BUDGET ACTIVITY: 02
PROGRAM ELEMENT: 0602271N
PROGRAM ELEMENT TITLE: RF SYSTEMS APPLIED RESEARCH

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
RF SYSTEMS APPLIED RESEARCH	48,462	64,640	47,302	53,521	76,407	66,723	63,489	61,796

A. MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION: The Radio Frequency (RF) Systems Applied Research Program addresses technology deficiencies associated with naval platform needs for new capabilities in RF Surveillance, RF Electronic Warfare, Communications, Navigation, RF Solid State Power Amplifiers, Vacuum Electronics Power Amplifiers, and Supporting RF Electronics Technologies. The program supports development of technologies to enable capabilities in Missile Defense, Directed Energy, Platform Protection (including Electric Warship), Time Critical Strike, and Information Distribution. RF Systems Applied Research Developments directly support the Department of Defense Joint Warfighter Plan and the Defense Technology Area Plans. Activities within this Program Element (PE) have attributes that focus on enhancing the affordability of warfighting systems. The program also provides for technology efforts to maintain proactive connectivity and collaboration between Department of the Navy (DON) Science and Technology (S&T) and Joint, Navy, and Marine Corps commands worldwide. This PE supports the Future Naval Capabilities (FNC) Programs in RF Communications Technology, Supporting Technologies, and RF Electronic Warfare (EW) Technology.

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	49,244	49,151	54,265	54,045
Cong Rescissions/Adjustments/Undist. Reductions	0	-697	0	0
Congressional Action	0	16,200	0	0
Execution Adjustments	329	0	0	0
FNC Realignment	0	0	-6,042	-5,778
Non-Pay Inflation Adjustments	-46	0	0	0
Program Adjustments	0	-14	-45	-43
Program Realignment	0	0	-949	5,001
Rate Adjustments	0	0	73	296
SBIR Assessment	-1,065	0	0	0
FY 2006/2007 President's Budget Submission	48,462	64,640	47,302	53,521

PROGRAM CHANGE SUMMARY EXPLANATION:
Technical: Not applicable.

Schedule: Not applicable.

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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
RF SYSTEMS APPLIED RESEARCH	48,462	64,640	47,302	53,521	76,407	66,723	63,489	61,796

A. MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION: This project addresses technology deficiencies associated with naval platform needs for new capabilities in Radar Frequency (RF) Surveillance, RF Electronic Warfare, Communications, Navigation, RF Solid State Power Amplifiers, Vacuum Electronics Power Amplifiers, and Supporting RF Electronics Technologies. The project supports development of technologies to enable capabilities in Missile Defense, Directed Energy, Platform Protection (including Electric Warship), Time Critical Strike, and Information Distribution. RF Systems Applied Research Developments directly support the Department of Defense Joint Warfighter Plan and the Defense Technology Area Plans. Projects within this Program Element (PE) have attributes that focus on enhancing the affordability of warfighting systems. The project also provides for technology efforts to maintain proactive connectivity and collaboration between Department of the Navy (DON) Science and Technology (S&T) and Joint, Navy, and Marine Corps commands worldwide.

B. ACCOMPLISHMENTS/PLANNED PROGRAM:

	FY 2004	FY 2005	FY 2006	FY 2007
ELECTRONICS AND COMMUNICATIONS TECHNOLOGIES	15,676	18,924	15,968	18,936

This activity includes Future Naval Capability (FNC) investments formerly reported for RF Communications Technology, Supporting Technologies, and Radio Frequency (RF) Electronic Warfare (EW) Technology. This additional breakout provides improved detail of the underlying investment. This activity includes support to the FNC Enabling Capabilities (EC) for Long Range RF Deception Missile Defense (MD EC-1C) and Multi-Source Intelligence Surveillance, and Reconnaissance (ISR) to the Warfighter Knowledge Superiority and Assurance (KSA EC-7B).
Controls fluctuate due to completion of initiatives, technology maturing and moving into 6.3.

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FY 2004 Accomplishments:

• Conducted lab testing of the near real-time processing of the ultra-wideband chirp subsystem under the Electronic Support (ES) Detection of Low Probability of Intercept (LPI) Periscope Detection Radar effort.
• Developed and tested the frequency agile prediction algorithm for advanced seekers under the Electronic Attack (EA) Techniques to Counter Advanced Threats effort.
• Advanced Multifunction Radio Frequency Concept (AMRFC) test bed hardware delivered, integrated and tested at the Naval Research Laboratory Chesapeake Bay Detachment site. Successful demonstrations of simultaneously conducting communications (commercial x-band satellite communication (SATCOM), x-band TCDL), surface search radar, and Electronic Warfare (both ES and EA) through the same set of multifunction apertures.
• Fabricated and tested linearizers with 2 GHz of bandwidth.
• Performed full RF life tests of Silicon Carbide (SiC) discrete devices and Monolithic Microwave Integrated Circuits (MMICs).
• Broadened the database for addressing infant mortality issues in Gallium Nitride (GaN) discrete devices and began to establish approaches to RF life testing of GaN High Electron Mobility Transistors (HEMTs).
• Demonstrated a 3 port, 6-18 GHz high power handling channelizer in the laboratory (1.2 dB insertion loss).
• Model of a 6-18 GHz isolator was calibrated and then used to design 20 watt isolator with reduced losses (<1 dB). Fabrication and revised design completed.
• Demonstrated a superconducting band pass sigma delta analog-to-digital converter (ADC) with a 5 GHz center frequency.
• Increased the performance and yield of devices used in the Direct Digital Synthesizer (DDS) frequency source.
• Optimized the wide bandgap low noise receiver amplifier designs by targeting specific spectral bands and exploring approaches to the utilization of these amplifiers with reduced limiter protection.
• Continued cost reduction technical approaches critical to the development of digitally programmable RF electronics components for electronically scanned arrays in the areas of architecture, scale of integration and packaging for multifunction RF component technology and systems.

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FY 2005 Plans:

• Complete Next Generation Buoyant Cable (NGBCA) and transition to development of Next Generation Communications at Speed and Depth (NGCSD) previously funded under PE 0603271N.
• Perform at-sea testing of the ultra-wideband chirp subsystem under the ES Detection of LPI Periscope Detection Radar effort.
• Perform shore based field testing against advanced seekers using the advanced techniques generator in the EA Techniques to Counter Advanced Threats effort.
• Initiate AMRFC Version 2 (V2) renamed Multi-Function Electronics Warfare (MFEW) program and aligned with DD(X), compliant to new DODI 5000.2 acquisition rules as the Technology Development Phase, to build an Electronic Warfare (EW) Advanced Development Model (ADM) for the DD(X) program using the technology from the AMRFC testbed as the basis. During this year the system design and architecture for the ADM will be decided and contracts awarded to produce the major hardware pieces. This system will maintain the scalability and multi-functionality from the AMRFC V1 program's architecture. This will enable adding the communications and radar functions when the next generation of transmit array is developed (starts in FY07 through FY11). Program will move from RF Communications Technology to Electronics and Communications Technology in FY06.
• Fabricate and test linearizers optimized with GaN high power amplifiers having a minimum of 4 GHz of bandwidth.
• Continue the effort to improve DDS and power digital to analog converter (Power-DAC) device performance and yield with a target of up to 20 GHz.
• Transfer results of initial SiC RF life tests into the manufacturing technology and initiate a second iteration of testing.
• Continue to investigate cost reduction and affordability technical approaches critical to the development of digitally programmable RF electronics components for use in electronically scanned arrays.
• Demonstrate True Time Delay (TTD) signal processing that can be integrated into DDS and Power-DAC componentry that support affordable multiGHz bandwidth RF microwave beamsteering.
• Initiate highly integrated and affordable RX component optimization supporting AMRFC/multifunction electronic warfare (MFEW) with a transition target of FY08. This include the optimization of entire component chains of low noise amplifier (LNA), ADC’s, channelizers, and radiating elements specific to the MFEW receiver, 2-D electronically scanned arrays.

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FY 2006 Plans:

• Complete Advanced Techniques Generator (ATG)/Digital Radio Frequency Memory (DRFM) laboratory waveform testing under the EA Techniques to Counter Advanced Threats effort.
• Continue development of RX components including ADCs to support AMRFC/MFEW.
• Continue development of RF technologies that support advances in receiver architecture, antenna performance, subsystem miniaturization, decoys and advanced signal processing.
• Conduct laboratory testing of the frequency modulated continuous wave (FMCW) and Advanced Phase Coded LPI radar detection subsystems with the BLQ-10(V) system.
• The Multi-Function Electronic Warfare (MFEW) program will be in production phase for the RF components of the ADM. The AMRFC V1 Testbed will be used for risk reduction and developmental testing of components as they come available from manufacturers. Software development to integrate system functions with DD(X) Total Ship Computing Environment will be conducted. Integrated with DD(X) developmental combat system will proceed.
• Establish industrial standard for RF life testing of GaN based Millimeter-Wave Integrated Circuits (MMICs) and devices and being to apply this standard to state-of-the-art (SOA) MMICs and devices.
• Demonstrate highly linear Power-DAC (or DDS linearized amplifier chain) supporting up to 20 GHz frequency and multiGHz Bandwidth at high power output levels required for AMFRC/MFEW.
• Initiate component chain optimization for AMRFC MFEW transmitter technology with a target of meeting FY11 transition target date.

FY 2007 Plans:

• Complete counter terminal and counter targeting techniques development under the EA Techniques to Counter Advanced Threats effort.
• Complete initial phase of GaN life testing with demonstration of greater than 10 hour lifetimes for 175 degree channel temperatures.
• Continue development of RF technologies that support advances in receiver architecture, antenna performance, subsystem miniaturization, decoys and advanced signal processing.
• Continue entire component chain optimization for AMRFC MFEW transmitter (TX) technology with a target of meeting FY10 transition to the AMRFC MFEW transmitter, with emphasis on affability and cost reduction of modules. This task includes optimization of the entire component chain consisting of at least the radiating element, digital synthesizer, channelizer, RF power amplifiers, isolators, beamformer, and module package. Affordable digital solutions to 20 GHz are sought after.

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• Conduct a trade off study of available and developmental two-dimensional, planar and non-planar phased array technologies for the Enhanced Nulka Payload effort.
• Initiate demonstration packaging techniques to provide cost reduction and affordability for modules, including component architecture, packaging, and scale of integration optimization.
• Demonstrate complete ARMFC/MFEW receiver (RX) component chains and modules with a target transition of FY08. A target metric of cost reduction to 1/3 of current is sought after for component chains and modules.
• MFEW program will accept, integrate and test RF components from contractors to demonstrate the EW ADM for DD(X). Testing will occur in a developmental test manner to support milestone B decision by the acquisition authority and transition of the ADM to Program Executive Office Integrated Warfare System (IWS)2 for System Development Demonstration (SDD) phase and subsequent acquisition and installation in DD(X). Testing will go through Technology readiness level (TRL) 7.

	FY 2004	FY 2005	FY 2006	FY 2007
RF ELECTRONIC WARFARE TECHNOLOGY	5,557	7,342	9,531	10,581

Supports technologies that enable the development of affordable, effective and robust Electronic Warfare (EW) systems that will increase the operational effectiveness and survivability of U.S. Naval units. Emphasis is placed on non-optical passive sensors and active and passive Radio Frequency countermeasure (RFCM) systems that exploit and counter a broad range of electromagnetic threats. The focus is on maintaining near perfect real-time knowledge of the enemy; countering the threat of missiles to deployed Naval forces; precision identification and location of threat emitters; and, development of technologies that have broad application across multiple disciplines within the EW mission area.

FY 2004 Accomplishments:

Technology development in the areas of Tactical Aircraft, Surface Ships, Submarines, Unmanned Aerial Vehicles (UAVs), and EW Enabling Technology was performed. Some specific accomplishments include:
• Completed full radio frequency-to-pulse descriptor word system functionality under the Wideband EW Channelizer effort;
• Completed portions of the Electronic Countermeasure (ECM) systems analysis and modeling for both onboard and offboard systems under the countermeasures for Wideband Antiship Threats effort;
• Continued to pursue the design and validation testing of a photonic millimeter wave detection hardware covering 20 to 40 GHz (NRL).

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• Continued development and quantitative evaluation of technology and algorithms to detect, identify, exploit and counter advanced wireless communication systems including third generation personal communication systems (PCS) by conducting flight tests of most effective/efficient techniques (NRL).
• Continued the development and demonstration of key technologies that will enable an air-launched unmanned platform carrying an advanced EW payload for the suppression of enemy air defense (SEAD) mission (NRL).
• Continued the development of key capabilities of an Autonomous millimeter wave (MMW) receiver and Coherent techniques to counter 18-40 GHz airborne threats (NRL).
• Continued development of miniature, low-cost electronic warfare devices that can be used in tactical unmanned vehicles or in unattended ground sensor and effector fields (NRL).
• Initiated the development of range/phase correction algorithms that can generate focused, distributed false images against synthetic-aperture radar (SARs) from an Electronic Attack (EA) platform (NRL) offset in range and azimuth (NRL).
• Initiated analysis and modeling to develop and refine the detailed direction findings (DF) antenna design for the Hybrid Interferometer Technology Development effort.

FY 2005 Plans:

Technology development in the areas of Tactical Aircraft, Surface Ships, Submarines, UAVs, and EW Enabling Technology continues. Some specific plans include:
• Complete the development and demonstration of key technologies that will enable an air-launched unmanned platform carrying an advanced EW payload for the suppression of enemy air defense (SEAD) mission (NRL).
• Complete the development of key capabilities of an Autonomous MMW receiver and Coherent techniques to counter 18-40 GHz airborne threats (NRL).
• Continue the development of miniature, low-cost electronic warfare devices that can be used in tactical unmanned vehicles or in unattended ground sensor and effector fields (NRL).• Continue the analysis and modeling to develop and refine the detailed direction findings (DF) antenna design for the Hybrid Interferometer Technology Development effort.
• Continue to incorporate the preliminary millimeter detection hardware into a systems concept and test against 35 GHz surrogate threat (NRL).
• Continue countermeasures technology and algorithm efforts against wireless communications and transition most useful techniques into operational Navy electronic attack (EA) systems (NRL).
• Continue the fabricating a hardware breadboard incorporating range/phase correction algorithms for offset (SAR) countermeasures (NRL).

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• Initiate the development of an integrated Digital electronic warfare (EW), electronic attack (EA) and electronic support (ES) suite using a tightly coupled common architecture (NRL).
• Initiate vulnerability analysis of seeker discrimination and home-on-jam (HOJ) subsystems to the ECM system as part of the countermeasure (CM) for Wideband Antiship Threats effort.
• Initiate and complete fabrication and perform lab demonstration of the DF antenna for the Hybrid Interferometer Technology Development effort.

FY 2006 Plans:

Technology development in the areas of Tactical Aircraft, Surface Ships, Submarines, UAVs, and EW Enabling Technology continues.
• Complete the development of miniature, low-cost electronic warfare devices that can be used in tactical unmanned vehicles or in unattended ground sensor and effector fields (NRL).
• Complete advanced wireless communication countermeasures systems technology and algorithm developments (NRL).
• Complete field test of offset SAR countermeasures hardware breadboard (NRL).
• Continue development of improvement concepts for electronic countermeasures (ECM) against advanced RF missile threats.
• Continue development, evaluation, and of test hardware independent algorithms to address known shortfalls in existing specific Emitter Identification (SEI) capabilities.
• Continue development of RF technologies that support advances in receiver architecture, antenna performance, subsystem miniaturization, decoys and advanced signal processing.
• Continue to expand the frequency coverage of the basic optical detector design up to 80Ghz and test (NRL).
• Continue the development of an integrated Digital EW, EA and ES suite (NRL).
• Initiate development of simulation capability to analyze and evaluate future countermeasure techniques.
• Initiate development of advanced signal processing architectures to assist in identification and classification of low probability of intercept (LPI) and other advanced emitter types.
• Initiate employment of modeling and simulation tools to optimize technique selection to maximum electronic attack effectiveness in counter targeting and counter surveillance operations.
• Initiate investigation of methods of improving pulse de-interleaving that will support detection and identification of complex emitters and allow sorting of multiple tracks and support of raid analysis.
• Initiate the investigation millimeter wave (MMW) technologies to support the development of off board and onboard countermeasures.

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FY 2007 Plans:

Technology development in the areas of Tactical Aircraft, Surface Ships, submarines, UAVs, and EW Enabling Technology continues.
• Complete development of capability to simulate returns from ship targets, decoys, jammers and clutter to assist in the analysis and evaluation of advanced RF countermeasures techniques.
• Complete development of extraction routines to extract modulation features of advanced waveforms that can be used for signal identification and classification.
• Complete expansion of the frequency coverage of the prior detector design up to 95Ghz and test (NRL).
• Continue development efforts in low cost receivers, digital RF memory (DRFM) and technique generators to support development of low cost EW payloads for unmanned aerial vehicles (UAVs).
• Continue investigations into MMW technologies to support the development of off board and onboard countermeasures.
• Continue development of RF technologies that support advances in receiver architecture, antenna performance, subsystem miniaturization, decoys and advanced signal processing.
• Continue fabricating and integrating Digital EW, EA and ES suite brassboard implementing algorithms in Field Programmable Gate Arrays (FPGAs) (NRL).
• Initiate implementation of advanced SEI algorithms into existing hardware using a flexible architecture that supports future widespread algorithm integration and application.

	FY 2004	FY 2005	FY 2006	FY 2007
RF SURVEILLANCE TECHNOLOGY	5,591	6,869	9,590	10,696

Emphasizes non-optical advanced sensor and sensor processing systems for continuous high volume theater-wide air and surface surveillance, battle group surveillance, real time reconnaissance and ship defense. Major technology goals include long-range target detection and discrimination, target identification (ID) and fire control quality target tracking in adverse weather, background clutter and electronic countermeasure environments.

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FY 2004 Accomplishments:

• Completed an exploded prototype of a distributed local oscillator in support of the Digital Array Radar (DAR) technology development effort.
• Completed an algorithm for characterization of advanced Non-Cooperative Target Recognition (NCTR) algorithms in congested harbor environments.
• Continued the architectural design of a one dimensional active phased array apertures for Harbor Surveillance and situational awareness.
• Demonstrated a critical enabling high power amplifier technology and lightweight cooling approach capable of supporting the Horizon Extension Sensor System (HESS) and X-band Unmanned Aerial Vehicle (UAV) efforts.
• Continued development and evaluation via simulation of an effective band-partitioned canceller of wideband interference (NRL).
• Continued designing and developing a testbed for conducting wideband jamming ECCM experiments (NRL).
• Continued developing algorithms for DARPA’s KASSPER I Datacube Challenges (an airborne Ground Moving Target Imaging (GMTI) adaptive array problem). With exact knowledge one can find 192 out of 268 targets (with one false alarm). 192 out of 268 targets were detected (clairvoyance signal-processing parlance) by using internally developed data-mining techniques and algorithms. Algorithms were developed for DARPA’s KASSPER II Datacube Challenges (an airborne GMTI adaptive array problem). With exact knowledge one can find 73 out of 127 targets (with one false alarm). 51 out of 127 targets were detected by using internally developed data-mining techniques and algorithms (NRL).
• Initiated Electromagnetic bandgap (EBG) structures design using computational codes and the effect of various dielectric layers were evaluated (NRL).
• Initiated development and demonstration of a broadband dual polarized array with coincident phase center and true time delay beam steering. Investigated both the single and double element methods (NRL).
• Initiated wideband experiments (NRL).

FY 2005 Plans:

• Complete development of prototype level hardware for DAR and characterize its performance at the element, sub-array and system levels. Effort will transition to the Knowledge, Superiority and Assurance (KSA) Future Naval Capability (FNC).
• Complete Radar ECCM algorithms and perform and evaluate associated wideband experiments (NRL).
• Initiate demonstrations of advanced NCTR algorithms in congested harbor environments.

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- Continue the HESS project with form factored integration of High Power Amplifier (HPA) and development of a Silicon Germanium (SiGe) downconverter in support of HESS and DAR efforts.
- Continue the development to demonstrate signal processing, waveform generation and one dimensional active phased array apertures for Harbor Surveillance and situational awareness.
- Continue the design and fabrication of EBG structures, validate computational-code designs through measurements, and test for isolation of RF waves (NRL).
- Continue broadband-array effort by designing and building an 8X8 element dual-polarized array with coincident phase center (NRL).
- Initiate the design and development of a field probe and radome assembly for a real-time calibration technique that will utilize an optical-to-RF distribution network to inject a low-level RF CW signal into each element of a phased array (NRL).

FY 2006 Plans:

- Continue the demonstrations of advanced NCTR algorithms in congested harbor environments by real time implementation of automated parameter extraction algorithms for small surface crafts.
- Continue the HESS project with form factored integration of High Power Amplifier (HPA) and development of SiGe downconverter in support of HESS and DAR efforts.
- Continue the development and testing of reconfigurable/tunable EBG structures (NRL).
- Continue the investigation of polarization compensation approaches to improve polarization purity, integrate results with 8X8 broadband element array, and demonstrate a 3:1 frequency bandwidth that can provide circular polarization and true-time-delay beam steering over large scan angles (NRL).
- Initiate the design and fabrication of a one-dimensional (1-D) planar light circuitry (PLC) network that includes optical-RF detectors and element probes and in-bed this in a small radome assembly (NRL).
- Initiate an element level digital array radar effort on down conversion and digital beam formers.

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FY 2007 Plans:

• Complete demonstration of advanced NCTR algorithms in congested harbor environments by real time implementation of automated parameter extraction algorithms for small surface crafts.
• Complete the development and testing of reconfigurable/tunable EBG structures (NRL).
• Complete the investigation of polarization compensation approaches to improve polarization purity, integrate results with 8X8 broadband element array, and demonstrate a 3:1 frequency bandwidth that can provide circular polarization and true-time-delay beam steering over large scan angles (NRL).
• Continue the HESS project with form factored development of a single Down conversion Digital Beam Former (DBF) slat board demonstration utilizing SiGe components in support of HESS and Digital Array Radar efforts.
• Continue the development of an element level digital array radar effort on down conversion and digital beam.
• Continue the design, fabrication and characterization of a 2-D PLC network assembly. Develop an automated calibration procedure using this completed network (NRL).
• Initiate a harbor surveillance tracking demonstration with integrated automated parameter extraction for small surface craft identification.

	FY 2004	FY 2005	FY 2006	FY 2007
SUPPORTING TECHNOLOGIES	1,647	5,427	1,946	1,668

Provides for the radiation, reception, signal control and processing of very high frequency (VHF), ultra high frequency (UHF), micro wave (MW), and millimeter wave (MMW) power for Navy all-weather radar, surveillance, reconnaissance, Electronic Attack (EA), communications, and smart weapons systems. The technology developed cannot, for the most part, be obtained through commercial off the shelf (COTS) as a result of the requirements placed on power, frequency, linearity, bandwidth, weight, and size. This activity includes SwampWorks efforts in FY 2005 which will develop and demonstrate technologies that address emergent and enduring operational problems in an accelerated timeframe. Swampworks initiatives to PE 0603758N in FY06 and out.

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FY 2004 Accomplishments:

• Continued digital mixer development including demonstration of 20MHz-20GHz Local Oscillator (LO) source circuit based on 20 GHz master clock.
• Completed design and compact finite bandwidth band rejector filter (NRL).
• Continued selection analog-to-digital control (ADC) modulator architectures and specific semiconductor device to be hybridized with Nb Josephson junctions.
• Behavior models and core systems identification methodology were implemented using hybrid automata models for characterizing ASCM processes of the Automated Anti-Ship Cruise Missile (ASCM) Thread Model Development effort (NRL).
• Continued collecting and analyzing propagation data at 94GHz, for various sea and climatic conditions. Full monopulse measurements (phase and amplitude) were made addressing angle of arrival due to atmospheric fluctuations (NRL).
• Continued to grow and fabrication of an npn heterojunction bipolar transistor (HBT) with an InGaSb base and AlInSbAs emitter and collector (NRL).

FY 2005 Plans:

• Continue to demonstrate in the laboratory a superconducting ADC/Programmable digital channelizer combination that derives 20MHz-20GHz Local Oscillator (LO) for digital down mixing from master clock and outputs software defined bandwidth signal centered on any center frequency in range supplied to ADC.
• Continue to demonstrate flip-chip bonding of semiconducting and superconducting devices to form a functional hybrid circuit.
• Continue developing prototype identification algorithms for the lock-logic and Electronic Counter Countermeasures (ECCM) components of the automated RF ASCM threat model (NRL).
• Continue measuring Monopulse tracking accuracy at low elevation angles using towed targets and low flying aircraft and tracking error mitigation techniques suitable for millimeter wave frequencies (NRL).
• Conduct research to enable growth, fabrication, and testing of 6.1-6.3 Angstrom HEMTS with allow alloy channels and barriers (NRL).
• Conduct efforts within Project Shield (Classified program).
• Develop and complete demonstration technologies that address emergent and enduring operational problems in an accelerated timeframe.
• Pursue development to extend the tuning range of band reject filters (NRL).

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FY 2006 Plans:

• Complete the development of prototype identification algorithms for the lock-logic and ECCM components of the automated radio frequency (RF) ASCM threat model and document results (NRL).
• Complete the 94GHz measurement effort and determine the effect of frequency agility on the diffuse multi-path component and implement a two-antenna configuration to measure atmospheric turbulence (NRL).
• Conduct development of 6.2-6.3 Angstrom HBT operating at microwave frequencies (NRL).
• Experimentally test concepts for bias current recycling in a repeated supercell superconducting circuit.
• Prove feasibility of hybrid Nb Josephson Junction/InP HBTs ADC modulator circuits operating properly at 4K and with 10 GHz clock when the hot InP transistors are <3mm away from the active Josephson junctions.
• Increase the performance of synthetic delay lines (NRL).

FY 2007 Plans:

• Demonstrate a current recycling technology for superconducting digital circuits that is mature enough to yield a four fold reduction of bias current.
• Pursue the development of a semiconductor-based frequency selective limiter (NRL).
• Pursue novel control components for mm-wave frequencies (NRL).

	FY 2004	FY 2005	FY 2006	FY 2007
RF SOLID STATE POWER AMPLIFIERS	2,966	3,461	4,282	4,792

Provides for the generation of Very High Frequency (VHF), Ultra High Frequency (UHF), Microwave (MW), and Millimeter Wave (MMW) power amplifiers for Navy all-weather radar, surveillance, reconnaissance, electronic attack, communications, and smart weapons systems. The technology developed cannot, for the most part, be obtained through Commercial-Off-the-Shelf (COTS) as a result of the simultaneous requirements placed on power, frequency, linearity, bandwidth, weight, and size.

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FY 2004 Accomplishments:

- Demonstrated silicon carbide (SiC) transistors with 300 W of output power at L-band.
- Demonstrated MBE-grown HEMT structure on a GaN substrate with record Hall mobility (NRL).
- Developed advanced transistor materials and structures to enhance amplifier efficiency with the emphasis to include development of complete monolithic integrated circuits.
- Continued development of MMW Aluminum Gallium Nitride/Gallium Nitride (AlGaN/GaN) Widebandgap High Electron Mobility Transistor (HEMT).
- Continued development of AlGaN HEMT broadband amplifiers for electronic warfare decoys with output powers up to 10 times that achieved with conventional solid state amplifiers.

FY 2005 Plans:

- Continue the development of MMW AlGaN/GaN wide bandgap HEMTs.
- Develop AlGaN HEMT broadband amplifiers with over 20W output power over the full band for electronic warfare decoys.
- Pursue further development of an InGaN HEMT with a ft*lg product of 20 GHz-microns (NRL).

FY 2006 Plans:

- Complete 4-20 GHz broad band amplifier development with 40 W demonstration.
- Develop application specific MMW AlGaN/GaN Widebandgap HEMT's that will allow AlGaN broadband amplifiers to be extended to various electronic attack applications.
- Pursue radiation effects and hardness studies of wide bandgap semiconductors (NRL).

FY 2007 Plans:

- Transition MMW AlGaN/GaN HEMTs to communications and missile seeker platforms.
- Transition broadband AlGaN/GaN amplifiers to communications and missile seeker platforms.
- Pursue further development of reliable wide bandgap semiconductors (NRL).

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PROJECT TITLE: RF SYSTEMS APPLIED RESEARCH

	FY 2004	FY 2005	FY 2006	FY 2007
RF VACUUM ELECTRONICS POWER AMPLIFIERS	2,589	3,461	3,442	3,727

Provides for the development of microwave (MW), millimeter wave (MMW), submillimeter wave power amplifiers for use in naval all-weather radar, surveillance, reconnaissance, electronic attack, and communications systems. The technology developed cannot, for the most part, be obtained through commercial off the shelf (COTS) as a result of the simultaneous requirements placed on power, frequency, bandwidth, weight, and size. Responding to strong interests from the various user communities, efforts are focused on the development of technologies for high-data-rate communications and high-power high-frequency radar applications. Technologies include techniques for power and efficiency enhancement of millimeter-wave amplifiers, multiple-beam amplifiers, notably the multi-beam klystron (MBK), and physics-based modeling and simulation.

FY 2004 Accomplishments:

- Released the large-signal time-dependent code GATOR incorporating the reflection models developed earlier for beta testing.
- Released MICHELLE v3.0 and TESLA v2.0 to the domestic vacuum electronics industry for beta testing.
- Demonstrated C-band helix Traveling Wave Tube (TWT) low-distortion performance (NRL).
- Optimized the single beam kylstron large signal code TESLA v2.0 to model multiple beams (NRL).
- Continued validation of a time-dependent, helix TWT block model with memory for modeling digital signal amplification (NRL).

FY 2005 Plans:

- Create techniques for TESLA as the design tool tailored for broadband single-beam klystron development.
- Initiate the development of a four-cavity narrow-band S-band multi-beam klystron for experiments (NRL).
- Pursue development of a high-data-rate TWT using 16 and 32 symbol quadrature amplitude modulation (QAM) (NRL).

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FY 2006 Plans:

- Continue the development of a broad-band (~ 400 MHz) S-band multi-beam (18 beams) klystron (NRL).
- Continue developing design techniques for a high power millimeter-wave TWT with quadrupole magnetic focusing (NRL).
- Release TESLA v3.0 capable of modeling broad-band single beam klystrons.
- Release the gun/collector code MICHELLE v4.0 with improved GUI and postprocessor or beta testing.
- Release TESLA MB v1.0 capable of modeling multiple beam klystrons incorporating the effect of beam-wave interaction for each beam separately.
- Conduct four-cavity narrow-band S-band multi-beam (8-beams) klystron performance (~ 600 kW and ~ 40% efficiency) experiments (NRL).
- Upgrade the large signal code CHRISTINE3D to model strong focusing effects for beam transport.

FY 2007 Plans:

- Complete design of a high power MMW TWT with quadrupole magnetic focusing (NRL).
- Release TESLA/GENOME v.1 large signal code capable of modeling broad-band multiple beam klystrons for beta testing.
- Release the gun/collector code MICHELLE with improved interface with the large signal codes CHRISTINE and TESLA.
- Integrate the large signal codes CHRISTINE and TESLA with the gun/collector code MICHELLE.
- Conduct broad-band S-band multi-beam (18-beams) klystron component performance (NRL).
- Investigate novel approaches to miniature high power wide bandwidth devices for mmwave applications (NRL).

	FY 2004	FY 2005	FY 2006	FY 2007
RF NAVIGATION TECHNOLOGY	2,216	3,113	2,543	3,121

Develops key navigation technologies for Naval Battle Groups, Aircraft, Unmanned Air Vehicles (UAVs), Unmanned Underwater Vehicles (UUVs), Ships, Submarines and other Navy vehicles and platforms. This activity applies leading-edge Science and Technology (S&T) to enhance Global Positioning System (GPS) capabilities in order to make GPS more resistant to noise and jamming. Much of the near-term effort concerns the development of antennas with special features.

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FY 2004 Accomplishments:

• Conducted laboratory testing to determine the effectiveness of its nulling functions of the Submarine Mast-mounted Controlled Radiation Pattern Antenna (CRPA) for the GPS.
• Developed additional, high ranking, techniques of those initially investigated Space-Time Adaptive Array Processing (STAP) for GPS antenna effort; implementation issues continued to address concerns for computational speed and performance reliability.
• Initiated a development of GPS AJ digital antenna electronics (DAE) based anti-jam systems, which use space-time adaptive processing (STAP) or space-frequency adaptive processing (SFAP); Also develop small patch antenna using low-loss ceramic materials for an array of 7 elements.

FY 2005 Plans:

• Continue DAE based anti-jam systems with small patch antenna using low-loss ceramic materials for an array of 7 elements.
• Continue to integrate STAP for GPS Antennas to one of the receiver-antenna systems developed in this task or to a system recommended by the GPS-Joint Program Office (GPS-JPO). Specific jammer types will be also addressed in this effort.
• Continue to design the STAP for GPS Antennas to one of the receiver-antenna systems developed in this activity and to strike weapon systems such as Paveway and Tactical Tomahawk.
• Conduct field testing of the Submarine Mast-mounted Controlled Radiation Pattern Antenna to determine if the laboratory performance can be achieved in a more realistic environment; conduct nulling optimization in submarine mast environment for the best broadband nulling performance.
• Initiate a development of GPS AJ processor with Poly-channelized, Code Gated Maximum Likelihood (CGML) technique to cancel the effect of a large number of jammers.
• Initiate a development of GPS AJ Antenna Electronics (AE) with low-cost analog processor technique for Direction of Arrival (DOA) estimation and nulling.
• Initiate a development of GPS AJ processor to reliably lock to the GPS carrier signal and in this way make it possible to extract very high precision positional information from the GPS receiver. Carrier slips are a measure of degraded GPS positional performance.

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FY 2006 Plans:

• Continue DAE based anti-jam systems with small patch antenna using low-loss ceramic materials for an array of 7 elements.
• Continue to integrate and test GPS anti-jam (AJ) antenna installed on strike weapon systems by using the STAP processing algorithm and assess the potential jamming mitigation; Develop beam forming/null steering techniques instead of a simple power minimization; Incorporate an algorithm to Antenna Electronics (AE) performance with the optimum sampling rate; Develop techniques to minimize the AE-induced errors on GPS signals.
• Continue to design and develop SFAP for GPS AJ antenna to improve receiver AJ performance by adding channelization to the existing Code Gated Maximum Likelihood (CGML) receiver; Evaluate the effectiveness of the Poly-Channel (PC) CGML technique by simulation and build it software radios.
• Continue to design and develop GPS AJ antenna electronics algorithm for providing AJ and jammer direction-finding capabilities; Three techniques (a low cost "analog", a high performance "digital", and a "hybrid") will be investigated for high-value platforms, where great jammer level dynamic range stresses analog-to-digital (A/D) capabilities suggesting all-digital solutions. For low-cost systems, digital control with analog weights initially appears to be cost effective. A cost-performance trade table will be generated to aid the selection of the best match for a particular application.

FY 2007 Plans:

• Continue AJ AE antenna development task, integrate testbed components and conduct chamber performance testing.
• Continue to integrate the small CRPA with SFAP/STAP Antenna Electronics; Perform RF tests with advanced threats.
• Continue to design and develop GPS AJ antenna electronics algorithm for providing nulling and DOA estimation capabilities; a low cost "analog", a high performance "digital", and a "hybrid" will be investigated for high-value platforms, where great jammer level dynamic range stresses analog-to-digital (A/D) capabilities suggesting all-digital solutions. For low-cost systems, digital control with analog weights initially appears to be cost effective. A cost-performance trade table will be generated to aid the selection of the best match for a particular application.

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	FY 2004	FY 2005	FY 2006	FY 2007
RF COMMUNICATIONS TECHNOLOGY	1,353	0	0	0

Addresses critical Navy communications technology deficiencies and needs that are not addressed by the commercial technology sector. The activity emphasis is on reliable interoperable communications between U.S. and coalition forces, at all levels of command, and rapid and reliable utilization of government and commercial telecommunications assets worldwide that are efficient and responsive to warfighting needs.

FY 2004 Accomplishments:

• Completed development of the Naval Battleforce Networking (NBN) technology projects Traffic Flow Engineering and Intra-Battlegroup Wireless Networking. Successful demonstration on USS ESSEX ESG.

CONGRESSIONAL PLUS-UPS:

	FY 2004	FY 2005
ADVANCED MICROWAVE FERRITE RESEARCH FOR RF SYSTEMS	1,442	1,188

Note: FY04 title was ADVANCED MICROWAVE FERRITE RESEARCH.

In FY04, preparation of initial sample advanced hexagonal microwave ferrites and their characterization for microwave radar circuit tuning were initiated.
For FY05, a selection of functional Perovskite oxides for passive microwave device application were deposited on both Silicon Carbide (SiC) and Gallium Nitride (GaN) wide gap semiconductors and subjected to in chemical, structural and microwave evaluation

	FY 2004	FY 2005
ADVANCED SEMICONDUCTOR MATERIALS	1,345	0

In FY04, the capability of deposition and characterization of functional oxides was advanced and microwave tuning performance investigations were initiated.

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	FY 2004	FY 2005
GALLIUM NITRATE RF POWER TECHNOLOGY	0	1,981

In FY04, this effort was funded under PE 0602114N and developed a reliable Gallium Nitride (GaN) Radio Frequency (RF) Power Technology that is more reliable and affordable by bringing 4 inch wafer processing on line and through the use of High Density Dielectric Passivation (HDDP) processes.
For FY05, improve the performance and reliability of GaN High Electron Mobility Transistors (GaN HEMTs) for RF power applications by exploiting innovative new methods for the production of GaN HEMT epitaxial material on SiC and by developing novel GaN HEMT device designs and fabrication techniques. Conduct accelerated lifetime test measurements to document improvements.

	FY 2004	FY 2005
HIGH BRIGHTNESS ELECTRONICS	2,021	1,485

In FY04, demonstrated prototype field emission electron source using back-gated structures for application to 50 W, 10 GHz vacuum electronic amplifier with 10 dB gain.
For FY05, device fabrication and material synthesis of carbon nanostructure for application to 50W, 10 GHz vacuum electronic power amplifier will be optimized.

	FY 2004	FY 2005
MARITIME SYNTHETIC RANGE	4,137	4,259

In FY04, this effort further developed the Maritime Synthetic Range by synchronizing the live systems, which replaced synthetic systems, to increase the complexity of training and testing to provide a realistic setting for joint-to-unit training with coordinated operational forces.
For FY05, this effort will develop and enhance the Maritime Synthetic Range with increased real-time participation in operational training; creation of synthetic forces; scenario generation; and creation of common synthetic battlespace (CSB) and advanced threat environments.

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	FY 2004	FY 2005
NOVEL SILICON CARBIDE TECHNOLOGY DEVELOPMENT	0	990

Techniques will be developed to provide a solid scientific framework for the growth of SiC epitaxial and bulk crystals using halo-carbon precursor gases.

	FY 2004	FY 2005
PACIFIC THEATER DATA FUSION TESTBED	0	2,476

The project will develop a Pacific-theater Data Fusion Testbed (PDFT) initiative and provide the U.S. Navy and Missile Defense Agency (MDA) with advanced discrimination and tracking capabilities. The program will develop a framework theater-wide sensor fusion center, develop multiple discrimination and tracking algorithms, and provide performance verification from development through testing. An open systems architecture will be utilized to support design integration and testing of next generation active and passive sensors, sensor data fusion, and discrimination tracking technology.

	FY 2004	FY 2005
RADAR/VIDEO FUSION VESSEL AND PORT SECURITY DEMONSTRATION	961	990

In FY04, developed techniques and algorithms for Automated Identification of vessels consistent with the Navy and Coast Guard requirements.
For FY05, use collected data to develop algorithms and automation techniques for planned autonomous operations.

	FY 2004	FY 2005
RF VACUUM ELECTRONICS POWER AMPLIFIERS	0	990

The development of design tools for the gun, collector and large signal analysis of vacuum electronics amplifiers with sheet electron beams will be initiated.

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	FY 2004	FY 2005
WIDE BANDGAP MATERIALS FOR POWER ELECTRONICS	961	1,684

In FY04, improved the process to investigate the perfection of Silicon Carbide (SiC) for high power electronic applications.
For FY05, reduce thermal strain-induced structural defects (which adversely affect device performance), unintentional impurities and allow more reproducible and affordable product. This would have the effect of further improving the performance and capability of DOD's high power electronics by reducing the defect densities in power semiconductor substrates and thin device films.

C. OTHER PROGRAM FUNDING SUMMARY:
NAVY RELATED RDT&E:
PE 0601153N (Defense Research Sciences)
PE 0602114N (Power Projection Applied Research)
PE 0602123N (Force Protection Applied Research)
PE 0603271N (RF Systems Advanced Technology)
PE 0603114N (Power Projection Advanced Technology)
PE 0603123N (Force Protection Advanced Technology)

NON NAVY RELATED RDT&E:
PE 0601102A (Defense Research Sciences)
PE 0601102F (Defense Research Sciences)
PE 0602204F (Aerospace Sensors)
PE 0602702F (Command, Control, and Communications)

D. ACQUISITION STRATEGY:
Not applicable.