Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Navy	Date: May 2017
Appropriation/Budget Activity 1319: *Research, Development, Test & Evaluation, Navy I* BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602271N *I Electromagnetic Systems Applied Research*

COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
Total Program Element	0.000	116.362	118.941	79.598	-	79.598	80.951	78.954	78.715	80.288	Continuing	Continuing
0000: *Electromagnetic Systems Applied Research*	0.000	116.362	118.941	79.598	-	79.598	80.951	78.954	78.715	80.288	Continuing	Continuing

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 (20 January 2015). 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 Electromagnetic Systems Applied Research Program addresses technology needs associated with Naval platforms for new capabilities in EO/IR Sensors, Surveillance, Electronic Warfare, Navigation, Solid State Electronics, Vacuum Electronics Power Amplifiers, and Nanoelectronics. The program supports development of technologies to enable capabilities in Missile Defense, Directed Energy, Platform Protection, 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.

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

B. Program Change Summary ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Previous President's Budget	114.644	118.941	132.104	-	132.104
Current President's Budget	116.362	118.941	79.598	-	79.598
Total Adjustments	1.718	0.000	-52.506	-	-52.506
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	4.157	0.000			
• SBIR/STTR Transfer	-2.439	0.000			
• Program Adjustments	0.000	0.000	-52.506	-	-52.506

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Navy					Date: May 2017
Appropriation/Budget Activity 1319: *Research, Development, Test & Evaluation, Navy I* BA 2: *Applied Research*		R-1 Program Element (Number/Name) PE 0602271N *I Electromagnetic Systems Applied Research*			
• Rate/Misc Adjustments	0.000	0.000	0.000	-	0.000

Change Summary Explanation

The funding decrease in FY 2018 reflects the realignment of the innovative naval prototypes Electronic Maneuver Warfare Command & Control (EMC2) and NEMESIS into the new Innovative Naval Prototypes (INP) Applied Research PE 0602792N.

Technical: Not applicable.

Schedule: Not applicable.

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy			Date: May 2017
Appropriation/Budget Activity 1319 / 2	R-1 Program Element (Number/Name) PE 0602271N / *Electromagnetic Systems Applied Research*	Project (Number/Name) 0000 / *Electromagnetic Systems Applied Research*	

COST ($ in Millions)	Prior Years	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total	FY 2019	FY 2020	FY 2021	FY 2022	Cost To Complete	Total Cost
0000: *Electromagnetic Systems Applied Research*	0.000	116.362	118.941	79.598	-	79.598	80.951	78.954	78.715	80.288	Continuing	Continuing

A. Mission Description and Budget Item Justification

This project addresses technology opportunities associated with Naval platforms for new capabilities in EO/IR Sensors, Surveillance, Electronic Warfare, Navigation, Solid State Electronics, Vacuum Electronics Power Amplifiers, and Nanoelectronics. The project supports development of technologies to enable capabilities in Missile Defense, Directed Energy, Platform Protection, Time Critical Strike, and Information Distribution. This project 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.

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

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Title: ELECTRONIC WARFARE TECHNOLOGY	72.742	70.269	44.008	0.000	44.008
Description: The overarching objective of this activity is to develop technologies that enable the development of affordable, effective and robust Electronic Warfare (EW) systems across the entire electromagnetic spectrum (EMS) that will increase the operational effectiveness and survivability of U.S. Naval units. Emphasis is placed on passive sensors and active and passive countermeasure (CM) 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 against 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. This activity also includes developments to protect these technologies from external interference, and modeling and simulation required to support the development of these technologies. Also included is technology development in support of the Integrated Distributed Electronic Warfare System (IDEWS) concept. The objectives reported in prior years under this R-2 Activity have been consolidated into the current objectives described below. The current objectives are:					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- EW RF Technology: Develop and demonstrate technologies in the Radio Frequency (RF) spectrum (covering frequencies from kilohertz to terahertz) that include developments in detection, signal processing and passive/ active techniques for wideband Electronic Attack (EA), Electronic Protection (EP) and the Electronic Support (ES) mission areas. - EW EO/IR Technology: Develop and demonstrate technologies in the Electro-Optic and Infrared (EO/IR) spectral domain (extending from the ultraviolet to the far infrared spectral bands) that include advances in multispectral sensors, multiband sources, beam forming/steering, and signal processing and transmission. - EW Integrated and Networked Technology: Develop and demonstrate technologies that will enable an increased situational awareness and response across the electromagnetic spectrum (EMS) with broad spatial coverage using all available EW assets to provide coordinated, adaptive and networked EW sensing, protection and attack. - Advanced EW Enabling Technologies: Develop classified advanced electronic warfare technology in support of current and predicted capability requirements. - Electromagnetic Maneuver Warfare Command & Control (EMC2) (FY16-FY20): Enable a battle group to work cooperatively in the EM Spectrum (EMS) to optimize Electronic Warfare (EW), Information Operations (IO), Communications (Comms) and Radar performance. EMC2 will build upon the Resource Allocation Manager (RAM) that was previously developed for single multifunction systems under the InTop program to optimize spectrum and functional use across a platform and an entire battle group. Decrease in funding from FY 2017 to FY 2018 is due to: - Completion of exploratory research into advanced technologies to counter emerging threats operating in higher bands of the radio frequency spectrum utilizing extreme spectral and temporal agility. - Starting in FY 2018, all Innovative Naval Prototype (INP) and Leap Ahead Technology (LA-Tech) investments in Electromagnetic Maneuver Command & Control (EMC2) Warfare will be shown in the new INP PE 0602792N Innovative Naval Prototypes (INP) Applied Research to better convey exactly what the Office of Naval Research is working on in this area.					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
The following are non-inclusive examples of accomplishments and plans for projects funded in this activity. ***FY 2016 Accomplishments:*** EW RF Technology: - Continued development of a monolithic optical chip set capable of multi-function radio-frequency signal processing for electronic warfare (EW) applications. - Continued development of technology to improve transmit/receive isolation by properly controlling surface currents with engineered materials. - Continued development of a millimeter wave Rotman Lens-based electronic attack transmitter. - Continued technology development in transmit-to-receive isolation technologies and techniques, relevant to the spectral range of 1 to 110 GHz. - Continued the development of Sub-System Demonstrators (SSDs) leveraging wideband radio frequency (RF) components and sub-systems from prior DoD investments to demonstrate advanced electronic warfare support (ES) and electronic attack (EA) capabilities covering a broad range of RF frequencies in support of Navy and Marine Corps mission areas. - Continued development of Infrared Gradient Index optics and associated SWaP advantages for multispectral imagers in a prototype system. - Completed the development of photonic techniques for broadband electronic surveillance systems. - Completed the development of innovative high date-rate protected communications to circumvent malicious cyber-attack (Project Calliope) EW EO/IR Technology: - Completed development of semiconductor-based, multi-wavelength integrated laser sources spanning multiple bands of the ultraviolet, visible, near infrared (IR), mid-wave IR, and long-wave IR. EW Integrated and Networked Technology: - Continued technologies that develop new methods to represent real-time dynamic spectrum knowledge, sense and learn signal characteristics and behaviors, and to reason about threat systems and the environment to form EA strategies on-the-fly. - Continued technologies that develop extremely high-volume processing capabilities for reconfigurable EW systems. - Continued development of fast signal classification of coherent radar signals for use in chanelized digital transceiver systems to support rapid countermeasure response.					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Completed development of a Bayesian statistical framework paired with a novel stochastic algorithm to support EW probability of raid annihilation analysis. Advanced EW Enabling Technologies (Formerly Titled: Electronic Warfare (EW) Roadmap): - Continued development of classified, advanced, electronic warfare technology in support of current and predicted capability requirements. Electromagnetic Maneuver Warfare Command & Control (EMC2): - Initiated Wideband Airborne Multifunction System design - Initiated Low Band RF Intelligent Distributed Resource (LowRIDR) SubSystem build - Initiated Electromagnetic Warfare Command and Control system design ***FY 2017 Plans:*** EW RF Technology - Continue all efforts of FY 2016 less those noted completed above. EW EO/IR Technology: - Continue all efforts of FY 2016 less those noted completed above. - Initiate the development of SSDs leveraging multiband EO/IR components and sub-systems from prior DoD investments to demonstrate advanced ES and EA capabilities covering a broad range of EO/IR wavelengths in support of Navy and Marine Corps mission areas. EW Integrated and Networked Technology - Continue all efforts of FY 2016 less those noted completed above. - Complete development of fast signal classification of coherent radar signals for use in chanelized digital transceiver systems to support rapid countermeasure response. Electromagnetic Maneuver Warfare Command & Control (EMC2): - Continue all efforts of FY 2016. ***FY 2018 Base Plans:*** The Electromagnetic Warfare applied research being conducted includes efforts in both RF countermeasures and EO/IR Countermeasure including both detection and defeat. Technology developments to provide capabilities indigenous to small UASs are a significant focus. Technology developments being addressed					

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Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
include laser based IR countermeasures, non-mechanical holographic means for optical beam steering for EO/IR countermeasures, the development of new optical lens technologies based on gradient indexed (GRIN) optics. This latter technology when coupled with another ongoing effort in multidimensional optics show significant promise for greatly reducing the weight of highly capable optical systems. Additionally there is a focus on developing the high payoff technology of chip scaled integration of optical photonic components with microwave components. Technology is being investigated to determine the potential for being able to conduct specific emitter identification and classification relative to gun blasts using IR imagers. RF efforts include work in developing engineered high transmit to receiver materials for significant improvements in isolation. Work is ongoing to expand EW jamming capabilities at high power levels covering previously unaddressed frequency bands with significant operational impact. The technologies to permit operations of EW attack in friendly communications bands without attendant fratricide is being researched using alternative technology approaches over current approaches. Cognitive electronic attack approaches in both the communications bands and radar bands are ongoing to address the need to address and defeat unidentified RF pop-up threats. Results have been obtained in ongoing research in metamaterials in the RF domain. Completed development of Infrared Gradient Index optics and associated SWaP advantages for multispectral imagers in a prototype system. ***FY 2018 OCO Plans:*** N/A					
Title: EO/IR SENSOR TECHNOLOGIES ***Description:*** The overarching objective of this thrust is to develop technologies that enable the development of affordable, wide area, persistent surveillance optical architectures, day/night/adverse weather, adaptable, multi-mission sensor technology comprised of optical sources, detectors, and signal processing components for search, detect, track, classify, identify (ID), intent determination, and targeting applications and includes developments to protect these technologies from external interference. Also included are modeling and simulation required to support the development of these technologies. Efforts will also include the development of optical RF components, infrared technologies including lasers and focal plane arrays using narrow bandgap semiconductors. The current specific objectives are: a) Optically Based Terahertz (THz) and Millimeter Wave (MMW) Distributed Aperture Systems:	5.913	5.314	7.078	0.000	7.078

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Develop optically based terahertz (THz) and millimeter wave distributed aperture systems for imaging through clouds, fog, haze and dust on air platforms. b) Wide Area Optical Architectures: Develop wide area optical architectures for persistent surveillance for severely size constrained airborne applications. c) Hyperspectral sensors and processing: Develop visible, shortwave IR, mid-wave IR, and long-wave IR hyperspectral sensors, along with processing algorithms to detect anomalies and targets. d) Coherent Laser Radar (LADAR): Develop and improve components for LADAR applications including fiber lasers, coherent focal planes, and advanced processing. e) Autonomous and Networked sensing: Develop algorithms and processing that supports autonomous sensing for UAV platforms and that supports networked sensing over multiple sensors and/or sensor platforms. The funding increase from FY2017 to FY2018 is due initiation of efforts to develop and test a short-wave infrared (SWIR) multispectral LIDAR system capable of simultaneous 4D spatial-spectral information for imaging and spectral discrimination through obscurations, and to develop wide field of view EO/IR Counter-measures to detect, track and/or jam sensors. The following are non-inclusive examples of accomplishments and plans for projects funded in this activity. ***FY 2016 Accomplishments:*** Optically Based Terahertz (THz) and Millimeter Wave Distributed Aperture Systems: - Continued development of a robust imaging capability to provide situational awareness in brownout conditions during takeoff/landing operations in desert environments. - Continued miniaturization and modularization of Millimeter Wave (MMW) imaging system components for small platform systems. - Continued progressing the integration of spectrally agile multi-band sensors into integrated system for use in persistent and time critical surveillance.					

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Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Continued progressing the processing architecture for data analysis and fusion of multi-spectral images. - Continued development of range-gated image reconstruction using optical phase conjugation. - Completed the development of range-gated image reconstruction using optical phase conjugation. (FY16) Wide Area Optical Architectures: - Continued development of mid and long wave infrared (IR) focal plane arrays (FPAs) using graded-bandgap, Wtype-II, superlattices with much higher detectivity than state-of-the-art Mercury Cadmium Telluride (HgCdTe,MCT) FPAs. - Continued design of read-out integrated circuits for temporally adaptive focal plane arrays. - Continued development of spectrally agile visible, near-infrared, short-wave infrared and midwave infrared imaging technology. - Continued development of super-resolution techniques in Wide Field of View Mid-Wave Infrared (WFOV MWIR) sensors. - Continued effort to develop components, study and demonstrate optical links that allow quantum key distribution (QKD) through free space using modulating retro-reflectors (MRRs). Hyperspectral sensors and processing: - Continued integration of hyperspectral instruments onto test platforms. - Continued processing of hyperspectral data from a maritime environment. - Completed effort to develop mid-wave infrared focal plane arrays using plasmonically coupled antimonide based majority carrier barrier device structures on advanced digital readouts for ultra low size, weight, and power night-time wide area surveillance. Coherent Laser Radar (LADAR): - Continued development of fiber lasers and coherent focal plane arrays suitable for LADAR applications. - Completed fabrication and modeling of silicon photonic chips for one dimensional beam steering. - Completed effort to develop fiber-based long wave infrared agile, narrow-band and broadband laser sources for sensing and counter measure applications. Autonomous and Networked sensing: - Continued development of algorithms and processing that supports autonomous sensing for UAV platforms					

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Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Continued development of algorithms and processing that supports networked sensing over multiple sensors and/or sensor platforms.					
FY 2017 Plans: Optically Based Terahertz (THz)and Millimeter Wave Distributed Aperture Systems: - Complete development of a robust imaging capability to provide situational awareness in brownout conditions during takeoff/landing operations in desert environments. - Complete miniaturization and modularization of MMW imaging system components for small platform systems. - Complete progressing the integration of spectrally agile multi-band sensors into integrated system for use in persistent and time critical surveillance. - Complete progressing the processing architecture for data analysis and fusion of multi-spectral images. Wide Area Optical Architectures: - Continue all efforts of FY 2016 less those noted as complete above. Hyperspectral sensors and processing: - Continue all efforts of FY 2016 less those noted as complete above. Coherent Laser Radar (LADAR): - Continue all efforts of FY 2016 less those noted as complete above. Autonomous and Networked sensing: - Continue all effort of FY 2016. - Initiate development of multi-mode (spectral, polarization, temporal) imaging sensors for detecting low observable targets and for imaging through degraded visual environments. - Initiate development of extremely sensitive mmW detector technology.					
FY 2018 Base Plans: Electromagnetic Warfare work is ongoing to address the critical deficiency with respect to operations in brownout conditions. IR and terahertz technologies are being modified and integrated with the expectations that combining these two technologies an effective solution can be obtained. Bistatic radar and imaging technology is being developed to extend surveillance capabilities and passively engage targets. A unique approach permitting rapid active scanning of a battlefield in the IR domain using a non-mechanically scanned mechanism is under development. This technology if successful will eliminate the multiple laser ball systems currently					

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Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
required to accomplish this same requirement at lower SWAP. Active work is also being focused on developing capabilities for high resolution, wide field of view sensors on modest sized UAS platforms. Research advanced materials and chemistry fabrication methods to develop micro-retro-reflectors operating in short wavelength IR systems. This study is directed to develop unique spectral bar codes. Major accomplishments include development of high refractive index glass composition. Create and explore new electronics concepts, components, techniques, and subsystems for the generation, and transmission of UV, visible, and infrared radiation to support current and future Navy and DoD needs. Continue research in optical components and infrared technologies including lasers and focal plane arrays using narrow bandgap semiconductors for the purpose of imaging through clouds, fog, haze and dust; persistent surveillance for severely size constrained airborne applications; detecting anomalies and targets; and autonomous sensing for UAV platforms and networked sensing over multiple sensors and/or sensor platforms. Complete effort to develop components, study and demonstrate optical links that allow quantum key distribution (QKD) through free space using modulating retro-reflectors (MRRs). Complete effort to develop a novel IR focal plane bolometric sensor based upon graphene electronic materials. ***FY 2018 OCO Plans:*** N/A					
Title: NAVIGATION TECHNOLOGY ***Description:*** The overarching objective of this activity is to develop technologies that enable the development of affordable, effective and robust Position, Navigation and Timing (PNT) capabilities using the GPS, non-GPS navigation devices, and atomic clocks. This project will increase the operational effectiveness of U.S. Naval units. Emphasis is placed on GPS Anti-Jam (AJ) Technology; Precision Time and Time Transfer Technology; and Non-GPS Navigation Technology (Inertial aviation system, bathymetry, gravity and magnetic navigation). The focus is on the mitigation of GPS electronic threats, the development of atomic clocks that possess unique long-term stability and precision, and the development of compact, low-cost Inertial Navigation Systems (INS). The following are non-inclusive examples of accomplishments and plans for projects funded in this activity.	4.451	7.281	6.120	0.000	6.120

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
The increase from FY 2016 to FY 2017 is due to increased funding for the Navigation and Precision Timekeeping initiative. The decrease in funding from FY 2017 to FY 2018 is due to the ramp down of the Navigation and Precision Timekeeping initiative. ***FY 2016 Accomplishments:*** GPS Anti-Jam Antennas and Receivers: - Continued development of Military User Equipment Integrated Fault Analysis effort. - Continued and completed Anti-tamper Investigation Support. - Continued and completed System for enhanced electronic protection, electronic support and precision navigation. - Completed Cognitive MGUE with Chaotic Timing Signals for GPS Denied Environments. - Completed Precise at-Sea Ship System for Indoor Outdoor Navigation (PASSION) project. Precision Time and Time Transfer Technology: - Continued Evolved Global Navigation Satellite System (GNSS) Signal Monitoring Receiver Element project. - Continued developing Advanced-Development of a Miniature Atomic Clock. - Continued analysis of Code Distortion in Modernized GPS Signals on GPS Timing Receiver. - Continued development of Compact and Versatile Passively CEP (carrier envelope phase) Stabilized Optical Clock system. - Initiated Precision Optical Clock Technology Development Non-GPS Navigation Technology: - Initiated Cold Atom Inertial Navigation System (INS) Sensor Technology Development. - Continued Optically Transduced INS Sensor Suite (OPTIMUSS) project. - Continued development of the Three-Axis Resonant Fiber Optic-based Inertial Navigation System with the accuracy of 10 milli(m)-degrees per hour and the angle random walk (ARW) of 10 milli (m)-degrees per root hour. - Continued development of Micro-Electro-Mechanical System (MEMS) Gyro effort. - Completed Embedded Sonar Aided Inertial Navigation Technology (SAINT) project. ***FY 2017 Plans:***					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
GPS Anti-Jam Antennas and Receivers: - Complete development of Military User Equipment Integrated Fault Analysis effort. - Initiate at multi-constellation GPS receiver effort for high anti-jam and anti-spoof with wideband frontend. - Initiate research in application of advanced processing methods for robust GPS operation in challenged environments. Precision Time and Time Transfer Technology: - Continue all efforts of FY 2016. - Continued analysis of Code Distortion in Modernized GPS Signals on GPS Timing Receiver. - Continued developing Advanced-Development of a Miniature Atomic Clock. - Complete development of Compact and Versatile Passively CEP (carrier envelope phase) Stabilized Optical Clock system. - Complete Evolved Global Navigation Satellite System (GNSS) Signal Monitoring Receiver Element project. - Initiate Optical Clock development efforts for compact, deployable next generation clock technology to greatly surpass current Rubidium and Cesium standards, providing the ultimate in time holdover in GPS denied environments. - Initiate RF and Optical time transfer effort for terrestrial, surface, and airborne platforms. Non-GPS Navigation Technology: - Continue all efforts of FY 2016. - Complete Optically Transduced Inertial Navigation System (INS) Sensor Suite (OPTIMUSS) project. - Complete development of Micro-Electro-Mechanical System (MEMS) Gyro effort. - Complete MEMS Inertial Navigation System Phase II project. - Initiate hybrid velocity measuring sonar system for compact underwater and surface platforms. - Initiate development of a thermal or cold atom beam 3 axis navigator. - Initiate investigation of compact indexed inertial for airborne, weapon, or unmanned UUV platforms. ***FY 2018 Base Plans:*** Continue applied research in position, navigation and timing. This research aims to develop techniques and technology to provide assured, cost-effective, and mission relevant PNT to the warfighter. Areas of investment included robust GPS, non-GPS navigation aids, and assured timekeeping. Specifically, GPS Anti-Jam Antennas and Receivers for Navy platforms for the purpose of providing precision navigation capabilities in the presence of electronic threats and anti-spoofer/anti-jam processors for the purpose of providing precision navigation					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
capabilities in the presence of emergent threats; Tactical grade atomic clocks that possess unique long-term stability and precision for the purpose of providing GPS-independent precision time and transferring GPS-derived time via radio frequency links for the purpose of providing GPS-independent precision time; and Inertial navigation systems for the purpose of providing an alternative means of providing precision navigation, a correlation navigation technique using earth maps of high precision, for those Naval platforms which may not have GPS navigation capabilities and/or loss of GPS signals. ***FY 2018 OCO Plans:*** N/A					
Title: SOLID STATE ELECTRONICS ***Description:*** The overarching objective of this activity is to develop higher performance components and subsystems for all classes of military RF systems that are based on solid state physics phenomena and are enabled by improved understanding of these phenomena, new circuit design concepts and devices, and improvements in the properties of electronic materials. An important subclass are the 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 weapon systems. Another subclass are the analog and high speed, mixed signal components that connect the electromagnetic signal environment into and out of digitally realized, specific function systems. These improved components are based on both silicon (Si) and compound semiconductors (especially the wide bandgap materials and narrow bandgap materials), low and high temperature superconductors, novel nanometer scale structures and materials. Components addressed by this activity emphasize the MMW and submillimeter wave (SMMW) regions with an increasing emphasis on devices capable of operating in the range from 50 gigahertz (GHz) to 10 terahertz (THz). The functionality of the technology developed cannot be obtained through Commercial-Off-the-Shelf (COTS) as a result of the simultaneous requirements placed on power, frequency, linearity, operational and instantaneous bandwidth, weight, and size. Effort will involve understanding the properties of engineered semiconductors as they apply to quantum information science and technology. This activity also includes Anti-Tamper development of innovative techniques and technologies to deter the reverse engineering and exploitation of our military's critical technology and critical program information in order to impede technology transfer and alteration of system capability and prevent the development of countermeasures to U.S. systems. The following are non-inclusive examples of accomplishments and plans for projects funded in this activity.	9.923	12.856	11.040	0.000	11.040

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
The increase from FY 2016 to FY 2017 is due to increased funding for the Electromagnetic Applied Research initiative. The decrease from FY 2017 to FY 2018 is due to a ramp down in funding towards the Anti-Tamper Program. ***FY 2016 Accomplishments:*** Solid State Transistors and Devices: - Initiated development of ultra-efficient mm-wave transistors. - Continued effort to develop and exploit reduced dimensionality transistors. - Continued effort to develop a high performance graphene base hot electron transistor. - Continued development of an integrated, tunable, frequency selective and low noise integrated module. - Continued effort to develop W-band high-power Gallium Nitride (GaN) Metal Insulator Semiconductor (MIS) transistors. - Continued MMW field plate GaN High Electron Mobility Transistor (HEMT) development. - Continued progressing mixed-signal GaN Monolithic Microwave Integrated Circuit (MMIC) technology development. - Continued investigations into ultra-low noise, Group III-Nitride, transistor structures for RF and mm-wave receivers and transmitters. - Continued group III-Nitride transistor development for 1 THz circuits. - Continued development of discrete, channelized, Gallium Nitride Transistors for linear and low noise transmit and receive amplifiers. - Completed effort to develop ultra-scaled AlN/GaN transistors to enable superior RF amplifier performance in G-band applications. High Efficiency, Highly Linear Amplifiers: - Initiated research into harmonic mm-wave amplifiers - Continued effort to develop transmit and receive components using reduced dimensionality transistors. - Continued development of MMW AlGaN/GaN wide bandgap HEMT. - Continued development of AlGaN HEMT broadband amplifiers for electronic warfare decoys with increased power and efficiency than achieved with conventional solid state amplifiers. - Continued high-efficiency microwave GaN HEMT amplifier development.					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Continued work on GaN MMW components at >44 GHz to allow for EHF SATCOM insertion and other MMW applications spanning to 95GHz. - Continued expansion of scope of the GaN MMW device program. - Continued and demonstrate Low-Noise, High Dynamic Range Receiver Chain for Simultaneous Transmit and Receive (STAR) Applications. - Continued component development in support of multifunctional electronic warfare. - Continued transition of GaN high-efficiency microwave HEMT amplifiers to radar and communications applications. - Continued development of MMW high efficiency amplifiers for satellite communications and compact high efficiency MMW sources for active denial systems. - Continued development of high-efficiency broadband GaN HEMT amplifiers for electronic warfare applications. - Continued Sub-MMW GaN Device technology for communications, target identification and high speed data processing. - Continued development of GaN Monolithic Microwave Integrated Circuit (MMIC) Amplifier Technology for operation greater than (>)100 GHz. - Continued development of high efficiency GaN amplifier MMICs for 50-100 GHz operation. - Continued low-noise, high dynamic range Group-III Nitride amplifier development for W-band receivers. - Continued development of group III-Nitride amplifiers for terahertz amplification. - Continued development of high power density, high output power, solid state mm-wave amplifiers. Superconducting Electronics: - Continued effort to develop reprogrammable superconducting digital filters capable of limiting Instantaneous Bandwidth (IBW) of output data stream from Analog-to-Digital Converter (ADC) to user defined choices and doing this with >10X lower processing latency and energy cost than possible in room temperature circuits. - Continued effort to design of Analog-to-Digital Converters (ADC) to enhance minimum detectable signal sensitivity levels by 10 dB. - Continued development of effort to improve superconducting analog to digital converter performance by more than 2 bits as well as 2x in sample rate. - Continued research on components needed to achieve improved interference immunity. - Continued heterogeneous component technology development to enable performance enhancement of analog-digital converters and ultra-wideband receivers and transmitters. Control, Reception, Transmission, and Processing of Signals:					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Continued efforts to develop compact, high performance switch, filter, and high isolation device technologies for agile, broadband signal processing in cluttered environments. - Continued development of Gallium Nitride-based low-noise components for Interference Immune Navy Satcom receivers. - Continued investigations into low-noise, high dynamic range group-III Nitride receiver components for W-band and higher signal detection. - Continued development of group III-Nitride terahertz receive technologies. - Continued work on multi-THz real-time signal processing using combination of high speed electronic, photonic, and metamaterial techniques. - Continued research into affordable digital array, interfacing technologies using low power, mixed signal approaches, wafer scale antennas, and analog photonic transmission techniques. - Continued research into compact, broadband filter and channelizer components targeting multi-octave operation in the range from VHF to W-band. - Completed effort to develop micro-miniature ferroelectrically active tunable acoustic wave devices for fast reconfiguration of circuits and systems operating at microwave through sub-millimeter-wave frequencies. - Continued RF electronics and photonics development to implement wideband Simultaneous Transmit and Receive sensing and communications apertures on disadvantaged platforms. Novel Nanometer Scale Logic/Memory Devices and Related Circuits and Architectures: - Continued developing new research in graphene synthesis and device concepts. - Continued work on graphene based devices and circuits for low power flexible electronics. - Continued research on graphene-organic hybrid materials interfaces and device structures. - Continued large-scale hexagonal boron nitride (hBN) synthesis as substrate for graphene and other 2D materials. Anti-Tamper: - Continued efforts to develop physically unclonable functions and high density 3D packaging technologies. - Continued efforts to develop destruct mechanisms that do not cause collateral damage. - Continued efforts to develop advanced sensors and coatings.					
FY 2017 Plans: Solid State Transistors and Devices: - Continue all efforts of FY 2016 less those noted as completed above.					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Initiate development of highly linear source electric field engineered HEMT devices. - Initiate development of ultra-efficient nitrogen-polar mm-wave transistors. - Initiate Electromagnetic Applied Research initiative. High Efficiency, Highly Linear Amplifiers: - Continue all efforts of FY 2016 less those noted as completed above. - Complete and demonstrate Low-Noise, High Dynamic Range Receiver Chain for Simultaneous Transmit and Receive (STAR) Applications. - Initiate high output impedance RF amplifier development for photonically-enabled STAR architectures. Superconducting Electronics: - Continue all efforts of FY 2016 less those noted as completed above. - Initiate realization of RF mixed signal components predicted to have significantly improved performance using newly available switching devices. Control, Reception, Transmission, and Processing of Signals: - Continue all efforts of FY 2016 less those noted as completed above. - Initiate development of high RF impedance electro-optic modulators for photonically-enabled STAR architectures. Novel Nanometer Scale Logic/Memory Devices and Related Circuits and Architectures: - Continue all efforts of FY 2016. Anti-Tamper: - Continue all efforts of FY 2016 less those noted as completed above. ***FY 2018 Base Plans:*** Continue research in the areas of solid state transistors and devices for high frequency analog and digital operation; high efficiency, highly linear amplifiers for microwave, millimeter-wave, low-noise, and power applications; superconducting and other technologies which are designed to deliver software defined, wide band, many simultaneous signal functionality over a wide range of frequencies, in increasingly field-ready packaging and demonstrate the ability of these components to deliver superior functionality in conventional system contexts, including, but not limited to, SATCOM, Surveillance Electronic Warfare (EW), signal intelligence					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
(SIGINT), and communications; electronics and photonics technology that provides for the control, reception, transmission and processing of signals; and Anti-Tamper: develop a undetectable, robust, low/no power, low cost set of technologies that can be deployed in many different systems from many different vendors for the purpose of protecting critical technology and critical program information contained in U.S. military systems from tampering and reverse engineering. Conduct exploratory research to develop electronic materials, devices, components, and circuits in the frequency range of ~ 1 MHz to ~ 10 THz that provide system performance edge compared to COTS-based solid state electronics to ensure supremacy of future radar, EW, communications, sensor, and intelligence systems. ***FY 2018 OCO Plans:*** N/A					
Title: SURVEILLANCE TECHNOLOGY ***Description:*** The overarching objective of this activity is to develop 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 and includes modeling and simulation required to support the development of these technologies. The current specific objectives are: a) Radar Architectures, Sensors, and Software which Address Ballistic Missile and Littoral Requirement Shortfalls: Develop radar architectures, sensors, and software which address Ballistic Missile and Littoral requirement shortfalls including: sensitivity; clutter rejection; and flexible energy management. b) Algorithms, Sensor Hardware, and Signal Processing Techniques for Automated Radar Based Contact Mensuration and Feature Extraction: Develop algorithms, sensor hardware, and signal processing techniques for automated radar based contact mensuration and feature extraction in support of asymmetric threat classification and persistent surveillance and to address naval radar performance shortfalls caused by: man-made jamming and Electronic Counter Measures (ECM), unfavorable maritime conditions, and atmospheric and ionosphere propagation effects.	10.869	9.749	8.998	0.000	8.998

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
c) Software and Hardware for a Multi-Platform, Multi-Sensor Surveillance System: Develop software, and hardware for a multi-platform, multi-sensor surveillance system for extended situational awareness of the battlespace. d) Small UAV Collision Avoidance/Autonomy Technology: Develop small UAV collision avoidance/autonomy technology. e) Long Range Radio Frequency (RF) Identification (ID): Develop, hardware, software, algorithms, and RF techniques to extend identification capabilities in support of Intelligence Surveillance and Reconnaissance (ISR). Funding decrease from FY16 to FY17 is a result of the completion of algorithm, sensor, and signal activities. The following are non-inclusive examples of accomplishments and plans for projects funded in this activity. ***FY 2016 Accomplishments:*** Radar Architectures, Sensors, and Software which Address Ballistic Missile and Littoral Requirement Shortfalls: - Continued Advanced Common Radar Architecture and mode development. - Continued High Power, High Duty Factor, X-band Amplifier Algorithms, Sensor Hardware, and Signal Processing Techniques for Automated Radar Based Contact Mensuration And Feature Extraction: - Continued demonstrations of advanced Non-Cooperative Target Recognition (NCTR) algorithms in congested harbor environments. - Continued development of a process to detect hostile camouflaged or hidden targets in shadows and diverse backgrounds of militarily challenged environments. - Continued investigation of means of optimally combining mensuration, classification, and noncooperative target recognition of surface craft. - Continued development of a technology architecture for the Persistent Autonomous Surveillance System. - Continued development of automated controls for an airborne persistent multi-node sensor network. - Continued progressing development of algorithms and signal processing for Electronic Protection in airborne radars.					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Continued progressing development of software and algorithms for multi-platform radar controls. - Completed development of a technique to measure motion with a multi-aperture synthetic aperture radar. - Completed development of amplitude control of radar transmit waveforms. - Completed development of design and full-wave characterization of phased-array systems using the domain decomposition-finite element method. Software and Hardware for a Multi-Platform, Multi-Sensor Surveillance System: - Continued development of signal processing techniques to improve situational awareness and autonomous detection of hostile fire events in a dynamic urban clutter environment. - Continued modeling and simulation of shipboard and airborne RF networked sensors to characterize their performance in a challenge environment. - Continued field measurement to characterize coherent and non-coherent position, navigation, timing and communications requirements. Small UAV Collision Avoidance/Autonomy Technology: - Continued development of research technologies and analytical algorithms for an effective and highly reliable collision avoidance system. Long Range Radio Frequency (RF) Identification (ID): - Continued studies for Long Range RFID techniques and initial hardware designees.					
FY 2017 Plans: Radar Architectures, Sensors, and Software which Address Ballistic Missile and Littoral Requirement Shortfalls: - Continue all efforts of FY 2016 less those noted as complete above. Algorithms, Sensor Hardware, and Signal Processing Techniques for Automated Radar Based Contact Mensuration And Feature Extraction: - Continue all efforts of FY 2016 less those noted as complete above. Software and Hardware for a Multi-Platform, Multi-Sensor Surveillance System: - Continue all efforts of FY 2016 less those noted as complete above. Small UAV Collision Avoidance/Autonomy Technology:					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Continue all efforts of FY 2016 less those noted as complete above. Long Range Radio Frequency (RF) Identification (ID): - Continue all efforts of FY 2016 less those noted as complete above. ***FY 2018 Base Plans:*** Continue applied research in sensors, networking and communication connectivity for the purpose of developing an affordable and fully automated network of time-coordinated mono-static, bi-static and passive surveillance sensors providing real-time tracking, identification, and engagement information with persistent wide area awareness. Specifics Surveillance Technology research objectives include: Radar - research into antenna apertures, electronics, and signal processing continue to provide enhanced capability to detect, track, and automatically identify targets and threats; Signal Intelligence - the use of interferometric and sophisticated signal processing algorithms enable the detection, geolocation, tracking, and identification of targets; Network Sensing - research areas include sensor data fusion, multi-hypothesis decision making, multi-target tracking, and methods for handling and fusing disparate and intermittent data sources; and Electronic Protection - develop methods to mitigate Electronic Attack (EA) and Electromagnetic Interference (EMI) to RF sensors and networks. Electromagnetic Warfare - Efforts in this area are expanding the surveillance of adversary platforms by developing advanced signal processing techniques to bistatically detect surface vessels by sensing reflected satellite transmissions and for the detection and discrimination of small UAS in a clutter filled environment. ***FY 2018 OCO Plans:*** N/A					
Title: VACUUM ELECTRONICS POWER AMPLIFIERS	3.464	2.747	2.354	0.000	2.354

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Description: The overarching objective of this activity is to develop millimeter wave (MMW) and sub-MMW 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, electronic warfare and high-power radar applications at MMW and upper-MMW regime. The emphasis is placed on achieving high power at high frequency in a compact form factor. Technologies include utilization of spatially distributed electron beams in amplifiers, such as sheet electron beams and multiple-beams, and creation of simulation based design methodologies based on physics-based and geometry driven design codes. The current specific objectives are: a) High Power Millimeter and Upper Millimeter Wave Amplifiers: Develop science and technology for high power millimeter and upper millimeter wave amplifiers including high current density diamond cathodes, sheet and multiple electron beam formation and mode suppression techniques in overmoded structures. b) Lithographic Fabrication Techniques: Develop lithographic fabrication techniques for upper-millimeter wave amplifiers. c) Accurate and Computationally Effective Device-Specific Multi-Dimensional Models for Electron Beams: Develop accurate and computationally effective device-specific multi-dimensional models for electron beam generation, large-signal and stability analysis to simulate device performance and improve the device characteristics. Funding decrease from FY16 to FY17 is a result of the completion of amplifier activities. The following are non-inclusive examples of accomplishments and plans for projects funded in this activity. ***FY 2016 Accomplishments:*** High Power Millimeter and upper Millimeter Wave Amplifiers					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Continued effort to develop and experimentally demonstrate a new class of miniature, broad-band-width millimeter wave (MMW) amplifiers having five times the power-to-weight ratio of existing state-of-the-art broadband MMW amplifiers. Lithographic Fabrication Techniques: - Continued effort to develop 220 GHz millimeter-wave amplifiers employing electromagnetic structures that are microfabricated using lithographic techniques. - Continued effort to develop new 3-D microfabrication techniques for upper millimeter-wave to terahertz electromagnetic (EM) circuits in complex geometries not possible by conventional methods, enabling unprecedented design freedom for high power active and passive devices. - Completed effort to produce a high-power (>100 W) millimeter-wave vacuum electronic amplifier at G-band using microfabrication techniques developed at NRL in conjunction with a new type of high-gain interaction circuit. Accurate and Computationally Effective Device-Specific Multi-Dimensional Models for Electron Beams: - Completed effort to develop a cascaded multiple-beam traveling wave amplifier, which is expected to provide unprecedented linear output power at millimeter wave frequencies (~30-40 GHz).					
FY 2017 Plans: High Power Millimeter and upper Millimeter Wave Amplifiers - Continue all efforts of FY 2016, unless noted as completed above. Lithographic Fabrication Techniques - Continue all efforts of FY 2016, unless noted as completed above.					
FY 2018 Base Plans: Conduct ongoing Vacuum Electronic applied research for: High Power Millimeter and upper Millimeter Wave Amplifiers - Complete effort to develop and experimentally demonstrate a new class of miniature, broad-band-width millimeter wave (MMW) amplifiers having five times the power-to-weight ratio of existing state-of-the-art broadband MMW amplifiers.					

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
Lithographic Fabrication Techniques - Complete effort to develop new 3-D microfabrication techniques for upper millimeter-wave to terahertz electromagnetic (EM) circuits in complex geometries not possible by conventional methods, enabling unprecedented design freedom for high power active and passive devices Electronics - Exploratore and develop electron beam physics, beam-wave interaction structures, microfabrication techniques, RF materials, and physics-based modeling to produce designs and prototypes of compact, efficient, broadband, linear, high power devices operating at mmW & sub-mmW frequencies ***FY 2018 OCO Plans:*** N/A					
Title: NEMESIS ***Description:*** The objective is to develop a System of Systems (SoS) able to coordinate distribute EW resources against many adversary surveillance and targeting sensors simultaneously. It will benefit the warfighter by providing platform protection across the battlespace against many sensors, creating seamless cross-domain countermeasure coordination, and enabling rapid advanced technology/capability insertion to counter emerging threats. a) Develop reconfigurable and modular EW payloads, Distributed Decoy and Jammer Swarms (DDJS), effective multi-spectral countermeasures (CM), and Multiple Input/Multiple Output Sensor/CM (MIMO S/CM) for platform protection across operational domains. The increase from FY16 to FY17 in the Nemesis program is due to hardware procurement and conducting field experiments of Nemesis technologies. The decrease from FY17 to FY18 is due to: - Starting in FY 2018, all Innovative Naval Prototype (INP) and Leap Ahead Technology (LA-Tech) investments in Electromagnetic Maneuver Warfare will be shown in the new INP PE 0602792N Inotative Naval Prototypes to better convey exactly what the Office of Naval Research is working on in this area. ***FY 2016 Accomplishments:*** - Continued development of the NEMESIS Electronic Warfare (EW) payloads and their integration into platforms.	9.000	10.725	0.000	0.000	0.000

Exhibit R-2A, RDT&E Project Justification: FY 2018 Navy		Date: May 2017
Appropriation/Budget Activity 1319 / 2	**R-1 Program Element (Number/Name)** PE 0602271N / *Electromagnetic Systems Applied Research*	**Project (Number/Name)** 0000 / *Electromagnetic Systems Applied Research*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018 Base	FY 2018 OCO	FY 2018 Total
- Continued research supporting distributed control, coordination and networking of NEMESIS payloads and platforms. ***FY 2017 Plans:*** - Continue all efforts of FY 2016. ***FY 2018 Base Plans:*** N/A ***FY 2018 OCO Plans:*** N/A					
Accomplishments/Planned Programs Subtotals	116.362	118.941	79.598	0.000	79.598

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

This PE supports the development of technologies that address technology needs associated with Naval platforms for new capabilities in EO/IR Sensors, Surveillance, Electronic Warfare, Navigation, Solid State Electronics, Vacuum Electronics Power Amplifiers, and Nanoelectronics. The program supports development of technologies to enable capabilities in Missile Defense, Directed Energy, Platform Protection, Time Critical Strike, and Information Distribution. Each PE Activity has unique goals and metrics, some of which include classified quantitative measurements. Overall metric goals are focused on achieving sufficient improvement in component or system capability such that the 6.2 applied research projects meet the need of, or produce a demand for, inclusion in advanced technology that may lead to incorporation into acquisition programs or industry products available to acquisition programs.

Specific examples of metrics under this PE include:

- Provide a secure, over the horizon, on-the- move capability to communicate with higher headquarters at a data rate of 256-512 Kbps at a cost of $75,000.
- Provide an array configuration suitable for installation on aircraft that will support Tactical Common Data Link (TCDL) data rates of 10.7 and 45 Mbps at greater than 150 nautical mile range.
- Develop prototype Ku band phased array apertures in a form factor suitable for installation on the CVN-78.