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FY 2009 RDT&E,N BUDGET ITEM JUSTIFICATION SHEET
Exhibit R-2

DATE: February 2008

BUDGET ACTIVITY: 02
PROGRAM ELEMENT: 0602271N
PROGRAM ELEMENT TITLE: RF SYSTEMS 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
RF SYSTEMS APPLIED RESEARCH	52,059	52,529	54,830	49,764	55,626	60,296	64,854

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 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.

The Radio Frequency (RF) Systems Applied Research Program addresses technology opportunities associated with Naval platform opportunities for new capabilities in RF Surveillance, RF Electronic Warfare, Navigation, RF Solid State Power Amplifiers, RF 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. This program directly supports the Department of Defense Joint Warfighter Plan and the Defense Technology Area Plans. Activities and efforts within this Program 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 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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B. PROGRAM CHANGE SUMMARY:

	<u>FY 2007</u>	<u>FY 2008</u>	<u>FY 2009</u>
FY 2008/FY 2009 President's Budget Submission	50,327	45,451	45,692
Congressional Action	0	7,800	0
Congressional Undistributed Reductions/Rescissions	0	-338	0
Execution Adjustments	2,893	0	0
Program Adjustments	-486	0	9,382
Rate Adjustments	0	0	-244
SBIR Assessment	-675	-384	0
FY 2009 President's Budget Submission	52,059	52,529	54,830

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 R-2a.

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RF SYSTEMS APPLIED RESEARCH	52,059	52,529	54,830	49,764	55,626	60,296	64,854

A. MISSION DESCRIPTION AND BUDGET ITEM JUSTIFICATION: This project addresses technology opportunities associated with Naval platform opportunities 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. This program directly supports the Department of Defense Joint Warfighter Plan and the Defense Technology Area Plans. Activities and efforts within this Program 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 2007	FY 2008	FY 2009
ELECTRONICS AND COMMUNICATIONS TECHNOLOGIES	10,673	11,654	14,210

This activity provides technologies developed under the Future Naval Capabilities (FNC) Program; specifically the Multi-Source Intelligence, Surveillance, and Reconnaissance (ISR) to the Warfighter and the Advanced Electronic Sensor Systems. Emphasis is placed on the development of Electronic Warfare, Multi-Function and advanced multifunction RF and microwave electronic components. Included are the development of capabilities to increase the effectiveness in countering a broad range of threats from anti-ship missiles, and increasing the overall real time situational awareness of operational forces through the detection and processing of RF signals designed with low probability of detection characteristics. The electronics components are developed, optimized and demonstrated in component chains that must meet size, weight and power requirements. These component technologies will form the basis of new multifunction modules to help support these functions.

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The funding profile in FY 2007 reflects the reorganization of Future Naval Capabilities (FNC) Program investments into Enabling Capabilities (ECs). As a result of this reorganization, the funding for each EC has been aligned to a Budget Activity 2 and Budget Activity 3 PE as appropriate. This Activity reflects the alignment of investments for the following ECs: Multi-Source ISR to the Warfighter; Advanced Electronic Sensor Systems for Missile Defense; Affordable Electronically Scanned Array Technology; and low cost over the horizon communications.

The increase from FY 2008 to FY 2009 is due to increased investment in FY 2008 initiated FNC EC efforts for Next Generation Airborne Electronic Attack; Long Range Detection and Tracking; Low Cost Over the Horizon Communication, SATCOM and Line of Sight (LOS) Apertures; and Affordable Electronically Scanned Array Technology for Next Generation Naval Platforms.

FY 2007 Accomplishments:

- Continued highly integrated and affordable receiver (RX) component optimization supporting Advanced Multifunctional Radio Frequency Concept (AMRFC)/Multifunction Electronic Warfare (MFEW). This includes the optimization of entire component chains of Low Noise Amplifiers (LNA's), Analog-to-Digital Converters (ADC's), tunable filters, channelizers, radiating elements specific to the MFEW receiver, and 2-D electronically scanned arrays. Objectives are to reduce cost to 1/3 of current multi-function RF systems for a minimum of 6-18 GHz bandwidth.
- Continued the development of Radio Frequency (RF) technologies that support advances in receiver architecture, antenna performance, subsystem miniaturization, decoys and advanced signal processing.
- Continued component chain optimization for AMRFC MFEW transmitter technology with a target of meeting FY11 transition target date.
- Continued establishment of an industrial standard appropriate for the demonstration of >1E6 hour lifetime for RF life testing of Gallium Nitride (GaN) based Millimeter-Wave Integrated Circuits (MMICs) and devices, and began to apply this standard to state-of-the-art (SOA) MMICs and devices.
- Completed the EA Techniques to Counter Advanced Threats effort by development of 100% of the EA technique modules for counter terminal and counter targeting.
- Completed initial phase of GaN High Electron Mobility Transistor (HEMT) life testing with demonstration of greater than 1E4 hour lifetimes for 175 degree channel temperatures.
- Completed the Applied Research Phase (6.2) of the Shipboard Electro-optic/Infrared (EO/IR) Closed Loop Self Protection effort by developing additional jam codes and tracking algorithms to be used during final at-sea

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testing of the Shipboard Integrated Electro-optic Defense System (SHIELDS) hardware in FY 2008. This effort previously funded in PE 0602123N.

- Completed MFEW program for DD(X), compliant to new DODI 5000.2 acquisition rules as the Technology Development Phase, to build an EW ADM for the DD(X) program using the technology from the AMRFC testbed.
- Initiated demonstration packaging techniques to provide cost reduction and affordability for modules, including component architecture, packaging, and scale of integration optimization.

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.
- Complete highly integrated and affordable receiver (RX) component optimization supporting multifunction electronics and array technologies. This includes the optimization of entire component chains of LNA, ADC's, tunable filters, channelizers, radiating elements specific to the MFEW receiver, and 2-D electronically scanned arrays. Objectives are to reduce cost to 1/3 of current multi-function RF systems for a minimum of 6-18 GHz bandwidth.
- Initiate the Next Generation Airborne Electronic Attack effort by conducting a requirements validation and technology assessment review.
- Initiate development of technology to provide a set of apertures (Line of Sight, Satellite Communications) and link electronics that are suitable for broad Naval applications.
- Initiate development of technology to provide open, programmable core terminal components applicable to multiple platforms to include airborne applications and Marine vehicles.
- Initiate design and development of a X-Band Digital Array Radar.
- Initiate development of Maritime Classification and Identification modes for APY-6.
- Initiate effort on Affordable Electronically Scanned Array Technology to include electronics component technologies supporting S-band radar, X-band radar and electronic attack.

FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Initiate the Enhanced Nulka Payload FNC effort by conducting a Transmitter and Receiver Technology Trade Space study.
- Initiate the Enhanced Surface Electronic Warfare Improvement Program (SEWIP) Transmitter FNC effort by conducting a Transmitter and Cooling Technology Trade Space study.

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	FY 2007	FY 2008	FY 2009
RF ELECTRONIC WARFARE TECHNOLOGY	9,764	10,226	16,564

This activity 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.

The increase from FY 2008 to FY 2009 is due to initiation of the following efforts: Antennas from VHF to THz, Cueing Receiver for Faster EA Response Management, the Digital Directional Correlator, and research for development of power amplifiers for future RF systems.

FY 2007 Accomplishments:

- Continued technology development in the areas of Tactical Aircraft, Surface Ships, Submarines, UAVs, and EW Enabling Technology.
- Continued the development of an integrated Digital EW, Electronic Attack (EA) and Electronic Support (ES) suite using a tightly coupled common architecture so that there is a synergistic coupling between the sub-functions of ES and EA. (NRL)
- Continued development of RF technologies that support advances in receiver architecture, antenna performance, subsystem miniaturization, decoys and advanced signal processing.
- Continued the EW Tactical Decision Algorithms (TDA) for Satellite Communications effort by evaluating two atmospheric propagation models to assist in visualizing the impact of satellite communications on future planning and tactics.
- Continued the investigation of Millimeter Wave (MMW) technologies to support the development of off board and onboard countermeasures.
- Continued the development and demonstration of a compact EA technology for tactical unmanned vehicle systems to counter wideband, spread spectrum active electronically steered array radars. (NRL)
- Completed the Autonomous Classification of Low Probability of Intercept (LPI) Radar Emitters effort by testing and evaluating feature extraction algorithms on actual digitized LPI radar signals.

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- Completed the Advanced Pulse De-interleaving effort by lab and field testing of the de-interleaving algorithms with an Electronic Support Enhancement (ESE) processor used for the SEWIP.
- Completed the Unmanned Vehicle Integrated Electronic Warfare Payload (UVIEWP) effort by conducting a multiplatform demonstration of an autonomous UVIEWP escort constellation that provides countertargeting and countersurveillance for expeditionary force ships.
- Completed the Specific Emitter Identification (SEI) Capabilities Extension effort with implementation of advanced SEI algorithms into Windows based SEI software and SEI hardware using a flexible architecture employing IFD-120 Field Programmable Gate Arrays (FPGA) with 3 million gates.
- Completed the development of a RF detection process at MMW using photonics. (NRL)
- Initiated the Ka/W Band Miniature Sensor Development effort with Ka/W Band architecture device selection and downconverter subsystem conceptual design.
- Initiated the Countermeasures to Anti-Helicopter Mines (AHM) effort by reviewing current and previous Army efforts and developing initial countermeasure concepts.
- Initiated the Compact Electro-Magnetic (EM) Source for Improvised Explosive Device (IED) and Engine Defeat effort by measuring the RF impedances of the materials and comparing the results with conventional theory.
- Initiated the design and development of a miniature coherent transponder to counter modern threats using advanced electronic protection techniques. (NRL)
- Initiated the development of a series of kinetically driven devices to generate RF. (NRL)

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.
- Complete the development of an integrated Digital EW, EA and ES suite using a tightly coupled common architecture so that there is a synergistic coupling between the sub-functions of ES and EA. (NRL)
- Complete the development and demonstration of a compact EA technology for tactical unmanned vehicle systems to counter wideband, spread spectrum active electronically steered array radars. (NRL)
- Complete the Ka/W Band Miniature Sensor Development effort by testing and delivering a prototype sensor system.
- Complete the Countermeasures to Anti-Helicopter Mines effort by conducting a field test of the system against AHM or simulators.
- Complete the Compact EM Source for IED and Engine Defeat effort by conducting a field test of an advanced source.
- Initiate the development of a novel approach to near real time active digital augmentation to improve the isolation of shipboard EW systems. (NRL)

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FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Complete the design and development of a miniature coherent transponder to counter modern threats using advanced electronic protection techniques. (NRL)
- Complete the development of a series of kinetically driven devices to generate RF. (NRL)
- Initiate the Miniature 2-70 GHz Integrated Optical Channelizer effort by starting Phase I and specifications development.
- Initiate the Antennas from VHF to THz effort through development of the log-periodic antenna.
- Initiate the Cueing Receiver for Faster EA Response Management effort by initiating system design.
- Initiate the Digital Directional Correlator effort by initiating by building and refining a more complete simulation of the correlator and determining via simulation and analysis the primary characteristics required for the system.
- Initiate the Exploiting Non-Traditional Signals Using a Photonics Based Signal Processor effort by performing proof-of-concept demonstrations for the three main modes of operation for the spatial spectral optical materials when used for Electronic Support Measures (ESM) applications.
- Initiate research for development of power amplifiers for future RF systems.

	FY 2007	FY 2008	FY 2009
RF SURVEILLANCE TECHNOLOGY	11,792	7,834	8,640

RF Surveillance 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.

Funding decreases from FY 2007 to FY 2008 are due to reduced level of investment to fund higher priority requirements identified as newly initiated efforts in RF Supporting Technologies R2 activity associated with NRL Base program.

Funding increases from FY 2008 to FY 2009 associated with newly initiated FNC effort to develop an Affordable Common Radar Architecture for surface ships.

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FY 2007 Accomplishments:

- Continued the Horizon Extension Sensor System (HESS) project with form factored integration of High Power Amplifier (HPA) and development of a Silicon Germanium (SiGe) downconverter in support of HESS and Digital Array Radar (DAR) efforts.
- Continued development efforts to demonstrate signal processing, waveform generation and one dimensional active phased array apertures for Harbor Surveillance and situational awareness.
- Continued demonstrations of advanced Non-Cooperative Target Recognition (NCTR) algorithms in congested harbor environments.
- Continued 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 Continuous Wave (CW) signal into each element of a phased array. (NRL)
- Continued an element level DAR effort on down conversion and digital beam formers.
- Continued a program to develop and demonstrate methodologies that provide small threat radar detection in the presence of large masking radar returns using an Adaptive Pulse Compression technique. (NRL)
- Completed the broadband-array effort by demonstrating a dual polarized array with coincident phase center and true time delay beam steering. (NRL)
- Completed the development and testing of reconfigurable/tunable Electromagnetic Bandgap (EBG) structures. (NRL)
- Initiated the assessment of vulnerabilities of modern side lobe canceling (SLC) algorithms to adversary jamming and develop mitigating SLC design improvements. (NRL)

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.
- Complete 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. Demonstrate the polarization properties of a wideband probe using a zero-bias optical detector. (NRL)

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FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Complete a program to develop and demonstrate methodologies that provide small threat radar detection in the presence of large masking radar returns using an Adaptive Pulse Compression technique. (NRL)
- Initiate investigation of means of optimally combining mensuration, classification, and non-cooperative target recognition of surface craft.
- Initiate the requirements analysis and trade studies of an Advanced Common Radar Architecture.

	FY 2007	FY 2008	FY 2009
SUPPORTING TECHNOLOGIES	2,688	4,571	5,232

Supporting Technologies provide 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, smart weapons, networked sensors, and precision time and navigation systems. Supporting Technologies is characterized by research outside of RF amplifiers, with emphasis in superconducting electronics and nanoelectronics technology. The technology developed which includes nanotechnology cannot, for the most part, be obtained through commercial off the shelf systems (COTS) as a result of the requirements placed on power, frequency, linearity, bandwidth, weight, and size.

The increase from FY 2007 to FY 2008 is due to increased level of investment associated with RF Solid State Devices, Enhanced Electronic Capabilities and Mitigation Technologies, RF Systems Technology for Surface Platforms, and Electronic and Electro-Optic Materials at the Naval Research Laboratory (NRL).

The increase from FY 2008 to FY 2009 is associated with initiation of Nanometer Scale Electronic Devices and Sensors research at NRL.

FY 2007 Accomplishments:

- Continued effort to develop carbon nanotube sensors for trace-level vapor detection of explosives, chemical agents, and toxic industrial chemicals. (NRL)
- Continued research to enable growth, fabrication, and testing of 6.2-6.3 Angstrom High Electron Mobility Transistors (HEMTs) with alloy channels and barriers. (NRL)

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- Continued development of 6.2-6.3 Angstrom Heterojunction Bipolar Transistor (HBT) operating at microwave frequencies. (NRL)
- Continued the development of analysis/modeling infrastructure and prototype improvement concepts for electronic countermeasures and counter-targeting against RF surveillance threats. (NRL)
- Continued the demonstration of a current recycling technology for superconducting digital circuits that is mature enough to yield a four fold reduction of bias current.
- Completed the proof of 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.
- Initiated demonstration of an improved signal processing technique that can be applied to state-of-the-art L, S, X, and Ka-band superconducting bandpass ADCs to realize an improvement in dynamic range of greater than 6dB.
- Initiated demonstration that arrays of Superconducting Quantum Interference Devices (SQUIDS) having intentionally dissimilar loop area ("SQIF") can act as wideband (1MHz - 1GHz) trans-impedance amplifiers having large (>100 dB) linear dynamic range and provide the basis of cm scale antennas for these frequencies.

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.
- Complete the development of analysis/modeling infrastructure and prototype improvement concepts for electronic countermeasures and counter-targeting against RF surveillance threats. (NRL)
- Initiate the development to assess the electronic protection capability of modern missiles using advanced processing and investigate the improvements needed to restore countermeasures effectiveness. (NRL)
- Initiate the development of techniques to identify and exploit the processing vulnerability of passive location systems. (NRL)
- Initiate development of Sb-based diodes and multipliers for the exploitation of the frequency spectrum from 94-1000 GHz. (NRL)
- Initiate development of an integrated tunable frequency selective and low noise integrated module. (NRL)

FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Complete development of 6.2-6.3 Angstrom HBT operating at microwave frequencies. (NRL)
- Initiate development of next generation superconducting front-end receiver component critical to successful

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delivery of superior system performance.

- Initiate research supporting development of Nanometer Scale Electronic Devices and Sensors. (NRL)

	FY 2007	FY 2008	FY 2009
RF SOLID STATE POWER AMPLIFIERS	4,357	4,461	4,322

This activity provides for the generation of VHF, UHF, MW, and 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.

FY 2007 Accomplishments:

- Continued development of MMW Aluminum Gallium Nitride/Gallium Nitride (AlGaIn/GaN) wide bandgap High Electron Mobility Transistor (HEMT).
- Continued development of AlGaIn HEMT broadband amplifiers for electronic warfare decoys with increased powers and efficiency than achieved with conventional solid state amplifiers.
- Continued the development of ultra-compact, low-loss ridge-waveguide frequency multiplexer. (NRL)
- Continued Field-Plate GaN HEMT Device development for MMW amplifiers.
- Continued high-efficiency microwave GaN HEMT amplifier development.
- Continued development of Wide Bandgap radiation detectors for celestial and nuclear monitoring applications. (NRL)
- Initiated work on GaN MMW components at >44 GHz to allow for Extremely High Frequency (EHF) SATCOM insertion and other MMW applications spanning to 95GHz.
- Initiated the expansion of scope of the GaN MMW device program.
- Initiated component development in support of multifunctional electronic warfare.

FY 2008 Plans:

- Continue all efforts of FY 2007.
- Complete and transition Wide Bandgap radiation detectors for celestial and nuclear monitoring applications. (NRL)
- Initiate transition GaN high-efficiency microwave HEMT amplifiers to radar and communications applications.
- Initiate development of MMW High efficiency Amplifiers for Satellite communications and compact high

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efficiency MMW sources for active denial systems.

- Initiate development of high-efficiency broadband GaN HEMT amplifiers for electronic warfare applications.
- Initiate Sub MMW GaN Device technology for communications, target identification and high speed data processing.
- Initiate development of high-current density cathodes using diamond for generating spatially-distributed beams. (NRL)

FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Complete high efficiency microwave GaN HEMT amplifier development.
- Complete MMW field plate GaN HEMT development.
- Initiate mixed-signal GaN Monolithic Microwave Integrated Circuit (MMIC) technology development.
- Initiate sub MMW GaN Amplifier development.

	FY 2007	FY 2008	FY 2009
RF VACUUM ELECTRONICS POWER AMPLIFIERS	3,419	3,147	2,908

This activity provides for the development of MW, MMW, sub-millimeter 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 2007 Accomplishments:

- Continued research on 3D modeling of beam transport with quadrapole magnetic focusing for high power Ka band Traveling Wave Tube (TWT). (NRL)
- Continued research effort on generation and transport of sheet beam with 5:1 aspect ratio. (NRL)
- Continued effort on the gun/collector code MICHELLE with improved interface with the large signal codes CHRISTINE and Telegrapher's Equation Solution for Linear Amplifiers (TESLA).

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- Completed the effort to identify and test algorithms to implement in the TESLA design code for broadband single-beam klystron development.
- Completed the effort on the broadband (~ 6%) S-band Multiple Beam Klystron (MBK) performance. (NRL)
- Completed the effort on the release of the gun/collector code MICHELLE v4.0 with improved Graphical User Interface (GUI) and postprocessor.
- Initiated the effort on developing algorithms and models in large signal code TESLA for multiple beam klystrons.
- Initiated the effort on developing algorithms and models in 1D Christine_CC for coupled cavity TWT application to the high power, MMW regime.
- Initiated the effort on the development and implementation of models and algorithms for electron emission physics in gun/collector code MICHELLE.
- Initiated the effort on developing and implementing models for multi-gap cavity coupling in TESLA for klystron.

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.
- Complete effort on experimental demonstration of beam propagation with quadrapole magnetic focusing that will result in a factor of 3 reduction in magnet volume and weight compared to Permanent Periodic Magnet (PPM) focusing system. (NRL)
- Complete the effort on the development and implementation of models and algorithms for electron emission physics in gun/collector code MICHELLE.
- Complete the effort on developing algorithms and models in 1D CHRISTINE_CC for coupled cavity TWT's.
- Initiate the effort on the development and implementation of models and algorithms in the large signal CHRISTINE 3D code to create capabilities for an end-to-end analysis of a Helix TWT.
- Initiate the effort on the development and implementation of models and algorithms in a large signal klystron code to model sheet electron beam - wave interaction.
- Initiate the effort on developing models and algorithms based on generalized model expansion (GENOME) techniques for large signal modeling of extended interaction klystrons (EIK).

FY 2009 Plans:

- Continue all efforts of FY 2008 less those noted as completed above.
- Complete the effort on developing and implementing models for multi-gap cavity coupling in TESLA for

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Exhibit R-2a

DATE: February 2008

BUDGET ACTIVITY: 02

PROGRAM ELEMENT: 0602271N

PROGRAM ELEMENT TITLE: RF SYSTEMS APPLIED RESEARCH

PROJECT TITLE: RF SYSTEMS APPLIED RESEARCH

klystron.

- Complete research effort on generation and transport of sheet beam with 5:1 aspect ratio. (NRL)
- Initiate the effort on the development and implementation of models and algorithms in a large signal TWT code to model sheet electron beam - wave interaction.
- Initiate the effort on the development of nonlinear stability analysis for broadband CC-TWT.

	FY 2007	FY 2008	FY 2009
RF NAVIGATION TECHNOLOGY	1,496	2,885	2,954

This activity 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.

Funding increases from FY 2007 to FY 2008 are due to initiation of multiple navigation research efforts in FY 2008 while continuing all prior year initiatives based on overall increased emphasis and level of investment in RF Navigation Technology research.

FY 2007 Accomplishments:

- Continued the development of GPS Anti-Jam (AJ) Antenna Electronics (AE) with low-cost analog processor technique for Direction of Arrival (DOA) estimation and nulling (up to 60dB nulling capability).
- Completed the design and development of a Space-Frequency Adaptive Processing (SFAP) processor for GPS AJ antenna to improve receiver AJ performance by adding channelization to the existing Code Gated Maximum Likelihood (CGML) receiver.
- Completed the evaluation of the effectiveness of the Poly-Channelized CGML technique by simulation and build it in software radios (up to 8 jammers with 4 array elements).
- Initiated the development of SFAP for GPS Anti-Spoofing using the existing CGML receiver.
- Initiated the Deeply Integrated Navigation Grade GPS Inertial System project.
- Initiated the Improved GPS/Inertial Navigation System (INS) Integration using Particle Filter Accelerometer project.
- Initiated the Advanced Spoofing Mitigation and Geolocation through Spoofing Tracking project.
- Initiated the development of GPS Anti-Spoofing Test Facility at NRL.

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- Initiated the installation of GPS simulator at NRL with GAS-1 and other antennas in an anechoic chamber and conduct tests for four GPS AJ systems.

FY 2008 Plans:

- Continue all efforts of FY 2007 less those noted as completed above.
- Initiate the Self-Locked Intra-Cavity Alkali Vapor Laser (ICAL) Opto-Atomic Clock project.
- Initiate the Precise and Accurate Stamping for Time Transfer Applications (PASTTA) project.
- Initiate the GPS Anti-spoofing mitigation by Direction of Arrival (DOA) project.
- Initiate the Micro Fiber Optical Gyro (MFOG) project.
- Initiate the Acquisition Problem in Deeply Integrated GPS Systems project.
- Initiate the Ship's Passive Inertial Navigation System (SPINS) project.

FY 2009 Plans:

- Continue all efforts of FY 2008.
- Complete the Improved GPS/INS Integration using a Particle Filter Accelerator project.
- Complete the Advanced Spoofing Mitigation and Geolocation through Spoofing Tracking project.
- Complete the development of GPS Anti-Spoofing Test Facility at NRL.
- Complete the installation of GPS simulator at NRL with GAS-1 and other antennas in an anechoic chamber and conduct tests for four GPS AJ systems.
- Complete the Precise and Accurate Stamping for Time Transfer Applications (PASTTA) project.
- Complete the GPS Anti-spoofing mitigation by Direction of Arrival (DOA) project.
- Complete the Acquisition Problem in Deeply Integrated GPS Systems project.
- Initiate the GPS Dual Receiver Hot Start Acquisition (DRHSA) project.
- Initiate the GPS Threat Assessment project at NRL.
- Initiate the Sonar Aided Inertial Navigation Technology (SAINT) project.
- Initiate the Multi-Frequency Continuously Operating GPS Anomalous Event Monitor (GAEM) project.
- Initiate the Evolved Global Navigation Satellite System (GNSS) Signal Monitoring Receiver Element project.

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CONGRESSIONAL PLUS-UPS:

	FY 2007	FY 2008
ADVANCED MICROWAVE FERRITE RESEARCH PHASE IV	996	0

Development of hexagonal ferrite films has concluded with significantly decreased losses and higher magnetic coercivity for RF device applications and performance. Microwave loss and insertion characterization has also ended with significant materials improvements. Microwave radar circuit tuning has completed, and planar MMW antenna compatible with RF system receivers is being transitioned to defense contractors.

	FY 2007	FY 2008
DOD REPARATIVE MEDICINE INITIATIVE	994	0

This effort supported the DoD Reporative Medicine Initiative.

	FY 2007	FY 2008
GALLIUM NITRIDE RF POWER TECHNOLOGY	995	1,986

FY 2007 - A comprehensive statistical analysis of fabrication process parameters and device test parameters was undertaken to advance the device reliability in discrete GaN HEMT transistor devices applicable to military communication systems such as the Joint Tactical Radio System (JTRS) and S-band RF systems. Test devices for evaluation were delivered to NRL.

FY 2008 - The activities related to the improvement in device reliability will continue, and the incorporation of Gallium Nitride discrete devices into high reliability (Hi-Rel) packaging process will be started. High reliability packaged parts will be provided to NRL for testing and evaluation.

	FY 2007	FY 2008
MICROWAVE FERRITES AND MULTIFUNCTIONAL INTEGRATED CIRCUITS	0	795

Thin film epitaxial growth of complex oxide structures involving magnetic ions will be initiated. Magnetic properties of resulting ferrites will be assessed for microwave passive element compatibility.

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	FY 2007	FY 2008
NATIONAL INITIATIVES FOR APPLICATIONS OF MULTIFUNCTIONAL MATERIALS	0	1,591

A crystal growth facility will be established at the University of Texas with the capability of growing thin oxide films with in-situ real-time surface characterization. A process for growing SrTiO₃ on Si as a virtual substrate for growth of functional oxides will then be developed. Figures of performance merit of these artificial structures, of interest for Navy's next generation sensors and RF applications, will be assessed.

	FY 2007	FY 2008
NOTRE DAME CENTER FOR THE ENGINEERING OF OXIDE NITRIDE STRUCTURES (CEONS)	1,297	1,591

FY 2007 - Procured equipment and materials and prepared facility for the preparation, characterization and application of monolithically integrated passive device elements in Gallium Nitride (GaN) RF circuits. Initial GaN RF experiments were performed.

FY 2008 - The prototype test deposition system will be delivered, installed and calibrated. Initial growths of Oxide thin films from metal organic sources will be initiated. A full scale molecular beam epitaxy (MBE) system for oxide hetero-junctions formation and investigation will be designed and acquired.

	FY 2007	FY 2008
PACIFIC THEATER DATA FUSION TESTBED	1,596	0

The deliverables included a demonstration and final report of an AEGIS radar electro-optic real-time fusion algorithm.

	FY 2007	FY 2008
REPARATIVE CORE MEDICINE	996	993

FY 2007 - This effort supported research that helped develop a methodology for the production of blood platelets from stem cells. The use of stem cells will provide a defined, pathogen-free, source of platelets

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for use in controlling hemorrhage in combat casualties.

FY 2008 - This effort is to develop the methods to permit the production of safe functioning blood cells for transfusion, eliminating the need for human donors of blood.

	FY 2007	FY 2008
SILICON CARBIDE MOSFETS FOR ELECTRIC POWER SYSTEMS	996	0

Specified and developed Silicon Carbide MOSFET devices and circuits to enable on board power conversion (for platforms such as towed decoys) that can utilize 600-1000V power feeds for 24-48 volt applications. Devices for testing and development of prototype power converters were delivered to NRL.

	FY 2007	FY 2008
ULTRA STABLE COHERENT LASER	0	795

This effort supports Ultra Stable Coherent Laser research.

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 0603114N Power Projection Advanced Technology
PE 0603123N Force Protection Advanced Technology
PE 0603271N RF Systems Advanced Technology

OTHER PROGRAM FUNDING SUMMARY - NON-NAVY RELATED RDT&E:

PE 0601102A Defense Research Sciences
PE 0602716E Electronics Technology
PE 0601102F Defense Research Sciences
PE 0602204F Aerospace Sensors
PE 0602702F Command Control and Communications

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D. ACQUISITION STRATEGY:

Not applicable.

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