Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	**Date:** February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* I BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602715E I *MATERIALS AND BIOLOGICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
Total Program Element	-	144.409	206.115	220.456	-	220.456	233.910	254.357	262.098	266.659	-	-
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	90.101	124.172	121.703	-	121.703	110.492	118.560	121.928	125.928	-	-
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	54.308	81.943	98.753	-	98.753	123.418	135.797	140.170	140.731	-	-

A. Mission Description and Budget Item Justification

This program element is budgeted in the Applied Research Budget Activity because its objective is to develop material, biological and energy technologies that make possible a wide range of new military capabilities.

The major goal of the Materials Processing Technology project is to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced materials, devices and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of materials including structural materials and devices, functional materials and devices, energetic materials and devices, low distortion optical lenses, and materials that enable new propulsion concepts for land, sea, and space vehicles.

The Biologically Based Materials and Devices project acknowledges the growing and pervasive influence of the biological sciences on the development of new DoD capabilities. This influence extends throughout the development of new materials, devices, and processes and relies on the integration of biological breakthroughs with those in engineering and the physical sciences. Contained in this project are thrusts in the application of biomimetic materials and devices for Defense, the use of biology's unique fabrication capabilities to produce structures that cannot be made any other way, the application of materials in biological applications, and the development of manufacturing tools that use biological components and processes for materials synthesis. This project also includes major efforts aimed at integrating biological and digital sensing methodologies and maintaining human combat performance despite the extraordinary stressors of combat. Finally, this thrust will develop new cognitive therapeutics, investigate the role of complexity in biological systems, and explore neuroscience technologies.

Exhibit R-2, RDT&E Budget Item Justification: PB 2017 Defense Advanced Research Projects Agency	Date: February 2016
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total
Previous President's Budget	150.389	220.115	263.319	-	263.319
Current President's Budget	144.409	206.115	220.456	-	220.456
Total Adjustments	-5.980	-14.000	-42.863	-	-42.863
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	-14.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-1.400	0.000			
• SBIR/STTR Transfer	-4.580	0.000			
• TotalOtherAdjustments	-	-	-42.863	-	-42.863

Change Summary Explanation

FY 2015: Decrease reflects reprogrammings and the SBIR/STTR transfer.

FY 2016: Decrease reflects congressional reduction.

FY 2017: Decrease reflects a reduction to Materials Processing and Manufacturing efforts and completion of the Manufacturable Gradient Index Optics (M-GRIN) program.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		**Date:** February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-01 / *MATERIALS PROCESSING TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	90.101	124.172	121.703	-	121.703	110.492	118.560	121.928	125.928	-	-

A. Mission Description and Budget Item Justification

The major goal of the Materials Processing Technology project is to develop novel materials, materials processing techniques, mathematical models and fabrication strategies for advanced materials, devices and components that will lower the cost, increase the performance, and/or enable new missions for military platforms and systems. Included in this project are efforts across a wide range of materials including structural materials and devices, functional materials and devices, energetic materials and devices, low distortion optical lenses, and materials that enable new propulsion concepts for land, sea, and space vehicles.

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
Title: Materials Processing and Manufacturing	18.479	20.387	15.234

Description: The Materials Processing and Manufacturing thrust is exploring new manufacturing and processing approaches that will dramatically lower the cost and decrease the time required to fabricate DoD systems. It will also develop approaches that yield new materials and materials capabilities that cannot be made through conventional processing approaches as well as address efficient, low-volume manufacturing. As a result of recent advances in manufacturing techniques (3D printing, manufacture on demand, etc.) and the push towards programmable hardware in embedded systems, the development cycle from design to production of both hardware and software is severely bottlenecked at the design phase. Further research within this thrust, will create methods to translate natural inputs into software code and mechanical design. This process will complete underspecified designs when possible and initiate an iterative dialog with a human to specify details as needed and actively suggest changes to designers when the intended design cannot operate within the required specifications.

FY 2015 Accomplishments:
- Demonstrated integrated, physics-based, location-specific computational tools that predict the thermal history, residual stress, residual distortion, and microstructure of In718 alloys produced by direct metal laser sintering (DMLS).
- Implemented in-process quality assurance (IPQA) sensors and technology capable of capturing DMLS processing data and initiated development of optimized capture of real-time data at appropriate resolutions to forecast article quality.
- Demonstrated initial operational phenomenological metallurgical models that link electron beam direct manufacturing (EBDM) process parameters to microstructure and material properties for location-specific prediction of ultimate tensile strength throughout a built structure.
- Demonstrated automated X-Y-Z wire position control system based on real-time, fast rate, solid-state backscattered electron sensor system.
- Simulated high-fidelity probabilistic process window (including tails) for bonded composite structures using Monte Carlo techniques and a priori knowledge of process variables.

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-01 / *MATERIALS PROCESSING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Completed verified 2D and 3D bonded composite pi-joint structure models. - Established interoperable process-material model assessment framework, and curated and standardized a data management system to capture and store data from materials and manufacturing research. ***FY 2016 Plans:*** - Complete design of experiments-optimized model for the probabilistic process model. - Demonstrate predictive capability of the probabilistic process model. - Complete optimized phenomenological yield strength model for electron beam additive manufacturing (EBAM). - Complete neural network and genetic numerical analysis for EBAM process. ***FY 2017 Plans:*** - Complete verification and validation of probabilistic processing model suite. - Validate phenomenological model framework. - Demonstrate rapid qualification capability on demonstration components.			
Title: Multifunctional Materials and Structures ***Description:*** The Multifunctional Materials and Structures thrust is developing materials, materials processing, and structures that are explicitly tailored for multiple functions and/or unique mechanical properties. One goal of this research is the ability to design, develop, and demonstrate materials with combinations of properties that are normally orthogonal (e.g., damage tolerance and biocompatibility). This capability will ultimately lead to enhanced lethality, survivability, and performance in future DoD platforms. This thrust will also include the exploration and development of dynamic models of complex systems across scale and develop new methodologies for understanding, architecting, and engineering complex systems. These computational tools will link material properties to physics across multiple length scales (from molecule to part) and provide the ability to model and exploit complexity, such as hierarchy and strongly correlated effects, in structural and functional materials. Development efforts under this thrust include reactive structures that can serve as both structure and explosive for lightweight munitions, novel materials and surfaces that are designed to adapt structural or functional properties to environmental and/or tactical threat conditions, and new thin film material deposition processes to improve the performance of surface dominated properties (friction, wear, and membrane permeability). In addition, this thrust will also explore new cost effective processes for ensuring DoD accessibility to future advanced materials. Examples of DoD applications that will benefit from these material developments include lower weight and higher performance aircraft, turbines with enhanced efficiency, erosion-resistant rotor blades, and high-temperature materials for operation in hypersonic environments. ***FY 2015 Accomplishments:*** - Experimentally validated computational models of low temperature thin-film growth. - Integrated in situ thin film characterization techniques for real-time qualitative and quantitative analysis of growth processes.	18.748	28.085	24.158

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Demonstrated deposition of thin film challenge material on a substrate at low temperature. - Improved film quality and properties by adjusting process component parameters/integration strategy. - Generated design intent and the initial materials solution for a baseline hypersonic flight trajectory. - Established and populated the data warehouse for initial boost-glide aeroshell data. - Developed an initial framework for modeling complex systems made from tailorable feedstock materials and forming processes applicable to many domains. ***FY 2016 Plans:*** - Deliver thin film and coating materials with technical summaries to transition partners, Army Research Office and the Naval Research Laboratory. - Demonstrate initial integrated material, process, design, and manufacturing tool demonstrations for hypersonic hot structure aeroshell. - Create material system development and design framework, and link material informatics results to identify aeroshell mission performance drivers. - Generate a sub-component design concept and a sub-element design for hypersonic hot structure aeroshell. - Establish an independent test and evaluation capability for hypersonic hot structure aeroshell. - Identify candidate reinforced matrix compounds for enabling multiple platforms to be manufactured from a single tailorable feedstock material. - Identify reconfigurable forming technologies for the rapid, cost effective manufacture of complex shapes from matrix compounds reinforced with short, aligned elements. ***FY 2017 Plans:*** - Demonstrate an aligned and tailorable material feedstock that meets or exceeds state of the art aerospace materials performance. - Demonstrate a reconfigurable forming method that maintains alignment and distribution in short element reinforced matrix compounds when formed into complex shapes for DoD parts. - Demonstrate that a multifunctional element can be incorporated into the feed stock and maintain performance. - Demonstrate that a multifunctional component can be formed without degradation of performance in either the structural or functional component. - Create a cost model that assesses cost competitiveness and rate insensitivity of the new material format and forming process. - Establish process limits of forming capabilities.			
Title: Materials for Force Protection ***Description:*** The Materials for Force Protection thrust is developing novel materials and materials systems that will greatly enhance performance against ballistic, blast, and chemical threats across the full spectrum of warfighter environments. Included	16.223	25.353	27.361

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017

in this thrust are energy management and armor approaches to address explosively formed projectiles and shaped charges as well as new novel approaches for containment and remediation of chemical agent threats. The thrust will also focus on novel topological concepts as well as entirely new structural designs and chemistries that will afford enhanced, sustainable protection, and functionality at reduced weight and/or cost.

FY 2015 Accomplishments:
- Demonstrated at least 30% enhancement in opaque vehicle ballistic armor performance for combined bullet-frag threats over state-of-the-art fielded designs.
- Demonstrated capability, based on small arms threat results, to achieve at least 30% enhancement in opaque vehicle ballistic armor performance to defeat bullets from heavier weapons.
- Developed capability, based on results of feasibility study, to achieve 2x enhancement in opaque vehicle ballistic armor performance for multiple threats in an integrated armor design.
- Developed and demonstrated ability of monohull design to spread impulsive load from enhanced (> 2x impulsive load) underbody blast and prevent breach at equivalent weight to current underbody structures.
- Integrated energy absorbing materials and components into passive hierarchical energy absorbing systems characteristic of various vehicle weight classes and demonstrated capability to reduce by > 2x the combined effects of local and global impulse in underbody blast events.
- Demonstrated capability to reduce by > 2x the combined effects of local and global impulse in active counter impulse systems characteristic of medium vehicle weights in underbody blast events.
- Demonstrated capability to reduce by > 4x the effects of both local and global impulse by combining hierarchical passive energy absorbing systems into an integrated system characteristic of light and medium vehicle weight class in underbody blast events.
- Explored novel approaches to chemical remediation of organic compounds with a focus on approaches that utilize readily available reagents (e.g., soil, water, and air).
- Developed modeling capability for predicting material properties relationships such as density, strength, and toughness in hierarchical structures.
- Initiated the development of knowledge-based tools to enable computational design and discovery of complex synthetic chemistry reaction pathways.
- Initiated the design of a user interface for exploiting computational synthetic chemistry to predict complex reaction pathways.

FY 2016 Plans:
- Validate chemical remediation approaches against a series of DoD-relevant model compounds.
- Demonstrate feasibility for achieving an efficiency of chemical agent remediation/conversion of > 99%.
- Expand computational methods for reaction pathway design of structurally simple active pharmaceutical ingredients (APIs) such as ibuprofen and atropine.

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Demonstrate continuous synthesis of APIs such as nevirapine and hydroxychloroquine. ***FY 2017 Plans:*** - Validate in-line analytical monitoring of newly developed chemical remediation approaches. - Increase chemical remediation/conversion of DoD-relevant model compounds to 99.9%. - Initiate designs for extension of small-scale, continuous flow molecular syntheses to metric ton/year equivalent. - Demonstrate the synthesis of one challenge molecule in a fully automated system.			
Title: Functional Materials and Devices ***Description:*** The Functional Materials and Devices thrust is developing advanced materials and components that can improve the performance of a wide variety of functional devices for DoD sensing, imaging, and communication applications. One focus area under this thrust is the development of improved transductional materials that convert one form of energy to another (i.e., thermal to electrical, magnetic to electrical, etc.). Improvements in transductional materials and devices require deliberate control of material structure at the scale of the relevant phenomena. This thrust leverages advances in multi-physics modeling to identify and predict optimal material and device designs for a broad range of DoD applications. Examples of DoD applications that will benefit from advanced transductional materials include low size, weight and power (SWaP) thermoelectric coolers for DoD infrared sensors and compact RF antennas. ***FY 2015 Accomplishments:*** - Began the identification of DoD application-specific system specifications that will provide performance requirements for thermoelectric material development efforts. - Initiated study of novel power electronic circuit topologies to take advantage of emerging multiferroic materials for reduced size and weight. ***FY 2016 Plans:*** - Initiate the development of an open source model architecture and platform applicable for multiple transductional material domains (e.g. thermoelectric, magnetoelectric, multiferroic). - Continue the identification of DoD application-specific system specifications that will provide performance requirements for thermoelectric material development efforts. - Begin development of a multi-physics transductional material modeling capability that incorporates interface modeling and phonon engineering. - Design, fabricate and characterize thermoelectric materials and devices with improved performance metrics over the state-of-the-art.	6.000	13.734	14.680

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Design, fabricate and characterize materials and devices based on multiferroic or phase change materials with improved performance metrics over the state-of-the-art. ***FY 2017 Plans:*** - Finalize development of multi-physics transductional material modeling capability that incorporates interface modeling and phonon engineering. - Deliver proof of concept thermoelectric devices with improved performance over the state-of-the-art. - Deliver proof of concept devices based on multiferroic or phase change materials with improved performance over the state-of-the-art.			
Title: Reconfigurable Structures ***Description:*** In the Reconfigurable Structures thrust, new combinations of advanced materials, devices, structural architectures, and platforms are being developed to allow military systems to adapt to changing mission requirements and unpredictable environments. This includes the demonstration of new materials and devices that will enable the military to function more effectively in the urban theater of operations. In addition, this thrust will develop a principled, scientific basis for improved robotic mobility, manipulation, and supervised autonomy; and, leverage these results to develop and demonstrate innovative robot design tools, fabrication methods, and control methodologies. One specific objective of this thrust is to create the scientific basis for understanding, modeling, developing, testing and evaluating autonomous systems with one or more human supervisors, and one or more remote physical agents. Another thrust is the development of architectures that harness systems and human organizations working collaboratively. ***FY 2015 Accomplishments:*** - Investigated new control algorithms to enable sensing and processing for fast autonomous maneuvers in cluttered environments. - Designed platforms for low-Size, Weight and Power (SWaP) experimentation involving fast autonomous maneuvers. ***FY 2016 Plans:*** - Determine limits for GPS free navigation for short duration missions. - Model and develop behavioral controls to enable an Intelligence Surveillance and Reconnaissance (ISR) mission in a moderate-clutter environment. - Exploit novel mathematical tools and techniques for understanding the fundamentals of design science and design phenomena in complex systems and systems-of-systems. - Investigate architectures that harness systems and human organizations working together. ***FY 2017 Plans:*** - Develop representations and behaviors that enable an ISR mission in a high-clutter environment.	11.337	17.694	23.310

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Establish new paradigms for how systems and their constituent modules are represented, manipulated, integrated, and optimized. - Demonstrate management of complexity to enable inverse design of systems and capabilities.			
Title: Compact Neutron Sources ***Description:*** The Compact Neutron Sources thrust will develop the platform technologies for revolutionary portable energetic sources for in-field sensing, detection, and imaging. A focus of this thrust will be the development of compact neutron sources. Today's neutron imaging technology allows for unique sensing modalities that can currently only be performed at facility-sized installations. The research and development pursued under this thrust will enable the use of neutron imaging and detection in the field at time-scales and logistical footprints compatible with DoD missions. Multiple component technologies, such as new multi-functional materials with tuned physical and electrical characteristics and high-efficiency ion sources, will be developed and integrated in laboratory demonstration test beds. ***FY 2015 Accomplishments:*** - Developed and refined notional high-voltage particle accelerator system architectures for neutron production. - Designed components with 10-100x performance in key metrics as determined by system architecture requirements. - Developed and used high-performance design tools to conduct design and feasibility studies on accelerator and plasma components. ***FY 2016 Plans:*** - Incorporate technical findings from component design into expected performance metrics for integrated accelerators. - Refine components and begin integration into demonstration neutron source testbed. - Use component performance tests for design tool validation and development. ***FY 2017 Plans:*** - Identify successful compact neutron source components and integrate them into prototype systems. - Perform initial integrated compact neutron source prototype testing.	11.500	15.854	16.960
Title: Manufacturable Gradient Index Optics (M-GRIN) ***Description:*** The Manufacturable Gradient Index Optics (M-GRIN) program seeks to advance the development of gradient index optics (GRIN) lenses from a Technology Readiness Level (TRL) 3 to a Manufacturing Readiness Level (MRL) 6. The program will expand the application of GRIN by providing compact, lightweight, and cost-effective optical systems with controlled dispersion and aberrations that will replace large assemblies of conventional lenses. The ability to create entirely new optical materials and surfaces creates the potential for new or significantly improved military optical applications, such as solar concentrators, portable designators, highly efficient fiber optics, and imaging systems. The program also seeks to extend GRIN manufacturing	7.814	3.065	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
technologies to glass, ceramic, and other inorganic materials in order to allow for small, lightweight, customized optical elements for mid-wave and long-wave infrared (MWIR and LWIR) applications. A key component of the program is to develop new design tools that enable optics designers to incorporate dynamic material properties, fabrication methods, and manufacturing tolerances. The integration of new materials, design tools, and manufacturing processes will enable previously unattainable 3-D optical designs to be manufactured. This new manufacturing paradigm will enable flexible production of GRIN optics in quantities of one unit to thousands of units. ***FY 2015 Accomplishments:*** - Completed GRIN lens production scale-up and demonstrated process control as measured against target yield and cost to enable sustainable manufacturing. - Upgraded design tools and expanded potential user pool from advanced to mid-level optical designers, through upgrades and improvements of the GRIN design modules, to provide user-friendly interface for customers. - Completed expansion of design tools to add 3D and arbitrary gradients as well as improve computational efficiency. - Completed process characterization and control to achieve target yields and turn-around times. - Initiated prototype builds to demonstrate system performance and/or size, weight and power (SWaP) improvement from GRIN optical systems. - Initiated thermal model and implement in optical system design to mitigate thermal effect on optical performance. - Initiated demonstration of rapid redevelopment/prototyping capability. ***FY 2016 Plans:*** - Complete prototype builds to demonstrate system performance and/or SWaP improvement from GRIN optical systems. - Complete thermal model and implement in optical system design to mitigate thermal effect on optical performance. - Complete demonstration of rapid redevelopment/prototyping capability.			
Accomplishments/Planned Programs Subtotals	90.101	124.172	121.703

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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COST ($ in Millions)	Prior Years	FY 2015	FY 2016	FY 2017 Base	FY 2017 OCO	FY 2017 Total	FY 2018	FY 2019	FY 2020	FY 2021	Cost To Complete	Total Cost
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	54.308	81.943	98.753	-	98.753	123.418	135.797	140.170	140.731	-	-

A. Mission Description and Budget Item Justification

This project acknowledges the growing and pervasive influence of the biological sciences on the development of new DoD capabilities. This influence extends throughout the development of new materials, devices, and processes and relies on the integration of biological breakthroughs with those in engineering and the physical sciences. Contained in this project are thrusts that apply biology's unique fabrication and manufacturing capabilities to produce novel chemicals and materials at scale, as well as research to develop new high-throughput methods and devices to analyze biological changes at the cellular and molecular level. This project also includes major efforts aimed at integrating biological, computational, and digital sensing methodologies to explore neuroscience technology and maintain human combat performance.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
Title: BioDesign	13.916	13.500	13.582
Description: BioDesign will employ system engineering methods in combination with advances in biological and chemical technologies to create novel methods for threat response. This thrust will develop new high-throughput technologies for monitoring the function of cellular machinery at the molecular level and the response(s) of that machinery to physical, chemical, or biological threats. While conventional approaches typically require decades of research, new high-throughput approaches will permit rapid assessment of the impact of known or unknown threats on identified biomolecules and cell function. Successful research in this thrust will both reduce the time required to understand the mechanism of action for new pharmaceutical compounds and enhance response capabilities for emerging and engineered threats. ***FY 2015 Accomplishments:*** - Utilized high throughput approaches to characterize intracellular components and mechanistic interactions that reveal the effects of challenge compounds on intracellular machinery. - Demonstrated high throughput methods using cells of human origin. - Demonstrated the ability to identify intracellular components and events that occur hours after the application of a challenge compound. - Demonstrated the ability to localize relevant molecules and events to one intracellular compartment (membrane, nucleus, or cytoplasm) upon the application of a challenge compound.			

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2015**	**FY 2016**	**FY 2017**
- Reconstructed and confirmed greater than 20 percent of the molecules and mechanistic events that comprise the canonical mechanism of action for a demonstration compound which has been applied to cells. ***FY 2016 Plans:*** - Demonstrate the ability to localize relevant molecules and events to one or more intracellular compartment(s) (e.g., membrane, nucleus, or cytoplasm) upon the application of a challenge compound. - Demonstrate the ability to identify intracellular components and events that occur within minutes after the application of a challenge compound. - Reconstruct and confirm greater than 60 percent of the molecules and mechanistic events that comprise the canonical mechanism of action for a demonstration compound which has been applied to cells. ***FY 2017 Plans:*** - Continue to demonstrate the ability to localize relevant molecules and events to one or more intracellular compartment(s) (e.g., membrane, nucleus, or cytoplasm) upon the application of a challenge compound. - Demonstrate the ability to identify intracellular components and events that occur within seconds after the application of a challenge compound. - Reconstruct and confirm greater than 80 percent of the molecules and mechanistic events that comprise the canonical mechanism of action for a demonstration compound which has been applied to cells.			
Title: Living Foundries ***Description:*** The goal of the Living Foundries program is to create a revolutionary, biologically-based manufacturing platform for the DoD and the Nation. With its ability to perform complex chemistries, be flexibly programmed through DNA code, scale, adapt to changing environments, and self-repair, biology represents one of the most powerful manufacturing platforms known. Living Foundries seeks to develop the foundational technological infrastructure to transform biology into an engineering practice, speeding the biological design-build-test-learn cycle and expanding the complexity of systems that can be engineered. Ultimately, Living Foundries aims to provide game-changing manufacturing paradigms for the DoD, enabling adaptable, on-demand production of critical and high-value molecules. Research thrusts will focus on the development and demonstration of open technology platforms to prove out capabilities for rapid (months vs. years) design and construction of new bio-production systems. The result will be an integrated, modular infrastructure across the areas of design, fabrication, debugging, analysis, optimization, and validation -- spanning the entire development life-cycle and enabling the ability to rapidly assess and improve designs. Key to success will be tight coupling of computational design, fabrication of systems, debugging using multiple characterization data types, analysis, and further development such that iterative design and experimentation will be accurate, efficient and controlled. Demonstration platforms will be challenged to build a variety of DoD-relevant, novel molecules with complex functionalities, such as synthesis of advanced, functional chemicals,	24.838	28.900	27.700

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
materials precursors, and polymers (e.g., those tolerant of harsh environments). This program has basic research efforts funded in PE 0601101E, Project TRS-01. ***FY 2015 Accomplishments:*** - Expanded the capabilities of the rapid design and prototyping infrastructure to target molecules that are difficult or costly to produce using traditional synthesis mechanisms. - Expanded access and experimental scale to promote the production capabilities of rapid design and prototyping facilities infrastructure. - Began establishing the efficacy of the integrated design-build-test-learn feedback cycle for forward design and rapid optimization of target molecules via the prototyping facility's established processes. ***FY 2016 Plans:*** - Demonstrate the ability of infrastructure pipelines to rapidly generate target molecules. - Initiate pressure tests of the Foundries to test capabilities of the design and prototyping pipelines in demonstrating the speed, breadth, and efficacy of the infrastructure designs. - Implement learn capabilities into design algorithms based on testing and characterization of previously prototyped targets in order to improve the processes. - Improve forward design and rapid optimization of target molecules via the prototyping facility's established processes. - Initiate development of computational infrastructure to link component technologies and enable end-to-end process monitoring. ***FY 2017 Plans:*** - Further advance infrastructure pipelines capable of rapidly prototyping and generating DoD-relevant molecules, with significant emphasis on system integration, throughput, and process optimization. - Continue pressure tests of the infrastructure facilities to test capabilities of the design and prototyping pipelines in demonstrating the speed, breadth, and efficacy of the infrastructure designs. - Test the ability to produce ten molecules that are relevant to the DoD. - Incorporate learn capabilities into design algorithms based on testing and characterization of previously prototyped targets in order to improve the processes. - Begin developing the infrastructure pipelines to prototype production of known, but currently biologically inaccessible, molecules.			
Title: Adaptive Immunomodulation-Based Therapeutics ***Description:*** The Adaptive Immunomodulation-Based Therapeutics program will develop platform technologies to interrogate and define the biological pathways that modulate the immune response and critical organ function. One approach to achieve this capability will require the development of new tools to stimulate and measure responses of the nervous system in order to	12.554	22.000	22.971

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Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602715E / *MATERIALS AND BIOLOGICAL TECHNOLOGY*	**Project (Number/Name)** MBT-02 / *BIOLOGICALLY BASED MATERIALS AND DEVICES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
map the bioelectric code modulates. This program will also identify immune function correlates for health and early detection of disease. An additional approach involves characterizing the host response in patients with severe infections, and developing a quantitative framework that can be used to guide modulation of the immune response. Algorithms will be developed to evaluate and predict various physiological conditions within an individual. Advances made under the Adaptive Immunomodulation-Based Therapeutics program will improve our response capability against severe infectious diseases and biological threats and offer new avenues for treating disease or organ function. ***FY 2015 Accomplishments:*** - Initiated development of capabilities to characterize the neural-immune interface, including real-time measurement of biomarkers. - Began identifying novel, actionable targets for neural immune modulation. - Started identifying specific neuro-visceral circuits which can be targeted by electrical, optical, ultrasonic, or other novel stimulation approaches to modulate function. ***FY 2016 Plans:*** - Develop novel interface technologies to monitor and stimulate peripheral nerves to selectively alter organ function. - Compare specificity of novel interface technologies with state of the art whole-nerve stimulation devices. - Define input/output models of mammalian autonomic functions such as the immune system and/or the autonomic stress response. - Identify peripheral intervention points and modulation parameters for control of mammalian autonomic function for improving health or treating disease. - Develop multi-site electrode array and stimulator to improve targeting of vagal nerve stimulation. ***FY 2017 Plans:*** - Initiate demonstrations of advanced peripheral nerve interface technologies in small and large animal models to improve inflammatory and neuropsychiatric disease outcomes. - Develop computational models to simulate noninvasive peripheral nerve modulation approaches for desired physiological outcome. - Elucidate mechanisms of action for peripheral nerve modulation via noninvasive techniques. - Identify panels of relevant biomarkers that are indicative of diseased state and provide a reliable and specific surrogate measure to track physiological response to peripheral nerve modulation.			
Title: Biological-Computational Platforms ***Description:*** The Biological-Computational Platforms program is a multi-disciplinary effort that combines neuroscience, biology, advanced computer science, mathematical modeling, and novel interfaces to create hybrid biological-computational platforms	-	8.468	10.382

Exhibit R-2A, RDT&E Project Justification: PB 2017 Defense Advanced Research Projects Agency		Date: February 2016
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
for DoD applications. The program will research and develop tools that enable improved integration of biological processes and computing systems for facilitating perception, communication, and control. Novel hardware and software developed through this program will be able to operate on relevant environmental, physiological and neural information. The ultimate goal of this work is to develop hybrid biological-computational interfaces that optimize human-computer effectiveness. ***FY 2016 Plans:*** - Analyze architectures and systems for utilizing complex biological signals generalizable across users. - Investigate new approaches for neural sensor design to provide high spatial and temporal resolution without the use of an invasive microelectrode implant. - Begin studying approaches to transform neural representations of meaning, content and intentionality to new communications protocols with devices and computers. ***FY 2017 Plans:*** - Integrate multimodal input processing and demonstrate successful capacity for real-time feedback signaling to enable task performance. - Facilitate neurophysiologic-computer interfaces that enable direct control of multiple aspects of fixed facilities and mobile platforms. - Identify and quantify parameters of normal task performance involving fixed and mobile platforms. - Develop methods for assembling and rapidly deploying suites of physiologic and environmental sensors for integration with machine learning.			
Title: Biological Robustness in Complex Settings (BRICS) ***Description:*** The Biological Robustness in Complex Settings (BRICS) program will leverage newly developed technologies to enable radical new approaches for engineering biology. This area will focus on the creation of enabling technologies that will facilitate the development and integration of fundamental tools and methods being explored under the BRICS program. Research within this area may focus on the development of tools for genetic engineering of traditionally intractable species and tools for high-resolution characterization of biological communities. Ultimately, this area seeks to integrate the fundamental component technologies developed under PE 0601101E, TRS-01 into a platform technology capable of engineering robust, stable, and safe communities for the prevention and treatment of disease. This program has basic research efforts funded in PE 0601101E, Project TRS-01. ***FY 2016 Plans:*** - Develop technologies to design and build biological pathways that will function in undomesticated microbial species from a wide range of phyla (prokaryotic or eukaryotic).	-	9.075	10.200

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
- Develop theoretical tools that allow the prediction of metrics of behavior and community dynamics, such as species composition, resource utilization, and small molecule communication within a multi-species consortium. - Fabricate generalizable culture substrates that provide control over community structure and composition and support the growth of both prokaryotic and eukaryotic cells. ***FY 2017 Plans:*** - Integrate promising component technologies that may be readily adapted into a platform for engineering robust, stable, and safe biological communities. - Demonstrate reliable function of engineered microbial communities in complex laboratory environments. - Demonstrate potential for safe use of engineered consortia under conditions relevant to specific applications.			
Title: Enhancing Neuroplasticity ***Description:*** The Enhancing Neuroplasticity program will explore and develop stimulation methods and non-invasive devices to promote synaptic plasticity that is expected to impact higher cognitive functions. Key advances anticipated from this research will both create an anatomical and functional map of the underlying biological circuitry that mediates plasticity and optimize stimulation and training protocols to enable long-term retention. Once successfully identified, the underlying mechanisms of targeted plasticity training can be applied to a broad range of cognitive functions with the Department of Defense, including foreign language learning, or data and intelligence analysis. ***FY 2017 Plans:*** - Determine the effects of nerve stimulation parameters (amplitude, rate, and timing) on brain regions that modulate plasticity. - Compare effectiveness of deep and superficial nerve stimulation sites in promoting synaptic plasticity and improving performance on language learning tasks. - Demonstrate effects of training on tuning functions of neurons in auditory and speech areas of the brain. - Perform studies to compare neurophysiology and learning effects of invasive and noninvasive stimulators.	-	-	13.918
Title: Neuroscience Technologies ***Description:*** The Neuroscience Technologies thrust leveraged recent advances in neurophysiology, neuro-imaging, cognitive science, molecular biology, and modeling of complex systems to sustain and protect the cognitive functioning of the warfighter faced with challenging operational conditions. Warfighters experience a wide variety of operational stressors, both mental and physical, that degrade critical cognitive functions such as memory, learning, and decision making. These stressors also degrade the warfighter's ability to multitask, leading to decreased ability to respond quickly and effectively. Currently, the long-term impact of these stressors on the brain is unknown, both at the molecular and behavioral level. This thrust area investigated modern neuroscientific techniques to develop quantitative models of this impact and explored mechanisms to protect, maintain, complement, or restore physical and cognitive functioning during and after exposure to operational stressors. In addition, new	3.000	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2015	FY 2016	FY 2017
approaches for using physiological and neural signals to make human-machine systems more time efficient and less workload intense were identified. ***FY 2015 Accomplishments:*** - Investigated methods to exploit recent advances in neurophysiology recording technologies, cognitive science, and engineering in conjunction with emerging solutions in neurally enabled human-machine interface technologies to characterize dynamics of human cognitive functions such as memory, learning, and decision making. - Exploited recent advances in computational analysis, systems identification, data intensive computing, and statistical inference methods to research novel computational tools for rapid analysis, validation, and integration of computational models of the brain. - Researched methods for joint computation and operations between biological systems and traditional digital computing systems.			
Accomplishments/Planned Programs Subtotals	54.308	81.943	98.753

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

E. Performance Metrics

Specific programmatic performance metrics are listed above in the program accomplishments and plans section.

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