FY 2004/2005 RDT&E,N BUDGET ITEM JUSTIFICATION SHEET DATE: February 2003
Exhibit R-2

BUDGET ACTIVITY: 2 PROGRAM ELEMENT: 0602271N
PROGRAM ELEMENT TITLE: RF Systems Applied Research

COST: (Dollars in Thousands)

PROJECT NUMBER & TITLE	FY 2002 ACTUAL	FY 2003 ESTIMATE	FY 2004 ESTIMATE	FY 2005 ESTIMATE	FY 2006 ESTIMATE	FY 2007 ESTIMATE	FY 2008 ESTIMATE	FY 2009 ESTIMATE
RF Systems Applied Research	58,922	74,208	44,019	51,415	54,418	54,265	55,245	56,255

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.

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

B. PROGRAM CHANGE SUMMARY:

	FY 2002	FY 2003	FY 2004	FY 2005
FY 2003 President's Budget Submission	68,300	56,263	57,974	57,702
Adjustments from FY 2003 President's Budget:				
Congressional Plus-Ups		19,700		
SBIR Reduction	-1,276			
Execution Adjustments	-7,771			
Congressional Rescissions/Adjustments/Undistributed Reductions	-331	-950		
S&T Program Adjustments			-12,412	-4,950
NWCF Rate Adjustments			-362	-42
Efficiencies at NWCF Activities			-166	-186
Pay Raise/Inflation Adjustments		-805	-1,015	-1,109
FY 2004/2005 President's Budget Submission	58,922	74,208	44,019	51,415

FY 2004/2005 RDT&E,N BUDGET ITEM JUSTIFICATION SHEET DATE: February 2003
Exhibit R-2

BUDGET ACTIVITY: 2 PROGRAM ELEMENT: 0602271N
PROGRAM ELEMENT TITLE: RF Systems Applied Research

PROGRAM CHANGE SUMMARY EXPLANATION:

Schedule: Not Applicable.
Technical: Not Applicable

FY 2004/2005 RDT&E,N BUDGET ITEM JUSTIFICATION SHEET DATE: February 2003
Exhibit R-2a

BUDGET ACTIVITY: 2 PROGRAM ELEMENT: 0602271N Project Title: RF Systems Applied Research
PROGRAM ELEMENT TITLE: RF Systems Applied Research

COST: (Dollars in Thousands)

PROJECT NUMBER & TITLE	FY 2002 ACTUAL	FY 2003 ESTIMATE	FY 2004 ESTIMATE	FY 2005 ESTIMATE	FY 2006 ESTIMATE	FY 2007 ESTIMATE	FY 2008 ESTIMATE	FY 2009 ESTIMATE
RF Systems Applied Research	58,922	74,208	44,019	51,415	54,418	54,265	55,245	56,255

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 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 02	FY 03	FY 04	FY 05
Surveillance Technology	11,144	7,723	5,689	6,447

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.

FY 2002 Accomplishments:
Developed design and system concepts for an Ultra High Frequency (UHF) Electronically Steered Array antenna applicable to the E-2C airborne early warning aircraft. Developed design and system concepts to guide development of a Data Distribution Module (DDM) based on commercial off the shelf (COTS) technology for the Common Affordable Radar Processor (CARP). The DDM will enable Naval radar system processors to be designed for COTS utilization and to be affordably up-graded by insertion of commercial processors, Information Protocols, and standards as the technology advances. Conducted a technology assessment and a study to determine availability and utility of Non-Cooperative Target Recognition (NCTR) techniques for long range all weather target identification. High-confidence, long range, all aspect, NCTR capability is an identified enabling capability for Missile Defense, Fleet Force Protection, and Time Critical Strike Future Naval Capability (FNC) programs. Support for the AN/APY-6 project continued with development of advanced modes and signal processing techniques for maritime situational awareness.

The effort also continued with high performance radar detection, discrimination and identification of stationary and moving surface sea and land targets. Continued development of the Horizon Extension Sensor System (HESS) with emphasis on technologies including high power, wide band, efficient amplifiers, advanced cooling and digital beam forming for electronically steered, light weight, radar arrays to enable beyond-the-horizon surveillance of low flying targets from surface combatants. It is expected that detection range increases of 3X/4X with corresponding increases in reaction time may be achievable. Studied Digital Array Radar (DAR) architectures including wideband digital beam-forming techniques, which enabled rapid steering and precision control of multiple radar beams. DAR technologies are identified in the Surface Navy Radar Roadmap as critical system enablers for planned Theater Air and Missile Defense radar developments. DAR is also identified as critical elements in Program Executive Office - Theater Surface Combatant (PEO-TSC), Naval Sea Systems Command high power S-band radar system development for application to future surface combatant platforms.

FY 2003 Plans:
Continue development of DAR technology with emphasis placed on element level and sub-array wideband digital beam-forming techniques to enable rapid steering and precision control of multiple beams. Continue development of advanced modes and signal processing for maritime situational awareness. Expand the study of NCTR technology to encompass harbor (short range) as well as long range all weather target identification. Continue the development of component prototyping relative to the Horizon Extension Sensor System (HESS) with emphasis on technologies for light weight arrays and high power Radio Frequency (RF) transmit/receive front-ends that can be made integral to multi-element electronically steered arrays for deployment from surface combatants. Continue integration of the Data Distribution Module (DDM) and CARP by incorporating and evaluating the performance of multiple parallel DDMs integrated into a simulated multi-channel radar front end. Perform evaluation of the entire processing chain from the Analog to Digital converter through the distribution of commercial Internet Protocol (IP) format data into the common affordable radar processor architecture. Conduct demonstrations within the AN/APY-6 project, in conjunction with NAVAIR’s Hairy Buffalo test-bed aircraft, to enable performance assessment of the Inverse Synthetic Aperture Radar (ISAR) and micro-doppler modes against small ship targets in harbor areas and against slow moving and idling ground targets such as trucks, tanks and armored vehicles.

FY 2004 Plans:
Develop hardware to demonstrate advanced modes and signal processing for harbor situational awareness. Continue the development of DAR technology with hardware demonstrations at the element and sub-array levels. Demonstrate critical enabling high power amplifier technology capable of supporting the Horizon Extension Sensor System (HESS) prior to prototype development. Demonstrate synchronization of multiple DDMs with asynchronous network topologies to enable the CARP.

FY 2005 Plans:
Continue development of system level hardware for DAR and characterize its performance at the element, sub-array and system levels. Continue demonstrations of advanced NCTR algorithms in a representative harbor surveillance demonstration. Continue the HESS project integration of High Power Amplifier (HPA) and digital beamforming X-band sub-arrays.

	FY 02	FY 03	FY 04	FY 05
RF Electronic Warfare Technology	9,975	13,573	12,579	16,341

Supports the Fleet Force Protection (FFP) Future Naval Capability (FNC) and those 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; and precision identification and location of threat emitters.

FY 2002 Accomplishments:
Identified candidate grid countermeasure devices and station keeping platforms and outlined candidate tactical scenarios under the Expeditionary EW Grid for Surface Unit Defense effort. Effort enabled offboard devices to be coupled with existing Electronic Attack (EA) systems to deny surveillance, targeting and missile seeker radars the capability to acquire and track surface platforms. Designed and fabricated the 8-channel Application Specific Integrated Circuit (ASIC) for the Wideband EW Channelizer effort. Effort enabled the development of low cost, small size and low power channelizers for use in tactical applications such as unmanned aerial vehicles. Reviewed past EA effectiveness efforts in order to pick the best methodology for designing, building and testing the effects monitor under the Hard Kill (HK)/EW Techniques Development effort. Work completed under this effort ultimately increased survivability of U.S. Naval units. Completed lab demonstration of the near real-time signal processing frequency modulation continuous wave (FMCW) subsystem for the Electronic Support (ES) detection of Low Probability of Intercept (LPI) Periscope Detection Radar effort. Effort enabled U.S. Naval units to approach, enter and operate in denied areas by detecting the presence of LPI threat systems. Conducted hardware-in-the-loop (HIL) anechoic chamber experiments using Foreign Military Exploitation (FME) seekers to evaluate off-board countermeasures (OCM) device field tactics in the Network Centric Battleforce EW effort. Results of this work assisted tactical commanders in the formulation of coordinated EA defense strategies. Completed integration of amplitude-to-phase conversion layout with the developed ASIC chip for the Digital Imaging Architecture for Multiple Large Target Generation effort that can increase platform survivability in the presence of advanced surveillance systems. Completed successful flight testing of the Anguila precision location system that can greatly increase the overall situation awareness of both tactical and strategic planners while having no affect on tactical aircrew workload. Completed final testing of signal processing algorithms against Binary Phase Shift Keying (BPSK) and Linear Frequency Modulation (LFM) signals for the Next Generation Specific Emitter Identification (SEI) effort that

aids in platform discrimination and identification. Conducted synthetic sea clutter generic waveform chamber tests in the EA Techniques to Counter Advanced Threats effort. Developed and demonstrated advanced EA techniques to counter advanced radio frequency guided missiles that can significantly increase platform survivability.

FY 2003 Plans:
Continue determination of EA obscuration technique gain via HIL and simulation experiments in the Expeditionary EW Grid for Surface Unit Defense effort. Fabricate and test sub-channelizer and full channelizer ASIC's for the Wideband EW Channelizer effort. Simulate effectiveness predictions of various EA techniques against the Scout radar under the hardkill/electronic warfare (HK/EW) Techniques Development effort. Conduct field testing/demonstration of the near real-time signal processing FMCW subsystem for the ES detection of LPI Periscope Detection Radar effort. Perform field demonstrations of OCM device field tactics against FME seekers as part of the Network Centric Battleforce EW effort. Integrate the ASIC chip with the Advanced Multifunction Radio Frequency-Concept (AMRF-C) Digital Radio Frequency Memory (DRFM) sub-system for the Digital Imaging Architecture for Multiple Large Target Generation effort. Perform testing of coordinated coherent/non-coherent techniques under the EA Techniques to Counter Advanced Threats effort. The Advanced EA Waveforms effort will further test and evaluate advanced multi-level pseudo-random EA waveforms and develop and design other new concept EA waveforms. Conduct analysis of short-term stability of Inertial Navigation System (INS)/Global Positioning System (GPS) for doppler recovery, and perform data analysis for modeling clutter returns from a coherent source under the countermeasure for Wideband Antiship Threats effort. Conduct analysis and model development to verify the theoretical concept of a compact combined azimuth and elevation direction finding (DF) antenna under the Hybrid Interferometer Technology Development effort.

FY 2004 Plans:
Identify effective offboard grid configurations and associated network requirements under the Expeditionary EW Grid for Surface Unit Defense effort. Demonstrate full radio frequency-to-pulse descriptor word system functionality under the Wideband EW Channelizer effort. Perform study and lab testing that investigates the utility of coordinated NULKA/EA responses under the HK/EW Techniques Development effort. Conduct lab testing of the near real-time processing of the ultra-wideband chirp subsystem under the ES detection of LPI Periscope Detection Radar effort. Develop and test the frequency agile prediction algorithm for advanced seekers under the EA Techniques to Counter Advanced Threats effort. The Advanced EA Waveforms effort will test and evaluate new EA waveforms and perform analysis of implementation requirements. Perform Electronic Countermeasure (ECM) systems analysis and modeling for both onboard and offboard systems under the countermeasures (CM) for Wideband Antiship Threats effort. Conduct analysis and modeling to develop and refine the detailed DF antenna design for the Hybrid Interferometer Technology Development effort.

FY 2005 Plans:
Perform field testing that investigates the utility of coordinated NULKA/EA responses under the HK/EW Techniques Development effort. 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. Conduct hardware and software implementation for fleet testing under the Advanced EA Waveforms effort. Conduct 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. Fabricate and perform lab demonstration of the DF antenna for the Hybrid Interferometer Technology Development effort.

	FY 02	FY 03	FY 04	FY 05
RF Communications Technology	8,096	8,319	4,236	5,269

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 2002 Accomplishments:
Developed system designs and concepts for an X/Ku band phased array antenna to provide surface combatants with improved Intelligence, Surveillance, and Reconnaissance (ISR) connectivity through the use of transmitting and receiving phased array antennas compatible with the shipboard environment. The X/Ku band antenna design facilitated wideband beyond line-of-sight connectivity to airborne relay assets via the Tactical Common Data Link (TCDL) in support of network centric warfare operations. Conducted investigations into K/Ka band phased array technologies, designs and concepts with emphasis on scalability of the array concepts and design to K/Ka/Q Band operations. Finalized initial design efforts for a Next Generation Buoyant Cable Antenna (NGBCA) which will specifically address Navy needs to provide submarines a multi-band buoyant cable antenna system capable of supporting network centric operations while operating at tactical depths and speed. The technology findings from this effort became the basis for development of an advanced technology demonstration antenna which supported the Knowledge Superiority and Assurance (KSA) Future Naval Capabilities (FNC) program. Conducted technology investigations to define a Naval Battle-force Network (NBN) architecture and system concept and to assess its technological feasibility. The designs included networking architectures that provided for integration of line-of-sight (LOS) wireless networks into the existing over-the-horizon (satellite-based) network and provided guidelines for development of a communications payload for Vertical Take-off Unmanned Air Vehicles (VTUAVs). The activity continued development of technologies that were previously (FY 2001 and prior) pursued within PE 0602232N. Specifically, efforts included the fabrication of demonstration hardware for an Ultra Small Aperture Terminal (USAT) K/Ka Band Phased Array that will provide a limited satellite communications capability for surface ships and moving ground vehicles. Multi-function communications apertures and architecture concepts were investigated and assessments of operational utility and benefit conducted. These technologies are planned for incorporation in designs of new communications systems and network architectures being developed within the Knowledge Superiority and Assurance Future Naval Capability program. Finalized system designs for a ship-based integrated very high frequency (VHF)/ultra high frequency (UHF)/L-Band (IVUL) antenna system that will consolidate antennas from those frequency bands into a single

configuration, thereby reducing topside space requirements while maintaining electromagnetic compatibility for legacy and future communications equipment. The co-site interference mitigation technology will permit multiple UHF systems to efficiently operate and co-exist on board the same surface platform. This effort successfully developed and demonstrated co-site interference mitigation technology that provides for dynamic range extension of receiving systems operating aboard ship. The Extremely Low Frequency (ELF) on-hull antenna technology successfully demonstrated that major acoustic noise sources that severely degrade ELF receiver performance can be eliminated. This technology is now available for insertion into ELF communications system product improvement programs and for insertion into programs pursuing development and acquisition of future ELF communications systems.

FY 2003 Plans:
Continue the X/Ku band phased array system design optimization and prepare a transition plan for development of an advanced technology demonstration unit under the KSA FNC in PE 0603271N. Continue development and characterization of a prototype K/Ka/Q band phased array with emphasis on simultaneous multi-beam operation across both frequency bands. This effort will be continued in FY 2004 and beyond in PE 0603271N. Demonstrations of the jointly (DARPA/ONR) developed Ultra Small Aperture Terminal (USAT) K/Ka Band Phased Array will be conducted aboard surface ships and moving ground vehicles. Perform final design for Next Generation Buoyant Cable Antenna and provide to the KSA FNC apertures program for advanced technology development within PE603271N. Continue development of the NBN architecture and technologies. The NBN development will incorporate the tactical communications payload for Vertical Take-Off Unmanned Air Vehicles (VTUAV) into the NBN architecture and will implement queuing management technology in Navy LOS networking radios. The queing management technology is expected to optimize end-to-end performance of mobile ad hoc wireless networks, augment the Quality of Service (QoS) strategy for the Automated Digital Network System (ADNS) and provide for protocol independent multicast routing over LOS networking radios. The NBN effort will also develop and publish a design document to guide development and testing of prototype networks prior to their integration in the Multi-Tactical Digital Information Link (TADIL) Processor. The design guide will also provide guidelines for selection of alternative protocols for ad hoc mobile wireless networking and for investigations into use of Internet Protocol QoS technology,and advanced routing and load distribution techniques to permit prioritization of mission critical information flows over congested Navy satellite links. Investigate
multi-function systems architectures and development of implementation techniques for incorporating high performance time critical communications functions such as Common Data Link (CDL), Tactical Common Data Link, and Defense Satellite Communication System (DSCS) capabilities into the Navy’s Advanced Multi-Function Radio Frequency Concept (AMRF-C) technology test bed.

FY 2004 Plans:
Development of the NBN technologies will continue with emphasis on system level integration and network demonstrations. The NBN efforts under this PE will transition to acquisition programs at Space and Naval Warfare Systems Command (SPAWAR) in this year. Continue development of methods and processes including standardized interfaces and Information Protocol (IP) standards to facilitate integration and efficient management and control of multiple data link and satellite communications functions into the Navy’s AMRF-C technology test bed.

FY 2005 Plans:
Integrate Common Data Link, Tactical Common Data Link and Defense Satellite Communication System functions into the Navy's AMRF-C technology test bed and develop resource management and control processes to maximize communication function performance while minimizing electromagnetic compatibility and interference issues with other functions such as Electronic Support (ES) and Electronic Attack (EA).

	FY 02	FY 03	FY 04	FY 05
RF Navigation Technology	1,928	2,054	2,285	2,648

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.

FY 2002 Accomplishments:
The High Dielectric Mini-Array Antenna effort completed extensive testing of an antenna that adaptively suppresses jammers by a null-steering approach. The antenna is being considered as a candidate for the next generation GPS Joint Program Office (JPO) Anti-jam (AJ) Antenna. The Miniature Controlled-Radiation-Pattern-Antenna (M-CRPA) effort used measured sensitivity patterns to confirm that the present configuration will allow not only earth-bound jamming signals to be suppressed but also clustered jammers to be suppressed. This performance will allow Navy aircraft to travel from carriers towards shore-based jammers and not be markedly affected. Determined that the Non-linear Array Antenna appears to be particularly effective if a jamming-field approach was employed by enemy forces. Algorithm development resulted in addressing initial implementation. The Digital Signal Processing (DSP) techniques under the Space Time Adaptive Processing (STAP) effort were determined to be implementable in an all-digital processing stage immediately following the receiver antenna array. Determined the techniques can be integrated into existing systems with minor impact on overall system architecture.

FY 2003 Plans:
Within the M-CRPA antenna effort, demonstrate an antenna, feed network and nulling electronics all integrated into a compact prototype unit. Within the Non-linear Array Antenna effort, develop a compact prototype antenna with adaptive, compact array elements, coupled-oscillators, and phase-locked-loop system (to null multiple jammers simultaneously) and demonstrate aspects of its expected unique performance. The Non-linear Array Antenna effort plans to demonstrate an array antenna with 20 to 35 elements in a 6-inch diameter that derives performance benefit from the significant mutual coupling of array elements that are inherent in close-spaced designs. Develop the Submarine Mast-Mounted Controlled Reception Pattern Antenna (CRPA) for the GPS that will fit into the 4.75" diameter area of the OE-538 Submarine Mast Identification Friend or Foe (IFF)/GPS Radome/ Antenna Subsystem. This effort will include computer modeling, brassboarding, and fabrication of the elements, the array, and the matching network to prove the concept. Digital Signal Processing techniques using Space Time Adaptive Processing (STAP) will

pursue a multistage architecture using nonlinear filtering methods for jammer-resistant code tracking. In addition, STAP and code tracking will be merged for improved timing acquisition in the presence of wideband jamming.

FY 2004 Plans:
STAP for GPS Antenna effort will continue with development of two of the best ranked techniques of those initially investigated. Implementation issues will continue to address concerns for computational speed and performance reliability. The Submarine Mast-mounted Controlled Reception Pattern Antenna (CRPA) for the Global Positioning System will undergo laboratory testing to determine the effectiveness of its nulling functions.

FY 2005 Plans:
STAP for GPS Antennas will be applied to one of the receiver-antenna systems developed in this program or to a system recommended by the GPS-Joint Program Office (GPS-JPO). Specific jammer types will be also addressed in this effort. The Submarine Mast-mounted Controlled Radiation Pattern Antenna will undergo field testing to determine if the laboratory performance can be achieved in a more realistic environment.

	FY 02	FY 03	FY 04	FY 05
RF Solid State Power Amplifiers	3,500	3,500	3,500	3,500

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.

FY 2002 Accomplishments:
The development of silicon carbide (SiC) bipolar junction transistors (BJTs), suitable for high radio frequency (RF) pulsed power generation at UHF-L band frequencies for application to naval airborne surveillance sytems, resulted in the first demonstration of a microwave SiC silicon carbide bipolar transistor and operated at 425 MHz with an output power of 50 watts per cell. Aluminum Gallium Nitride/Gallium Nitride (AlGaN/GaN) wide bandgap high electron mobility transistor (HEMT) technology for naval electronic warfare and surveillance system applications will provide the basis for demonstration of a 10 W amplifier with 45% power added efficiency at 35 GHz. Demonstrated AlGaN HEMTs operating at 28 Gigahertz (GHz) with a power density of > 5 watts per millimeter (W/mm) The design of ultra broadband, multi-octave, power amplifiers continued to be optimized for efficiency and packaged parts were tested for future application to highly versatile, multifunction systems with multiple simultaneous RF beams. Demonstrated record output power for the broadband operation achieved.

FY 2003 Plans:
Continue development of SiC bipolar transistors and extend their frequency of operation to L-band. Continue the development of MMW AlGaN/GaN wide bandgap HEMT technology with an emphasis on output signal quality and linearity.

Continue the development of multi-octave wide bandgap power amplifiers with broadband EW applications addressed as demonstration vehicles for the current technology with emphasis placed on the 4-18 GHz band. Continue development of the AlGaN HEMT broadband amplifiers for electronic warfare decoy applications.

FY 2004 Plans:
Continue development of SiC bipolar transistors and demonstrate 300 W of output power at L-band. Continue development of MMW AlGaN/GaN wide bandgap HEMTs with an emphasis on output signal quality and linearity. Develop advanced transistor materials and structures to enhance amplifier efficiency. Emphasis will include development of complete monolithic integrated circuits. Continue 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 with an emphasis on output signal quality and linearity. Develop advanced transistor materials and structures to enhance amplifier efficiency and linearity. AlGaN HEMT broadband amplifiers will demonstrate over 20W output with flat output over the full band for electronic warfare decoys.

	FY 02	FY 03	FY 04	FY 05
RF Vacuum Electronics Power Amplifiers	6,500	4,500	4,500	4,500

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 multiple-beam amplifiers, notably the multi-beam klystron (MBK), modeling and simulation, and field emitter arrays.

FY 2002 Accomplishments:
Designed experimental high dynamic range vacuum power booster using current analog standards of linearity and fabricated for use as a test vehicle to validate physics-based time-dependent codes and simplified communication-link models. This design effort addressed the need for improved amplifier models and vacuum power booster (VPB) designs that support increased dynamic range, phase linearity, and bandwidth requirements associated with multi-level, broadband digital signals needed by systems such as the Wideband Gapfiller System and the improved AN/WSC-6 shipboard terminal. Developed a basic time-dependent block model for modeling digital signals in helix Traveling Wave Tubes (TWTs). Ongoing efforts in industry to develop K_a-band Coupled Cavity Traveling Wave Tubes (CC-TWTs) for radar Patriot Advanced Capability (PAC-3) and communications applications are adversely affected by limitations in available circuit design capabilities. In response, the extension of GATOR, a multi-dimensional, large-signal code for coupled-cavity circuits, continued with the insertion of an improved alternating current (AC) space charge model. For computational simplicity, all current nonlinear circuit design codes operate in the frequency domain. Proper understanding of device physics relevant to amplification of the complex digital waveforms to be used in high data rate (HDR) communications will require the availability of codes operating in the time domain.

CHRISTINE1D, the 1-dimensional (1D) large signal circuit design code, was used interactively with HDR vacuum power booster (VPB) experiments to guide the development and validate the code. CHRISTINE1D v1.43 AND CHRISTINE3D v1.4 were released to industry for testing and validation. Tested telegrapher's equation solution for linear amplifiers (TESLA), the 2D klystron design code for single-beam configurations. The W-band gyro-klystron technology was integrated into the Naval Research Laboratory (NRL) Wideband Advanced Radar for Low Observable Control (WARLOC) radar, which has application to space object identification, and demonstrated 70 kW peak power output. The prototype K_a-band gyro-TWT, developed using a ceramic loaded circuit to obtain a 3% bandwidth, demonstrated a peak power performance of 137 kW, 47-dB gain, with a 1.1 GHz bandwidth. The 94-GHz gyro-twystron demonstration achieved peak power of 59 kW at a bandwidth of 1.5 GHz in low-duty testing. **Reliable (> 10^5 hrs), high current density (>10 A/cm^2) cathodes will be required for the development of the multiple beam klystrons needed for reduced noise improvement of shipboard radars.** Based on the success of the rhenium coating studies, the scandate emitter effort was extended to investigate the use of pulsed laser deposition (PLD) to tailor the emitting surface for uniformity, stability, and high current density.

FY 2003 Plans:
Continue high dynamic range VPB experiments to improve digital signal error performance with a goal of yielding a two-fold increase in power margin and data rates in excess of 1 Gbps by incorporating memory effects into the time-dependent block model for helix TWTs. With a focus on multi-beam amplifiers, investigate the "cold" bandwidth capabilities of a multi-gap klystron with eight electron beams and design broadband input and output waveguides for such cavities. Two-dimensional/three dimensional (2D/3D) CC-TWT design code development continues with the addition of a model to handle reflections at internal matching elements. 3D models for alternating current (AC) space charge for both helix and coupled-cavity TWTs will be developed, as will a hybrid mesh capability (hexahedra and tetrahedra) for MICHELLE. A 3D stability analysis for helix TWT design codes will be developed. Continuing the investigation of high-brightness scandate cathodes using PLD techniques, the optimum chemical composition required for high-current-density scandate emission will be investigated.

FY 2004 Plans:
Continue the development of physics-based models and demonstration of low-distortion TWTs, using C-band as a demonstration communication band. Validate the time-dependent block models for digital signal amplification in helix TWTs and release to the domestic vacuum electronics industry. Using TESLA, perform an RF optimization for multi-beam klystrons. Release to the U.S. vacuum electronics industry the large-signal time-dependent code GATOR incorporating the reflection models developed earlier for beta testing. Extend CHRISTINE3D development to incorporate a self-consistent model for background ion effects in the helix and subsequently release to the domestic vacuum electronics industry. Introduce automatic mesh refinement algorithms into the 3D Gun/Collector code MICHELLE. Release MICHELLE v3.0 and TESLA v2.0 to the domestic vacuum electronics industry for beta testing. Investigate mechanisms to replenish scandium to the surface of the electron emitter to support cathode longevity.

FY 2005 Plans:

Use two-and three-cavity narrow-band S-band multi-beam klystron experiments to validate the multi-beam design tools developed earlier. In order to reduce computational cycle times and improve predictive accuracy of the physics-based codes, develop algorithms suitable for parallelization in MICHELLE, the 3D Gun/Collector code. Develop similar parallelization techniques for TESLA as it is tailored for multiple-beam klystron development; both improved codes will be released to the domestic vacuum electronics industry. Demonstrate a high-data-rate (> 1 Gbps) TWT using 16 bit quadrature amplitude modulation (QAM). Transfer the technology for scandate cathode fabrication to the domestic vacuum electronics and cathode industries.

	FY 02	FY 03	FY 04	FY 05
Supporting Technologies	9,361	10,425	11,230	12,710

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.

FY 2002 Accomplishments:
Performed architectures studies to provide the basis for the design of octave bandwidth linearizers needed for use in high power microwave amplifier circuits to enable Navy systems to simultaneously operate over greater bandwidths, higher power and improved sensitivity. The materials and processing issues that contribute to the instability failure mechanisms of wide bandgap devices (SiC and GaN) at microwave frequencies were initially determined. Results of this work accelerated the insertion of wide bandgap technologies into DoD systems and have collateral return in the area of power switching for applications such as the all-electric ship. Developed the design of the individual channel filters to be used in high power (20W/channel) channelizers, small enough to be used behind a transmitter array face as power combiners in a multifunction system. The high power channelizer effort is essential to multiple simultaneous signal transmission and is currently unavailable except in units about 4 times the required size. Transitioned the development of a high power, wideband isolator technology needed for Naval surveillance systems from the low frequency range (1-4 GHz) to the high frequency range (4-20 GHz) by redesigning the edge mode isolator device. An alternative approach to achieve wide bandwidth using a circulator device was evaluated. Continued development of a direct digital synthesizer (DDS) frequency source to 20 GHz with programmable integral modulation capabilities for application to a new class of multifunction electronically scanned arrays with the demonstration of low phase noise performance. Continued the high performance analog-to-digital converter (ADC) effort with the development of bandpass designs to reduce the complexity, hardware parts count, and cost of receivers used in multifunction system arrays. Continued the development of compact tunable filters by designing a variable bandpass filter that can have the frequency tuned in 100 MHz steps over most of the 6 to 18 GHz band. This design, based on radio frequency (RF) Micro Electromechanical Systems (MEMS) technology, will enable a significant reduction in package size compared to other tunable filter techniques and will enable testbed demonstrations of software-selected digital reception. Continued development of the 100 GHz low noise clock

to enhance the range of frequency tuning with the demonstration of methods to produce 100 nW of output at exactly 100 GHz. Continued development of robust, wide bandgap low noise amplifiers with the integration of AlGaN HEMTs to form high gain, low noise amplifier (LNA) circuits. The use of AlGaN will provide for a more compact LNA by eliminating the need for input protection diodes. Continued development of ultra low-noise, broadband, high linearity receiver amplifiers for multifunction systems applications with the demonstration of 4-20 GHz receiver amplifiers using an optimized Metamorphic HEMT structure with increased linearity and dynamic range to further reduce intermodulation products. Developed large Silicon Carbide (SiC) BJT's with optimized design to realize Ion = 10A and VB=1200 for application to a 16-40 kW motor drive. Development of a MW frequency DDS capable of generating very stable RF/microwave frequency sources for use in wide bandwidth communications, high-resolution radar and electronically scanned arrays operating to 4.5 GHz continued with the efforts to package the DDS with an integral modulator in integrated circuit form. Demonstrated a low phase noise digitally programmable true-time delay (TTD) monolithically integrated circuit which can be used in high performance RF beamsteering. Continued development of silicon-compatible 4 Gb/in^2 giant magneto-resistance (GMR) non-volatile memory technology to implement a hard-drive on a chip by successfully fabricating a 4 Gb/in^2 basic GMR non-volatile memory cell and demonstrating a methodology to address the cell. The fabrication and testing transitioned to government contractors to increase production and testing.

FY 2003 Plans:
Continue the development of octave bandwidth linearizers with emphasis placed on circuit design using the results of the architecture study as a basis. Continue the wide bandgap transistor reliability effort with insertion of the knowledge gained in FY 2002 into the device technology and subsequent testing to document the improvements in the stability and lifetime of next-generation SiC and GaN devices. Continue the effort to develop high power channelizers by demonstrating the feasibility of meeting channelizer size and power requirements in a single filter. Develop a preliminary design for the channelizer. Continue the development of high power, wideband, isolators by applications of improved modeling and control of low frequency losses (<2 dB insertion) to a low power isolator with >15dB of isolation operating over the 4-20 GHz frequency range. Continue development of a DDS frequency source with programmable integral modulation capabilities with the demonstration of submicron scaling of Indium Phosphide (InP) transistors to 0.8 microns needed for complex circuits operating at clock speeds to 20GHz. Demonstrate packaging of microwave frequency DDS with integral modulator in integrated circuit form for use in an electronically scanned array operating to 4.5 GHz. Continue development of a high performance analog-to-digital (ADC) by demonstrating the desired band pass characteristic along with the hardware design, fabrication, and test of critical components. Continue development of compact tunable filters with the fabrication and demonstration of RF MEMS filter elements and modules that will demonstrate size and RF performance requirements in a 5 bit filter assembly. Demonstrate expected ultra-low phase noise performance of free running oscillator over the short time scales, critical for accurately clocking digital circuits, and develop the phase locking circuit to provide, over long time scales, the same noise performance required to accurately beam steer a 10 m^2 phased array. Develop monolithic wide bandgap low noise receiver amplifiers with increased survivability under RF drive, enhanced linearity, and high temperature operation. Within the SiC power converter effort, develop and demonstrate BJT's and PiN diodes with Ion=25A and Vb=1200 for application to a 40-100 kW motor drive.

FY 2004 Plans:
Continue the development of octave bandwidth linearizers by fabricating and testing linearizers with 2 GHz of bandwidth. The Silicon Carbide (SiC) reliability effort will emphasize full RF life tests for both discrete devices and Monolithic Microwave Integrated Circuits (MMICs). GaN efforts will continue to broaden the database for infant mortality issues in discrete devices and begin to establish approaches to RF life testing of GaN HEMTs. Within the high power channelizer effort the complete channelizer will be iterated with packaging and manufacturability issues addressed. Continue the development of high power, wideband, isolators by demonstrating increased power handling (up to 20 Watts) and reduced losses (<1 dB). The effort on DDS frequency source development to 20 GHz will emphasize enhanced performance and yield of the InP transistor devices in order to demonstrate improved DDS speed and increased spurious free dynamic range. Improve the performance of the superconducting ADC with respect to signal-to-noise (S/N) ratio and bandwidth. Pursue techniques to realize a reliable, rugged cryocooler and other special packaging required for superconducting parts. Within the 100 GHz low noise clock effort, evaluate full circuit phase noise performance for a packaged unit and analyze issues of clock signal distribution in arrays. Optimize the wide bandgap low noise receiver amplifier designs by targeting specific spectral bands. Explore approaches to the utilization of these amplifiers with reduced limiter protection.

FY 2005 Plans:
Continue the development of octave bandwidth linearizers with the fabrication and testing of linearizers with 4 GHz of bandwidth. Continue the effort to improve DDS device performance and yield for InP transistors. Transfer results of initial SiC RF life tests into the manufacturing technology and initiate a second iteration of testing. GaN reliability will begin to emphasize RF life testing of discrete devices and will establish approaches to RF life testing of GaN based MMICs. The first channelizer units will be available for the Advanced Multifunction Radio Frequency Concept (AMRF-C) Version 2 (V2) testbed system construction and next generation specifications will be developed. Continue development of high power, wideband isolator technology by focusing on size reduction and geometry to fit the 20 GHz array spacing. Continue the effort to improve InP device performance and yield for application to the 20 GHz DDS. Incorporate true Time Delay (TTD) into the DDS to facilitate RF microwave beamsteering in a single packaged monolithic integrated circuit. Perform testing of the superconducting ADC, demonstrate a fieldable cryocooler and plan for integrating superconducting ADC with the cryocooler. Demonstrate functionality of the 100 GHz low noise clock by integrating the clock with the high speed superconducting ADC. Develop MMIC designs for the optimal utilization of the wide bandgap LNAs with enhanced survivability.

	FY 02	FY 03	FY 04	FY 05
Naval Fleet/Force Technology Office	1,870	4,849	0	0

Ensures the Fleet/Force (F/F) helps shape the DoN investment in S&T, develop teaming relationships to rapidly demonstrate and transition technology, support development of technology-based combat capability options for naval forces, and enable warfighting innovations based on technical and conceptual possibilities. This is accomplished

through proactive connectivity and collaboration between DoN S&T and Joint, Navy, and Marine Corps commands worldwide. Efforts executed by NFFTIO are used to accelerate the process of exploring good ideas and initiatives that originate in the Fleet/Force. Special emphasis is given to force protection, development of transformational capabilities, and Command, Control, Communications, Computers, Intelligence, Surveillance, & Reconnaissance (C4ISR).

FY 2002 Accomplishments:
Special emphasis was given to efforts in force protection, development of transformational capabilities, and C4ISR. Specifically, support to develop the following systems was provided: Ship Suitability Test for Unambiguous Warning Device; Tactical Evaluation of Mine Countermeasures (MCM) Performance and Mine Jamming Against Advanced Sea Mines; and Remote Water Craft (RWC) project for force protection and counter-drug applications. Amphibian Suit and the Flight Deck Planning Tool addressed F/F operational readiness and combat capability issues that were amenable to the demonstration and application of technology solutions. Other applications were Force Protection Range Training Software and Tactical Exploitation of Side Scan Sonar Data.

FY 2003 Plans:
The efforts within NFFTIO listed above will be completed.

FY 2004 Plans: Not Applicable.

FY 2005 Plans: Not Applicable.

Congressional Plus-Ups:

	FY 02	FY 03
Advanced Semiconductor Material Research	0	1,467

Advance the performance and capability of monolithic multifunctional crystalline oxide on semiconductor films for high power amplifiers.

	FY 02	FY 03
Development of Magnetic Random Access Memory	*0	0

(*$966 appropriated in PE 0602234N)
Explored materials and developed a fabrication approach to demonstrate high density magnetic random access nonvolatile memory technology.

	FY 02	FY 03
High Brightness Electron Sources	*0	2,054

(*$1,442 appropriated in PE 0602234N)
FY 2002: Fabricated and characterized low work function materials for application to high brightness sources.
FY 2003: Field emitters will be fabricated and tested using the results of the FY 2002 efforts as a basis.

	FY 02	FY 03
Highly Mobile Tactical Communications (HTMC)	0	977

Explore the feasibility of integrating Iridium satellite communications with current Expeditionary Maneuvering Warfare Line-of-Sight terrestrial tactical communication systems.

	FY 02	FY 03
Maritime Synthetic Range	4,141	4,988

FY 2002: Developed the synthetic virtual range at the Pacific Missile Range Facility (PMRF) to extend PMRF's capability. This tied the Maui High Performance Computer Center (MHPCC's) resources to inject realistic world models with real time systems. Combining various aspects of the UHF Electronically Scanned Array (UESA) radar testbed, Theater Under Sea Warfare (TUSW), and other sensors with the Tactical Component Network (TC) as the backbone architecture, the Navy developed a synthetic range capability centered at PMRF to extend the capability of PMRF.
FY 2003: Expand the Pacific Missile Range Facility (PMRF) capabilities integrating synthetic systems with live systems to provide a wargaming setting with multiple training range integration. These systems will be synchronized to increase the complexity of training and tests and provide a realistic setting for joint-to-unit training with coordinated operational forces.

	FY 02	FY 03
MicroArray Technology	*0	0

(*$3,366 appropriated in PE 0602234N)

Developed protein microarray and advanced DNA technology for Navy and Marine Corps needs. Applications included technology to improve force health protection; analyzed critical stages in the function of pathogenic microoganizms and developed tools for advanced forensic analysis; identified targets for the development of vaccines, antibiotics and antitoxins; and served as a diagnostic tool for military health care delivery.

	FY 02	FY 03
Nanoscale Devices	963	0

Developed nano-meter dimension electronic devices based on wide bandgap semiconductor materials which were used as sources of high power, high frequency electromagnetic radiation for applications in radar and communications systems.

	FY 02	FY 03
Nanoscale Science and Technology	1,444	1,467

FY 2002: Performed applied research to advance the understanding and application of magnetic, electronic and optical nanostructures leading to programmable logic, mass storage, non-volatile storage, and electromagnetic devices.
FY 2003: Focus on development of prototype electronic piezoelectric and optical devices made with new materials, including nanoscale magnetoresistive sensors, piezoelectric sensors, and neuromorphic networks.

	FY 02	FY 03
Silicon Carbide (SiC)Semiconductor Material Development	*0	0

(*$1,352K appropriated in PE 0602234N)
Developed techniques to provide a solid scientific framework for the growth and wafering of SiC that is useful to industry, academia, and government laboratories.

	FY 02	FY 03
Silicon Carbide High Powered Diode Development	0	1,711

Investigate silicon carbide thin film and bulk growth with the goal of controlling defects and doping to the level required to achieve diode structures with high power performance.

	FY 02	FY 03
Thick Film Ferrite Magnetic Material	*0	0

(*$970 appropriated in PE 0602234N)

Developed the growth technology to produce thick hexagonal ferrite films with large saturation magnetization for use in microwave applications.

	FY 02	FY 03
Vacuum Electronics	0	4,890

Provide an enhanced modeling code for millimeter wave countermeasures against millimeter wave sensing missiles, using vacuum tubes.

	FY 02	FY 03
Wide Bandgap Silicon Carbide Semiconductor Research Initiative	0	1,711

Bulk crystal growth and wafering of SiC for high power electronics will be developed.

C. OTHER PROGRAM FUNDING SUMMARY:

RELATED RDT&E:

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.