BUDGET ACTIVITY: 01
PROGRAM ELEMENT: 0601153N
PROGRAM ELEMENT TITLE: DEFENSE RESEARCH SCIENCES

COST: (Dollars in Thousands)

Project Number & Title	FY 2004 Actual	FY 2005 Estimate	FY 2006 Estimate	FY 2007 Estimate	FY 2008 Estimate	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate
DEFENSE RESEARCH SCIENCES	364,243	380,441	356,885	366,680	380,244	388,940	397,009	405,922

A. MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION: This program element (PE) sustains U.S. Naval Science and Technology (S&T) superiority, provides new technological concepts for the maintenance of naval power and national security, and helps avoid scientific surprise. Additionally, it exploits scientific breakthroughs and provides options for new Future Naval Capabilities (FNCs) and Innovative Naval Prototypes (INPs). It responds to S&T directions of the DON Naval Power 21 (NP21) Transformational Roadmap, and Chief of Naval Operations (CNO) N70 Mission Capability Package (MCP) requirements for long term Navy and Marine Corps improvements. Defense Research Sciences is in consonance with future warfighting concepts and doctrine developed at the Naval Warfare Development Command and the Marine Corps Combat Development Command, and enables technologies to significantly improve the Joint Chiefs of Staff (JCS) Future Joint Warfighting capabilities. It is managed by the Office of Naval Research (ONR) through Program Officers at ONR Headquarters, and the base program of the corporate Naval Research Laboratory (NRL).

The vision of the DON S&T strategy is "to inspire and guide innovation that will provide technology-based options for future Navy and Marine Corps capabilities", where "Innovation is a process that couples Discovery and Invention (D&I) with Exploitation and Delivery". DON basic research is the core of D&I. It includes scientific study and experimentation directed toward increasing knowledge and understanding in national security related aspects of physical, engineering, environmental and life sciences. Basic research efforts are developed, managed, and related to more advanced aspects of research in some hundred-plus technology and capability-related 'thrusts', which are consolidated in fifteen research areas. These in turn support the major motivational research focus areas of the Navy and Marine Corps; maritime and space environments that impact operational capability, information science/knowledge management in network-centric operations, sensors and electronic systems for surveillance and tactical applications, energy/power/propulsion for performance gain and sustainment, advanced air/surface/undersea and multi-environment Naval platforms design/signature reduction, weapons systems for naval forces, and superior human performance/training/care of Sailors and Marines.

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Key aspects of the program are the four ONR Grand Challenges which 'inspire and guide' the direction of research: Naval Battlespace Awareness, Electric Power Sources for the Navy and Marine Corps, Naval Materials by Design, and Multifunctional Electronics for Intelligent Naval Sensors. Key aspects also include the National Naval Responsibilities (NNRs), fields upon which a wide range of fundamental naval capabilities depend, and in which ONR is and likely will remain the principal US research sponsor. NNRs are ratified only after close scrutiny, and currently comprise Ocean Acoustics (started FY99), Underwater Weaponry (started FY02), and Naval Engineering (started in FY03). The basic research portfolio can be represented in three segments of emphasis identified as naval unique, participation, and harvest. Naval unique defines a category where the S&T is important to naval operations and largely undertaken only by the DON. It includes the NNR areas. Participation refers to S&T elements vital to naval operations, and naval investment can leverage funding sources other than DON such as airborne radars, communications and networks, materials sciences, and advanced energetic materials. Harvest defines cross cutting areas of science and engineering with potential to generate unanticipated naval capabilities or savings, and which DON should nurture such as nanoscience (potential new material properties) and the behavioral sciences.

Due to the number of efforts in this PE, the programs described herein are representative of the work included in this PE.

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PROGRAM CHANGE SUMMARY:

	FY 2004	FY 2005	FY 2006	FY 2007
FY 2005 President's Budget Submission	375,363	375,812	390,131	397,748
Cong Rescissions/Adjustments/Undist. Reductions	0	-3,737	0	0
Congressional Action	0	8,400	0	0
Program Adjustments/realignments	0	-34	-33,560	-32173
Execution Adjustments	-3,837	0	0	0
Federal Technology Transfer	-31	0	0	0
Non-Pay Inflation Adjustments	-369	0	2	3
Rate Adjustments	0	0	312	1,102
SBIR Assessment	-6,883	0	0	0
FY 2006/2007 President's Budget Submission	364,243	380,441	356,885	366,680

PROGRAM CHANGE SUMMARY EXPLANATION:
Technical: Not applicable.

Schedule: Not applicable.

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PROGRAM ELEMENT: 0601153N PROGRAM ELEMENT TITLE: DEFENSE RESEARCH SCIENCES
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B. ACCOMPLISHMENTS/PLANNED PROGRAM:

	FY 2004	FY 2005	FY 2006	FY 2007
AIR, GROUND AND SEA VEHICLES	26,349	24,293	25,040	25,788

Efforts include: Surface/subsurface reduced signatures; free-surface, subsurface, and propulsor hydromechanics; hull life assurance; advanced ship concepts; distributed intelligence for automated survivability; advanced electrical power systems; air vehicles; air platforms propulsion and power; air platforms survivability and signature control; special aviation projects; Unmanned Air Vehicle/Unmanned Combat Air Vehicle (UAV/UCAV); environmental quality; and logistics. Accomplishments and plans below are examples for each effort category.

Reflects realignment of R2 activities based on Chief of Naval Research (CNR) requirements.

FY 2004 Accomplishments:

Air Vehicles
• Continued exploration of communications and control concepts for autonomous collaboration between unmanned air vehicles.

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• Continued investigations into controlled initiation and recovery from aggressive non-linear aero-maneuvers conducted by unmanned air vehicles.

Ship Concepts and Hydrodynamics
• Continued the computational and experimental study of Coanda (fluid flow along surfaces) Flows.
• Continued detailed measurements of total wave field and resulting ship motions using new instrumentation.
• Continued development of Large-Eddy Simulation (LES) method for unsteady Propulsor tip-gap flow predictions.
• Continued development of reliable sea-keeping prediction methods for advanced surface ship hull forms in heavy seas.
• Continued wind tunnel experiments to characterize unsteady tip-gap flow in turbomachinery.
• Continued development of measurement technique for unsteady field point velocity using Particle Image Velocimetry (PIV).
• Continued vortex/vortex interaction experiments to understand the tip gap cavitation inception physics.
• Completed a ship breaking wave prediction method.
• Completed ranking of non-propulsor bubble sources around surface ships.
• Completed validation of new optimization procedure for prediction methods for ducted propellers and podded propellers.
• Completed seabase protection studies including concept design for a seabase, use of seaplanes including database of seaplanes with parametric studies for FY 2010+ assessment.
• Initiated nonlinear seakeeping code for structural loading of multi-hulls.
• Initiated modeling of two-way, unsteady, non-spherical bubble/vortical flow interaction and resulting acoustics.
• Initiated modeling and optimization techniques for Naval Design of Multi-Hulls, Optimal functional arrangements for both ship and submarine design, and optimization for semi-displacement craft.
• Initiated database of multi-hull and monohull small craft with tow tank test data for incorporation into new theories for scalable multi-hull design and high speed small vessels.
• Initiated hydrodynamic analysis of fast multi-hull ships.
• Initiated Vision based wave sensing for active ride control for small high speed craft (verified concept of predicting waves in the laboratory environment).
• Implemented web-based technical lessons/instruction/lab experiments for interested students/general public in Naval engineering principles.
• Instituted a nationwide distribution of small underwater remotely operated vehicles for hands-on instruction of Naval engineering principles at high schools.

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• Transitioned Unified Test Environment/Technical Identification, Evaluation System (UTE/TIES) design methodology to the Littoral Combat Ship to assess for monohull, trimaran, catamaran and surface effect ships (SES).

Ship Signatures, Structures, and Materials
• Continued development of computational mechanics to provide predictive capabilities of acoustics, linear and nonlinear dynamic response and failure mechanisms of structures.
• Continued study of ductile fracture in naval steels from materials issues through ship sections including ongoing modeling efforts.
• Developed reliability methodology for hull structures and hybrid joints.
• Developed physics based understanding of composite materials to characterize thermo-mechanical behavior, response to multi-axial loads and improve mechanical properties.
• Developed methods to reduce acoustic modeling requirements and techniques for physical modeling at small scale to better characterize signature phenomenology and control and structure amplified flow noise.
• Developed expanded scaleable simulation capabilities for virtual distributed control.
• Evaluated electromagnetic signature basic physics including scattering from multi-scaled dielectric materials and evaluation of visual rendering studies into high fidelity infrared modeling.

Environmental Sciences
• Continued examination of scientific methods for pollution prevention, waste reduction, and hazardous material reduction for Naval Operations.
• Determined durability of foul-control marine coatings to reduce energy use and adverse environmental impacts and to extend the time between physical removal of hull and marine structure foulants.
• Developed high thermal conductivity polymer nanocomposites.
• Initiated assessment of the fate and effects of chemical and biological contaminants in marine/estuarine environments.

Ship and Air Platform Machinery and Systems
• Continued efforts to understand and control the generation and propagation of far-field jet noise.
• Quantified a three-dimensional (3D) turbo machinery flow using stereo PIV.
• Conducted studies of thermoelectric material requirements for shipboard cooling applications.
• Explored and evaluated control system algorithms and strategies in a virtual environment including affordability issues.
• Established limits for energy-time transients as a function of power system impedance parameters.

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- Constructed and conducted test run of a thermoacoustic piezoelectric generator.
- Completed work on quantification of active combustion control.
- Initiated efforts to design and test stability and control mechanisms for power distribution in nonlinear circuits.
- Initiated scientific approaches to alternate heat transfer and cooling methodologies.

FY 2005 Plans:

Air Vehicles
- Continue all efforts of FY 2004.

Ship Concepts and Hydrodynamics
- Continue all efforts of FY 2004 less those noted as completed above.
- Complete detailed measurements of total wave field and resulting ship motions using new instrumentation.
- Complete development of LES method for unsteady propulsor tip-gap flow predictions.
- Complete wind tunnel experiments to characterize unsteady tip-gap flow in turbomachinery.
- Complete development of unsteady field pressure measurement technique using PIV.
- Complete vortex/vortex interaction experiments to understand the tip gap cavitation inception physics.
- Complete Database efforts for multi-hull and monohull small craft with transfer of two dimensional (2D) body plans into 3D computer aided design (CAD) models.
- Complete efforts in development of Vision based wave sensing for active ride control for small high speed craft.
- Initiate investigation of the use of LES for acoustic prediction.
- Initiate comprehensive laser-doppler velocimetry (LDV) development for unsteady propulsor gap flow characterization.
- Initiate development of LES modeling of highly unsteady separated flow around ducted propulsor.
- Initiate Reynolds Averaged Navier-Stokes (RANS) predictions of surface ship motion for high speeds.
- Initiate quantification and modeling of bubble sources around surface ships for prediction methods.
- Initiate validating a breaking wave prediction method against experimental data.
- Initiate modeling and experiments for roughness-wall boundary layer noise.
- Initiate the Research Tools Development Consortia Program under the Program Decision Memorandum (PDM) for University Research - Engineering Design Consortia.
- Initiate and complete modeling of surface piercing propellers.
- Apply validated optimization procedure for ducted propellers and podded propellers to design analysis

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tools.
• Expand nationwide distribution of small underwater remotely operated vehicles for hands-on instruction of Naval Engineering principles at high schools.
• Transition UTE/TIES design methodology for application on Submarine Synthesis Tool.
• Implement a nationwide program to educate high school guidance counselors on Naval engineering career opportunities.

Ship Signatures, Structures, and Materials
• Continue all efforts of FY 2004 less those noted as completed above.
• Evaluate electromagnetic signature basic physics to further understand low observable and IR technology performance against evolving threats.
• Initiate further examination of computational mechanics in order to address prediction of acoustic signatures in complex structures, modeling of structural failures and optimization, sensitivity analysis, and error control.

Environmental Sciences
• Continue all efforts of FY 2004 less those noted as completed above.
• Determine most promising foul-release approaches based on silicones to meet Navy durability requirements for further development and testing.
• Assess durability of foul-control marine coatings to reduce energy use and adverse environmental impacts and to extend the time between physical removal of hull and marine structure foulants.
• Conduct membrane research to correlate filtration efficiency with nano-fibrous membrane porosity, thickness, fiber diameter and chemical composition.
• Conduct efforts to improve membrane materials for high-flux and low-fouling efficiency with proper composite design, chemical modifications and materials selection.
• Conduct work on characterization of solute-membrane interactions using strongly fouling solutes (silica, proteins, CaCO3, oil, etc.) using long-term permeation and Fourier Transform Infrared Spectroscopy - attenuated total reflectance (FTIR-ATR) data.
• Conduct studies of mixed polyethyleneglycole (PEG), quantitative polyvinylpyrrolidone (PVP) surfaces & fouling release behavior.
• Conduct initial analysis of feasibility of medium dense plasma for liquid purification.
• Conduct efforts to measure the mechanisms for fouling release and to compare the skin friction properties of conventional and fouling release ship hull coatings.
• Explore low-energy laser induced incandescence schemes to avoid soot vaporization and extend light

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scattering measurements to soot burn-out regime.
• Develop bryozoans as new model organism used in assessment of coatings.
• Use hydrodynamic drag measurements to quantify force vs. speed on pseudo barnacles attachment to various surfaces.
• Investigate molecular structures of fluorinated polymers in air and in water to reveal their molecular surface structure.
• Study interactions between newly developed biofouling control/release polymers and mussel adhesive.
• Initiate investigation of effect of fluorinated block co-polymer uniformity on fouling release.
• Initiate efforts in rotating drum testing of anti-fouling coatings.
• Initiate new anti-fouling coating testing capabilities in international locations.
• Initiate effort on pier side robotic hull fouling control/surveillance technologies.
• Initiate emphasis on ultrafiltration membranes for bioreactors.

Ship and Air Platform Machinery and Systems
• Continue all efforts of FY 2004 less those noted as completed above.
• Examine turbomachinery flow using holographic PIV.
• Validate LES predictions of turbomachinery flow against experimental data.
• Integrate distributed heterogeneous control simulation capability into the overall control system simulation infrastructure.
• Test and evaluate control system algorithms and strategies in a virtual environment including affordability issues.
• Further evaluate stability and control of model electrical power systems.
• Perform half and full-scale engine testing of most promising on-board noise reduction technologies (e.g. air/water injection).
• Initiate development of advanced magnetocaloric materials for magnetic refrigeration.
• Initiate effort on pier side robotic hull fouling control/surveillance technologies.
• Initiate seabasing effort for an Advanced Logistics Delivery System including new technologies for gliders and ship launching methods.

FY 2006 Plans:

Air Vehicles
• Continue all efforts of FY 2005.

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Ship Concepts and Hydrodynamics
- Continue all efforts of FY 2005 less those noted as completed above.
- Complete the computational and experimental study of Coanda flows.
- Complete comprehensive LDV development for unsteady propulsor gap flow characterization.
- Complete modeling of two-way, unsteady, non-spherical bubble/vertical flow interaction and resulting acoustics.
- Complete validating a breaking wave prediction method against experimental data.
- Complete efforts in nonlinear seakeeping code for structural loading of multi-hulls.
- Complete efforts in modeling and optimization techniques for Naval Design of Multi-Hulls, Optimal functional arrangements for both ship and submarine design.
- Complete efforts in modeling of surface piercing propellers.
- Initiate the investigation of the effect of roughness on turbulent boundary layers.
- Initiate holographic PIV system development for unsteady 3D turbo machinery flow.
- Initiate modeling of two-phase flow using LES method.
- Initiate and complete validation of panel-code prediction of nonlinear waves and capsize using model scale data.
- Initiate and complete validation of prediction methods for bubble sources around surface ships.
- Initiate and complete validation of RANS predictions of surface ship motion in pitch and heave.
- Initiate further examination of computational mechanics in order to address prediction of acoustic signatures in complex structures, modeling of structural failures and optimization, sensitivity analysis and error control.
- Initiate the Research Tools Development Consortia Program for University Research - Engineering Design Consortia.

Ship Signatures, Structures, and Materials
- Continue all efforts of FY 2005 less those noted as completed above.
- Complete efforts in modeling of ductile fracture in naval steels.

Environmental Sciences
- Continue all efforts of FY 2005 less those noted as completed above.

Ship and Air Platform Machinery and Systems
- Continue all efforts of FY 2005 less those noted as completed above.
- Integrate distributed heterogeneous control simulation capability into the overall control system

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simulation infrastructure.
• Test and evaluate control system algorithms and strategies in a virtual environment including affordability issues.
• Complete efforts in seabasing for an Advanced Logistics Delivery System.

FY 2007 Plans:

Air Vehicles
• Continue all efforts of FY 2006.

Ship Concepts and Hydrodynamics
• Continue all efforts of FY 2006 less those noted as completed above.
• Complete modeling and experiments for roughness-wall boundary layer noise.
• Complete RANS predictions of surface ship motion for high speeds.
• Complete LES modeling of highly unsteady separated flow around ducted propulsor against water tunnel measurements.
• Initiate and complete validation of six degrees of freedom (6DOF) RANS for surface ship motions (without capsize).
• Initiate and complete validation of prediction of ship wave breaking and bubbly flow at full scale.
• Determine most promising foul-release approaches based on silicones to meet Navy durability requirements for further development and testing.
• Perform half and full-scale engine testing of most promising on-board noise reduction technologies (e.g. air/water injection).

Ship Signatures, Structures, and Materials
• Continue all efforts of FY 2006 less those noted as completed above.

Environmental Sciences
• Continue all efforts of FY 2006.
• Complete efforts to increase strength in silicone based polymers for antifouling/friction reduction (AF/FR) coatings.

Ship and Air Platform Machinery and Systems
• Continue all efforts of FY 2006 less those noted as completed above.

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- Further examine turbomachinery flow.
- Integrate distributed heterogeneous control simulation capability into the overall control system simulation infrastructure.
- Test and evaluate control system algorithms and strategies in a virtual environment including affordability issues.

	FY 2004	FY 2005	FY 2006	FY 2007
ATMOSPHERE AND SPACE SCIENCES	38,514	40,848	23,500	18,985

Efforts include: Marine Meteorology and Prediction; High Frequency Active Auroral Research Program (HAARP) and Space Sciences. Accomplishments and plans below are examples for each effort category.

Reflects realignment of activities based on CNR requirements.

FY 2004 Accomplishments:

Marine Meteorology and Prediction
- Assessed validation of environmental data and models used by S&T community to ensure reliability and realistic depiction of actual ocean and atmospheric conditions.

High Frequency Active Auroral Research Program (HAARP)
- Continued project to complete HAARP. All antennas were installed by the end of 2004.

Space Sciences
- Continued calibration/validation of WINDSAT polarimetric passive microwave data. (NRL)
- Continued the development of 3D magneto-hydrodynamic code for simulations of solar filament eruptions leading to flare and coronal mass ejection (CME) activity. (NRL)
- Substantial progress in the development of 3D magneto-hydrodynamic code for simulations of solar filament eruptions leading to flare and coronal mass ejection (CME) activity. (NRL)
- Completed extensive studies of the major Oct.-Nov. 2003 solar activity events and associated effects on the near-Earth space environment. (NRL)
- Assessed improvements to specification and prediction of the space environment to improve space system performance and their on-call availability.
- Developed and initiated validation of advanced techniques and algorithms for remote sensing of ocean and

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atmospheric properties including winds, waves, currents, and surface topography.

FY 2005 Plans:

Marine Meteorology and Prediction
• Continue all efforts of FY 2004.
• Investigate and better understand the bulk exchanges, aerosol-cloud interaction, and physical processes that take place at the atmospheric boundary layer interface. (Includes NRL investment/performance in this effort.)

High Frequency Active Auroral Research Program (HAARP)
• Complete improvements in the performance of the HAARP with the installation of transmitters.

Space Sciences
• Continue all efforts of FY 2004 less those noted as completed above.
• Investigate the near-earth environmental effects on electromagnetic propagation. (NRL)
• Expand modeling of the near-Earth space environment with the development a self-consistent coupled model of the solar wind/magnetosphere/ionosphere system. (NRL)
• Evaluate/develop techniques for remediation of nuclear-enhanced radiation belts using amplification induced whistler waves or turbulent plasma created by ionizable chemical release. (NRL)
• Improve understanding of tropospheric and stratospheric bulk exchanges through observations and modeling. (NRL)

FY 2006 Plans:

Marine Meteorology and Prediction
• Continue all efforts of FY 2005.
• Complete validation of environmental data and models used by S&T community to ensure reliability and realistic depiction of actual ocean and atmospheric conditions.
• Initiate the design next-generation ocean-atmosphere coupled models.

Space Sciences
• Continue all efforts of FY 2005.
• Assess advanced improvements to specification and prediction of the space environment to improve space

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system performance and their on-call availability. (Includes NRL investment/performance in this effort.)
• Assess advanced techniques and algorithms for remote sensing of ocean and atmospheric properties including winds, waves, currents, and surface topography.

FY 2007 Plans:

Marine Meteorology and Prediction
• Continue all efforts of FY 2006 less those noted as completed above.
• Continue programs to develop the next-generation ocean-atmosphere coupled models.
• Assess status of aerosol observation, prediction, and understanding for use in slant-range visibility models.

Space Sciences
• Continue all efforts of FY 2006.
• Initiate program to develop advanced improvements to specification and prediction of the space environment to improve space system performance and their on-call availability.
• Initiate monitoring of other-agency efforts for Naval Harvest of advanced techniques and algorithms for remote sensing of ocean and atmospheric properties including winds, waves, currents, and surface topography.
• Demonstrate skill in modeling and predicting near-earth environmental effects on electromagnetic propagation. (NRL)

	FY 2004	FY 2005	FY 2006	FY 2007
HUMAN SYSTEMS	9,525	8,028	8,360	8,719

Efforts include: human factors and organizational design; manpower, personnel, and training; integrated avionics, displays, and advanced cockpit; and pattern recognition. Accomplishments and plans below are examples for each effort category.

Reflects realignment of activities based on CNR requirements.

FY 2004 Accomplishments:

Cognitive, Neural and Social Science
• Continued study of social networks for counterterrorism.

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- Continued expansions to cognitive models to include spatial reasoning.
- Continued studies of attention management in multi-tasking.
- Continued study of retinal information processing and modeling.
- Continued research on human cognition and performance to create more realistic simulations for training.
- Initiated program to combine cognitive architectures with computational neuroscience to better predict human performance.
- Initiated development of novel multidisciplinary approaches to human-activity inference from video imagery to enable force protection and counterterrorism.
- Initiated program on implantable electronics for performance enhancement.
- Initiated studies of hierarchical, cellular, and hybrid organization structures for command and control.
- Initiated schema theory applications to multi-echelon command decision making.

FY 2005 Plans:

Cognitive, Neural and Social Science
- Continue all efforts of FY 2004.
- Complete study of retinal information processing and modeling environments.
- Initiate study of neuro-control of Unmanned Underwater Vehicles (UUVs) and active vision and cognitive navigation skills in mobile robots.

FY 2006 Plans:

Cognitive, Neural and Social Science
- Continue all efforts of FY 2005 except those noted as completed above.
- Complete studies of attention management in multi-tasking.

FY 2007 Plans:

Cognitive, Neural and Social Science
- Continue all efforts of FY 2006 except those noted as completed above.
- Complete development of novel multidisciplinary approaches to human-activity inference from video imagery to enable force protection and counterterrorism.
- Complete expansions to cognitive models to include spatial reasoning.

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	FY 2004	FY 2005	FY 2006	FY 2007
INFORMATION SCIENCES	21,399	23,396	23,470	23,300

Efforts include: Computational theory and tools for design, communication, and control of intelligent autonomous systems; decision theory, algorithms, and tools; heterogeneous information integration, management, and presentation; information assurance, secure and reliable information infrastructure for Command and Control; mathematical optimization for optimal resource allocation and usage; modeling and computation of complex physical phenomena; modeling and computation for electromagnetic and acoustic wave propagation and scattering; seamless, robust connectivity and networking; and expeditionary operations Command, Control, Communications, Computers Intelligence Surveillance and Reconnaissance (C4ISR). Accomplishments and plans below are examples for each effort category.

Reflects realignment of activities based on CNR requirements.

FY 2004 Accomplishments:

• Continued development of mathematical optimization framework and heuristic algorithms that serve as theoretical and computational basis for network design, optimal sensor allocation, and logistics.
• Continued refinement of techniques for ensuring privacy of information transferred across public networks.
• Continued development of improved tactical and battlespace decision aids through creation of synthetic natural environments.
• Continued to refine techniques for extracting maximum knowledge from multi-modal imagery, text, and electromagnetic signal data.
• Continued to investigate methods to deal with light dispersion on image formation underwater to enable precise navigation, station keeping, and mapping capabilities for unmanned underwater vehicles.
• Continued efforts for enabling teams of autonomous systems to work together and work on representations for evolution of cooperative behaviors, including efforts in multi-modal interactions with autonomous systems.
• Continued developing framework for dealing with effect of variable latencies in communication within teams of humans and autonomous systems.
• Continued efforts on development of mathematical foundations for image enhancement, feature extraction, feature-based/texture-based compression, denoising, and segmentation; data representation and metrics, content-based indexing and retrieval; reconstruction, interpolation, and registration; and scene analysis and image understanding.
• Continued efforts on quantum computing and cryptography.

BUDGET ACTIVITY: 01
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- Continued efforts on general automated theorem prover technologies and biometric technologies for authentication.
- Continued efforts in multi-modal dialog.
- Continued efforts in physics-based modeling of natural phenomena.
- Continued efforts in mathematical techniques for inverse problems, including reliable approximate solutions in 3D; adequate representation of the physics of the media and the scatterer; and improved resolution of structural and material properties.
- Continued development of technology for the automated construction of high assurance software. (NRL)
- Completed development of technology for multimodal interaction with autonomous systems. (NRL)
- Completed development of new technology for hiding and detecting information hidden in pictures. (NRL)
- Initiated efforts on modeling chaotic phenomena in network operations.
- Initiated efforts for integrating domain knowledge into learning methods.
- Initiated efforts for semantic-based information gathering.
- Initiated efforts in extended augmented/virtual reality with haptics, sound, and olfactory components.
- Refined theory and algorithms for autonomous systems to recognize a particular scene from different perspectives.
- Refined turbo-codes and iterative processing techniques to enable high data rates for wireless communication applications.
- Developed a framework for collaborative mission planning tools to facilitate knowledge sharing and management, regulation of information flow, and work-process monitoring.
- Developed adaptive routing protocols to select the links for routing information packets that maximize communication network throughput with minimum energy consumption.
- Investigated Extremely Low Frequency (ELF) modulation and efficiency improvements and magnetospheric propagation.
- Initiated development of technology for maximizing information delivery in tactical networks via encoding information under speech. (NRL)
- Initiated development of technology for increasing efficiency of tactical wireless networks based on fundamental invariants for random-access protocols. (NRL)
- Initiated development of technology for improving behavior of coordinated teams of autonomous systems. (NRL)

FY 2005 Plans:

- Continue all efforts of FY 2004 less those noted as completed above.

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• Develop computational framework for integrating information of disparate sources - Program Decision Memorandum (PDM) for University Research - Surveillance & Knowledge Systems.
• Develop a systematic approach that will serve as a theoretical and computation basis for automated image understanding and automatic object recognition.
• Complete refinement of techniques for ensuring privacy of information transferred across public networks.
• Complete collaborative mission planning tools to facilitate knowledge sharing and management, regulation of information flow, and work-process monitoring.
• Complete development of technology for the automated construction of high assurance software (NRL)
• Initiate the development of technology to improve tactical wireless ad hoc networks via development of cross-layer design approaches (NRL)

FY 2006 Plans:

• Continue all efforts of FY 2005 less those noted as completed above.
• Continue efforts in extended augmented/virtual reality with haptics, sound, and olfactory components.
• Complete development of techniques for maximizing information delivery in tactical networks via encoding information under speech. (NRL)
• Complete development of technology for increasing efficiency of tactical wireless networks based on fundamental invariants for random-access protocols. (NRL)
• Initiate development of technology to improve secure information sharing. (NRL)

FY 2007 Plans:

• Continue all efforts of FY 2006 less those noted as completed above.
• Complete efforts in extended augmented/virtual reality with haptics, sound, and olfactory components.
• Complete the development of technology to improve tactical wireless ad hoc networks via development of cross-layer design approaches. (NRL)
• Initiate development of technology to re-engineer legacy code. (NRL)

	FY 2004	FY 2005	FY 2006	FY 2007
MATERIALS/PROCESSES	69,162	73,256	74,208	81,885

Efforts include: Structural materials; functional materials; and maintenance reduction. Accomplishments and plans below are examples for each effort category.

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Reflects realignment of activities based on CNR requirement.

FY 2004 Accomplishments:

Structural Materials
- Continued to develop understanding and constitutive models of dynamic behavior of naval steels.
- Developed and validated physics-based models of thermal and materials flow during friction stir welding of steels, including the development of residual stresses that will lead to distortion.
- Developed first-principles based methodologies for predicting the thermodynamics and kinetics controlling microstructural evolution for the design of advanced Naval steels.
- Designed, synthesized, and developed welding consumables and process methodologies for joining superaustenitic stainless steels.
- Developed theoretical basis for composite materials behavior based on x-ray computed micro-tomography.
- Advanced the understanding of deformation mechanisms in nanometer scale aluminum and steels to provide new high strength-high toughness alloys for naval platforms.
- Developed models and simulations to understand and predict high deformation rate blast behavior for engineered topological structures.
- Developed understanding linking complex reaction paths and atomic diffusion in the formation of environmental and diffusion barrier coatings for high temperature thermal and environmental barrier coatings.
- Developed the dynamic response (constitutive behavior, failure) for marine composites and sandwich structures.
- Developed nanocomposites for enhancing mechanical properties of marine composites.
- Optimized the role of oxygen in titanium alloys. (NRL)
- Demonstrated chemical synthesis of carbon nanotubes in large quantities and high yield in bulk solid. (NRL)
- Developed laser-based machining techniques and data acquisition equipment have been used to create arrays of defects, deposit local DC potential drop sensors and measure five simultaneous combinatorial experiments in a single fatigue specimen. (NRL)
- Determined structure of analog of elastin (component of the walls of arteries) and a probable mechanism for elasticity on a molecular level. (NRL)
- Demonstrated successful brazing and sintering of high-purity ceramics. (NRL)
- Completed effort in Magnetic Phenomena in Reduced Dimensions (NRL)

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Functional Materials
• Developed first principle methods to calculate second and third rank tensor properties of sonar materials such as lead zirconate titanate and lead magnesium niobate.
• Developed integrated bio-magneto-electronic structures and devices for experimental evaluation.
• Developed a computational model of the interaction of fine water mist with an opposed-jet flame for flame suppression. (NRL)
• Identified, quantified, and controlled the atomic scale properties that limit or enhance the performance of magnetic semiconductor materials.
• Designed and synthesized a new porous carbon platform for fuel cell catalysis where 86% of the surface Pt atoms are electrocatalytic. (NRL)
• Invented/Patented a New Class of Nanoscale Hierarchical Optical Polymers. (NRL)
• Demonstrated unification of basic concepts from propulsion, combustion, and astrophysics led to concepts for two new types of micropropulsion devices based on controlled interactions of flames and boundary layers. (NRL)
• Demonstrated that Dip Pen Nanolithography (DPN) can be used to produce versatile chemical templates on silicon oxide surfaces. (NRL)
• Demonstrated high definition masks for measurements in left handed materials. (LHM) (NRL)
• Demonstrated use of virus as a scaffold for signal amplification. (NRL)
• Demonstrated an innovative detonation initiation technique and PDE operation with liquid JP10. (NRL)
• Determined changes in optical properties of organic matter during estuarine transport. (NRL)
• Evaluation of tunable pulsed laser systems for growth of organic thin films by Resonant Infra Red Pulsed Laser Deposition. (RIR-PLD) (NRL)
• Characterized (mechanistically and quantitatively) the rate of iron bioreduction in ferruginous smectite within the contexts of marine suspended particle dynamics and sediment geotechnical properties. (NRL)
• Analyzed nanostructures formed in silicon and thin film wafers by novel, laser-assisted direct imprinting (LADI) technique. (NRL)

Maintenance Reduction
• Identified stress corrosion control methods for friction stir welded high-strength aluminum alloys using advanced thermal treatments, chemical modifications, and surface mechanical processes to tailor compressive stresses.
• Developed the science of sliding contact and lubrication using physical and chemical first principles.
• Explored transgranular crack tip damage mechanism in ultra high strength steels.
• Investigated the use of photorefractive crystals for the demodulation of a distributed fiber optic Bragg

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gratings structural health monitoring system.
• Completed effort in Magnetic Phenomena in Reduced Dimensions. (NRL)
• Initiated investigation of continuous growth of single and multiwall nanotubes for next generation polymer matrix composite materials.

FY 2005 Plans:

Structural Materials
• Continue all efforts of FY 2004 less those noted as completed above.
• Explore superplasticity in advanced high strain nanometer scale ceramic composites to provide the basis for the development of such materials in naval applications.
• Develop materials and fabrication science for fugitive phase processes for engineered topological structures for ship blast protection.
• Begin to explore the design of advanced steels for weldability based on previous first-principles efforts.
• Initiate investigation of the role of hydrogen and nitrogen on mechanical properties of titanium alloys. (NRL)
• Initiate investigation of joining of dissimilar ceramics and sintering of light metal composites. (NRL)

Functional Materials
• Continue all efforts of FY 2004 less those noted as completed above.
• Extend first principle calculations of sonar materials tensor piezoelectric and dielectric properties to complex solid solutions to provide the basic understanding and predictive capability for ultra high strain materials.
• Explore and develop materials for high energy density passive power electronics.
• Optimize nanoimprinting process. Eliminate grain boundaries, triple points and diffusion of substrate elements in nanoimprinted metal thin films. (NRL)
• Initiate development of Materials/Fabrication Science to Exploit the New Structured Optical Polymers. (NRL)

Maintenance Reduction
• Continue all efforts of FY 2004 less those noted as completed above.
• Begin first lubrication-by-design experiments.
• Identify hydrogen embrittlement resistant high strength alloys based on nickel-cobalt-chrome-molybdenum material systems.
• Explore advanced coatings with multifunctional corrosion/fouling properties.

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- Explore advanced theoretical concepts for corrosion control.
- Explore multienergy processes for zero maintenance coatings.
- Complete effort in Fault Identification and Failure Prediction Technologies. (NRL)

FY 2006 Plans:

Structural Materials
- Continue all efforts of FY 2005 less those noted as completed above.
- Complete design, synthesis and development of welding consumables and process methodologies for joining superaustenitic stainless steels.
- Initiate exploration into the processing and microstructures of novel titanium alloys that may be enabled by new co-reduction of mixed metallic oxide processes.
- Develop progressive damage models for blast effects on composite marine structures.
- Develop concepts for enhancing resistance to dynamic loading on composite marine structures.
- Explore microstructural evolution during solid-state joining and localized processing of weldments in titanium alloys for improved toughness and fatigue resistance.
- Explore advanced techniques for Blast Mitigation. (NRL)
- Evaluate Polycrystalline Ceramic Laser Materials. (NRL)
- Investigate the role of rare earth additions to titanium alloys using newly developed processing technique. (NRL)
- Fabricate extended 2-D LHM structures. (NRL)

Functional Materials
- Continue all efforts of FY 2005 less those noted as completed above.
- Explore and predict new sonar materials based on first principle methods.
- Explore new transduction mechanisms.
- Complete projects in 1) Nanofilaments: Interfacial Interactions, Manipulation and Assembly and 2) Half-Metallic Electronic Materials. (NRL)
- Complete protection of carbon nanotubes against oxidation at elevated temperatures and transition into other spin-off programs. (NRL)
- Initiate examination of the effects of acoustic perturbations and interactions in reacting flows and determine how they can be used. (NRL)
- Initiate investigation of Radically New Hierarchical Polymer GRIN Lenses that Mimic the Focusing of an Eye. (NRL)

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- Initiate single molecule binding detection using optical trap. (NRL)
- Initiate effort to fabricate extended 2-D LHM structures. (NRL)

Maintenance Reduction
- Continue all efforts of FY 2005 less those noted as completed above.
- Test a statistically relevant number of combinatorial specimens to rank defects, microstructure and their interactions for fatigue crack initiation and growth. (NRL)

FY 2007 Plans:

Structural Materials
- Continue all efforts of FY 2006 less those noted as completed above.
- Complete development and validation of physics-based models of thermal and materials flow during friction stir welding of steels, including the development of residual stresses that lead to distortion.
- Complete the development of understanding of deformation mechanisms in nanometer scale aluminum and steels for new high strength-high toughness alloys for naval platforms.
- Complete efforts to understand links between complex reaction paths and atomic diffusion in the formation of environmental and diffusion barrier coatings for high temperature thermal and environmental barrier coatings.
- Complete analysis of dynamic response (constitutive behavior, failure) for marine composites and sandwich structures.
- Investigate rapid annealing of surface layers and their effects. (NRL)

Functional Materials
- Continue all efforts of FY 2006 less those noted as completed above.
- Synthesize and measure the properties of new sonar materials predicted by first principle methods.
- Develop and transition advanced bio-magneto-electronic materials and devices.
- Complete development of first principle methods to calculate second and third rank tensor properties of sonar materials such as lead zirconate titanate and lead magnesium niobate.

Maintenance Reduction
- Continue all efforts of FY 2006 less those noted as completed above.
- Complete efforts to identify stress corrosion control methods for friction stir welded high-strength aluminum alloys using advanced thermal treatments, chemical modifications, and surface mechanical processes to

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tailor compressive stresses.
• Complete exploration of transgranular crack tip damage mechanism in ultra high strength steels.

	FY 2004	FY 2005	FY 2006	FY 2007
MEDICAL/BIOLOGY	15,545	14,665	15,072	15,563

Efforts include: biosensors, biomaterials, bioprocesses; marine mammals; casualty care and management; fit and healthy force; casualty prevention; biorobotics; expeditionary operations training and education; and chemical-biological defense. Accomplishments and plans below are examples for each effort category. Reflects realignment of activities based on CNR requirements.

FY 2004 Accomplishments:

Medical Sciences
• Continued research to understand individual variability in stress response.
• Continued non-lethal weapons bioeffects research.
• Continued work on stress physiology, hyperbaric physiology, and biological effects of naval operational exposures (e.g., directed energy).
• Continued work on genomics/genetic immunization for infectious organisms of military relevance, stem cells, and signal transduction.
• Completed functional genomic and proteomic analysis of early stages of anthrax infection.

Biological Sciences
• Continued studies of effects of noise on marine mammal hearing and behavior.
• Continued studies on fate and effects of energetic and other organic compounds in marine environments.
• Continued research on virus-based nanoarchitectures.
• Continued work on microbial synthesis of energetic materials.
• Continued development of novel genetic sequencing tools for marine algae and seaweeds.
• Continued research on biofouling.
• Continued studies of marine mammal biomimetic/biorobotic systems.
• Completed marine mammal immunobiology studies.
• Initiated efforts to develop next-generation, supramolecular antibiotics.
• Initiated development of genetically encoded markers of signal transduction.
• Initiated work to recharge naval ocean instruments with sediment biofuel cells.

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FY 2005 Plans:

Medical Sciences
- Continue all efforts of FY 2004 less those noted as completed above.

Biological Sciences
- Continue all efforts of FY 2004 less those noted as completed above.
- Complete development of novel genetic sequencing tools for marine algae and seaweeds.
- Initiate development of ultra-high performance cell sorters.
- Initiate research to understand physiological effects of naval sonar exposures on marine mammals.

FY 2006 Plans:

Medical Sciences
- Continue all efforts of FY 2005.
- Complete studies on fate and effects of energetic and other organic compounds in marine environments.

Biological Sciences
- Continue all efforts of FY 2005 less those noted as completed above.
- Complete studies of marine mammal biomimetic/biorobotic systems.

FY 2007 Plans:

Medical Sciences
- Continue efforts of FY 2006 less those noted as completed above.

Biological Sciences
- Continue efforts of FY 2006 less those noted as completed above.

	FY 2004	FY 2005	FY 2006	FY 2007
OCEAN SCIENCES	79,356	87,612	87,881	90,814

Efforts include: Littoral Geosciences, Optics, and Biology; Marine Mammals; Physical Oceanography and

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Prediction; Ocean Acoustics; and University National Oceanographic Laboratory System (UNOLS). Accomplishments and plans below are examples for each effort category.

Reflects realignment of activities based on CNR requirements.

FY 2004 Accomplishments:

Littoral Geosciences, Optics, and Biology
• Developed programs to validate techniques for utilizing high resolution, motion imagery methods to predict beach evolution.
• Implemented investigation of fate and effects of unexploded ordnance in the marine environment to reduce the threat to civilian population and military explosive ordnance disposal personnel.
• Initiated field programs to understand physical and biological processes responsible for the formation, maintenance, and breakdown of thin oceanographic layers which have a significant impact on undersea warfare sensors and weapons.
• Initiated effort to improve accuracy of the "5-cm geoid" and precise geodesy. (NRL)

Marine Mammals
• Initiated field trials of an integrative ecosystem study to provide environmental predictors of whale presence or absence to reduce impacts of naval systems to marine mammals.

Physical Oceanography and Prediction
• Continued to develop state of the art numerical model assimilation and initialization techniques, improved physical parameterizations, air-sea interactions, and fidelity for atmospheric and ocean prediction systems. (Includes NRL investment/performance in this effort.)
• Conducted opportunistic validation of global on-scene, accurate, theater scale, high resolution environmental characterizations and forecasts to improve all weather operations and defense capabilities of acoustic, electro-optical, and infrared (EO/IR) sensors, and the performance of Naval weapons in the atmosphere and under the sea.

Ocean Acoustics
• Continued development of a coupled hydrodynamic-acoustic model for sound generation from breaking waves. (Includes NRL investment/performance in this effort.)
• Continued development of numerical methods to predict the effects of the sub-surface bubble layer on

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underwater acoustics propagation and scattering. (Includes NRL investment/performance in this effort.)
• Continued to research effect of solitons and internal wave bores on acoustic propagation and buoyancy. (Includes NRL investment/performance in this effort.)
• Developed advanced methods for combining "through the sensor" data with other views of the battlespace environment to improve real-time environmental predictions. (Includes NRL investment/performance in this effort.)

FY 2005 Plans:

Littoral Geosciences, Optics, and Biology
• Continue all efforts of FY 2004.
• Develop techniques to exploit hyperspectral data from a geostationary platform to better understand coastal ocean dynamics. (Includes NRL investment/performance in this effort.)
• Better understand extent and intensity of seafloor gas hydrate accumulations and coastal bio-optical response to air-ocean forcing. (Includes NRL investment/performance in this effort.)

Marine Mammals
• Continue all efforts of FY 2004.

Physical Oceanography and Prediction
• Continue all efforts of FY 2004.
• Initiate an assessment of the role of emerging sub-mesoscale parameterization techniques for improving next generation high resolution/high accuracy environmental models.
• Initiate design evaluation for a persistent mobile sampling network based on autonomous undersea vehicle platform and sensor technologies.

Ocean Acoustics
• Continue all efforts of FY 2004.
• Complete development of the coupled hydrodynamic-acoustic model for sound generation from breaking waves. (Includes NRL investment/performance in this effort.)
• Initiate development of an improved Nonlinear Progressive Wave Equation model for shallow water applications. (NRL)
• Initiate comparison of numerical methods that predict effects of sub-surface bubble layers on acoustics to laboratory measurements. (NRL)

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FY 2006 Plans:

Littoral Geosciences, Optics, and Biology
• Continue all efforts of FY 2005.
• Initiate programs to estimate optical properties of coastal ocean water from above-surface sensing, using in-situ data for validation.

Marine Mammals
• Continue all efforts of FY 2005.
• Initiate new efforts on tracking of marine mammals using data fusion based on tags and remote sensing.

Physical Oceanography and Prediction
• Continue all efforts of FY 2005.
• Initiate field efforts for a persistent mobile sampling network based on autonomous undersea vehicle platform and sensor technologies.

Ocean Acoustics
• Continue all efforts of FY 2005 less those noted as completed above.
• Complete development and comparisons with data of numerical methods to predict effects of sub-surface bubble layers on acoustic propagation and scattering. (NRL)
• Complete incorporation of stochastic parameters into underwater acoustic propagation models. (Includes NRL investment/performance in this effort.)
• Complete development and comparisons with data of numerical methods to predict effects of sub-surface bubble layers on acoustic propagation and scattering. (NRL)
• Initiate studies of adaptive beam-forming using mobile, autonomous sensors.
• Initiate numerical simulations to investigate the analogs of condensed matter physics phenomena in ocean acoustics. (NRL)

Ocean Class Research Vessel- $4,000
• Assess optimum hull forms for Ocean Class platform/craft oceanographic research mission.
• Assess novel mission equipment options to ensure technology infusion.
• Initiate preliminary and detailed design studies of the selected hull form.
• Initiate a review and prioritize science mission requirements in conjunction with oceanographic research

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community and University National Oceanographic Laboratory System (UNOLS) members.
• Initiate program management.

FY 2007 Plans:

Littoral Geosciences, Optics, and Biology
• Continue all efforts of FY 2006.
• Begin to incorporate improved understanding of tropospheric and stratospheric bulk exchanges, air-sea interface, boundary layer interface, coastal ocean dynamics, gas hydrate accumulation, and biological responses into atmospheric and ocean prediction models and tactical aids. (Includes NRL investment/performance in this effort.)

Marine Mammals
• Continue all efforts of FY 2006.
• Complete study of an integrative ecosystem study to provide environmental predictors of whale presence or absence to reduce impacts of naval systems to marine mammals.

Physical Oceanography and Prediction
• Continue all efforts of FY 2006.

Ocean Acoustics
• Continue all efforts of FY 2006 less those noted as completed above.
• Assess “time-reversal” propagation techniques for mitigation of environmental variability.
• Complete development of the Nonlinear Progressive Wave Equation model. (NRL)
• Complete investigations of analogs of condensed matter physics phenomena in ocean acoustics. (NRL)
• Initiate field work on adaptive beamforming using mobile, autonomous sensors.

Ocean Class Research Vessel- $25,000
• Continue all efforts of FY 2006.
• Initiate construction of vessel

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	FY 2004	FY 2005	FY 2006	FY 2007
SCIENCE AND ENGINEERING EDUCATION, CAREER DEVELOPMENT AND OUTREACH	35,698	42,749	40,555	42,887

Science and Engineering Education and Career Development activities include DON participation in science fairs, summer research interns/fellows at Navy laboratories, graduate fellowships for individuals expected to become members of the engineering faculty at Historically Black Colleges and Universities and Minority Institutions (HBCU/MIs), and curricular enrichment programs. Outreach includes the encouragement, promotion, planning, coordination and administration of Naval Science and Technology. In previous submissions, this activity has not been identified separately but rather integrated into the other PE activities as it applied.

Reflects realignment of activities based on CNR requirements.

FY 2004 Accomplishments:

- Continued awarding prizes at 400 regional science fairs and three national competitions.
- Continued supporting 200 students as summer research interns at Navy laboratories.
- Continued providing graduate fellowship support to eight HBCU engineering faculty candidates.
- Assisted JASON project to provide video ocean science pre-college course enrichment materials.
- Supported 60 HBCU/MI faculty members as summer research fellows at Navy laboratories.
- Continued the encouragement, promotion, planning, coordination and administration of Naval Science and Technology.

FY 2005 Plans:

- Continue all efforts of FY 2004 less HBCU/MI faculty support and JASON assistance which were one-year efforts.

FY 2006 Plans:

- Continue all efforts of FY 2005.

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FY 2007 Plans:

• Continue all efforts of FY 2006.

	FY 2004	FY 2005	FY 2006	FY 2007
SENSOR, ELECTRONICS AND ELECTRONIC WARFARE (EW)	50,931	48,810	50,041	48,209

Efforts include: Sensing, diagnostics, and detectors; navigation and timekeeping; nano-electronics; wide band gap power devices; real-time targeting; EO/IR electronics; EO/IR electronic warfare; EO/IR sensors for surface/aerospace surveillance; Radio Frequency (RF) sensors for surface/aerospace surveillance; solid state electronics; vacuum electronics; advanced multi-function RF system (AMRFS); and RF electronic warfare. Accomplishments and plans below are examples for each effort category.

Reflects realignment of activities based on CNR requirements.

FY 2004 Accomplishments:

• Continued effort to incorporate non-equilibrium considerations into modeling of realistic superconducting tunnel junctions when barrier is near the metal/insulator transition.
• Continued to explore optical super resolution techniques with atmospheric turbulence reduction techniques.
• Continued investigation of temporal-spatial sampling circuits and architectures for digital-to-analog conversion.
• Continued to improve room temperature 4.5-4.8 micron quantum cascade laser by reducing emission wavelength and further increasing power to meet laser source requirements for infrared countermeasures against heat-seeking missiles.
• Continued advanced height finding and detection algorithms for high frequency radar.
• Continued comprehensive study of compressive and tensile strain patterned semiconductor quantum wells using micromachining. (NRL)
• Continued proof of principle demonstration of microcavity chemical sensor. (NRL)
• Continued invention of a new technique for micromachining quantum wells using InAlGaAs barriers. (NRL)
• Continued achievement of >1% power conversion efficiency in an organic plastic solar cell based on C60 and a transparent hole transporter, and a conducting polymer electrode. (NRL)
• Continued demonstration of mid-IR type-II "W" laser diodes with record external quantum efficiencies (49% at 78K). (NRL)

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- Continued development of technique that suppressed the formation of “killer” GaSb pyramid defects in antimonide superlattice growth. (NRL)
- Continued demonstration of optical coherence in mid-IR 2DDFB lasers with record beam quality for very broad stripes - e.g., 4 times the diffraction limit at w = 400 microns. (NRL)
- Continued development of Adaptive Pulse Compression and Adaptive Pulse Compression Repair Algorithms, which unmask small targets in the presence of large targets and are vastly superior to conventional pulse-compression methods. (NRL)
- Continued efforts in radiation effects studies to determine suitability of electronic components for space application. (NRL)
- Continued the design and fabrication of high performance silicon oscillators. (NRL)
- Completed demonstration of the crossover between the Bardeen-Cooper-Schrieffer and Bose-Einstein condensation phase transitions.
- Completed development of multiple target extraction techniques from single and adjacent range cells to handle unresolved targets. Integrated the extractor in the existing Missile Defense Benchmark for system performance evaluations.
- Completed assessment of impact of field plate technology on scaling of power density of High Electron Mobility Transistors (HEMT) output periphery, broad band matching and reliability.
- Completed demonstration of sub 100 micron cell sized sensor circuitry.
- Completed design and testing of coupled miniature fluxgate magnetometers to improve sensitivity.
- Completed laboratory demonstration of Vertical Magnetic Random Access memory (VMRAM).
- Completed investigations of the ability of many common polymers and crystalline solids to function as permanently recording radiation dosimeters.
- Completed measurements of off-board radiated acoustic pressure from an internally shaker-driven Essex scale model hull. (NRL)
- Completed the development of the theory of robust median adaptive processing and a number of associated processing forms: Median Cascaded Canceller, Multi-stage Median Cascaded Canceller, Reiterative Median Cascaded Canceller, and Loaded Reiterative Median Cascaded Canceller. (NRL)
- Completed the development of the robust FRACTA.E Algorithm for Space-Time Adaptive Processing, a combination of 10 different processing methods, which resulted in an effective solution for detecting signals in highly non-homogeneous and non-stationary interference environments. (NRL)
- Created a new technique for passivation of GaN HEMTs, which resulted in more than an order-of-magnitude increase in device lifetime. (NRL)
- Created a theory for the effective spin de-phasing in quantum dots due to hyperfine interactions with nuclei and predicted de-coherence times on the order of microseconds. (NRL)

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- Modeled electromagnetic behavior of left-handed materials-based waveguiding structures. (NRL)
- Demonstrated 3D high energy laser code for atmospheric propagation (HELCAP) studies in a maritime environment with many physical effects for Navy DEW. (NRL)
- Determined a technique to radiation-harden shallow trench oxides for 150 nm CMOS ICs. (NRL)
- Initiated project to develop linear higher power microwave wide bandgap semiconductor bipolar transistors based on distributed polarization effect (graded composition) base growth and processing technology.
- Initiated creation of techniques for guiding and transporting cooled and trapped rubidium atoms through hollow waveguides. (NRL)
- Initiate the knowledge base for multi-phase array space-time sampling demonstrating that the spectral band can be doubled at no cost in element density for the linear array and for 15% more elements in the planar case. (NRL)
- Initiated research to extend and implement Magnetic Resonance Elastography for low spin density materials. (NRL)
- Initiated development of Nyquist limits for multi-phase array sampling in 4-D spacetime for linear arrays and formulated the problem for planar arrays. (NRL)

FY 2005 Plans:

- Continue all efforts of FY 2004 less those noted as completed above.
- Further development of microcavity gas sensor. (NRL)
- Complete tests of the ability of superconducting analog to digital converters (ADC) to allow digital recovery of 2 distinct signals of arbitrary bandwidth (BW) from a wide spectral analog band with the same clarity as a tuned bandwidth ADC (already proven for case of a single signal in the band).
- Complete research to determine feasibility of locking a laser and etalon to precision frequency standards and generate stable reference optical and microwave frequency lines across a broad spectrum. (NRL)
- Complete investigation of piezoelectric effects in micromachined quantum wells. (NRL)
- Complete increasing the performance of device power conversion efficiency of organic solar cells by optimizing overlap with solar spectrum using highly absorbing dyes and nanocrystals. (NRL)
- Complete development of Inverse Boundary Element methods to reconstruct sources of off-board radiated acoustic pressures. (NRL)
- Complete study to understand the ultimate performance (highest possible Q) of intermediate scale silicon oscillators. (NRL)
- Initiate investigation of superresolution signal processing techniques for closely spaced and unresolved targets in Doppler, range and direction of arrival spaces for a variety of radars.

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- Initiate non-cooperative target identification from multiple aspects.
- Initiate investigation of ultra high speed logic and multiple-quantum-well devices with a goal of >500 giga hertz (GHz) samplers, in support of analog-to-digital conversion, for advanced multifunction RF systems.
- Initiate investigation of physical basis for improved time and frequency standards using quantum-entangled ions and atoms.
- Initiate project to explore physical behavior of full arrays of nanoscale devices for logic, memory, and imaging, with a first step being the integration of Cellular Nonlinear Network (CNN) fast image processor with multi-spectral focal plane array sensors.
- Initiate exploration of functioning of sensitive miniature fluxgate magnetometers.
- Initiate experimental investigations into the bulk thermodynamic properties of phononic crystals. (NRL)
- Initiate investigations into developing highly radiation-tolerant electronic/optoelectronic devices from nanocrystals and quantum dots. (NRL)
- Initiate performing experiments and collecting fundamental data to study electromagnetic scattering from canonical objects undergoing micro-motions. Expand study of mathematical solutions of micro-motion induced Doppler modulations. (NRL)
- Initiate developing waveform/environment interference model that encompasses known waveforms and stochastic information extracted from environment and non-users; investigating known/unknown EM environmental characteristics; and investigating separation/deconvolution of multiple signals. (NRL)
- Pursue methods for preparation, functionalization and characterization of SiC and GaN nanowire surfaces. (NRL)
- Begin the synthesis and modeling of tailored response magneto-dielectric materials. (NRL)
- Perform experiments and collect fundamental data to study electromagnetic scattering from canonical objects undergoing micro-motions. (NRL)
- Determine the radiation-hardening mechanisms related to silicon nanoclusters in oxides. (NRL)

FY 2006 Plans:

- Continue all efforts of FY 2005 less those noted as completed above.
- Complete determination of the feasibility of quantum cascade 2DDFB lasers with enhanced power and a high-quality beam. (NRL)
- Complete patterning of GaN photonic crystal devices on Silicon. (NRL)
- Complete the evaluation and assessment of hardware-compatible space-time algorithms for DSP applications to T/R arrays. (NRL)
- Complete conduct numerical scattering simulations of canonical objects undergoing micro-motion dynamics and

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compare the results with the Doppler modulations observed. (NRL)
• Complete development of Magnetic Resonance Elastography to characterize low spin density materials. (NRL)
• Initiate monolithic integration of multifunctional materials to enable passive devices and sensors into semiconductor circuits.
• Initiate program to extend device physics and architectures to frequencies approaching tera hertz (THz).
• Initiate program to incorporate Magnesium Diboride (MgB2) and related intermediate temperature superconductors into active electronic device structures.
• Initiate development of stabilized optical sources and low-noise photodetectors for the fabrication of an ultrastable microwave-frequency source. (NRL)
• Determine if the coupling between spins in quantum dots mediated by the virtual excitions is sufficiently strong for use in solid state implementations for quantum information. (NRL)
• Optimize power and efficiency of high power, electron beam pumped Ar-Xe laser for Navy compact DEW. (NRL)

FY 2007 Plans:

• Continue all efforts of FY 2006 less those noted as completed above.
• Complete suite of semiconductor multilayer and superlattice based infrared (IR) sources and sensors in 3-5 micron range.
• Complete exploitation of atom condensates to reach physical limit of frequency precision and control.
• Complete development of bipolar wide bandgap semiconductor linear amplifiers.
• Complete the analysis and characterization of micro-motion Doppler modulation. (NRL)
• Complete investigation of extension of interference model and adaptive structures to produce waveforms that are transparent to non-users. (NRL)
• Complete research into the bulk thermodynamic properties of phononic crystals. (NRL)
• Study the feasibility of a solid state implementation of a quantum computer. (NRL)
• Using the large area plasma processing system (LAPPS), investigate the modification of metal surfaces by nitriding and other processes to maximize hardness, wear and corrosion resistance for Navy gun barrel applications. (NRL)
• Initiate program to apply innovative mass nanofabrication techniques to previously developed nanodevice arrays.

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	FY 2004	FY 2005	FY 2006	FY 2007
WEAPONS	7,089	8,463	8,758	10,530

Efforts include: Undersea Weaponry; Energetic Materials and Propulsion; Expeditionary Operations; Energy Generation, Conversion and Storage. Accomplishments and plans below are examples for each effort category.

Reflects realignment of activities based on CNR requirements.

FY 2004 Accomplishments:

Undersea Weaponry
• Continued conducting basic research related to critical S&T (including vehicle control, maneuverability, and stability) associated with the development of high-speed supercavitating vehicles (HSSV).
• Continued expansion of the University Laboratory Initiative program to provide a further infusion of educated and career minded scientists and engineers in support of the NNR for undersea weapons research.
• Completed conduct of 4-inch powered HSSV test at the Aberdeen Superpond, and assessed the self noise levels of HSSV.
• Completed Visual/Optical approach to determine supercavitating projectile dynamics with its cavity.
• Completed creation of meta-model-Kriging models for performance measurement of potential HSSV designs.
• Completed development of 6 degrees of freedom (6DOF) simulation environment of HSSV motion and trajectories.
• Completed development of improved and new sensor technology that will include (but not be limited to) low-volume and high-directivity acoustic arrays, laser-based passive acoustic arrays, magnetometers for target classification and signal processing algorithms for counter-countermeasure.
• Completed research of basic science for laser-based passive acoustic arrays.
• Completed expansion of investigation of signal processing algorithms for connectivity between weapons, platforms and off-board sensors.

Energetic Materials and Propulsion
• Continued development of a fundamental understanding of initiation mechanisms of explosive crystals subjected to shock stimulus.
• Continued to develop fundamental understanding of nitramine and perchlorate decomposition mechanisms for propellant applications.

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• Continued to develop spectroscopic capabilities to accurately determine aluminum combustion characteristics in various oxidizing environments.
• Continued to develop synthesis routes to difluoramino-based and organometallic-based highly energetic ingredients.
• Continued exploring the use of quantum mechanics and molecular dynamics to provide fundamental properties for energetic materials to predict initiation/detonation criteria for insensitive munitions applications.
• Completed demonstration of passive combustion control of supersonic and subsonic flows to reduce combustion instability and pressure oscillations and to improve performance, while reducing emissions.
• Completed demonstration of cyclic pulse detonation of single tube combustor for pulse detention engine (PDE) operation with JP-10 fuel.
• Completed numerical simulations of multi-tube multi-cycle PDE operation with nozzles.
• Completed performance evaluation of PDE technology for operation on logistics fuels.
• Completed synthesis and characterization of new energetic materials with higher energy density and acceptable sensitivity.
• Initiate efforts to explore alternative fuel concepts for naval applications to include hydrogen, synthetic diesel, and biodiesel.

Expeditionary Operations
• Demonstrated that seismic Rayleigh waves can be used to generate detectable resonances in anti-personnel landmines buried in a wide range of soil types.

Energy Generation, Conversion, and Storage
• Continued analyzing synchronization of 19 diode lasers to produce intense beams.
• Continued conducting preliminary studies on multivalent ion insertion in nanoscale vanadium pentoxide cathode materials to improve the capacity of rechargeable lithium batteries.
• Continued development of nanostructured electrode and polymer electrolyte materials for electrochemical power sources.
• Continued improvements to catalyzed carbon microfiber electrode development for semi-fuel cells.
• Continued work on developing the scientific basis of nanostructure enhancement of direct energy conversion materials performance for power generation.
• Continued design of a thermoacoustic piezoelectric generator working via a temperature gradient.
• Continued development of materials for enabling rechargeable batteries with an energy density approaching 500 watt-hours per kilogram.
• Continued expanding the fundamental understanding of direct electrochemical oxidation in solid oxide fuel

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cells and the use of logistic fuels.
• Continued expanding research into new materials and processes for converting thermal to electric energy.
• Continued identification of record high figure of merit bulk thermoelectric material for power generation.
• Initiated identification of new approaches to efficiently transfer thermal, electrical and optical energy from primary sources.
• Initiated research in materials and processes for novel concepts in efficient energy conversion.

FY 2005 Plans:

Undersea Weaponry
• Continue all efforts of FY 2004 less those noted as completed above.
• Initiate conduct of computer code refinements and investigation of supercavitating vehicle dynamics and instability.

Energetic Materials and Propulsion
• Continue all efforts of FY 2004 less those noted as completed above.
• Complete work on quantification of active combustion control.
• Initiate development of multi-parameter sensor for multi-phase combustion flows (UAV and underwater PDEs).
• Initiate investigation of JP-10 combustion-based Proton-Exchange-Membrane (PEM) fuel cells.
• Initiate investigation of multi-tube multi-nozzle PDEs and multi-tube common nozzle PDEs.
• Initiate investigation of nanometallic-hydrocarbon hybrid catalytic combustion for increased energy release rates.
• Initiate investigation of novel initiation techniques, optimize injection parameters, and demonstrate integrated single tube operation for PDEs.
• Initiate PDM II Advanced Energetics research in reactive, explosive, and propulsive energetic materials, including high energy ingredient synthesis & characterization, and fundamentals of initiation and decomposition mechanisms, to tailor energy release processes in order to achieve substantial performance gains and/or enhanced survivability in harsh environments.

Expeditionary Operations
• Continue all efforts of FY 2004.
• Investigate modeling and exploiting the nonlinear seismic interactions between buried land mines and their surrounding soil for purposes of landmine detection.
• Investigate catalysts that reduce the pre-processing requirements for using logistic fuels in solid oxide

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fuel cells.
• Synchronize coupled diode laser arrays.

Energy Generation, Conversion, and Storage
• Continue all efforts of FY 2004 less those noted as completed above.

FY 2006 Plans:

Undersea Weaponry
• Continue all efforts of FY 2005 less those noted as completed above.
• Initiate evaluation of viable synthesis methodologies and characterize emerging underwater explosive ingredients.
• Initiate development of diagnostic capabilities to accurately determine aluminum combustion characteristics in oxidizing environments.

Energetic Materials and Propulsion
• Continue all efforts of FY 2005 less those noted as completed above.
• Initiate implementation of new & nanostructured materials design concepts for direct energy conversion and waste energy conversion.
• Initiate investigation of integrated pulse detonation engine-airframe for autonomous vehicles, and pulse detonation for passive weapons (noise, jamming).

Expeditionary Operations
• Continue all efforts of FY 2005.

Energy Generation, Conversion, and Storage
• Continue all efforts of FY 2005 less those noted as completed above.

FY 2007 Plans:

Undersea Weaponry
• Continue all efforts of FY 2006 less those noted as completed above.

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Energetic Materials and Propulsion
- Continue all efforts of FY 2006 less those noted as completed above.
- Initiate development of PDE for underwater applications.

Expeditionary Operations
- Continue all efforts of FY 2006.

Energy Generation, Conversion, and Storage
- Continue all efforts of FY 2006 less those noted as completed above.

CONGRESSIONAL PLUS-UPS:

	FY 2004	FY 2005
ACADEMY FOR CLOSING AND AVOIDING ACHIEVEMENT GAPS	961	990

FY 2004 Accomplishments:
- Initiated a program for: (1) systemic mentoring, including research participation, of 50-100 undergraduate college Science, Technology, Engineering, and Mathematics students known as scholars, (2) extensive educational enrichment services for 150-200 K-12th grade students during summer, and (3) the conducting of research, publishing, and delivering presentations and workshops for the community at large.

FY 2005 Plans:
- Basic research to examine methods of determining college students' strengths and weaknesses in sciences and tailor a program to improve in these gaps.

	FY 2004	FY 2005
BRAIN-BASED INTELLIGENT SYSTEM	0	1,982

Investigate the design of embedded low-power, self-instructing computational systems through architecture studies, analysis, and experimentation. If the research is successful, with subsequent development, these systems could be utilized for Navy applications that could improve human performance, increase training capabilities, and enhance human communication. The design of the proposed computational device is based on the emulation of neuroanatomy and the dynamics known to be present in the brain.

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FY 2005 Plans:
• Initiate a program to explore the circuit architectures of an array of neural cores which will replicate the functional elements of the brain and its interconnectivities. Configure these architectures to respond to a variety of signals without the need for prior specific programming or instruction.

	FY 2004	FY 2005
CENTER FOR PHOTOCHEMICAL SCIENCES	482	0

Basic research associated with development and use of a photopolymerization process for rapid curing of novel anti-corrosive bilge coatings, nonskid deck coatings, and/or low solvent hull anti-fouling coatings.

FY 2004 Accomplishments:
• Initiated work on a novel approach to encourage the cure front in a photocured coating to propagate into dark regions obscured from photo-initiation.

FY 2005 Plans:
• Continue by expanding the previous effort to allow development of very low or no volatile organic compound (VOC) coatings for ship hulls and carrier decks.

	FY 2004	FY 2005
FACIAL RECOGNITION TECHNOLOGY RESEARCH AND DEVELOPMENT	0	1,585

Research and development of facial recognition technology for security application at entry locations on US military bases and facilities.

FY 2005 Plans:
• Initiate research to combine advanced face recognition technology with a novel skin texture metric in order to develop a highly accurate and robust face biometric to verify the identity of personnel entry a DoD facility.
• Validate research by measuring accuracy and speed of this technology for identification of personnel within vehicles who enter a smart gate.

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	FY 2004	FY 2005
HYDROGEN FOR FUEL CELLS	0	990

Research into hydrogen generation for use as fuel for electricity production by environmentally-friendly fuel cells.

FY 2005 Plans:
• Initiate efforts to design, implement and test new catalysts for hydrogen evolution from alcohols and other biofeedstocks under ambient conditions of temperature and pressure.

	FY 2004	FY 2005
INTEGRATED WMD DETECTION AND COLLECTION SYSTEM	2,017	0

Basic research in the area of micro sensors for unmanned air vehicle (UAV) reconnaissance systems.

FY 2004 Accomplishments:
• Completed a baseline “Tradeoff Analysis” (TOA) study which will compare and analyze requirements and available capabilities of Chemical/Biological/Radiological/Nuclear (CBRN) threat detection technologies.
• Completed evaluation and selection of the optimum technical approach to achieve the objective system. Designed a prototype CBRN system suitable for UAV, ground vehicle and stand alone implementations.

	FY 2004	FY 2005
INTELLIGENT AUTONOMOUS NETWORKS & SYSTEMS (AINS)	0	990

Commercialization of Ad Hoc Routing Protocols to develop an initial product capability delivering a network connection device for Class 2 UAV platforms within 18 months. This communication system will be positioned to support multiple types of Unmanned Vehicles.

FY 2005 Plans:
• Initiate commercialization of Ad Hoc Routing Protocols to develop an initial product capability delivering a network connection device for Class 2 UAV platforms.

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	FY 2004	FY 2005
NANOSCALE ARCHITECTURES FROM PROTEIN NANOCAGES	1,923	0

Basic research in three areas: 1) biomedical nanoparticles for drug delivery and imaging; 2) magnetic nanoparticles; and 3) catalytic nanoparticles.

FY 2004 Accomplishments:
• Established a multidisciplinary research center, the Center for Bio-Inspired Nanomaterials (CBIN), which focuses on research aimed at understanding and utilizing nanoscale architectures based on protein cages.

	FY 2004	FY 2005
NEUTRON DETECTOR	961	0

Neutron detectors are used to monitor nuclear weapons, detect fissionable materials, and assess radiation exposure of personnel in real time. Existing devices are very large, expensive, easily damaged, inefficient, and require large amounts of power. Novel neutron detection devices based on boron carbide semiconductors are small, lightweight, able to withstand high temperatures and corrosion, and can be powered by small batteries or solar cells. Thus they can be used in handheld systems, or in applications where such monitoring must be stealthy.

FY 2004 Accomplishments:
• Completed research and testing to improve the solid state neutron detector gain by factor of 100, efficiency by a factor of 10, and energy range of the detected neutrons by a factor of 100 as compared to current technology.
• Completed design of CMOS interface circuitry to the detector.

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	FY 2004	FY 2005
QUANTUM OPTICAL SCIENCE AND ENGINEERING	2,408	0

Basic research into quantum optics shows promise in the development of novel device configurations for infra-red sources and detectors that have high applicability to Naval sensors and weapons. Light Detection And Ranging (LIDAR) based measurements employing Brillouin scattering allows for determining ocean sound speed depth profiles.

FY 2004 Accomplishments:
• Completed construct of mid/far-infrared semiconductor lasers based on resonant stimulated Raman scattering in quantum cascade lasers to operate as injection-pumped tunable lasers generating up to 1 watt of power in Raman lasing modes.
• Completed measurement of the determination of the dependence of Brillouin shifts (using iodine absorption lines) on temperature and sound speed in fresh water.

	FY 2004	FY 2005
ROBOTIC COUNTERMINE TECHNOLOGIES	1,923	0

Mine countermeasures in shallow water, and particularly the surf zone, are extremely challenging. Use of robots designed with aquatic characteristics and features have been shown to be particularly promising in this task based on earlier ONR and Defense Advanced Research Projects Agency (DARPA) research.

FY 2004 Accomplishments:
• Completed modification of the current robot design to improve stability and maneuverability.
• Completed reconfiguration of the battery location, redesigned the leg assemblies.

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	FY 2004	FY 2005
UNOLS RESEARCH VESSEL	0	1,784

Acoustical studies in the Littoral zone have been seriously hampered by interference from noise caused by shipboard machinery and propulsion equipment and radiated through the hull of the vessel. At the present there are no United States research vessels which meet the International Council for Exploration of the Seas (ICES) 209 standard (radiated noise standard for research vessels). UNOLS vessels have been extensively used by NRL and ONR funded investigators to conduct such studies. This funding will be used to provide augmentation for propulsion and machinery quieting for the University of Delaware vessel presently under construction in order to provide enhanced capability for Navy investigators.

FY 2005 Plans:
• Initiate efforts to identify potential noise sources and implement ameliorating strategies to meet ICES standards.

C. OTHER PROGRAM FUNDING SUMMARY:
NAVY RELATED RDT&E:
PE 0601152N In-House Laboratory Independent Research
PE 0601103N University Research Initiatives

NON-NAVY RELATED RDT&E:
PE 0601102A Defense Research Sciences (Army)
PE 0601101E Defense Research Sciences (DARPA)
PE 0601102F Defense Research Sciences (Air Force)

D. ACQUISITION STRATEGY:
Not applicable.