Exhibit R-2, **RDT&E Budget Item Justification:** FY 2018 Army	**Date:** May 2017
Appropriation/Budget Activity 2040: *Research, Development, Test & Evaluation, Army* **/** BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602705A **/** *Electronics and Electronic Devices*

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	-	62.654	56.322	58.352	-	58.352	59.780	61.345	63.424	64.963	-	-
EM4: *Electric Component Technologies (CA)*	-	9.000	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-
EM8: *High Power And Energy Component Technology*	-	11.673	11.416	10.632	-	10.632	14.263	14.873	15.653	15.943	-	-
H11: *Tactical And Component Power Technology*	-	11.353	8.714	8.332	-	8.332	7.652	7.850	8.048	8.215	-	-
H17: *Flexible Display Center*	-	1.091	2.356	2.143	-	2.143	1.200	0.752	0.301	0.313	-	-
H94: *Elec & Electronic Dev*	-	29.537	33.836	37.245	-	37.245	36.665	37.870	39.422	40.492	-	-

A. Mission Description and Budget Item Justification

This Program Element (PE) designs and evaluates, power components and power management technologies, frequency control and timing devices, high power microwave devices, display technologies; and electronic components. The applied research on these technologies enable the ability to perform precision deep fires against critical mobile and fixed targets; investigate all-weather, day or night, theater air defense against advanced enemy missiles and aircraft; as well as investigate enhanced communications and target acquisition through support of capabilities such as autonomous missile systems, advanced land combat vehicles, smart anti-tank munitions, electric weapons, secure jam-resistant communications, automatic target recognition, foliage-penetrating radar, and combat identification. Project EM8 designs and evaluates high-power electronic components and technologies. Project H11 designs, investigates and validates advanced power and energy technologies (batteries, alternative energy and hybrids) and power management and distribution techniques (wireless power, intelligent power management). Project H17 designs and evaluates flexible displays in conjunction with the Flexible Display Center. Project H94 researches and evaluates electronic component technologies such as photonics, micro electromechanical systems, imaging laser radar, magnetic materials, ferroelectrics, microwave and millimeter-wave components, and electromechanical systems.

Work in this PE complements and is fully coordinated with efforts in PE 0602120A (Sensors and Electronic Survivability), PE 0602709A (Night Vision Technology), PE 0602782A (Command, Control, Communications Technology), PE 0602783A (Computer and Software Technology), PE 0603001A (Warfighter Advanced Technology), and PE 0603772A (Advanced Tactical Computer Science and Sensor Technology).

The cited work is consistent with the Assistant Secretary of Defense for Research and Engineering Science and Technology priority focus areas and the Army Modernization Strategy.

Work is performed by the Army Research Laboratory, Adelphi, MD. and the Army Communications-Electronics Research, Development, and Engineering Center, Aberdeen Proving Ground, MD.

Exhibit R-2, RDT&E Budget Item Justification: FY 2018 Army	**Date:** May 2017
Appropriation/Budget Activity 2040: *Research, Development, Test & Evaluation, Army* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*

B. Program Change Summary ($ in Millions)	**FY 2016**	**FY 2017**	**FY 2018 Base**	**FY 2018 OCO**	**FY 2018 Total**
Previous President's Budget	64.301	56.322	58.884	-	58.884
Current President's Budget	62.654	56.322	58.352	-	58.352
Total Adjustments	-1.647	0.000	-0.532	-	-0.532
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-	-			
• SBIR/STTR Transfer	-1.647	-			
• Adjustments to Budget Years	0.000	0.000	-0.786	-	-0.786
• Civ Pay Adjustments	0.000	0.000	0.254	-	0.254

Congressional Add Details ($ in Millions, and Includes General Reductions)

	FY 2016	**FY 2017**
Project: EM4: *Electric Component Technologies (CA)*		
Congressional Add: *Silicon Carbide (SiC) Research-Army Research Laboratory*	3.600	-
Congressional Add: *Advanced Intelligent Battery Eliminator / Lithium-ion Capacitor Material Research, Electrolyte and Cell Experimentation*	5.400	-
Congressional Add Subtotals for Project: EM4	9.000	-
Congressional Add Totals for all Projects	9.000	-

Exhibit R-2A, **RDT&E Project Justification:** FY 2018 Army	**Date:** May 2017
Appropriation/Budget Activity 2040 / 2 · **R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices* · **Project (Number/Name)** EM4 / *Electric Component Technologies (CA)*	

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
EM4: *Electric Component Technologies (CA)*	-	9.000	0.000	0.000	-	0.000	0.000	0.000	0.000	0.000	-	-

A. Mission Description and Budget Item Justification

Congressional Interest Item funding for Electronic Component applied research.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017
Congressional Add: Silicon Carbide (SiC) Research-Army Research Laboratory ***FY 2016 Accomplishments:*** Investigated advanced wide band gap device processing technology that utilizes current silicon process facilities to provide lower cost components. Researched high performance packaging with increased thermal performance to enable full performance operation of wide band gap devices. Evaluated performance advantages of wide band gap power devices when applied to current circuit designs.	3.600	-
Congressional Add: Advanced Intelligent Battery Eliminator / Lithium-ion Capacitor Material Research, Electrolyte and Cell Experimentation ***FY 2016 Accomplishments:*** blank	5.400	-
Congressional Adds Subtotals	9.000	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

N/A

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		**Date:** May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** EM8 / *High Power And Energy Component Technology*

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
EM8: *High Power And Energy Component Technology*	-	11.673	11.416	10.632	-	10.632	14.263	14.873	15.653	15.943	-	-

A. Mission Description and Budget Item Justification

This Project provides for the research, development, and evaluation of high-power electronic components, materials, and related technologies. These technologies have application in compact and efficient power conversion, conditioning, and management sub-systems; energy storage and conversion devices; radio frequency (RF)/ microwave and solid-state laser directed energy weapons (DEW); traditional and non-traditional RF and laser electronic attack; and RF photonics. All project elements are coordinated with and, as appropriate, leveraged by DEW and power/energy programs in the Air Force, Navy, High Energy Laser Joint Technology Office, Defense Threat Reduction Agency, national labs, university consortia, and relevant industry and foreign partners. The products of this research are required by developers of Army and Department of Defense (DoD) systems to evolve traditional (mechanical-based) sub-systems such as geared transmissions, plate armor, and kinetic projectiles to electrically-based ones. These products will provide the Soldier enhanced survivability and lethality through increased power management and energy savings as well as new fighting capabilities offered only by electrical power.

This Project sustains Army science and technology efforts supporting the Ground Maneuver, Lethality and Soldier portfolios.

The work in this Project is coordinated with the Army Tank and Automotive Research, Development, and Engineering Center (TARDEC); Armaments Research, Development, and Engineering Center (ARDEC); the Army Aviation and Missile Research, Development, and Engineering Center (AMRDEC); and the Army Communications-Electronics Research, Development, and Engineering Center (CERDEC).

The cited work is consistent with the Assistant Secretary of Defense for Research and Engineering Science and Technology priority focus areas and the Army Modernization Strategy.

Work on this Project is performed by the Army Research Laboratory (ARL), Adelphi, MD.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: High Power and Energy Technologies ***Description:*** Research and evaluate electronic materials, structures, and components that will enable the realization of higher energy density and efficiency required by future Army systems such as electromagnetic armor, directed energy weapons, power grid protection, and other pulsed-power systems. Special emphasis is on components operating at high voltages - greater than (>) 10 kilovolts (kV). ***FY 2016 Accomplishments:***	1.187	-	-

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		Date: May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** EM8 / *High Power And Energy Component Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Validated a 20 kV device and packaging concept; continued to extend the voltage and current capabilities of power switching components through modeling and research of the materials and fabrication processes; and researched materials and device technologies required to understand device operation at 40 kV for use in advanced Directed Energy systems and other Lethality and Survivability applications.			
Title: Advanced Solid-State Laser Technology and RF Photonics for Broadband Signal Processing ***Description:*** Research novel solid-state laser concepts, architectures, and components with the goal of providing advanced laser technology to Army directed energy weapon and tactical laser developers. Exploit breakthroughs in laser technology, develop and employ innovative laser gain material, and utilize photonics to meet the stringent weight/volume requirements for Army platforms, especially to enhance and improve the generation, transmission, reception, and processing of RF (radio frequency) signals. Applied laser research will be conducted in close collaboration with domestic and foreign material vendors, university researchers, and major laser diode manufacturers ***FY 2016 Accomplishments:*** Explored novel fiber designs to increase power while preserving high beam quality for enabling laser directed energy weapons; and investigated power scaling of continuous wave (CW) and pulsed mid-wave infrared (IR) sources for IR countermeasure (IRCM) applications as well as pulsed eye-safe lasers for scanning Laser Development (LADAR) application ***FY 2017 Plans:*** Will investigate bulk solid-state and fiber laser materials and architectures for power scaling with the high beam quality required for directed energy, targeting, and IRCM applications; and design and develop RF photonic optical signal processing capabilities which will enable the near instantaneous, high resolution spectral analysis of broadband RF signal pulses with bandwidths up to 75 GHz. ***FY 2018 Plans:*** Will investigate innovative glass fiber laser architectures and bulk solid state laser materials and designs best suited for high energy per pulse operation with emphasis on low size, weight and power (SWAP) for applications including track illuminator lasers for DEW, Joule-class pulsed in-band Mid-Infrared sources for imaging sensor defeat, and Light Wave Infrared (LWIR) illuminators for operation in degraded visual environments; and will develop structures, devices, and architectures to enable optical phased arrays capable of handling high peak power transmission and low loss reception.	1.922	2.000	2.006
Title: Directed Energy (DE) /Electronic Attack Technologies/Spectrum Sensing and Exploitation ***Description:*** This effort investigates and evaluates emerging technologies related to electronic warfare (EW) applications, non-kinetic survivability/lethality, and emerging concepts of operation, such as cognitive radar, in the increasingly contested and	2.234	2.346	2.456

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		Date: May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** EM8 / *High Power And Energy Component Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
congested electromagnetic environment, with the goal of enhancing the survivability/lethality of Army platforms through electronic attack (EA), electronic warfare support (ES), and electronic protection (EP). ***FY 2016 Accomplishments:*** Designed EP device technologies for Next Generation Radar requirements by examining the adaptive RF technology threat against Army radar performance. ***FY 2017 Plans:*** Will apply EW device forensic concepts, methodologies, and techniques to Army Counter Unmanned Aerial System (CUAS) mission applications; and study the effects of RF energy against various unmanned aerial vehicle (UAV) targets in order to develop neutralization techniques that can be incorporated into existing and emerging EW systems. ***FY 2018 Plans:*** Will develop multi-device waveform packages for CUAS EA applications; will explore distributed low-cost ES sensors and applications to enhance situational awareness and enable novel and precise EA capabilities; will investigate next-generation radar EP performance in a complex electromagnetic environment; will develop a cognitive spectrum sensing test-bed with advanced signal processing algorithms to support EP and RF spectrum exploitation objectives such as cognitive radar; and will design and develop a full array of Cyber Electromagnetic Activities (CEMA) to investigate and validate the impact on developmental technologies and systems.			
Title: Electronic Components and Materials Research ***Description:*** Investigate and evaluate compact, high-efficiency, high-temperature, and high-power component technologies (e.g., semiconductor, magnetic, and dielectric devices) for hybrid-electric propulsion, electric power generation and conversion, and smart micro-grid power distribution. Research addresses current and future Army-unique performance and operational requirements. ***FY 2016 Accomplishments:*** Evaluated and designed reliability models of current and next generation wide band-gap semiconductor electronic components for device enhancements; determined advanced control and diagnostic methods for power switches to improve fault tolerance and efficiency; and validated concept for high voltage, high performance devices for operations above 20kV. ***FY 2017 Plans:*** Will evaluate the relationship between material quality and growth processes on electronic properties in Gallium Nitrade (GaN)-based wide-bandgap materials; investigate available GaN power device architectures and material systems for improving	3.109	3.464	2.993

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		Date: May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** EM8 / *High Power And Energy Component Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
reliability of electronic switching devices; and validate physics-based models of high-voltage power devices to enable improved performance and understanding of device operation. ***FY 2018 Plans:*** Will investigate ultra-wide band-gap power devices, architectures, and materials for power switching and distribution; will modify and validate high voltage physics-based model to support GaN based devices to provide better understanding of device operation and physics for improved reliability and performance; will conduct analysis of motor operation at high frequency or high voltage to determine feasibility of high torque, low revolutions per minute (RPM) motors; will investigate high frequency circuit topologies and, through modeling and component analysis, evaluate reliability and performance of circuit designs; will investigate designs, materials, and additive manufacturing processes that enable low cost, high performance power device packaging; will research AlGaN (aluminum GaN) material properties leading to the growth of high speed transistors and diode devices; and will explore AlGaN structures by varying substrate and epitaxial growth conditions.			
Title: Power System Components Integration and Control Research ***Description:*** Research and evaluate the configuration of electronic components and control strategies required to achieve high-power density and high-efficiency power utilization in current and future platform sub-systems and vehicle and micro-grid (installation) applications, to include the operation of military-specific power distribution topologies at the circuit and system levels. ***FY 2016 Accomplishments:*** Researched and validated a universal power conversion concept that converts any input power to any output power for vehicle and micro-grid power applications; investigated controls for Tactical Energy Network control and prediction techniques, allowing any power input to feed any output power specification; designed distributed control and storage models to demonstrate more reliable and failure tolerant grids; and investigated, through modeling and analysis, the use of direct current and hybrid grid based technologies for the Army Tactical Energy Network. ***FY 2017 Plans:*** Will design electric- and magnetic-field sensors and processing algorithms to monitor micro-grid power; characterize power system components and support self-aware energy network architectures; validate distributed models and control algorithms enabling fault tolerance in Army energy networks; evaluate models of novel, distributed control and storage methods to improve energy efficiency of Army tactical energy networks; and investigate concepts for significantly reducing the volume of high-voltage power conditioning circuits, thereby enabling use in a projectiles and other compact lethality and protection systems. ***FY 2018 Plans:*** Will investigate control methods and components that enable reconfigurable power conversion based on varying voltage to reduce the size, weight, and power of conductors in constrained applications; will investigate concepts for compact and efficient high voltage power distribution topologies and control methodologies for continuous power applications; will analyze and model	3.221	3.606	3.177

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		Date: May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** EM8 / *High Power And Energy Component Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
concepts for significantly reducing the volume of high-voltage power conditioning circuits for use in projectiles and other compact lethality and protection systems; will develop designs and control methodologies for novel, low voltage alternating current (AC) and direct current (DC) distributed control and storage technologies to improve energy efficiency of Army tactical energy networks; will develop underpinning electric- and magnetic (E/H)-field technologies to support persistent power and energy monitoring of microgrid infrastructures and other systems; and will develop algorithms to robustly characterize E/H-field multi-scale events in complex noise environments.			
Accomplishments/Planned Programs Subtotals	11.673	11.416	10.632

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

N/A

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army			**Date:** May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** H11 / *Tactical And Component Power Technology*	

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
H11: *Tactical And Component Power Technology*	-	11.353	8.714	8.332	-	8.332	7.652	7.850	8.048	8.215	-	-

A. Mission Description and Budget Item Justification

This Project identifies, advances, and enhances emerging power generation, energy storage, and power management components and software. This Project researches advancements in enabling power management, decision making, and distribution across the battlefield. This Project also researches materials and components to develop lightweight, higher capacity, safer and more efficient power technologies that will enable self-sustainable, energy aware, continuous power generation while on the move and across battlefield environments.

The cited work is consistent with the Assistant Secretary of Defense for Research and Engineering Science and Technology priority focus areas and the Army Modernization Strategy.

Work in this Project is performed by the Army Research, Development and Engineering Command (RDECOM), Communications-Electronics Research, Development, and Engineering Center (CERDEC), Aberdeen Proving Ground, MD.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Tactical Power Generation Technology	6.451	4.034	3.625

Description: This effort designs, investigates and validates Soldier-borne power generation and energy storage technologies in order to decrease Soldier load and power burden, increase power capabilities by providing more energy to prolong mission run-time. This effort will investigate energy harvesting devices while on the move which will enable a net zero capable Soldier. This effort will also investigate advanced hybrid battery chemistries for wearable, flexible battery designs.

FY 2016 Accomplishments:

Matured hybrid power sources to increase power and energy densities and reliability for high energy density devices; optimized electrolyte formulations and cathode materials to improve safety for higher energy and power solutions; researched existing and novel energy storage and power generation components to ensure their compatibility within the Soldier power grid; increased efficiency and optimized internal components of multi-fueled generator to facilitate development of a smaller, more portable device; investigated various wireless power transfer technologies and increased efficiencies to enhance power transmission distances; researched and designed interoperable devices capable of utilizing energy harvesting technologies to charge Soldier wearable hybrid power sources to achieve a net-zero energy posture; and investigated wireless solution for net-zero energy approach.

FY 2017 Plans:

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		Date: May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** H11 / *Tactical And Component Power Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Will continue to investigate energy harvesting technologies and power generation components that produce usable power/energy for charging conformal batteries, mature internal component to facilitate a reliable power output, and conduct experiments on energy harvesting components to validate designs for increasing efficiency and power output; continue to investigate advanced lithium and hybrid battery chemistries for conformal battery designs; research novel energy storage chemistries, mature electrolyte and cathode materials to ensure safe, bullet tolerant conformal batteries, and mature components and formulations to safely increase power and energy densities to support extended missions. ***FY 2018 Plans:*** Will investigate and evaluate improvements to generator component technologies in energy harvesting devices for power conversion efficiency and enable more power generation on the move for near NetZero (produces as much energy as it uses) operations; investigate advanced lithium primary and rechargeable battery chemistries that are low cost and have the potential to double the runtime of current battery technology; conduct lab experiments on advanced battery cells configured with new chemistries, electrodes and electrolytes to validate the stability of the formulation and improvements in capacity; develop cell components to further improve the usable capacity within the ballistic battery to enable 20+ hours of continuous power; investigate fuel reformation techniques along with advanced materials to develop a small form factor, multi-fueled, wearable power source.			
Title: Energy Informed Operations ***Description:*** This effort investigates power management technologies, components and systems to increase the efficiency of energy output, reduce weight and increase reliability, while increasing fuel and cost efficiency across battlefield environments. This effort funds research in control and interface standards for effective power management, novel power distribution techniques, situational awareness, predictive, and prognostic and diagnostics capabilities for tactical power missions. This effort will also investigate scalable brass board designs for power management and distribution in support of missions in the 60 kilowatt (kW) – 360kW range. Work in this effort complements Program Element (PE) 0603772A/Project 101. ***FY 2016 Accomplishments:*** Investigated new software and physical architectures to more efficiently distribute and manage power across the battlefield while reducing size and weight; developed predictive-analysis modeling software to enhance selection and employment of energy sources during the planning and execution mission phases, respectively; continued investigating techniques to reduce the energy demand of Soldier-worn peripherals; assessed draft standards for a centralized micro-grid approach and develop standards for a distributed micro-grid; designed a micro-grid architecture that distributes control to various power managers between the mission command system and smart power devices allowing for a mesh power network; continued research and design of smart power devices that can be monitored and controlled by the Commander, staff, or autonomously to prioritize loads, reduce fuel	4.902	4.680	4.707

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		Date: May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** H11 / *Tactical And Component Power Technology*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
consumption, and ensure reliable mission power; designed and fabricated improved renewable, alternative fuel, and high fuel-efficiency power sources to supplement base power and further reduce logistic footprint. ***FY 2017 Plans:*** Will draft interface specification for new software and physical architectures to more efficiently distribute and manage power across the battlefield; assess draft standards for distributed micro-grid; investigate additional approaches to distributed designs such as hierarchal design; continue research and design of smart power devices that can be monitored and controlled by the Commander, staff, or autonomously to prioritize loads, reduce fuel consumption, and ensure reliable mission power; investigate novel distribution (wireless) technologies to reduced power loss or ease set up burden in power distribution systems. ***FY 2018 Plans:*** Will simulate power micro-grid architecture, standards and interface specification for controller software and expand and update interface specification for software and physical architecture design to more efficiently distribute and manage power across the battlefield based on results of simulation; explore a domain-based approach for standards for distributed micro-grid; investigate performance and design of smart power generation and distribution devices such as generators, inverters, distribution boxes, energy storage and renewable energy systems, that can be managed, monitored and controlled by Soldiers or autonomously to prioritize load, reduce fuel consumption and ensure reliable mission power based on a distributed, rather than a centralized control approach; design architecture and software to incorporate wireless data technologies for the purpose of reducing power loss, complexity of setup and startup, and weight in power distribution systems; investigate the use of secure WiFi (wireless internet) and power line carrier methods to transmit control and status signals; analyze novel wireless power transmission technologies such as far field (for distances over 0.25 kilometers) power transfer based on microwave and laser power transmission technologies.			
Accomplishments/Planned Programs Subtotals	11.353	8.714	8.332

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

N/A

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		**Date:** May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** H17 / *Flexible Display Center*

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
H17: *Flexible Display Center*	-	1.091	2.356	2.143	-	2.143	1.200	0.752	0.301	0.313	-	-

A. Mission Description and Budget Item Justification

The flexible electronics program conducts applied research on the integration of electronics, power components, and sensors on non-traditional flexible substrates. The program builds upon two-dimensional flexible electronics to incorporate the integration of electronic components, power systems, and sensors into three-dimensional flexible architectures. The research includes electronic modeling, design, fabrication, experimentation and analysis. The applied research supports the demonstration of Army-relevant sensors on flexible substrates for Army applications such as monitoring of the human state.

This project supports Army science and technology efforts in the Command, Control, Communications and Intelligence portfolio.

The cited work is consistent with the Assistant Secretary of Defense for Research and Engineering Science and Technology priority focus areas.

Work in this project is executed by the Army Research Laboratory (ARL), Adelphi, MD.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Flexible Electronics Development (previously Flexible Display Center (FDC) and Flexible Electronics Development) ***Description:*** The flexible electronics program is advancing applied research towards the integration of electronics, power components, and sensors on non-traditional flexible substrates and into three-dimensional (3D) architectures. ***FY 2016 Accomplishments:*** Designed flexible hybrid electronic systems integrating traditional silicon electronics, sensors, and power. The applications included flexible sensing systems with components mounted on two-dimensional flexible substrates and integrated into three-dimensional structures for Soldier and small platform applications. ***FY 2017 Plans:*** Will design flexible hybrid electronic systems for human assessment, integrated three-dimensional support structures, and appropriate controls and sensor processing for health monitoring; and explore team or squad level resource optimization. ***FY 2018 Plans:*** Will investigate hybrid 3D printed sensors with integrated silicon (Si) complementary metal-oxide-semiconductor (CMOS) electronics; investigate co-design of algorithms, power distribution, and 3D printed sensors and electronics for extended duration monitoring of soldier's physiological and environmental state; examine and develop noise resistant and computationally efficient algorithms coupled to distributed sensing and computation hardware to enable real-time estimate of the human physiological state; investigate hardware, algorithms, and architectures to enable efficient, robust physiological monitoring of individuals within	1.091	2.356	2.143

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		Date: May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** H17 / *Flexible Display Center*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
small, distributed groups; and will develop silicon-fiber based liquid metal inductors as well as develop and improve the fabrication process for stretchable gallium nitride (GaN) in silicon, which enables electronic monitoring of Soldiers performance on or close the skin without discomfort.			
Accomplishments/Planned Programs Subtotals	1.091	2.356	2.143

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

N/A

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army			**Date:** May 2017
Appropriation/Budget Activity 2040 / 2	**R-1 Program Element (Number/Name)** PE 0602705A / *Electronics and Electronic Devices*	**Project (Number/Name)** H94 / *Elec & Electronic Dev*	

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
H94: *Elec & Electronic Dev*	-	29.537	33.836	37.245	-	37.245	36.665	37.870	39.422	40.492	-	-

A. Mission Description and Budget Item Justification

This Project designs and characterizes electronics, electronic components, and electronic devices for Command, Control, Communications, Computers, Intelligence, Surveillance, and Reconnaissance (C4ISR) applications and battlefield power and energy applications. Significant areas of component research relevant to C4ISR include: antennas, millimeter wave components and imaging, micro- and nano-technology, eye-safe laser radar (LADAR), vision and sensor protection, infrared (IR) imaging, photonics, and prognostics and diagnostics. Areas of research relevant to power and energy include power and thermal management, micro-power generators and advanced batteries, fuel reformers, fuel cells for hybrid power sources, and photosynthetic routes to fuel and electricity.

This Project supports Army science and technology efforts in the Command Control and Communications, Soldier, Ground and Air portfolios. Work in this Project is fully coordinated with PE 0602709A (Night Vision Technology), PE 0603001A (Warfighter Advanced Technology), PE 0603004A (Weapons and Munitions Advanced Technology), PE 0603005A (Combat Vehicle and Automotive Advanced Technology), PE 0603008A (Command, Control, Communications Advanced Technology), PE 0603313A (Missile and Rocket Advanced Technology) and PE 0603772A (Advanced Tactical Computer Science and Sensor Technology).

The cited work is consistent with the Assistant Secretary of Defense, Research and Engineering Science and Technology priority focus areas.

Work in this Project is performed by the Army Research Laboratory (ARL), Adelphi, MD.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Title: Antennas, Microwave Components, and Millimeter Wave Imaging (formerly Antennas and Millimeter Wave Imaging)	8.193	0.657	5.733
Description: This effort designs, characterizes, and validates high performance antenna, microwave components, and software for multifunction radar, radio frequency (RF) sensing, and communication systems. Research areas include scanning techniques, broadbanding, beamforming, polarization, platform integration, and affordability. For microwave components, research areas include software defined radios, analog-to-digital conversion rates, bandwidth resolution, bit accuracy, circuit design and affordability. ***FY 2016 Accomplishments:*** Devised and characterized carbon nanotube antennas woven into the fabric of the soldier's uniform; and performed in-situ simulation of printed antenna designs and low-profile metaferrite antenna designs. ***FY 2017 Plans:*** Will design and develop low profile apertures which meet future low-visibility signature requirements while maintaining RF performance; use advanced modeling to characterize electromagnetic performance of antennas and RF devices for Army			

B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
applications; exploit the latest developments in engineered metamaterials with high permeability as the enabling technology for low-profile antennas; create antennas suitable for dismounted operations using carbon nanotube technology; develop antenna array designs using phase-change materials as the enabling technology to allow high performance beam steering; and develop specialized antenna designs for human health monitoring suitable for use by dismounted soldiers actively engaged in tactical operations. ***FY 2018 Plans:*** Will develop an analytical methodology that will define key electrical parameters for antenna optimization; will use this methodology to define electrical parameters in computer simulations; will develop experimental antennas exploiting previous materials development work at ARL; will investigate devices and materials for two-dimensional steering of millimeter-wave radar beams for applications such as helicopter collision avoidance in degraded visual environments; will design, fabricate, and characterize gallium nitride (GaN)-based integrated circuits for multi-mode radar applications; will examine techniques to achieve compact, linear RF front-end components to increase radar range and sensitivity; will mature RF micro-electromechanical system (MEMS)-enabled electronics for cognitive and adaptable radio and electronic warfare systems; and will investigate small, low-power sensors and control systems for use by soldiers and in unmanned applications.			
Title: Advanced Micro and Nano Devices ***Description:*** This effort designs and characterizes micro- and nano-technology components for multi-functional and integrated RF applications, micro-robotics, integrated energetics, control sensor interfaces, and sensors for improved battlefield situational awareness. Work being accomplished under PE 0601102A / Project H47 (Applied Physics Research) complements this effort. ***FY 2016 Accomplishments:*** Designed and characterized MEMS components for cognitive RF systems, low power Global Positioning Systems (GPS), and sensor technologies for improved Position, Navigation and Timing (PNT); designed and developed hardware and algorithms for distributed sensing, micro-autonomous system control and chip-scale integration of energetic nanoporous silicon for fuze initiation; characterized digital circuits on flexible stacked 2-dimensional (2D) electronic materials (e.g. graphene, molybdenum disulphide, boron nitride); and explored and optimized the RF performance of stacked 2D electronic materials. ***FY 2017 Plans:*** Will develop, integrate, and characterize RF MEMS components (e.g., filters, tunable passives and switches) for cognitive and adaptable radio and electronic warfare systems; continue development of a MEMS quad mass gyroscope with integrated active materials and sensor methods for assured PNT; design, analyze and formulate 2D material device structures for high frequency and low power analog RF and digital electronics; validate chip-scaled integration of energetic nanoporous silicon for device	2.080	2.155	1.947

Exhibit R-2A, RDT&E Project Justification: FY 2018 Army		Date: May 2017
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
protection and fuze initiation; and integrate and characterize size, weight, power, and processing-constrained electronics, MEMS, and control algorithms for micro-autonomous systems, smart munitions, and soldier cognitive systems. ***FY 2018 Plans:*** Will explore 2D stacked electronic materials and tunable electronic properties for multifunctional integrated RF circuits; will mature piezoelectric-enabled RF MEMS components for cognitive and adaptable radio and electronic warfare systems; and will investigate integration of on-chip energetic materials for low-cost electronic device protection.			
Title: Security and Survivability for Wireless Tactical Networks (formerly Millimeter Wave and Microwave Components and Architectures for Advanced Electronic Systems) ***Description:*** This effort researches, designs and implements protocols and algorithms for networks of physical devices and autonomous systems operating under severe energy and bandwidth constraints, and which are vulnerable to adversarial infiltration. The objective is to enhance the performance and survivability of these tactical wireless networks through improved monitoring and detection of network problems, resulting from both adversarial activity and the operating environment, and through proactive adaption of the computer and network routers to these dynamics. ***FY 2016 Accomplishments:*** Investigated trade space for device and circuit performance requirements for application to future radar and sensing systems; correlated trade space results with emerging needs from communication systems to enable multiple-function hardware as RF frequency-performance requirements converge. ***FY 2017 Plans:*** Will investigate non-linear and linear RF architectures for advanced sensing applications; develop thermal models for III-V semiconductor devices enabling operations at multiple millimeter-wave bands; explore tunable and adaptive RF circuit topologies to enhance performance over conventional broadband circuit designs; design, model, and characterize circuits capable of supporting multiple bands while maintaining high power-added efficiency and output linearity; fabricate device and chip-level devices to validate improved RF capability in output power, efficiency, and bandwidth; develop miniature acoustic particle velocity sensors for battlefield threat awareness; develop MEMS-scale electric- and magnetic-field sensors to attach to power-lines for reconnaissance and surveillance applications; establish techniques to quantify protocols; generate secure networking protocols for deployment on resource-constrained devices and wireless/wired networks; and improve situational awareness through event and data reasoning via machine learning and statistical methods. ***FY 2018 Plans:***	0.369	5.617	1.567

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2016**	**FY 2017**	**FY 2018**
Will investigate and implement scheduling algorithms that dynamically adapt based on local- and network-wide conditions; will investigate network capacity improvement techniques; and will develop machine learning approaches for detecting, characterizing, diagnosing, and defeating potentially malicious activities in networks of physical devices and autonomous systems.			
Title: Vision Protection (formerly Imaging Laser Radar (LADAR) and Vision Protection) ***Description:*** This effort develops and characterizes materials for passive protection of electro-optic (EO) vision systems from lasers. ***FY 2016 Accomplishments:*** Researched active EO shutter systems that do not need a focal plane to activate and explored their implementation in Army optical systems; explored magneto-optic materials for use in protecting IR systems; investigated LADAR concepts for ultra-light or large UAV navigation; and studied novel and advanced optical science concepts, such as computational imaging and holography for enhanced imaging and sensing applications. ***FY 2017 Plans:*** Will extend the potential of EO techniques for the protection of shortwave-infrared (SWIR) detector and imaging systems against laser threats; and research and improve large-area EO shutters for simplified protection of optical systems on Army platforms. ***FY 2018 Plans:*** Will deposit EO material for protection on substrates with very high thermal conductivity to provide improved temperature control and reduced power consumption in fast EO shutter devices; and will optimize active protection concepts in the infrared (IR) for improved speed and threat laser wavelength rejection.	2.194	2.780	2.914
Title: Hazardous Material Detection (formerly Photonics and Opto-Electronic devices) ***Description:*** This effort investigates and characterizes novel sensor components and architectures to enable detection of hazardous substances for enhanced Soldier situational awareness and survivability. ***FY 2016 Accomplishments:*** Conducted spectral analysis investigations of candidate spectroscopic detection technologies to include femtosecond Coherent Anti-Stokes Raman Scattering and infrared photothermal spectroscopy; studied functional biomaterials in austere environments including the effect of temperature and other degradation pathways; and studied and modeled biological materials designed with specific functionality and stability for their interaction and affinity with non-biological materials such as metals. ***FY 2017 Plans:*** Will develop capability to integrate biological materials into biological assays and sensor systems and evaluate performance after thermal exposure to simulated harsh unconditioned storage conditions; and extend peptide material discovery to develop	0.950	1.910	1.957

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
bio-hybrid materials which incorporate benefits of biological and synthetic materials for advantages such as self-assembly and self-healing and environmental response materials. Will investigate fiber-based collinear Multiplex Coherent Anti-Raman Spectroscopy (M-CARS) as a viable technique for explosives detection in liquid and solid samples; will characterize sensor components using different technical approaches, including magnetic and electromagnetic induction, to detect buried explosive devices; and investigate sensor node components that enable local data processing on the sensor node, communications between nodes in a sensor network, and distributed sensor information fusion. ***FY 2018 Plans:*** Will evaluate, characterize, and model mechanisms in semiconductor materials that can reduce thermal noise in IR devices and allow them to operate at higher temperatures, reducing the need for cryogenic cooling; will model and simulate to improve IR system-level performance; will model and develop energy efficient, compact semiconductor ultraviolet (UV) laser sources and detectors for short-range, non-line-of-sight communications; and will develop interfaces to connect biochemical signal detection with on-chip photonics and electronics for improved detectors.			
Title: Power and Thermal Management for Small Systems ***Description:*** This effort investigates, designs, and fabricates MEMS-based components to improve power generation and micro-cooling technology for both dismounted Soldier and future force applications. ***FY 2016 Accomplishments:*** Implemented techniques for thermal interface measurements to characterize heat transfer in novel materials; developed compact 3-Dimensional (3D) integration techniques for power electronic devices; investigated novel methods for improving condensation heat transfer through acoustic excitation and surface enhancement; investigated integration of phase change materials into electronic packages for temperature spike suppression; investigated improved micro-fabrication techniques for microscale power devices to be used in power supply systems; investigated wireless energy conversion techniques for powering wearable and portable devices; developed fabrication processes for stretchable, wearable, and light-weight power components; investigated thermoelectric, pyroelectric, and thermo-photovoltaic power generation techniques and materials for applicability in direct power generation; and characterized advanced materials for improved fuel conversion efficiency and apply them toward developing improved reaction models. ***FY 2017 Plans:*** Will use new thermal interface measurement techniques to identify interface properties for optimizing heat transfer in new materials systems; implement methods for improving condensation heat transfer using acoustic excitation and surface enhancement; optimize micro-fabrication techniques for micro-scale power devices for compact power sources and conversion; experimentally validate stretchable, wearable, light-weight power components integrated into fabric; identify optimum phase change materials for temperature spike suppression in electronic packages; implement superlattice thermoelectric materials, thin-	3.299	2.026	0.891

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
film pyroelectrics, and multi-fuel thermophotovoltaic devices for direct power generation; and optimize reaction models and apply them towards the development of micro-combustion applications with improved fuel conversion efficiencies. ***FY 2018 Plans:*** Will improve the size, weight, and packaging of electronics with higher thermal handling characteristics; and will utilize excess heat through thermal-to-electric conversion for more energy efficient electronics via new materials, device technologies and structures, as well as the use of novel physical phenomena.			
Title: Emerging Electronic Devices and Circuits ***Description:*** This effort investigates and characterizes emerging electronics such as analog, mixed signal, and millimeter wave. Efforts entail design, fabrication, and analysis of electronic devices and integrated circuits for use in extreme environments necessary for Army applications. ***FY 2016 Accomplishments:*** Explored emerging materials, components, and circuits that enable low energy and power efficient RF devices; designed novel integrated circuits that provide improvements in power efficiencies, linearity, and noise; and explored system/chip constraints for ultra-linear performance to enable Soldier-level communication in contested RF environments.	1.644	-	-
Title: Advanced Infrared Technology (foremly Infrared (IR) Imaging) ***Description:*** This effort designs and characterizes materials, components, and focal plane arrays (FPAs) for the next generation of night vision systems, missile seekers, and general surveillance devices. Materials and devices investigated include mercury cadmium telluride (MCT) and resonant quantum well infrared photodetector (R-QWIP) arrays for both the mid-wave infrared (MWIR) and long-wave infrared (LWIR) spectral regions with goals to increase the operating temperature and decrease the cost of FPAs. Additionally, modeling of infrared device performance, at both the device and system levels, is being performed for all major infrared systems (MCT, R-QWIP, Indium antimonide (InSb), and strained layer superlattices) of importance to the community. ***FY 2016 Accomplishments:*** Investigated extremely low-doped MCT IR material grown on domestically available lattice matched substrates for different spectral regions, including SWIR and LWIR applications; studied effects of thermal cycle annealing on MCT material as it pertains to dopant species and profiles; studied the implementation of resonant features on MCT for higher temperature operation; and characterized and analyzed R-QWIP material and devices for improved quantum efficiency and operating temperature. ***FY 2017 Plans:*** Will characterize and analyze broadband and two-color (LWIR/LWIR and LWIR/VLWIR) R (Resonant)-QWIP and resonant strained layer superlattice arrays for hyperspectral and other Army applications; investigate resonant MCT structures for LWIR imaging at higher operating temperatures than is currently available; expand device modeling capabilities to three dimensions	2.194	1.695	-

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2016**	**FY 2017**	**FY 2018**
to garner a better understanding of the interplay between photon absorption, charge drift and diffusion, and passivation with the choice of device architecture (mesa or planar) and material parameters; and develop a process for passivation of MCT IR arrays using cadmium telluride atomic layer deposition for maximal conformal coverage.			
Title: Power and Energy ***Description:*** This research focuses on the design and characterization of chemistries, materials, and components for advanced batteries, fuel reformers, and fuel cells. Potential Army applications include hybrid power sources, smart munitions, hybrid electric vehicles, and Soldier power applications. Additionally, investigate the applicability of photosynthesis to provide fuel and electricity for Soldier power applications, and investigate silicon carbide (SiC) power module components that could enable compact, high efficiency, high temperature, and high power density converters for motor drive and pulse power applications. The research accomplished under PE 0601104A/Project VS2 (multi-scale modeling) complements this effort. ***FY 2016 Accomplishments:*** Characterized and transitioned 5-volt lithium ion battery electrodes and electrolytes for development of a sample cell for laboratory testing and assessment; investigated novel battery chemistries for Soldier power; characterized new alkaline membranes for fuel cell applications; developed lower cost catalysts for alkaline fuel cells; developed regenerable sulfur sorbents for desulfurization of JP8 at temperatures of 300-400 degrees C; and determined degradation mechanisms and lifetimes of sulfur-tolerant palladium alloys for hydrogen separation from JP8 reformate for use in fuel cells. ***FY 2017 Plans:*** Will characterize aqueous lithium ion surface electrode interface mechanisms to develop safe, novel, aqueous battery chemistries; fabricate bipolar membrane materials and membrane electrode assemblies for reduced size, weight and complexity of compact fuel cells; investigate effects of 3D anode/cathode electrolyte cell structures versus conventional structures in lithium ion batteries; further improve regeneration of sulfur-sorbent materials for room temperature JP8 fuel desulfurization; and perform spectroscopic analysis of hydrogen separation in palladium alloys to establish JP8 reformate reaction mechanism. ***FY 2018 Plans:*** Will investigate the deactivation mechanism of hydrocarbon combustion catalysts through in-situ studies with advanced spectroscopy and electron microscopy and develop strategies to design highly active and durable catalyst materials for compact power generation; will develop improved electrolytes for high voltage storage chemistries; will optimize development of high voltage electrolytes, additives and cathodes for energy density and safety; will improve rise time and duration of thermal batteries within size, weight and power (SWAP) constraints; and will develop an acid-alkali fuel cell membrane electrode assembly.	3.882	2.837	2.783
Title: Sensor Protection Technologies	2.444	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2016**	**FY 2017**	**FY 2018**
Description: This research will develop technologies to specifically address laser threats at different frequencies (e.g. ultraviolet, infrared) and at a variety of pulse widths (continuous wave (CW), nanosecond, femtosecond). This research will develop technologies to protect Army radars by agile spectrum exploitation, reconfigurable high speed switching technology, and novel RF power limiters and switching devices to protect RF front-ends (RFFEs) in contested environments as well as from self-interference challenges where multiple RF systems are operating in close proximity. ***FY 2016 Accomplishments:*** Studied new materials and devices to counter the laser threat against sensors, particularly the threat of wavelength-agile lasers as threats evolve toward directed high energy weapons and ultrafast femtosecond pulsed lasers, to include short-wavelength infrared and MWIR sensor protection; investigated new techniques for protection against continuous-wave (CW) high energy laser threats; and characterized materials as optical limiters against femtosecond pulsed laser threats across a variety of wavelengths (visible through MWIR).			
Title: Energy Harvesting ***Description:*** This research develops technologies to substantially reduce the number of batteries required to accomplish dismounted Soldier/Squad mission objectives, thereby significantly reducing Soldier-borne load and logistics requirements. Research will explore technologies to harvest electrical power by converting and storing energy via engineered structures and electronic bandgaps, MEMS-based micro-scale power conversion, and heterogeneous 3D assembly of MEMS with other devices to enable efficient, distributed power conversion. Research explores novel paths to local fuel and energy production, including artificial photosynthesis, to extract hydrogen and electricity directly from water and sunlight. ***FY 2016 Accomplishments:*** Studied the properties of bandgap engineered indium gallium nitride and highly mismatched alloys to develop the capability to split water to produce hydrogen to use for fuel or as intermediates for fuel; characterized thermoelectric and pyroelectric material properties for energy harvesting; investigated and characterized properties of ultra-energetic (isotopic/isomeric) materials and matched energy conversion structures as a long endurance energy source; and refined growth parameters for novel photoelectric materials for use with non-solar applications. ***FY 2017 Plans:*** Will characterize electrical and optical performance of bandgap-engineered gallium nitride for water splitting for hydrogen-derived fuel intermediaries; develop improved, thin-film pyroelectric and thermal materials and packaging for high-rate thermal cycling; investigate properties of ultra-energetic (e.g., isotopic/isomeric) materials for enhanced energy and/or gamma release mechanisms; develop photovoltaic devices with surface nanostructures for broad-angle, anti-reflection and light-trapping	2.288	2.524	2.764

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
capabilities to improve power generation; and investigate integration of novel, stretchable, passive electronics for Soldier energy harvesting applications and wireless energy transfer. ***FY 2018 Plans:*** Will develop photo-corrosion mitigation strategies that will enable stable photo-electrolysis to produce hydrogen gas; will develop catalysis process for faster electron transfer, create engineered polarization in gallium nitride devices, develop highly mismatched alloy material with good electronic and optical properties for water molecule splitting; will develop spectral emission/transmission with spectrally tailored bandgap cells to increase far-field thermo-photovoltaic conversion efficiency; and will develop polariton modes between emitter and cell to increase conversion efficiency and power density. Will develop photo-corrosion mitigation strategies that will enable stable photo-electrolysis to produce hydrogen gas; develop catalysis process for faster electron transfer, create engineered polarization in gallium nitride devices, develop highly mismatched alloy material with good electronic and optical properties for water molecule splitting; develop spectral emission/transmission with spectrally tailored bandgap cells to increase far-field thermo-photovoltaic conversion efficiency; and will develop polariton modes between emitter and cell to increase conversion efficiency and power density.			
Title: Energy Efficient Electronics & Photonics (formerly Energy Efficient Electronics) ***Description:*** This effort addresses sustainment operations by unburdening the Soldier and reducing logistics requirements (e.g., fewer batteries) for communications, computing, and sensing. The objective is to improve the underlying energy efficiency of supply and demand for soldier-portable and unattended sensor electronics to enable the dismounted Soldier to maintain communications, freedom of movement, and increase mission duration. The majority of the electronics power used by the dismounted soldier and by unattended sensors is attributable to RF communications. In addition, freedom of movement and action during sustained and high tempo operations requires seamless battery recharging. To address these challenges, energy efficient electronics research includes RF circuits, devices, materials and wireless power distribution. Energy efficiency improvements will be developed and investigated in support of five key sensor and electronic areas: RF component devices, passively powered components, low-power, long-lived sources, wireless power transfer, and advanced battery chemistries. Additionally, materials and devices used for photonic applications, such as laser diodes and fiber lasers, will be studied and improved with an emphasis on overall size, weight, and power consumption efficiency gains. ***FY 2017 Plans:*** Will measure and characterize performance of heterogeneous materials integrated into radio frequency front-end components (e.g., amplifiers, filters, and switches); design and simulate performance of realistic waveforms on ultra-low power field-programmable gate arrays (FPGA) and accelerator cores; develop an analog integrated circuit characterization capability; explore extramural prospects for low-power RF transceiver design techniques using leading node (analog) device technologies; and	-	5.023	5.538

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2016**	**FY 2017**	**FY 2018**
characterize passive voltage amplification with MEMS piezo-transformers and multi-layer copper air-core designs, efficient power management of isotopic power sources, and improved coupling in wireless transmission. ***FY 2018 Plans:*** Will explore heterogeneous integration of efficient III-V and II-VI semiconductor devices with leading edge process technology to enable small form-factor, highly linear RF circuits; will examine digital back-end accelerators for implementing realistic communication waveforms at substantially reduced power; will explore energy efficiency improvements by utilizing sub-threshold RF front-ends and high efficiency and high linearity analog components; will investigate vertical and lateral carrier transport in semiconductor laser diode structures towards the realization of large area UV emitters; will investigate the use of water-in-salt electrolytes to increase voltage window of supercapacitors and Li ion batteries and investigate the use of LiS in aqueous electrolytes for improved safety and improved energy storage; will increase coulombic efficiency of dual intercalation electrodes for inexpensive grid energy storage; will investigate additives to limit dendrite formation of Li metal batteries for high energy density rechargeable batteries; will investigate solid-state chemistries for safe Li batteries; will investigate enhanced acoustically-coupled inductive wireless power transfer; will reduce circuit power consumption through the design and fabrication of passively powered ambient sensors that enable zero power sleep mode for electronics; and will develop extremely low power, intelligent power management for low power, long-life electronics.			
Title: Precision Measurement Technology for Contested Environments (Technologies for Anti Access / Area Denial) ***Description:*** This research focuses on technologies that will enable precise and assured position, navigation and timing in GPS-denied environments. The first objective of this research is to improve the size, weight, power, cost, and accuracy of current micro-Inertial Measurement Systems (IMS) through the design, fabrication, and testing of MEMS gyroscopes. The second objective is to develop an opto-electronic device that can be used as an ultra-precise local oscillator with improved stability for precision timing applications. The third objective is to address the ability to transmit jam-resistant precision timing signals by investigating the transmission of precision, synchronized timing signals over optical fibers and free-space using lasers. The fourth objective is to explore new RF antenna concepts to extend the reach of IMS systems through pseudolites (ground-based substitutes for GPS satellites) and Soldier-borne systems, and to integrate multiple sensor modalities with the IMSs using sensor fusion techniques to reduce drift and increase positional accuracy. ***FY 2017 Plans:*** Will design and fabricate a MEMS quad mass gyroscope (QMG) to improve MEMS gyro performance to less than 1 degree-per hour bias instability; design and fabricate a vacuum packaging solution for a MEMS QMG that will achieve an in-package pressure a million times less than atmospheric pressure; investigate and analyze Optoelectronic oscillators (OEOs) and laser frequency comb architectures and the direct synchronization of an atomic cell signal to an OEO in order to create an ultra-stable local oscillator source that could increase the period of desired accuracy of military geolocation systems that require GPS synchronization from less than 1 minute to more than 1 hour; identify and develop techniques to suppress noise induced in a	-	2.512	2.941

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
transmission media, such as free-space, air, or optical fiber, by transmission of frequency signals via lasers to maintain frequency stability ten times better than GPS; and explore more compact anti-jam GPS and body-worn, textile-integrated antenna designs to support future pseudolite and dismounted Soldier navigation. ***FY 2018 Plans:*** Will characterize and analyze the residual frequency instability of a free-space, laser-based frequency transfer system that could be used to synchronize the Army's PNT devices in the absence of signals from GPS; will mitigate environmentally induced noise sources to increase the timing stability on optical-electronic devices used for precision timing; will investigate and develop MEMS inertial sensors, aiding sensors, and sensor fusion approaches to enable navigation-grade inertial measurement units for assured PNT; will conduct simulations and explore development of a new technique for anti-jam GPS antennas distributed on the human body; will develop methods for night-time three-dimensional reconstruction using thermal imagery for autonomous navigation and detection of medium to low emissivity surfaces (e.g., metals) at night to assist warfighters in locating manmade targets; will develop methods for real-time vegetation and land classification for aiding position/locality determination.			
Title: Anti-Tamper (AT) Technology Development ***Description:*** This effort develops tools, devices, and techniques to protect acquisition program systems and Critical Program Information (CPI) from adversarial threats. This work is executed by the Army Anti-Tamper Office located at the Aviation and Missile Research, Development and Engineering Center (AMRDEC) at Redstone Arsenal, AL. ***FY 2017 Plans:*** Will begin development of AT tools and techniques for commercial microelectronics, architecture-level AT technologies, threat-based sensors, and secure processor Intellectual Property (IP). ***FY 2018 Plans:*** Will mature AT tools, techniques and IP for projects Rigor 1 and Rigor 1a; will complete design of architecture-level AT integration technologies; will continue development of threat-based sensors and secure processor Intellectual Property (IP); will finalize contractual scope and tape-out for production of test parts from Trusted Foundry; and will receive and begin laboratory testing of Rigor devices.	-	4.100	5.025
Title: Cognitive Countermeasures Technology Development ***Description:*** This effort investigates and matures novel materials, components, and techniques to counter legacy and emerging threats to Army platforms. Emphasis will be placed on technologies and approaches to enable a robust, holistic countermeasure capability for target defeat, regardless of threat characteristics or guidance mode. ***FY 2018 Plans:***	-	-	2.010

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2016	FY 2017	FY 2018
Will design, model, and characterize advanced laser materials and architectures with low size, weight, power and cost to improve laser output power for aircraft survivability applications. Will explore potential for radio frequency technologies to enable early warning threat detection.			
Title: Technologies for Alternative Energy: ***Description:*** Design and develop novel concepts of energy generation, energy capture materials, and component technologies for efficient conversion of ambient energy to electrical energy for use and storage. Design components to include microscale power devices for multimodal harvesting and efficient distributed power conversion. ***FY 2018 Plans:*** Will investigate catalyzing carbon dioxide (CO2) to longer chain hydrocarbons for energy storage; will design a photo-electrochemical cell for studying CO2 conversion to a fuel; will develop cost effective energy storage solutions for microgrid applications to enable renewable resource integration; and will develop advanced concepts that lead to the development of nanophotonic components for energy harvesting and optimization of hybrid nanostructured materials for more efficient solar energy conversion.	-	-	1.175
Accomplishments/Planned Programs Subtotals	29.537	33.836	37.245

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

N/A