

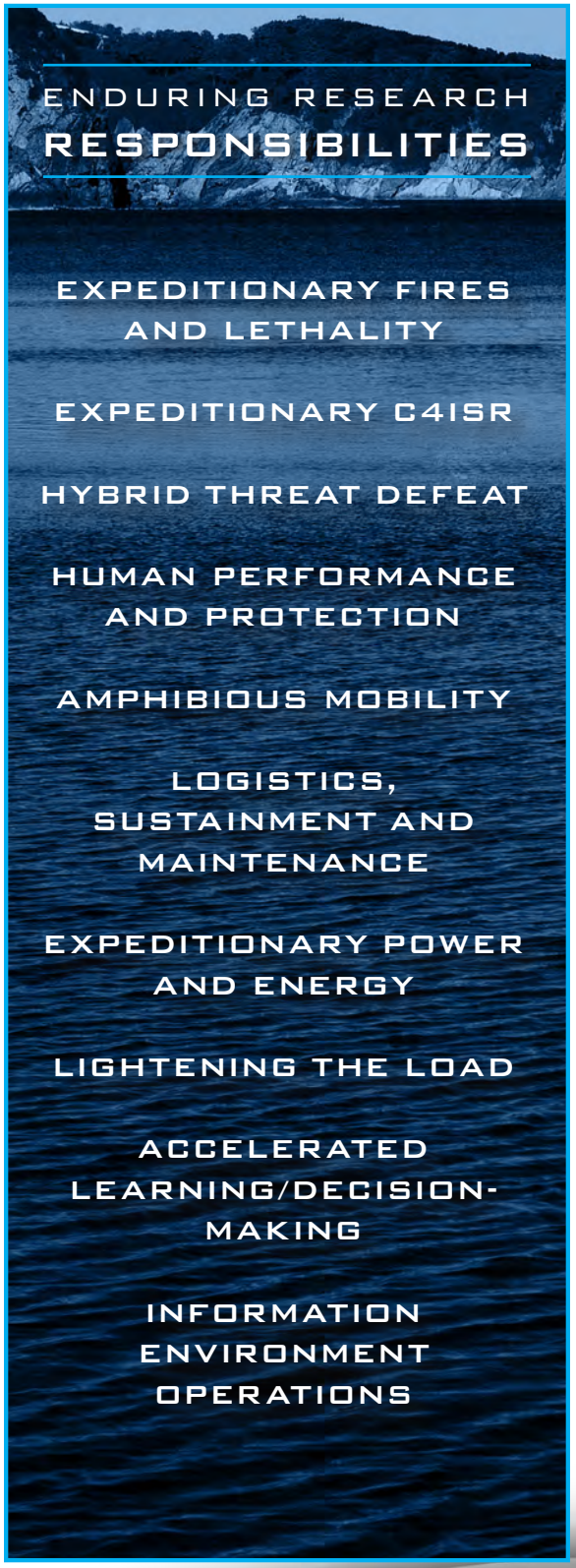
The renewed focus on "expeditionary maneuver" spans numerous technical disciplines to address the unique problems imposed by being naval and expeditionary where managing size, weight, power, cost—SWAP-C—information warfare and signature is vital.

In particular, expeditionary C4 and decision support requires small, form-factor packages to minimize volume that are man- or ground vehicle-portable and deployable on amphibious ships. Complementary, flexible and scalable effects must be achieved through a modern combined arms approach that embraces more intelligent weapons and information warfare across five domains—air, land, sea, space and cyber. Criteria for naval expeditionary forces include:

- Design for both austere and urban conditions
- Lightweight, deployable in character
- Support a force that can distribute, disaggregate and reform
- Fully integrated with joint and naval forces
- Operate across and through the land-sea interface

Resultant capabilities must be cheap enough to buy, simple to use, robust enough to survive yet advanced enough to prevail against peer and near-peer adversaries.

Additionally, technologies addressing complex multicultural terrain will continue to improve the warfighter's ability to interact with target populations, identify threat activities, solve complex problems, and adapt to ambiguous situations via kinetic and non-kinetic means—at a tempo that outpaces that of our adversaries.



ARCH PORTFOLIO

TIONARY MANEUVER

HOW WE ARE PROCEEDING

GROUND AND LITTORAL C4, INFORMATION AND DECISION SUPPORT

- Resilient Low SWAP-C Networks
- Over-the-Horizon Connectivity
- Low SWAP-C Local Computing & Software-Defined Radios
- Non-GPS Positioning, Navigation, & Timing (PNT)
- Ground Expeditionary Cyber/Electronic Warfare
- Cognitive Advantages/Artificial Intelligence
- Big Data Analytics/Machine Learning
- Augmented Reality

AUTONOMY AND MAN-UNMANNED TEAMING

- Collective Behaviors
- Real-time mission adaptation
- Multi-domain Amphibians
- Distributed, Collaborative, Coordinated & Cognitive Autonomy Technology
- Human Machine Integration/Interaction

FLEXIBLE, SCALABLE EFFECTS

- Directed Energy
- Guidance & Controls
- Weapons Energetics
- Enhanced Indirect Fires
- Cyber/EW Payloads

AMPHIBIOUS MANEUVER

- Vehicle Mobility and Maneuver
- Lightweight protection systems
- Mine countermeasures

EXPEDITIONARY AIR SYSTEMS

- Airborne Sensors
- Airborne Weapons
- Autonomous Air-delivered Logistics
- Communications

SUCCESS STORY

ADVANCED CAPABILITY EXTENDED RANGE MORTAR

Using dual-mode guidance, GPS and Semi-active Laser (SAL), ACERM will be capable of high-precision strikes resulting in a reduction of rounds required per kill, collateral damage, and operational costs. Its near-vertical approach will enable strikes against targets in deep defilade and increases warhead effectiveness. These attributes of ACERM will allow battalions and companies to engage targets in larger operational areas with increased flexibility, responsiveness and lethality, without reliance on external fires.

Unlike a conventional mortar that flies a ballistics trajectory, ACERM utilizes modified glide architecture without in-flight propulsion to increase range. Having demonstrated a 3x extended range compared to conventional mortar systems in recent flight tests, next steps will see the ACERM demonstrate improved accuracy through SAL guidance and increased experimentation with the Marine Corps to facilitate an accelerated path to acquisition.

INTEGRATED RESE

INFORMATION, CYBER AND

AT A GLANCE

An increasingly interconnected force with more rapid and effective decision-making is enabled by persistent sensing, advanced data analytics, digital integration and assured spectrum access.

WHY THIS IS IMPORTANT

- Decreasing advantage in information and cyber superiority against state and non-state actors
- Information/cyber threats evolving and proliferating at unprecedented rates.
- Data volume, variety, veracity and velocity requires dramatically improved analysis and management techniques
- Expanding commercial/military spectrum use, along with universal availability of high-quality components, limit naval applications

CURRENT SUPPORT OF FRAMEWORK PRIORITIES

DESCRIPTION

This portfolio spans three strategic areas:

- Assured Command and Control (C2)
- Electromagnetic Maneuver Warfare (EMW)
- Full Spectrum Cyber technologies.

Assured C2 is enabled by persistent sensing, timely intelligence and decision support tools that will accelerate “data to decisions” timelines. Leveraging machine reasoning and data analytics, an end-to-end approach achieves protected data transport, resilient networking, and assured apps and services that result in trusted information and actions. The need for increased spectral efficiency and diversity, coupled with the information domain, is critical to our naval freedom of maneuver on a global scale.

EMW efforts include electromagnetic spectrum management technologies and techniques that fluidly combine communications, surveillance electronic warfare (EW), and electronics to understand and shape the battlespace. Ultra-wide band systems, which continuously monitor the spectrum, are needed to facilitate optimized use.

Intrinsically secure and resilient computing systems with robust computational and communications architectures will provide the capability to manipulate and interpret rapidly growing amounts of data in support of C2, Combat Systems (CS), and Intelligence Surveillance and Reconnaissance (ISR) effects. Assuring secure access to the full spectrum is essential to operate at will or deny adversary access in more complex and dynamic future EMW environments.

Full-Spectrum Cyber approaches must be developed to protect our networks, data, information systems and real-time control systems. Total platform cyber protection is becoming an essential element of Information Warfare. Cyber technologies provide the ability to assess and counter potential threats. Future information systems must provide agile capabilities for achieving and maintaining communications and data integrity in rapidly evolving, dispersed and disadvantaged environments. Computational architectures need more resilient information infrastructure through assured system design, automated defensive tools for advanced persistent threats, hardening of the hosts and data assurance.

ENDURING RESEARCH RESPONSIBILITIES

ADVANCED RF ELECTRONICS & MATERIALS

COMMUNICATIONS AND NETWORKING

COMPUTATIONAL METHODS FOR DECISION MAKING

DATA SCIENCE AND ANALYTICS

ELECTRONIC WARFARE

SENSORS AND SENSOR PROCESSING

MACHINE LEARNING, REASONING AND INTELLIGENCE

RESOURCE OPTIMIZATION

PRECISION NAVIGATION & TIMEKEEPING

EARCH PORTFOLIO

D SPECTRUM SUPERIORITY

HOW WE ARE PROCEEDING

COMMUNICATIONS AND NETWORKS

- Dynamic, Scalable, Secure, Tactical Communication Networks
- High-performance, Low-Cost Communication Solutions
- Increased Bandwidth and Resiliency
- Communication Denial Mitigation
- Satellite Communications and ISR
- Quantum Computing

FULL SPECTRUM CYBER OPERATIONS

- Information Operations
- Resilient Cyber-Physical Systems
- Total Platform Cyber Protection
- Computer Network Defense

ELECTROMAGNETIC MANEUVER

- Force Level EMW Visualization
- Disaggregated Active/Passive Operations for Elements of Surprise
- Multi-Ship Dynamic Spatial, Temporal, Spectral and Functional Agility
- Geographically Disbursed Deception
- Cognitive Engine for Dynamic Control of EM Resources
- Own-Force Monitoring, Emissions Control and Spectrum Compliance
- Force-on-Force Exploitation And Vulnerability Assessment
- Exploitation of Environmental Awareness and Propagation Models
- Development of an Open and Extensible Architecture

COMMAND & CONTROL AND DECISION-MAKING SUPERIORITY

- C2/CS/ISR in Big-Data Environments
- Machine Reasoning and Intelligence
- Distributed Mission-Focused Autonomy
- Data Science and Analytics
- Automated Battle Management Tools

ADVANCED COMPONENT TECHNOLOGIES

- High-Performance, Solid-State Electronic Components, Subsystems and Devices for All Classes Of Military Radar and Rf Systems
- Reliable, Wideband, High Power, High Linearity, Efficient VHF, UHF, Microwave and Millimeter-Wave Power Amplifiers for Surveillance, EW, Communication and Smart Weapon Systems
- Advanced Electromagnetic Materials to Enable High Performance Electronics and Photonics
- Superconducting Devices, Circuits and Signal Processing

SUCCESS STORY

GALLIUM NITRIDE

ONR-sponsored research at numerous academic institutions and the Naval Research Laboratory were critical to the discovery and application of Gallium Nitride (GaN) as a next-generation material for semi-conductors, which now enable the high-power capability of advanced radars for naval ships and aircraft.

As a semiconductor material, GaN devices offer much greater energy efficiency than silicon, the previous industry standard. GaN transistors have roughly one-tenth the resistance of silicon-based transistors, allowing for much higher energy efficiency, faster switching frequency and smaller power-electronic systems.

Getting to the point of making GaN into a usable material—for the Navy and the commercial world—took nearly 30 years of scientific investment. The creation of single crystal GaN films in the late 1960s, and the subsequent development of millimeter-wave GaN devices and amplifiers, are products of ONR-funded efforts.

MISSION CAPABLE, PERSISTENT

AT A GLANCE

Concepts, systems and component technologies that improve the performance and survivability of naval ships/submarines in an increasingly distributed yet interconnected force.

WHY THIS IS IMPORTANT

- Threats to the fleet/force are increasing in number, range, precision and effectiveness of adversary weapons and sensors
- Sustainable operations in increasingly diverse environments require affordable, modular, survivable and rapidly upgradeable platforms
- Maritime superiority requires enduring, self-sustaining platforms able to deter/defeat aggression through overwhelming capability

CURRENT SUPPORT OF FRAMEWORK PRIORITIES

DESCRIPTION

New platforms will need to deliver advanced weapons, as well as increased mobility and survivability. Power and energy for surface ships is a key enduring investment for the efficiency of legacy platforms, while enabling the power requirements of future electric weapons. High-power electric weapons and sensors have advanced significantly, creating technical requirements for dramatic increases in energy management and pulsed power.

Computational tools that model the platform's interaction with the anticipated operational environment are essential to the development of integrated designs and protections such as stealth, counter directed energy weapons, tactical decision aids, electronic warfare and hard-kill systems.

Undersea dominance remains a priority as the Navy designs and builds the next generation of strategic and tactical submarines. Resurgence by peer adversaries in ultra-quiet submarine technology is closing the gap in undersea warfare.

Platform mobility and survivability is critical to successful operational strategies calling for more distributed forces. Advancements in materials, acoustics, intelligent control and hydro, electro and computational mechanics are required, as well as countermeasures for ships and submarines.

Platforms will become more self-sustaining to extend endurance and forward presence while reducing the logistics tail for fuel. Future platforms must have reduced sustainment requirements and be easier to maintain. Efforts are focused on platform interfaces as well as platform efficiency to reduce sustainment needs. Enhanced interface standards and modularity provide flexibility, ease of maintenance and upgrades.

Finally, affordability permeates all modernization concepts. The development of validated design tools capable of rapidly and accurately analyzing and evaluating novel platforms with advanced system performance characteristics is a high priority.

ENDURING RESEARCH RESPONSIBILITIES

NAVAL ENGINEERING

ADVANCED NAVAL POWER SYSTEMS

ADVANCED SURVIVABLE SEA PLATFORMS

UNMANNED SEA PLATFORMS, AUTONOMY AND POWER

ADVANCED NAVAL MATERIALS

UNDERSEA WEAPONS, COUNTER-WEAPONS AND ENERGETICS

SEA PLATFORM ENVIRONMENTAL QUALITY

CORROSION CONTROL

ARCH PORTFOLIO

& SURVIVABLE SEA PLATFORMS

HOW WE ARE PROCEEDING

MOBILITY AND SURVIVABILITY

- Advanced Platform Efficiency, Agility and Affordability
- Autonomous and Unmanned Vehicle Mobility
- Innovative Ship-to-Shore Technologies
- Rigorous Platform Performance Models
- Low Observable (LO) and Counter-LO Technologies
- Soft-kill Techniques and Counter Directed Energy
- Active and Adaptive Protection Technologies
- Ultra-Lightweight and Low-Cost Armor
- Automated Response and Recovery Technologies
- Acoustics for Ohio and Virginia Submarine Replacements

POWER AND ENERGY CONSIDERATIONS

- Pulsed Power Architectures
- Cyber-secure Power Architectures
- Increased Efficiency and Power Density
- Power Conversion, Switching, Distribution and Control
- Efficient Power Generation Machinery
- Electrochemical, Thermal, Dielectric and Kinetic Energy Storage
- Thermal Management
- Resilient Power Networks for Shore-Based Critical Infrastructure

OPTIMIZED PAYLOAD CAPABILITIES

- Modeling and Simulation Tools
- Modular/Affordable Platforms
- Advanced Structural, Mechanical and Electrical Support Infrastructure
- Platform Performance for Range/Loiter/Payload
- Undersea weapons and countermeasures

PLATFORM DESIGN & SUSTAINMENT

- Platform, Aircraft, Payload and Weapons Planning and Movement
- Affordable Fuel Distribution
- Fixed-Wing and Rotorcraft Durability, Maritime Compatibility
- Multi-Disciplinary Design and System Approaches

AFFORDABLE FLEET/FORCE MODERIZATION

- Modular Systems
- Interfaces and Standards
- New Materials and Methods to Increase Reliability and Reduce Maintenance Costs
- Technology Advancement During Shipyard Midlife Overhaul and New Construction

SUCCESS STORY

SWARMBOATS

CARACaS (Control Architecture for Robotic Agent Command and Sensing) was development by ONR and enables boats conceivably of any size to become swarming, unmanned surface vehicles (USVs). It allows boats to operate autonomously, without a Sailor physically needing to be at the controls—including operating in sync with other unmanned vessels; choosing their own routes; swarming to interdict enemy vessels; and escorting/protecting naval assets.

This first-of-its-kind technology was successfully demonstrated over two weeks in August 2014 on the James River in Virginia. It allows unmanned Navy vessels to overwhelm an adversary, while its sensors and software enable swarming capability, giving naval warfighters a decisive edge.

Autonomous swarmboats could play a vital role in protecting U.S. Navy ships, ports and commerce.

INTEGRATED RESEA

AVIATION, FORCE PROJECTIO

AT A GLANCE

Sea-based aviation, including platform and weapons research is focused on new or enhanced capabilities to defend against, and/or deter, disable, damage, defeat or destroy adversaries at extended ranges and speeds.

WHY THIS IS IMPORTANT

- Increased numbers, range, precision and lethality of adversary weapons neutralize current U.S. advantages
- Naval forces must be able to effectively engage targets with survivable, cost-effective weapons
- Future scenarios require sufficient range, speed and accuracy to nullify any adversary's ability to conduct effective operations

CURRENT SUPPORT OF FRAMEWORK PRIORITIES

DESCRIPTION

Offsetting technologies must continue to provide naval forces with an edge in any future battle. In the future battlespace, electric weapons with deep magazines and low cost-per-kill will be required to engage large numbers of threats simultaneously.

Directed-energy systems will be used in layered defense to counter ISR capabilities, defeat or destroy threats, both before and during combat.

Networked weapons will improve the probability of kill and reduce the need for multiple weapons targeting the same platform. Advanced warhead materials will decrease the size of rounds. Electromagnetic railguns will allow more, smaller and longer-range rounds.

Future naval fires efforts include targeting, decision support and precision strike by air, surface, undersea and expeditionary forces.

Improved aerodynamic control will allow unprecedented maneuverability for unconventional aircraft designs. Advanced aircraft power and propulsion technologies, such as variable-cycle advanced technology, will provide more efficient operation over a wider range of flight conditions. They will also enable technologies for providing the power and thermal management of electric weapons for next-generation aircraft. Advances in structures and materials will allow for reduced life-cycle costs as well as stronger and lighter airframes.

Autonomous systems will reduce operational risk and improve mission performance. For today's missions, autonomy can improve manning effectiveness and provide options for mission tasks. For future missions, autonomy can provide new persistent, pervasive and rapid response capabilities to do tasks that would be unaffordable or impractical today.

ENDURING RESEARCH RESPONSIBILITIES

DIRECTED ENERGY (DE) & COUNTER DE

AERODYNAMICS

FLIGHT DYNAMICS & CONTROL

PROPULSION

STRUCTURES AND MATERIALS

ENERGETIC MATERIALS

HYPERSONICS

AUTONOMY

ARCH PORTFOLIO

ON & INTEGRATED DEFENSE

HOW WE ARE PROCEEDING

AIR POWER

- Lightweight Durable Structures
- High Lift to Drag vehicles
- Flexible, Fuel Efficient and High Specific Thrust Propulsion

FUTURE NAVAL FIRES

- Precision Direct and Indirect Fires
- Deeper and More Cost-Effective Conventional Magazines
- Electric Weapons

EXTENDED THREAT NEUTRALIZATION CAPABILITIES

- Near Real-Time Engagement through Directed Energy
- Higher-Speed, Longer-Range Kinetic Weapons
- Collaborative, Networked Weapons Technologies

TIME-CRITICAL PRECISION STRIKE

- Insensitive Munitions-Compliant Weapons
- Extended-Range Engagement and Assessment of Time-Critical Targets
- Hardened/Moving Target Strike Capabilities
- Enhanced Maneuverability for Precision Engagement
- Enhanced Lethality Warheads

INTEGRATED LAYERED DEFENSE ACROSS THE ENTIRE DETECT-TO-ENGAGE CONTINUUM

- Detection, Classification, Identification and Tracking of Potential Threats
- Hard/Soft Kill and Lethal/Non-Lethal Scalable Options
- Networked Engagement
- Battle Management Aids
- Directed Energy (DE) and Counter-DE weapon technologies

AUTONOMY WITHIN THE FUTURE HYBRID FORCE

- Cross-Domain, Multi-Mission Human/Machine Teaming
- Intelligent Perception and Control/Decision-Making
- Scalable, Distributed and Robust Collaboration
- Intelligence Enablers and Architectures
- Novel Autonomous Systems

SUCCESS STORY

SOLID STATE LASER

The military began experimenting with laser weapons in the late 1970s. Although they demonstrated high output levels, these systems often were very large, difficult to integrate, costly and had insufficient target engagement ranges. With the advent of solid-state laser technologies, systems improved in size, weight and power to make shipboard compatibility practical.

Solid-state laser weapons cost about $1 per shot to fire. They allow escalating power projection (deter, damage or destroy) and are highly effective for countering unmanned aerial vehicles and small boats. They have deep magazines, depending only on a ships electrical power and cooling to fire.

As a result of ONR programs, Naval Research Laboratory science and industry development, higher-power lasers are now under development, providing defense against more robust threats.

INTEGRATED RESE

UNDERSEA BATTLESPACE AND

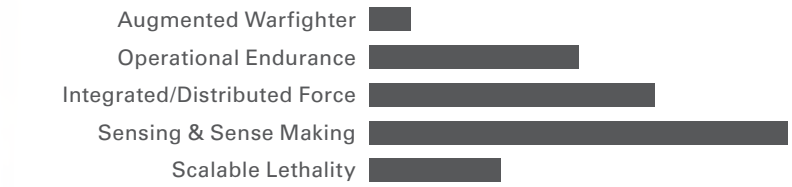
AT A GLANCE

Enables maritime domain access for naval forces to operate in contested ocean environments through undersea threat neutralization and maritime battlespace awareness.

WHY THIS IS IMPORTANT

- Proliferation of ultra-quiet submarines and undersea mine technology is a threat
- Expanded use of autonomous undersea vehicles can be an advantage for U.S. naval forces
- Maritime domain awareness is a warfighting advantage for naval forces to maintain
- Changing environmental conditions are increasing the complexity of predicting the ocean battlespace

CURRENT SUPPORT OF FRAMEWORK PRIORITIES



DESCRIPTION

Assuring access to the global maritime domain begins with the ability to sense and predict ocean environmental properties in support of both tactical and strategic naval operations. Remote sensors (including space), autonomous ocean observation, and prediction/forecasting capability provide a distinct advantage for commanders who rely on accurate predictions and actionable information.

Distributed and networked surface and underwater sensors provide real-time data and predictions for improving battlespace awareness and decision-making.

Unmanned and autonomous underwater vehicles will provide increasing support to core naval missions in antisubmarine warfare (ASW), mine warfare (MIW), explosive ordnance disposal, and naval special warfare.

The objective is to provide next-generation sensors and autonomous platforms to augment traditional naval vessels. These novel capabilities will allow greater capacity and provide greatly increased warfighting capabilities.

Forecasting for safety of naval operations is also a critical mission that requires ongoing research to account for the changing dynamics in the open-ocean, Arctic, and littorals. Major subjects include:

- Understanding and synthesis of ocean-atmosphere-land processes and interactions
- Real-time environmentally adaptive sensors, data processing and systems that can be distributed and operated effectively (without perfect knowledge)
- Modeling support for the maritime warfare areas such as sensing, tracking, navigation, communications, neutralization and exploitation

The foundation of maritime access is built upon strong, geophysical models for atmosphere and ocean monitoring/prediction—knowledge of the battlespace is a key warfighting advantage.

ENDURING RESEARCH RESPONSIBILITIES

ARCTIC AND GLOBAL PREDICTION

LITTORAL GEOSCIENCES AND OPTICS

MARINE MAMMALS AND BIOLOGY

MARINE METEOROLOGY

MARITIME SENSING

OCEAN ACOUSTICS

OCEAN ENGINEERING & MARINE SYSTEMS

PHYSICAL OCEANOGRAPHY

RESEARCH FACILITIES

SPACE ENVIRONMENT

UNDERSEA SIGNAL PROCESSING

ARCH PORTFOLIO

D MARITIME DOMAIN ACCESS

HOW WE ARE PROCEEDING

ACHIEVE AND MAINTAIN UNDERSEA DOMINANCE

- Adaptive, automated and autonomous technologies to detect, classify, localize and track submarines and threats in littoral, deep and under-ice ocean conditions
- Off-board sensing and cooperative vehicle autonomy with increased endurance
- Data exfiltration and networking in unmanned systems to expand reach, reduce threat exposure and deny or restrict adversarial maneuver
- Next-generation data and information processing to advance ASW, MIW, amphibious warfare and decision support from the regional to the theater level
- Rapid, autonomous neutralizing of mines from deep water through the beach exit zone

MOBILE AUTONOMOUS ENVIRONMENTAL SENSING AWARENESS

- Autonomous sensing of global maritime and littoral environments (up to the beach exit zone)
- Environmental sensing that adapts to changing conditions
- Autonomous in-buoy signal processing

ENVIRONMENTAL PREDICTION FROM TACTICAL TO THEATER LEVELS

- Fully coupled (ocean-atmosphere-land-wave-ice) global, regional and local modeling and prediction for operational planning at tactical, strategic and climate scales
- Forecasts for refractivity, duct heights, fog, rain, clouds, visibility, trafficability and tropical cyclones at global, regional and tactical scales to increase mission success
- SATCOM exfiltration of networked sensors
- Satellite remote sensing
- Space weather as critical to communications and HF radar
- Ocean acoustic prediction models

INTELLIGENT ADAPTATION OF SYSTEMS PERFORMANCE TO THE ENVIRONMENT

- Optimize sensing, situational awareness and autonomous behaviors by adapting in dynamic, uncertain and unstructured environments
- Predict system performance (a priori and in situ) from environment, threat and tactical context
- Undersea communications and networked systems of longer range UUVs

SUCCESS STORY

REMUS

Nearly 25 years ago, ONR recognized the potential of unmanned underwater vehicles (UUVs) to solve some of the Navy's important operational issues—especially in the areas of mine countermeasures, naval special warfare, and the need for rapid environmental assessment.

Small UUVs such as the man-portable REMUS 100—originally developed with ONR's support at the Woods Hole Oceanographic Institution—were seen as ideal platforms for the challenging very shallow water environment. The REMUS 100 would later become the Mk-18 Mod 1 Swordfish program, which saw its first operational use during port clearance operations in Umm Qasr, Iraq during Operation Iraqi Freedom in 2003. UUVs with ONR-developed sensors are now the core mine-hunting platforms for the newly formed expeditionary mine countermeasures teams, which have recently completed their first proof-of-concept deployments.

INTEGRATED RESE
WARFIGHTER

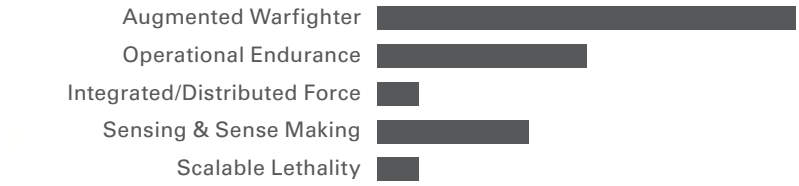
AT A GLANCE

People underpin all missions. Advances in autonomy, human-machine teaming, command and control, training and education, human performance optimization, protective equipment, medicine, neurosciences, and bio-engineered systems will ensure their advantage.

WHY THIS IS IMPORTANT

- Complex missions involving human/machine teaming are changing manning requirements
- Challenging operating environments drive dynamic decision-making and training needs
- Answers increased demand for warfighter resiliency, adaptability and survivability

CURRENT SUPPORT OF FRAMEWORK PRIORITIES



DESCRIPTION

People are the most critical element of military performance. As technology progresses, so must manpower and personnel technologies to enhance recruitment, retention and force structure through advanced selection, development and assessment tools. A healthy force that is both cognitively and physically resilient is essential.

Training and education needs are met through research to modernize and accelerate learning. These technologies create a technical foundation for agile, deployable, compact, affordable, integrated cross-platform, multi-mission training that aligns to point-of-need.

Ongoing naval warfighter health and survivability efforts optimize state-of-the-art health, fitness, performance, life-saving and sustaining technologies. Warfighter effectiveness is enhanced with human systems design and decision support research to provide commanders with an environments to inform allocation of forces to best effect. Warfighter advantage is further achieved through model-based performance assessment and simulation technologies using live, virtual and constructive elements.

In addition, Sailors and Marines will need technologies to help make complex decisions quickly, with limited and/or uncertain information. Rapid assimilation and action on diverse, complex and/or ambiguous information will require new analytical tools. Naval warfare challenges posed by nontraditional adversaries can be addressed through the use of social, political, economic, ethnic and religious factors in training and decision-support systems

Warfighter effectiveness and efficiency can also be enhanced through bioengineered and biorobotic systems. Bioengineering bridges the science of biology and the art of naval engineering, such as, biomechanics and fluid mechanics of underwater propulsion; artificial muscle-based actuators and their neural control for the advancement of autonomous systems; and, finally, synthetic biology offers the potential to design purpose-specific organisms for environmental sensing, production of needed high-value materials, tissue cell growth, or possibly, information processing in autonomous systems.

These investments reduce costs for the Navy and Marine Corps while enhancing readiness.

ENDURING RESEARCH RESPONSIBILITIES

UNDERSEA MEDICINE

BIOLOGICAL SCIENCES

BIOROBOTICS

CAPABLE MANPOWER

COMMAND DECISION MAKING

FORCE HEALTH PROTECTION

HUMAN-ROBOT INTERACTION

NOISE-INDUCED HEARING LOSS

TRAINING AND SIMULATION

SUPREMACY

HOW WE ARE PROCEEDING

MANPOWER, PERSONNEL, TRAINING AND EDUCATION

- Enhanced Manpower Selection and Assignment, Training, Education and Human-Systems
- Advanced Approaches to Professional Development
- Information-Processing Abilities in Naval Personnel
- Tools and Techniques to Achieve Scenario-Based Training and Performance-Based Readiness Assessment
- Training Tailored to the Individual and Team Through Simulation-Based Technologies

WARFIGHTER HEALTH AND SURVIVABILITY

- Casualty Care from Point-of-Injury to Definitive Care at Treatment Facilities
- Forward, Automated Intensive Care Products
- Noise-Induced Hearing Loss Prevention technologies and Techniques
- Physical and Psychological Stressors Mitigations
- Advanced Materials for Lightweight Body Armor
- Undersea Operation Human Factors, Including Dietary and Pharmacological Approaches
- Warfighter Resilience Technologies and Methods

BIO-ENGINEERED SYSTEMS AND SYNTHETIC BIOLOGY

- Biologically Inspired Sensors and Autonomous Systems
- Computational Cognitive Models for Intelligent Systems
- Novel Autonomous Platforms
- Synthetic Biological Sentinel Organisms and Circuit Designs

HUMAN SYSTEMS DESIGN AND DECISION SUPPORT

- Efficient Training Tools and Techniques
- Design Engineering Tools and Standards
- Design and Control Tools
- Decision Support System
- Human- Social- Cultural-Based Simulation

SUCCESS STORY

FIST

Fleet Integrated Synthetic Training (FIST) develops, tests and demonstrates simulator training technology, blending various combinations of live, virtual and constructive exercises that include virtual assets and adversaries.

FIST is configurable technologies that enable endless possibilities without the expense and logistical challenges of putting hundreds of ships at sea and aircraft in the sky, while also supporting OPSEC. It enables users to confront artificially intelligent forces in countless virtual settings—and train for multiple missions simultaneously. The system can replicate situations involving aircraft carriers, helicopters, lethal and nonlethal weapons and more.

FIST was created in response to an urgent need for a more portable way for ships to train in any given operating area. It allows Sailors to “train like they fight” by presenting realistic forces in a visual, tactical and operational environment.

U.S. NAVAL RESEARCH LABORATORY