FY 2009 RDT&E,N BUDGET ITEM JUSTIFICATION SHEET DATE: February 2008
Exhibit R-2

BUDGET ACTIVITY: 02
PROGRAM ELEMENT: 0602235N
PROGRAM ELEMENT TITLE: COMMON PICTURE APPLIED RESEARCH

COST: (Dollars in Thousands)

Project Number & Title	FY 2007 Actual	FY 2008 Estimate	FY 2009 Estimate	FY 2010 Estimate	FY 2011 Estimate	FY 2012 Estimate	FY 2013 Estimate
COMMON PICTURE APPLIED RESEARCH	86,853	103,751	77,054	83,719	65,279	69,613	68,718

A. MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION: The efforts described in this Program Element (PE) are based on investment directions as defined in the Naval Science and Technology (S&T) Strategic Plan approved by the S&T Corporate Board (Jan 2007). This strategy is based on needs and capabilities from Navy and Marine Corps guidance and input from the Naval Research Enterprise (NRE) stakeholders (including the Naval enterprises, the combatant commands, the Chief of Naval Operations (CNO), and Headquarters Marine Corps). It provides the vision and key objectives for the essential science and technology efforts that will enable the continued supremacy of U.S. Naval forces in the 21st century. The Strategy focuses and aligns Naval S&T with Naval missions and future capability needs that address the complex challenges presented by both rising peer competitors and irregular/asymmetric warfare.

Activities and efforts in this program examine concepts and technologies that enable the transformation to network centric warfare. Network centric capabilities rely on information to connect assets and provide timely and accurate understanding of the environment. The mission area requirements for rapid, accurate decision-making; dynamic, efficient, mission-focused communications and networks; and pervasive and persistent sensing drive network centric S&T investments. The program focus is on S&T enabling technologies that provide decision making and mission execution to achieve battlespace superiority. Program activities seek to develop hardware and software technologies that (1) identify and integrate informational content from multi-media sources including images, and intelligence sources; (2) integrate massive amounts of information; and (3) provide automatic correlation, fusion, and insight to support user-cognitive processes. Particular programmatic emphasis will be placed on automating the association of objects and events in the battlespace and automatically transforming this information into actionable knowledge (e.g., indications and warnings of intent). In current and future operational environments such as Global War on Terrorism (GWOT) and Maritime Domain Awareness (MDA), warfighters require technologies evolved to support information needs regardless of location and that are consistent with the user’s level of command or responsibility within varying operational situations. Net-centric operations include communications and information assurance capabilities to enable

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all-source data access, multi-source processing, and tailored dissemination of information to Command and Control (C2) and Intelligence, Surveillance and Reconnaissance (ISR) users across the network. The operational benefits sought are increased speed of response, accuracy and precision of command; distributed self-synchronization; flexibility and adaptability to an operational situation; and decision superiority. Technologies emphasized provide warfighters with a robust, secure, mission responsive network; integrated information leading automated courses of action; and presentation of knowledge to speed understanding. The payoff is access to tailored information in near real time with corresponding increases in speed of command, improved decision-making, and reduction in manpower.

This program explores and demonstrates technologies that enable options for the Navy's FORCEnet, Sea Shield, and Sea Strike pillars and contains investments in the following Enabling Capabilities (ECs): Hostile Fire Detection and Response, Next Generation Command, Control and Decision Support, Combat Identification (ID) Information Management of Coordinated Electronic Surveillance, Combat ID in the Maritime Domain to Reveal Contact Intent, Automated Control of Large Sensor Networks, and Real-Time Long Range Air Defense Combat ID in Support of Early Engagement. In the context of the Naval Transformation Roadmap construct, this investment will achieve capabilities required by FORCEnet (Persistent Intelligence, Surveillance, and Reconnaissance; Time Sensitive Strike; and Sea Based Information Operations), Sea Strike (Ship-to-Objective Maneuver), and Sea Shield (Theater Air and Missile Defense).

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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B. PROGRAM CHANGE SUMMARY:

	FY 2007	FY 2008	FY 2009
FY 2008/FY 2009 President's Budget Submission	88,929	93,376	54,443
Congressional Action	0	12,000	0
Congressional Undistributed Reductions/Rescissions	0	-701	0
Execution Adjustments	-275	0	0
Program Adjustments	-508	0	23,024
Rate Adjustments	0	0	-413
SBIR Assessment	-1,293	-924	0
FY 2009 President's Budget Submission	86,853	103,751	77,054

PROGRAM CHANGE SUMMARY EXPLANATION:
Technical: Not applicable

Schedule: Not applicable

C. OTHER PROGRAM FUNDING SUMMARY:
Not applicable.

D. ACQUISITION STRATEGY:
Not applicable.

E. PERFORMANCE METRICS:
Performance metrics are discussed within the R2a.

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Next Generation Command, Control and Decision Support, Combat ID Information Management of Coordinated Electronic Surveillance, Combat ID in the Maritime Domain to Reveal Contact Intent, Automated Control of Large Sensor Networks, and Real-Time Long Range Air Defense Combat ID in Support of Early Engagement. In the context of the Naval Transformation Roadmap construct, this investment will achieve capabilities required by FORCEnet (Persistent Intelligence, Surveillance, and Reconnaissance; Time Sensitive Strike; and Sea Based Information Operations), Sea Strike (Ship-to-Objective Maneuver), and Sea Shield (Theater Air and Missile Defense).

B. ACCOMPLISHMENTS/PLANNED PROGRAM:

	FY 2007	FY 2008	FY 2009
NETWORK COMMAND, CONTROL AND COMBAT SYSTEMS	10,716	26,544	24,272

This Activity explores development of advanced technologies that contribute to integrated decision-making and mission execution to achieve battlespace superiority. In current and future operational environments, such as the GWOT and MDA, warfighters require technologies evolved to support information needs regardless of location and consistent with the user's level of command or operational situation. To achieve this, it must be possible to automate understanding of the battlespace by identifying objects, determining relationships among the objects, assessing intent, and automatically generating courses of action with associated risks and uncertainty. This initiative focuses on information integration, examining the critical S&T needs of automatic association and merger of information for unified presentation; automated recognition and cueing for significant patterns of information, computer-aided reasoning for task-oriented information dissemination; timely, accurate information and sensor fusion from heterogeneous sources, as well as supporting technologies to provide the understanding and relationship of different entities shown in the battlespace and their collective intent. This initiative will focus on advanced or novel approaches for processing and fusing information from disparate sources (e.g., images, intelligence sources); optimal decision aids incorporating rigorous decision theory and automated inference and reasoning; and assuring information integrity and availability according to mission objectives.

This Activity is focused on and has absorbed projects dealing with information fusion efforts — a critical element of network centric warfare and the emerging technologies that enable more automated support to warfighters. While completing earlier projects, this Activity is also initiating a number of efforts that focus on two very critical efforts: Automated Image Understanding (developing the capability to automatically understand image/scenes and assess threats which help the battlefield commander in making efficient and

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accurate decisions) and Automated Information Integration (leverage emerging technologies to manage and exploit sensors and other sources of data or information to develop approaches and tools for (semi)-automated data integration and reasoning about information from diverse sources in ways that support decision makers with timely, actionable information at operational and tactical levels of command).

In FY 2008, many of the investments will be approaching demonstration and experimentation phases. The increase from FY 2007 through FY 2008 reflects the cost of field demonstrations, limited objective experiments and sea trials which will be used to validate the utility of the concepts developed along with initiating the development of software and algorithms for integrating the functions of target acquisitions, tracking, data computation, and engagement control across multiple platforms for engaging multiple threats.

In FY 2009, a number of efforts will be completing experimentation demonstration phases and entering final analysis and reporting activities requiring less investment.

FY 2007 Accomplishments:

- Continued the development of algorithms and demonstration of data reduction through joint classification and feature optimization, realizing transfer of data to information, realizing automation and integration vis-a-vis Analog/Digital data (reduced bandwidth requirements and reduced burden on analysts and warfighters).
- Continued the development of a feature extraction module that segments the video based on video mosaicing.
- Continued the development of algorithms with Naval/Joint imagery systems to handle video metadata, which includes Global Positioning System, time, and sensor information.
- Continued the development of recommendations for standardizing the storage and linking of feature descriptions within a common database framework.
- Continued the development and characterization of new target detection and recognition algorithms to exploit higher dimensional data (spatial, temporal, and spectral) within the Network Centric Warfare framework. Approach uses advanced correlation approaches to provide improved target detection and recognition performance by integrating multiple sensor measurements.
- Continued the development of a suitable ontology for exercising large-scale distributed situational threat awareness in Naval battlespace environments.
- Continued the development of a Case-Based Reasoning simulation/model for implementing situation, threat awareness fusion solutions and a Bayesian Network inference engine for manipulating uncertainty and learning from data.
- Continued the development of an initial prototype for an information sharing infrastructure that maintains

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data integrity and confidentiality for enclaves of networked workstations running Commercial Off the Shelf (COTS) operating systems and applications.

- Continued the demonstration and conducted image registration error analysis for the multi-resolution and multi-scale image processing effort.
- Continued the augmentation of the real world information with computer-generated information in the Battlefield Augmented Reality System effort. The activity designed a modular framework to support the system design and enables the insertion of custom scheduling and replication solutions. Other efforts focused on the middleware layer to support emerging network centric sensor-to shooter systems.
- Continued development of automated methods for identifying significant changes between temporally separated images (not video) to extend work on automatic target recognition and pattern recognition into change detection algorithms.
- Continued demonstration of a FORCEnet limited objective experiment involving the application of new techniques of discrete optimization, statistical discrimination, and artificial intelligence for the resource allocation of weapons. Compared initial results with high fidelity physics based models for threat and anti-threat weapon systems for continued development of Anti-Air Warfare optimization algorithms.
- Continued research and demonstrations of modulated near-infrared (IR) optical retroreflector data to develop spacecraft to spacecraft data exchange techniques. (NRL)
- Continued development of "through-the-sensor" exploitation techniques to obtain environmental information from shipboard radars, and use of that information in nowcasting. (NRL)
- Continued development of technology to improve reliability of systems to survive Information Warfare attacks.
- Continued development of technology for improved steganography and watermarking. (NRL)
- Continued development of technology for improving voice data interpretation and presentation to cope with audio information overload in Navy Systems. (NRL)
- Continued development of technology to improve collaborative operational planning for tactical users using Head-Up Displays. (NRL)
- Continued development of sensor management algorithms that reduce the amount of labeled training data required, employing semi-supervised classifier and active learning techniques motivated by asymmetric threat, which limited training data anticipated.
- Continued demonstration of predictive surface platform threat behavior algorithms and software employing techniques using pattern recognition on geospatial and attribute data. Also developed autonomous monitoring and reporting of high interest and anomalous maritime vessels.
- Continued demonstration of a trusted data store which maintains data pedigree and detects anomalies in a limited objective experiment.

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- Continued efforts in ontology-based information fusion for enhanced situational awareness and classification-based knowledge discovery.
- Continued efforts in Joint Director of Laboratory's Data Fusion Model Level 1/2/3 data fusion using abductive reasoning, Bayesian networks, agent-based techniques, statistical-based methods, and other approaches.
- Continued efforts in automated image understanding that use active computations and visual pattern recognition for networked target recognition systems in maritime domain awareness.
- Continued efforts in the automated integration of disparate sources of information that involve data mining methods and game theory.
- Completed development of improvements in face recognition technology via enhanced image registration software. (NRL)
- Completed the implementation of a real-time anti-ship missile state assessment capability against modern threats by conducting an empirical performance evaluation and analyze system implications. (NRL)
- Initiated demonstration of anomaly detection, feature-based target tracking, track-to-pattern association and scoring, track-to-group clustering, pattern discovery and learning, pattern templates/descriptions and predictive modeling tools in a limited objective experiment.
- Initiated development of an interface between the Level 1 and Level 2/3 data fusion processes across federated service oriented architectures.
- Initiated development of new data schemas and methods to allow more efficient assembly of a common operational picture (COP) integrating informational content from images, track data, intelligence and incomplete track data.
- Initiated development of semi-supervised detection algorithms for multi-sensor imagery, video and human intelligence that will enable self-deploying sensor networks.
- Initiated Level 1 fusion algorithm and architecture design with associated ontology to manage information from automated sensors to provide a more dynamic and accurate battlespace picture through improved object refinement.
- Initiated development of a scalable system design for coordinated Unmanned Aerial Vehicle (UAV) formation control that integrates onboard and offboard sensor data. (NRL)

FY 2008 Plans:

- Continue all efforts from FY 2007 less those noted as completed above.
- Complete the development of algorithms and demonstration of data reduction through joint classification and feature optimization, realizing transfer of data to information, realizing A/I vis-a-vis Analog/Digital data

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(reduced bandwidth requirements and reduced burden on analysts and warfighters).
- Complete the development of a feature extraction module that segments the video based on video mosaicing.
- Complete the development of algorithms with Naval/Joint imagery systems to handle video metadata, which includes Global Positioning System, time, and sensor information.
- Complete the development of recommendations for standardizing the storage and linking of feature descriptions within a common database framework.
- Complete the development and characterization of new target detection and recognition algorithms to exploit higher dimensional data (spatial, temporal, and spectral) within the Network Centric Warfare framework. Approach uses advanced correlation approaches to provide improved target detection and recognition performance by integrating multiple sensor measurements.
- Complete the development of a suitable ontology for exercising large-scale distributed situational threat awareness in Naval battlespace environments.
- Complete the augmentation of the real world information with computer-generated information in the Battlefield Augmented Reality System effort. The activity designed a modular framework to support the system design and enables the insertion of custom scheduling and replication solutions. Other efforts focused on the middleware layer to support emerging network centric sensor-to shooter systems.
- Complete demonstration of a FORCEnet limited objective experiment involving the application of new techniques of discrete optimization, statistical discrimination, and artificial intelligence for the resource allocation of weapons. Compare initial results with high fidelity physics based models for threat and anti-threat weapon systems for continued development of Anti-Air Warfare optimization algorithms.
- Complete development of technology to improve collaborative operational planning for tactical users using Head-Up Displays. (NRL)
- Initiate the development of software and algorithms for integrating the functions of target acquisition, tracking, data computation, and engagement control across multiple platforms for engaging multiple threats.
- Initiate the investigation of service oriented methods to automatically retrieve relevant information for a community of interest. (NRL)
- Initiate the development of a new radar signature analysis technique based on nonlinear dynamics. (NRL)
- Initiate the development of a novel particle filter-based elevation angle tracking algorithm to improve the capability to track low-angle targets over the sea surface under multipath conditions using passive sensors. (NRL)
- Initiate the development of the theory and technology for near-field electromagnetic (EM) phenomenology relevant to high resolution, through-the-wall imaging at close ranges in urban operations. (NRL)

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FY 2009 Plans:

- Continue all efforts from FY 2008 less those noted as completed above.
- Complete the development of a Case-Based Reasoning simulation/model for implementing situation, threat awareness fusion solutions and a Bayesian Network inference engine for manipulating uncertainty and learning from data.
- Complete the development of a prototype for an information sharing infrastructure that maintains data integrity and confidentiality for enclaves of networked workstations running Commercial Off the Shelf (COTS) operating systems and applications.
- Complete development of automated methods for identifying significant changes between temporally separated images (not video) to extend work on automatic target recognition and pattern recognition into change detection algorithms.
- Complete sensor management algorithms that reduce the amount of labeled training data.
- Complete ontology-based information fusion for enhanced situational awareness and classification-based knowledge discovery.
- Complete efforts in Joint Director of Laboratory's Data Fusion Model Level 1/2/3 data fusion using abductive reasoning, Bayesian networks, agent-based techniques, statistical-based methods, and other approaches.
- Complete efforts in automated image understanding that use active computations and visual pattern recognition for networked target recognition systems in maritime domain awareness.
- Complete efforts in the automated integration of disparate sources of information that involve data mining methods and game theory.
- Complete development of technology for improving voice data interpretation and presentation to cope with audio information overload in Navy Systems. (NRL)
- Complete development of technology for improved steganography and watermarking. (NRL)
- Complete development of a scalable system design for coordinated Unmanned Aerial Vehicle (UAV) formation control that integrates onboard and offboard sensor data. (NRL)
- Initiate approaches and tools for (semi)-automated data integration and reasoning about information from diverse sources in ways that support decision makers with timely, actionable information at operational and tactical levels of command, with an emphasis on missions that are related to GWOT and force protection.

	FY 2007	FY 2008	FY 2009
KNOWLEDGE SUPERIORITY AND ASSURANCE	6,951	24,291	18,485

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This Activity explores fundamental technologies that enhance the Navy's capability to exploit, manage and integrate complex, heterogeneous, multi-source information for the next generation common picture. S&T work in information processing, discovery, integration and presentation; expeditionary ISR; and networked sensors is being focused on Navy and Marine Corps Warfighter Capability Gaps identified through analysis of operational and exercise lessons learned, as well as campaign analysis of capabilities required in the 2010-2024 time frame.

The significant increase from FY 2007 through FY 2008 is the result of two ECs, Combat ID Information Management of Coordinated Electronic Surveillance and Automated Control of Large Sensor Networks, that were initiated in FY 2007. These ECs have a substantial increase in total investment in FY 2008 to support technology development, limited objective experiments, and sea trials to validate metrics and utility in FY 2008.

The decrease from FY 2008 to FY 2009 is due to completion of FNC efforts to develop object-level data fusion algorithms to improve maritime common operational picture development in a service oriented architecture environment, and the development of technologies for smart tactical sensors, platforms, and algorithms in an urban/cluttered environment. The balance of the reduction reflects a reduced level of investment in ongoing efforts to fund higher priority requirements.

FY 2007 Accomplishments:

- Continued the Electronic Warfare Integrated System for Small Platforms (EWISSP) effort by exploration and refinement of the subsystem interface software that will operate via Versa Module Eurocard (VME)-64 and Recommend Standard (RS)-422 buses.
- Continued the exploration of rapid course of action development using synthetic semi-automated forces for fast, large-scale, and high-fidelity simulations; including models of human cognition and visualization techniques for assessing outcomes and uncertainties.
- Continued Actionable Information from Multiple Intel Sources in a Global Information Grid Enterprise Services (GIG-ES) Environment (previously reported in PE 0603235N). Result in: automated integration of multi-INT surveillance & reconnaissance of red, white, and blue force locations for Combat ID by providing software integrated into Navy and Marine Corps Command Control & Combat Systems; order of magnitude less false recognition; and identification of significant military entities consistent with sensor capabilities.
- Continued effort for Improved Maritime Common Operational Tactical Picture in a GIG-ES Environment (previously reported in PE 0603235N). This effort provides software to perform level one fusion of

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intelligence sources and tactical organic sensors to provide knowledge about battlespace objects including location, track, and Combat Identification.
- Continued design of tools enabling mission-specific tactical sensor fields for at least two separate mission areas (previously reported in PE 0603235N).
- Continued design of tactical distributed data analysis and automated indications and warnings for 50% of tactical data (previously reported in PE 0603235N).
- Continued design of automated tactical platform and sensor planning and management sufficient for one operator to control multiple sensors (previously reported in PE 0603235N).
- Continued developing and testing airborne and shipboard battle manager platforms for UAVs operating from Littoral Combat Ships. Continued developing and began testing an open architecture airborne control station that can be used onboard a P-3 type aircraft for the control of multiple UAVs (Previously reported in PE 0602114N).
- Completed development of multi-vehicle cooperation technologies.
- Completed medium-fidelity simulation of multi-vehicle cooperation technologies for multiple classes of Naval unmanned vehicles in littoral ISR (Previously reported in PE 0602114N).
- Initiated development of object-level data fusion algorithms to improve maritime common operational picture development in a service oriented architecture environment.
- Initiated Joint Director of Laboratories Data Fusion Model Level 2/3 data fusion research exploring techniques using Bayesian networks, Dempster-Schafer Evidential Reasoning and other techniques for analyzing operational data in establishing routine behaviors & dependencies based on multi-intelligence fusion and anomaly recognition that indicates hostile intent in the maritime/littoral domain.
- Initiated investigation of smart tactical sensors, platforms, and algorithms in an urban/cluttered environment for at least 2 sensing modalities.
- Initiated investigation of human to tactical sensor field interface to enable the user to locate relevant knowledge within 3 minutes.
- Initiated investigation of local tactical net and Distributed Common Ground Station information interfaces to achieve Level 1 integration.
- Initiated the all-source track and identity fusion effort integrating a broad range of intelligence product information including: Kinematic Radar Reports, Organic and UAV imagery, electronic and communications emissions and human spot reports for tactical and organic sensors to be augmented with national sensors.

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.

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- Complete development of object-level data fusion algorithms to improve maritime common operational picture development in a service oriented architecture environment.
- Complete investigation of smart tactical sensors, platforms, and algorithms in an urban/cluttered environment for at least 2 sensing modalities.

FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Initiate effort to develop and apply emerging technologies that support delivery of Technology Oversight Group approved FNC enabling capabilities structured to close operational capability gaps that involve the common picture.
- Initiate packaging of emerging common picture technologies into deliverable FNC products and ECs that can be integrated into acquisition programs within a five year period.
- Initiate efforts for the mature common picture technologies that support naval requirements identified within the FORCEnet naval capability pillar.
- Initiate effort to develop new, and leverage emerging, technologies that support dynamic and response management and control of net-centric enterprise theater and tactical ASW operations. This includes automation support for synchronized planning of resources and multi-mission execution, and access and shared awareness of data activities and status among Maritime Operation Centers and tactical forces through in a tactical, netted service-oriented architecture (SOA) environment.
- Initiate effort to develop and apply emerging technologies that support self organizing networking and assured communications exchange in tactical communications networks.

	FY 2007	FY 2008	FY 2009
COMMUNICATION AND NETWORKS	11,688	9,272	9,417

This Activity develops wireless communications network technologies critical to the performance and robustness of naval communications for air, ship, submarine, and land platforms. Developments include bandwidth efficient communication techniques; advanced networking techniques for robust, highly dynamic environments; interoperable wireless networks for secure communications and protocols; and bandwidth and network management techniques that can effectively manage and allocate bandwidth across tactical and theater levels in support of wireless network centric operations. The exploration payoffs include increased network data rates, improved coalition interoperability, dynamic bandwidth management, greater mobile network connectivity, and efficient waveforms to improve information processing and communications with land forces.

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The decrease from FY 2007 to FY 2008 reflects a reduced level of investment to fund higher priority requirements.

FY 2007 Accomplishments:

- Continued efforts to mature the superconducting cross-correlator to technology readiness level 4 to enable the development of a multi-function multi-net digital-Radio Frequency dehopping receiver for Link-16. This involves the integration of High Temperature Superconductors analog and Low Temperature Superconductors digital circuits in a COTS two-stage cryocooler.
- Continued project to architect multi-Mega bits per second (Mbps) naval laser communication system for ships. Designed rate-adaptable optical receiver using avalanche photo-diodes and array-detection techniques for improved performance in poor weather conditions.
- Continued construction and characterization of spectrally clean, out-phased high-power transmitter using X-band monolithic microwave integrated circuit (MMIC) technology, developing Continuous Wave (CW) radar receiver technology implementing wideband 500-MHz linear chirp at the X-band transmitter, and Ballistic Missile Defense (BMD) discrimination by performing experiments to study micro-Doppler signatures from BMD targets that undergo micro-motions. (NRL)
- Continued development of a concept for recovering Global Positioning Systems (GPS) signals in a "friendly" jamming environment thus allowing GPS to be used while denying that capability to an adversary. (NRL)
- Continued research and demonstrations of modulated near-infrared (IR) optical retroreflector data to develop spacecraft to spacecraft data exchange techniques. (NRL)
- Continued development of high data rate (HDR) communications (> 1 Gbps data links) for small tactical Unmanned Aerial Vehicles (UAV) in ISR applications, meeting the size, weight and power requirements.
- Continued development of Robust Airborne Networking Extensions (RANGE) for joint battlespace networking, networking UAVs, and hybrid mobile ad hoc networking (MANET)/satellite operation. Implemented MANET protocols for cross-layer optimized routing, including disruption tolerant networking to sensors and platforms.
- Continued development of an ultra-wide band (UWB) groundwave communication transceiver for a distributed sensor network and gateway buoys.
- Continued Broadband Electronically-steerable Array for Mission Security (BEAMS), a low cost analog beam forming and steering technique for UAV to UAV and UAV to ground station communications.
- Continued development of protocols and algorithms for mobility and security in emerging IPv6 next generation MANET.
- Continued development of technology to improve tactical network Satellite Communication linkage and multi-

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user detection. (NRL)
- Continued development of an adaptive rate terminal to maintain laser communications in poor weather conditions.
- Continued the development of free space hybrid Infrared laser communications links with greater than 10X bandwidth of digital link for same power. (NRL)
- Completed cryogenic packaging, test, and demonstrate direct digital dehopping of multiple Link-16 waveforms. Establish transition path to Joint Tactical Radio System (JTRS) -compliant communications.
- Completed research and development in Multiple-in-Multiple-out (MIMO) antenna technology and OFDM signaling to improve data throughput (500 Mbps) in strong multipath environments. Finish prototyping of lab models. Finish demo in urban environment. Explore possible transition to United States Marine Corps and/or JTRS.
- Completed the development of an adaptive rate terminal to maintain laser communications in poor weather conditions. Test the system at NRL's 32 km maritime Chesapeake Bay test bed. Establish transition path to fleet deployment.
- Completed BEAMS prototyping and demonstrating Rotman lens beamformer on small UAVs for additional range and mission security.
- Completed development of technology to improve mobile, ad hoc networks via multi-agent programs. (NRL)
- Completed communications Specific Emitter Identification (SEI) by transitioning best approaches into operational Navy electronic support and electronic attack systems. (NRL)
- Completed the design, fabrication and testing of the phased array RF elements for autonomous systems with the fabrication of a prototype unmanned system. (NRL)
- Completed development of technologies in support of responsive micro-satellites including high speed W-band communications, compact deployable structures, and small, xenon electric propulsion systems. (NRL)
- Initiated development of digital beam forming and steering for small UAVs in upper Ka band (38 GHz), including Risley prism conformal antennas and lightweight switched beam antennas made of composite materials.
- Initiated development of small foot-print, low-power fly-by optical communications underwater between unmanned underwater vehicles (UUV)/unmanned surface vehicles (USV) and bottomed sensor field, utilizing blue-green directly modulated semiconductor lasers.
- Initiated development of submarine to UUV/USV/sensor Comms using underwater Modulating Retroreflector technology.
- Initiated development of advanced topology and medium access control (MAC) for extremely low power consuming sensor networks.
- Initiated techniques for UWB range extension by time reversal and other methods, including receiver prototyping.
- Initiated development of low-cost integrated stub antenna and ferroelectric phased array technology for

directional communications.
• Initiated expanded study of "friendly" GPS jamming techniques to include those designed specifically to minimize fratricide while maintaining effectiveness of jamming against threat GPS receivers. (NRL)
• Initiated the development of pattern recognition algorithms to allow detection and identification of intruders into remote or urban areas. (NRL)
• Initiated the development of technical characteristics of a Communications Electronic Attack (EA) system that consists of a master EA platform that operates in concert with a network of simple subordinate platforms. (NRL)
• Initiated investigation of the feasibility of performing emissive hyperspectral imaging for detection and recognition of targets at night with high search rates and high resolution ground samples. (NRL)

FY 2008 Plans:

• Continue all efforts of FY 2007 less those noted as completed above.
• Complete prototyping of the HDR communications (> 1 Gbps data links) for small tactical UAVs in ISR applications, meeting the size, weight and power requirements.
• Complete development of RANGE protocols and software kit for dynamic inter-UAV networking.
• Complete development of an UWB groundwave communication transceiver and high frequency (HF) antenna for a distributed sensor network and gateway buoys.
• Complete development of protocols and algorithms for mobility and security in emerging IPv6 next generation MANETs.
• Complete development of a concept for recovering GPS signals in a "friendly" jamming environment thus allowing GPS to be used while denying that capability to an adversary. (NRL)
• Initiate development of underwater Extremely Low Frequency (ELF) antenna and RF technology for submarine comms at speed and depth.
• Initiate development of metamaterial structures and periodic L-C loading for submarine HF-IP buoy-cable antennas (BCA).
• Initiate development of service oriented networking protocols and middleware for the tactical warfighter and platforms.
• Initiate the development of wireless-ready, reliable data transport technologies suitable for tactical-edge and afloat networks. (NRL)

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FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Complete prototyping of the conformal array for digital beam forming and steering on small UAVs in upper Ka band (38 GHz).
- Complete development of small foot-print, low-power fly-by optical communications underwater between UUVs/USVs and bottomed sensor field, utilizing direct modulated semiconductor lasers or modulating retro-reflectors (MRR)in the blue-green band.
- Complete development of advanced topology and MAC for extremely low power consuming sensor networks.
- Complete prototyping of receivers that demonstrate UWB range extension by time reversal methods.
- Complete the development of free space hybrid Infrared laser communications links with greater than 10X bandwidth of digital link for same power. (NRL)
- Complete the development of pattern recognition algorithms to allow detection and identification of intruders into remote or urban areas. (NRL)
- Initiate development of Line of Sight (LOS) high data rate UAV-sensor communications for expeditionary forces.
- Initiate development of advanced signal processing, coding and switching amplifier techniques for high power amplification.
- Initiate metamaterials based dish antennas development for Ka-Ku band satellite communications (SATCOM).
- Initiate development of low intercept and low probability of Detection (LPD), jam resistant communications/networks for distributed nodes.
- Initiate blue-green fiber laser technology development for space-based submarine communications.
- Initiate development of network coding and cognitive radio networking technologies with heterogeneous links.

	FY 2007	FY 2008	FY 2009
MULTI-SOURCE INTEGRATION AND COMBAT IDENTIFICATION	8,563	1,940	3,183

This activity addresses theater air and missile defense (TAMD) needs for rapid, high confidence Combat Identification (CID) of air and missile threats at long range using real time and non-real time threat attributes and intelligence information. This activity supports the Sea Shield Pillar Enabling Capability of Real Time Long Range Air Defense CID in Support of Early Engagements and related CID Science & Technology to be worked under the FORCEnet FNC.

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The funding decrease from FY 2007 to FY 2008 is due to completion of the technology/algorithm development for Multi-Source Integration (MSI), Composite Combat Identification (CCID), and Advance Sensor Netting Technology (ASNT) in FY 2007.

The increase between FY 2008 and FY 2009 is to support completion of research for networked sensors.

FY 2007 Accomplishments:

- Continued development of a robust test environment to elucidate the design principles of human and sensor network interactions. (NRL)
- Completed ASNT, CCID, and MSI development. MSI, ASNT, and CCID transitioned to the E-2C/D Program Management Office (PMA-231), Intelligence, Surveillance, Reconnaissance, and Information Operations Program Office (PMW-180), and Program Executive Office-Integrated Warfare Systems (PEO-IWS).
- Initiated effort to improve the resolution of the High Frequency Relocatable Over-the-Horizon Radar (HF-ROTHR) more than two orders of magnitude using time-reversal methods. (NRL)

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.

FY 2009 Plans:

- Continue all efforts of FY 2008.
- Complete development of a robust test environment to elucidate the design principles of human and sensor network interactions. (NRL)

	FY 2007	FY 2008	FY 2009
HUMAN FACTORS AND ORGANIZATIONAL DESIGN	5,519	6,708	4,978

This activity (formerly Human Computer Interface) focuses on improving platform, task force, and battle group operations by developing decision support technology for incorporation into operational systems. The goals are to enhance human performance effectiveness; improve decision support and decision-making collaboration; improve human-centered design; and accelerate insertion of advanced human factors engineering technology into existing and new weapons systems. The payoff is the creation of decision-action cycles that are faster than

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an enemy's, and reduced workload and staffing requirements. Specific objectives include achieving improved situational awareness and speed of command through a deeper understanding of human capabilities and limitations, as well as accomplishing quality performance in complex, dynamic, high-tempo, and uncertain threat environments. These objectives are being pursued in three focus areas: Decision Support and Organizational Design, Collaboration and Knowledge Management, and Human-Computer Interaction/Visualization.

The increase from FY 2007 to FY 2008 is due to additional emphasis and expansion of the exploration of cognitive modeling and exploration of Human and Organizational Interfaces to large complex data sets including the GWOT.

The decrease from FY 2008 to FY 2009 reflects the completion of development of a user tool to counteract perceptual errors associated with 3D perspective-view visual displays, research on tools to assist in the management of task interruptions, and overall reduced level of investment to fund higher priority requirements.

FY 2007 Accomplishments:

- Continued evaluation of Latent Semantic Analysis (LSA) of operator communications as an effective metric of shared situational awareness in unmanned aerial vehicle control teams.
- Continued demonstration of Electronic Card Wall (EWALL) (a computational human cognitive processing system) for representation and transfer of meaning among heterogeneous and distributed team members engaged in complex problem solving.
- Continued developing jointly with the Naval Air Systems Command, a FORCEnet-based test bed to identify and evaluate the cognitive processes to be employed to optimize collaborative decision-making in a geographically distributed and time-delayed situation.
- Continued model-based simulations and experiments to investigate the effectiveness of hierarchical organizational structures in network-centric operational environments in order to evaluate the implementation of FORCEnet concepts.
- Continued development of new threat scenarios incorporating Joint Force Maritime Component Commander operations, counter-insurgency and humanitarian operations with the staff of the Naval War College. These new threat scenarios will provide the basis for Limited Objective Experiments in the Innovation Laboratory at the Naval War College.
- Continued development of Dynamic Network analysis (a terrorist network analysis tool) in operational command setting at U.S. Pacific Command.

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- Continued the improvement of terror network analysis decision tools for combatant command use and military planning, including testing of tools, development of metrics, and validation.
- Continued evaluation of the effectiveness of a change history tool to minimize the effect of interruptions.
- Continued application of cognitive architecture modeling to the design of interface analysis tools.
- Continued deployment of models for Effects-Based Operations (EBO) aboard naval vessels to support Expeditionary Group One to conduct kinetic and non-kinetic tactical operations in a measured manner.
- Continued development of a cognitive model of human performance with 3D audio displays.
- Continued jointly with the Air Force applied research on the integration of Information Operations in Air Control Centers.
- Continued applied research on command and control adaptive architectures for Expeditionary Strike Groups working with OPNAV N-75B and Expeditionary Strike Group ONE, San Diego.
- Continued development of a user tool to counteract perceptual errors associated with 3D perspective-view visual displays.
- Completed development of technology to improve voice biometrics via the development of multi-dimensional, adaptive speaker verification technology. (NRL)
- Initiated the development of advanced computational models capable of analyzing multi-dimensional networks of thousands of nodes. Current capabilities enable the analysis of networks consisting of hundred of nodes.
- Initiated the development of computational models of influence that incorporate the social structure, values and cultural processes of urban non-western communities for achieving post-conflict stabilization.
- Initiated the development of social network models to model the human element in maritime domain awareness.
- Initiated effort to improve response speed of the LSA tool to a near-interactive level and incorporate into a fleet experiment. Collect and evaluate data to validate improved speed and effectiveness of developing situational awareness.
- Initiated effort to incorporate the EWALL prototype into a simulation of the Tactical Operations Center of the Special Operations Forces and collect performance data to validate effectiveness.
- Initiated Sea Basing research on rehearsal for Expeditionary Strike Groups in the conduct of maritime interdiction missions and developing reach-back capability for computationally intense analysis for evaluating courses of action.

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.
- Complete development of a user tool to counteract perceptual errors associated with 3D perspective-view visual displays.

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- Complete research on tools to assist in the management of task interruptions.
- Complete 3D audio experiments in the context of Common Enterprise Display System (CEDS) to evaluate cognitive models of 3D audio perception.
- Initiate research on advanced computational models to incorporate additional capabilities in the analysis of terror networks and on various types of flow in these networks (such as the flow of expertise, resources).
- Initiate effort to improve social network models to analyze merchant marine traffic.
- Initiate development of metrics to identify and measure the contribution to team performance of the cognitive processes underlying ad-hoc team decision making.
- Initiate effort to improve the model of ad-hoc team decision making by including collaborative agent-based contribution to team performance.
- Initiate research on the application of information architectures (DOD Architectures Framework), executable models (Petri Nets) and cognitive models to the systematic design of Human-Computer Integration.
- Initiate effort to develop tools for more automated, cost-efficient modeling of human system interaction.
- Initiate research on adaptive command and control architectures in support of the Navy's new Maritime Strategy.
- Initiate methods to introduce key cognitive abilities to autonomous vehicles that will enable warfighters and vehicles to work together more collaboratively. (NRL)

FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Initiate development of a computational model of subjective reasoning for course of action selection activity in distributed, asynchronous teams.
- Initiate test and validation of a cognitive processes model of team collaboration in a Maritime Interdiction Operations domain.
- Initiate human cultural and social modeling to improve warfighting, civilian military operations and humanitarian operations in non-Western environments.
- Initiate research on quantitative formalisms for developing and assessing the completeness, consistency and accuracy of rules of engagement (ROEs).
- Initiate research on executable models and optimization algorithms for adaptive command structures that are congruent with mission requirements to support the design of Maritime Headquarters with Maritime Operations Centers (MHQ/MOC) organizations.
- Initiate research on models to support the design of scalable joint and coalition Maritime Operations Centers that allocate responsibilities to elements afloat and ashore.

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	FY 2007	FY 2008	FY 2009
TACTICAL SPACE EXPLOITATION	17,463	23,072	16,719

The Tactical Space Exploitation initiative explores the application of new space craft technologies on small, light-weight and low-cost satellites to enhance naval warfighting capabilities; taking advantage of the global access, revisit and connectivity provided by orbital platforms. Initial efforts will be aimed at developing integrated signals electronics packages to test new concepts for global ship tracking and two-way data exfiltration using next-generation Internet Protocol (IP) technology from an array of sea-based and land-based sensors. Advanced multispectral/hyperspectral electro-optical sensors will be developed to demonstrate new warfighting constructs and communications payload technology deployed on satellites to demonstrate augmented mobile satcom capabilities over a theater.

The significant increase in planned funding in FY 2008 represents resources required to cover costs of hardware, research, and demonstration of technology associated with all programs, with a significant portion of this funding being allocated in support of the communications satellite payload for augmented mobile satellite communications over a theater of operations.

In FY 2009, investments in this activity are curtailed in response to completion of the development of communications satellite payload to provide augmented mobile satcom over a theater from high altitude earth orbit with payload launch in late FY 2008.

FY 2007 Accomplishments:

- Continued development of communications satellite payload to provide augmented mobile satcom over a theater from high altitude earth orbit.
- Continued development of integration plans, algorithms, and satellite concept of operations to demonstrate the integrated signals payload as a secondary payload on an FY 2007 small satellite launch.
- Continued development of small multifunctional integrated signals electronics systems for ship tracking from space and two-way data exfiltration from distributed global sensors.
- Continued development of a satellite-borne electro-optical sensor system for FY 2008 launch on a small satellite to test new techniques for surveillance of environments and targets of naval interest for anti-submarine warfare and mine warfare.
- Completed preliminary environmental and flight testing of hardware components.

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- Initiated program to use chemical release from satellites launched into selected low-Earth orbits to de-populate intense trapped electrons in radiation belts following a low-altitude nuclear explosion in space. (NRL)

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.
- Complete development and launch of communications satellite payload to provide augmented mobile satcom over a theater from high altitude earth orbit.
- Initiate the development of a highly capable self-inspection vehicle for spacecraft with large complex deployables. (NRL)
- Initiate the development of a preliminary design for electrodynamic propulsion technology demonstration spacecraft. (NRL)

FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Complete and launch maritime hyperspectral payload on TacSat or Space Test Program (STP) satellite. Develop improved maritime hyperspectral payload for flight on the International Space Station through STP. Complete analysis of TacSat 3 data.

CONGRESSIONAL PLUS-UPS:

	FY 2007	FY 2008
ADVANCED PANORAMIC SENSOR SYSTEMS FOR UAVS	971	795

FY 2007 - This effort developed advanced visual imaging technologies and related sensors and associated computing technologies for UAVs.

FY 2008 - This effort supports Advanced Panoramic Sensor Systems for UAVs research.

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ALL WEATHER SENSE & AVOID FOR UAVS	0	2,384

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This project will design and integrate a system of sensors that create a direction finder interface to enable automatic collision avoidance for UAVs flying in national airspace, in crowded theaters of operations, and hazardous weather.

	FY 2007	FY 2008
M2C2	5,978	3,180

FY 2007 - This effort has developed and demonstrated innovative communications concepts and technologies, such as improved satellite communications, digital data and laser technology and improved chat capabilities, for integration into the Marine Corps Mobile Modular Communications and Command unit.

FY 2008 - This effort supports M2C2 research.

	FY 2007	FY 2008
MULTICULTURAL OPERATIONS TRAINING & TACTICS SYSTEMS (MCOTTS)	1,644	0

This project developed an agent-based software system that rapidly gathers cultural information, provides situational understanding, models, and interactively simulates cultural norms under expected operational conditions and scenarios.

	FY 2007	FY 2008
PACIFIC MISSILE RANGE FACILITY/PEARL HARBOR INTEGRATED NETWORK	2,815	0

This effort developed improved computer software/technologies to monitor and display increased volumes of data collected during tests and exercises at the range.

	FY 2007	FY 2008
PACOM AGILE COALITION ENVIRONMENT	6,775	0

The Pacific Agile Coalition Environment (ACE) effort developed crypto devices agile enough to create virtual private networks (VPNs) to support bilateral and tailored multi-lateral relationships without having to build

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or lock-down unique networks for each community-of-interest security enclave. ACE enabled CENTRIXS to converge from a set of independent networks to a single network that supports multiple security enclaves on an on-demand basis.

	FY 2007	FY 2008
RADIO SENSOR MODULE (RASM)	2,192	1,590

FY 2007 - This project developed concepts and designed radio technology with ultra-broad band, operating frequency capability to enable communication flexibility in a complex, jamming environment.

FY 2008 - This effort supports Radio Sensor Module (RASM) research.

	FY 2007	FY 2008
THEATER UNDERSEA WARFARE INITIATIVE (TUSW)	5,578	3,180

FY 2007 - This project developed Theater Undersea Warfare (TUSW) Program tools including operations rehearsal simulations and enhancements to the Asset Allocation Tool (AAT). It also evaluated TUSW tools in Undersea Warfare exercises and the studied composable FORCENet integration.

FY 2008 - Develop data fusion technology to help bring clarity to the USW picture by integrating disparate, real-time tactical and sensor data and the Navy's best oceanographic, geophysical, and hydrographic data.

	FY 2007	FY 2008
UGV MOBILITY & COORDINATION IN JOINT URBAN/LITTORAL ENVIRONMENTS	0	795

The UGV effort will develop technologies to address robotic communications (such as signature reduction techniques) and control (including mobility) in support of tactical Marine Corps units in all environments, but specifically those in urban and littoral terrains.

C. OTHER PROGRAM FUNDING SUMMARY - NAVY RELATED RDT&E:
PE 0204152N E-2 Squadrons
PE 0205601N HARM Improvement

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PE 0206313M Marine Corps Communications Systems
PE 0601153N Defense Research Sciences
PE 0602114N Power Projection Applied Research
PE 0602123N Force Protection Applied Research
PE 0602131M Marine Corps Landing Force Technology
PE 0602236N Warfighter Sustainment Applied Research
PE 0602271N RF Systems Applied Research
PE 0603114N Power Projection Advanced Technology
PE 0603123N Force Protection Advanced Technology
PE 0603235N Common Picture Advanced Technology
PE 0603236N Warfighter Sustainment Advanced Technology
PE 0603271N RF Systems Advanced Technology
PE 0603609N Conventional Munitions
PE 0603640M USMC Advanced Technology Demonstration (ATD)
PE 0603658N Cooperative Engagement
PE 0604307N Surface Combatant Combat System Engineering
PE 0604518N Combat Information Center Conversion

OTHER PROGRAM FUNDING SUMMARY - NON-NAVY RELATED RDT&E:
PE 0602782A Command, Control, Communications Technology
PE 0602204F Aerospace Sensors
PE 0602702F Command Control and Communications

D. ACQUISITION STRATEGY:
Not applicable.