Exhibit R-2, **RDT&E Budget Item Justification:** PB 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
Total Program Element	-	158.948	150.389	220.115	-	220.115	263.319	255.711	286.955	288.338	-	-
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	121.280	101.213	130.140	-	130.140	138.903	120.669	130.560	125.928	-	-
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	37.668	49.176	89.975	-	89.975	124.416	135.042	156.395	162.410	-	-

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 2016 Defense Advanced Research Projects Agency	**Date:** February 2015
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 2014**	**FY 2015**	**FY 2016 Base**	**FY 2016 OCO**	**FY 2016 Total**
Previous President's Budget	166.654	160.389	200.725	-	200.725
Current President's Budget	158.948	150.389	220.115	-	220.115
Total Adjustments	-7.706	-10.000	19.390	-	19.390
• Congressional General Reductions	-	-			
• Congressional Directed Reductions	-	-10.000			
• Congressional Rescissions	-	-			
• Congressional Adds	-	-			
• Congressional Directed Transfers	-	-			
• Reprogrammings	-2.779	-			
• SBIR/STTR Transfer	-4.927	-			
• TotalOtherAdjustments	-	-	19.390	-	19.390

Change Summary Explanation

FY 2014: Decrease reflects reprogrammings and the SBIR/STTR transfer.
FY 2015: Decrease reflects congressional reduction.
FY 2016: Increase reflects expanded efforts in therapeutic interventions to modulate immune response, and increased focus on improving integration of biological processes and computing systems to optimize human-computer effectiveness.

Exhibit R-2A, **RDT&E Project Justification:** PB 2016 Defense Advanced Research Projects Agency		**Date:** February 2015
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 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	121.280	101.213	130.140	-	130.140	138.903	120.669	130.560	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 2014**	**FY 2015**	**FY 2016**
Title: Materials Processing and Manufacturing	23.753	20.716	27.049

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 2014 Accomplishments:
- Validated predictive capability of process models on material properties and microstructure as well as component performance, quality level, and manufacturing effectiveness.
- Developed new probabilistic models and reliability quantification methodologies for rapid qualification.
- Developed and demonstrated manufacturing assessment tools for select new manufacturing technologies.
- Established cost models for additive manufacture of selected components that provide a reduction in cost and time over standard fabrication baselines.
- Established a library of process models and manufacturing data to support model use and improvement.

FY 2015 Plans:
- Demonstrate 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).

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Implement in-process quality assurance (IPQA) sensors and technology capable of capturing DMLS processing data, and initiate development of optimized capture of real time data at appropriate resolutions to forecast article quality. - Demonstrate 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. - Demonstrate automated X-Y-Z wire position control system based on real-time, fast rate, solid-state backscattered electron sensor system. - Simulate high fidelity probabilistic process window (including tails) for bonded composite structures using Monte Carlo techniques and a priori knowledge of process variables. - Complete verified 2D and 3D bonded composite pi-joint structure models. - Establish interoperable process-material model assessment framework, and curate and standardize a data management system to capture and store data from materials and manufacturing research. - Formulate approaches for accepting natural inputs for mechanical and software design. ***FY 2016 Plans:*** - Complete design of experiments (DOE)-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. - Formulate approaches for accepting natural inputs for mechanical and software design. - Develop techniques for identifying underspecified elements in mechanical and software designs. - Develop interactive dialog techniques for obtaining design information from a human user.			
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,	22.665	18.734	22.900

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016

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 2014 Accomplishments:
- Integrated flux, mobility and reactivity process components to validate low-temperature deposition of DoD-relevant thin film coatings that currently require high bulk temperature.
- Quantified temporal and spatial stability of reactive species at ambient temperature for a DoD-relevant thin film coating in an integrated deposition system.
- Initiated comprehensive local control approach to thin film synthesis.
- Integrated fiber-reinforced reactive matrix and high-stiffness amorphous metals into reactive case structures and characterized dynamic mechanical response.
- Demonstrated ability to survive penetration into reinforced concrete with a minimal amount of strain deformation.
- Demonstrated survivability of impact into reinforced concrete at ballistic velocities.
- Demonstrated scalability to low-rate manufacturing scales while maintaining blast enhancement of survivable materials over inert cased charge.

FY 2015 Plans:
- Experimentally validate computational models of low temperature thin film growth.
- Integrate in situ thin film characterization techniques for real-time qualitative and quantitative analysis of growth processes.
- Demonstrate deposition of thin film challenge material on a substrate at low temperature.
- Improve film quality and properties by adjusting process component parameters/integration strategy.
- Generate design intent and the initial materials solution for a baseline hypersonic flight trajectory.
- Establish and populate the data warehouse for initial boost-glide aeroshell data.
- Develop an initial mathematical modeling framework for modeling complex systems applicable to many domains.

FY 2016 Plans:
- Deliver thin film coating materials, and technical summaries to transition partners, Army Research Office and the Naval Air Systems Command.
- 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- 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. - Explore analytical techniques for characterizing complex system phase transitions and regimes of emergent behavior across scales of time and space. - Design an open source, agent based hardware/software platform for evaluating algorithms for modeling complex systems across multiple scales. - Explore coupling of agent based modeling with amorphous computing methods and new meso and macro-scale representations of complex, dynamic systems for design and modulation of local interactions for desired global properties.			
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 in this thrust are energy management and armor approaches to address explosively formed projectiles (EFP) 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 2014 Accomplishments:*** - Integrated material properties and energy management mechanisms into ballistic armor materials optimized for single threat defeat in each regime (bullet, frag, EFP) to meet survivability objectives. - Demonstrated at least 30% enhancement in opaque vehicle ballistic armor performance in each regime (bullet, frag,) for single threats over state-of-the-art fielded designs. - Conducted a study, based on single threat results, to establish feasibility of achieving 2x enhancement in opaque vehicle ballistic armor performance for multiple threats. - Continued to identify and evaluate promising new armor concepts from non-traditional organizations both for military personnel and vehicles. - Demonstrated >2x enhancement in energy absorption capability of candidate materials over currently employed materials. - Determined feasibility to reduce effects of localized dynamic loading in an underbody blast event by 50% over state-of-the-art. - Determined feasibility to reduce effects of global impulse in an underbody blast event by 50% over state-of-the-art. ***FY 2015 Plans:*** - Demonstrate at least 30% enhancement in opaque vehicle ballistic armor performance for combined bullet-frag threats over state-of-the-art fielded designs. - Demonstrate 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.	26.159	18.749	19.633

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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 2014	FY 2015	FY 2016
- Develop 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. - Incorporate the best promising new armor concepts from non-traditional organizations into integrated ballistic armor design and demonstrate performance. - Develop and demonstrate 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. - Integrate energy absorbing materials and components into passive hierarchical energy absorbing systems characteristic of various vehicle weight classes and demonstrate capability to reduce by >2x the combined effects of local and global impulse in underbody blast events. - Demonstrate capability to reduce by >2x the combined effects of local and global impulse in active counter impulse systems characteristic of various vehicle weight classes in underbody blast events. - Demonstrate capability to reduce by >4x the effects of both local and global impulse by combining hierarchical passive energy absorbing and active counter impulse systems into integrated systems characteristic of various vehicle weight classes in underbody blast events. - Explore novel approaches to chemical remediation of organic compounds with a focus on approaches that utilize readily available reagents (e.g., soil, water and air). - Develop modeling capability for predicting material properties relationships such as density, strength, and toughness in hierarchical structures. ***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%. - Explore the feasibility of exploiting rational, hierarchical design approaches to enable adaptive smart structures that can sense and actuate in response to environmental challenges. - Couple computational physics/mechanical tools with emerging material design concepts to achieve combinations of structural and functional properties that do not coexist in conventional materials. - Initiate the development of functional materials and structures with properties that are invariant across varying operational environments (for example, pressure and temperature).			
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 area of focus under this thrust is the development of wearable (i.e., ultra-low size, weight and power) optical systems to enhance warfighter situational awareness. Another focus area is the development of improved transductional materials that convert one	9.668	6.000	12.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
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 SWaP thermoelectric coolers for DoD infrared sensors and compact RF antennas. ***FY 2014 Accomplishments:*** - Demonstrated and conducted user testing of hands-free zoom capability. - Assembled and tested wide field of view compact camera. - Demonstrated integrated software environment for image collection and processing. ***FY 2015 Plans:*** - Explore and develop an open source model architecture and platform applicable to multiple transductional material domains (e.g. thermoelectric, magnetoelectric, multiferroic). - Identify canonical DoD relevant system specification that will provide performance requirements for transductional material development efforts. ***FY 2016 Plans:*** - Develop multi-physics transductional material modeling capability that incorporates aperiodic interface modeling and phonon engineering. - Improve multi-physics transductional material modeling capability to include surface and quantum confined structures. - Integrate new multi-physics models with experimental data from transductional materials development efforts.			
Title: Manufacturable Gradient Index Optics (M-GRIN) ***Description:*** The Manufacturable Gradient Index Optics (M-GRIN) program seeks to advance the development of GRIN lenses from a Technology Readiness Level (TRL) 3 to a Manufacturing Readiness Level (MRL) 6. The program will expand the application of gradient index optics (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 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	11.800	7.814	7.500

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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-01 / *MATERIALS PROCESSING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
unattainable 3D 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 2014 Accomplishments:*** - Demonstrated GRIN lens-based systems with at least 2x weight reduction from homogenous system with equivalent performance. - Advanced MRL and commenced process characterization and control to improve yields and rapid redevelopment cycles. - Commenced demonstration of rapid redevelopment/prototype manufacturing capability by producing multiple GRIN lenses from the same manufacturing process. - Completed prototype designs to demonstrate breadth of improved DoD-relevant parameters/properties (wide field-of-view, f-number, bandwidth, etc.) in manufactured optical components. - Established physical models for diffusion and molding to inform manufacturing processes. - Expanded IR metrology for program materials. - Characterized thermal properties of M-GRIN materials and began thermal modeling for optical properties. - Commenced expansion of design tools to add 3D and arbitrary gradients as well as improve computational efficiency. ***FY 2015 Plans:*** - Complete GRIN lens production scale-up and demonstrate process control as measured against target yield and cost, to enable sustainable manufacturing. - Upgrade design tools and expand 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. - Complete expansion of design tools to add 3D and arbitrary gradients as well as improve computational efficiency. - Complete process characterization and control to achieve target yields and turn-around times. - Initiate prototype builds to demonstrate system performance and/or size, weight and power (SWaP) improvement from GRIN optical systems. - Initiate thermal model and implement in optical system design to mitigate thermal effect on optical performance. - Initiate 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. - Achieve MRL 6 and demonstrate stable GRIN manufacturing capability. - Demonstrate intermediate volume capability through repeatable production of several small lots.			
Title: Reconfigurable Structures	14.735	14.200	18.058

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Description: In the Reconfigurable Structures thrust, new combinations of advanced materials, devices, and structural architectures are being developed to allow military platforms to move, morph, or change shape for optimal adaptation 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. ***FY 2014 Accomplishments:*** - Completed design of actuation system for a humanoid robot, including bench-top testing of high-risk components and/or subsystems. - Designed actuation systems for a humanoid robot that increases its energy efficiency by 20x, using the same kinematic structure, energy source, computing, and low-level control software. - Demonstrated advanced energy-efficiency improvement actuation approaches by quantitative analysis and/or simulation. - Initiated experiments to validate advanced energy-efficiency improvement actuation approaches. ***FY 2015 Plans:*** - Explore materials systems with capacity to create self-assembled obstacles to structures. - Investigate self-assembled structures that can self-adhere to surfaces. - Investigate new control algorithms and sensing modalities to enable sensing and processing for fast autonomous maneuvers in cluttered environments. - Design platforms to be used as Government-Furnished Equipment (GFE) for low-Size, Weight and Power (SWaP) experimentation involving fast autonomous maneuvers. ***FY 2016 Plans:*** - Identify designs for self-assembling obstacle system architectures with compact dimensions. - Demonstrate feasibility for self-assembling obstacles that can resist assault. - Determine limits for GPS free navigation for short duration missions. - Model and develop sensor, processor, and behavioral controls to enable an ISR mission in a moderate-clutter environment.			
Title: Advanced Technology Heat to Electricity Nuclear Alternatives (ATHENA)	-	5.500	7.500
Description: The Advanced Technology Heat to Electricity Nuclear Alternatives (ATHENA) program is an experimental program to determine if it is possible to provide electrical power for military missions with very high energy density and power density, at a scale where nuclear reactors are unworkable, where combustion is infeasible, and where solar power is impractical,			

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
for space, maritime, and ground applications. The program pursues advancements in radioisotope technology, which has essentially stagnated for fifty years. Specifically, the program seeks to identify and develop radioisotopes that better capture DoD requirements by providing improved power density and allow safer, more convenient handling, explore better and more efficient electricity conversion technology than thermocouples, and to develop an operations framework leading to a solution that is capable of deployment. ***FY 2015 Plans:*** - Initiate isotope evaluation and selection. - Develop competing technologies for electricity conversion at small (battery) scale and large (~10 kW) scale. - Conduct assessment of costs of production, deployment, and handling of selected radioisotope material. ***FY 2016 Plans:*** - Demonstrate prototype conversion technology for radioisotope energy at power density better than solar arrays. - Demonstrate production and handling of candidate radioisotopes for power use. - Conduct testing of battery scale and heat engine scale conversion devices to determine real-world efficiency.			
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 Plans:*** - Develop and refine notional high-voltage particle accelerator system architectures for neutron production. - Design components with 10-100x performance in key metrics as determined by system architecture requirements. - Develop and use 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 accelerator. - Refine components and begin integration into demonstration neutron source testbed.	-	9.500	15.000

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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-01 / *MATERIALS PROCESSING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Use component performance tests for design tool validation and development.			
Title: Structural Materials and Coatings ***Description:*** The Structural Materials and Coatings thrust explored and developed new materials to provide enhanced structural and/or surface properties for DoD applications. Included were approaches that avoid corrosion through engineered material, provide superior strength at greatly reduced material density, provide the basis for a new generation of structural composite and submarine propeller materials, and enable prolonged lifetimes for DoD systems and components. The Hybrid Multi Material Rotor Full-Scale Demonstration (HyDem) program, an outgrowth of the Structural Materials and Coatings effort's Hybrid Multi Material Rotor (HMMR) program, dramatically improved U.S. Navy submarine superiority. The HyDem program designed, manufactured, and supplied the Navy with a novel component for integration into a new construction Virginia Class Submarine. The Navy is evaluating this component in sea trials. If successful, it is envisioned that the Navy will integrate this design change into the future development of the Virginia Class and Ohio Replacement Submarines, and possibly back-fit previously constructed Virginia Class Submarines. Beginning in FY 15 this program will be funded from PE 0603766E, Project NET-02, Maritime Systems. ***FY 2014 Accomplishments:*** - Completed concept design, demonstrating the ability to scale from 1/4-scale HMMR to full-scale component. - Completed preliminary design, demonstrating that the design accommodates stated performance parameters. - Performed analysis of shock test of scaled components. - Developed manufacturing process plans for full-scale components. - Delivered large-scale rotor component to the Navy for in-water testing and assessment. - Initiated fabrication of large-scale rotor for Navy assessment.	12.500	-	-
Accomplishments/Planned Programs Subtotals	121.280	101.213	130.140

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.

Exhibit R-2A, RDT&E Project Justification: PB 2016 Defense Advanced Research Projects Agency		Date: February 2015
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*

COST ($ in Millions)	Prior Years	FY 2014	FY 2015	FY 2016 Base	FY 2016 OCO	FY 2016 Total	FY 2017	FY 2018	FY 2019	FY 2020	Cost To Complete	Total Cost
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	37.668	49.176	89.975	-	89.975	124.416	135.042	156.395	162.410	-	-

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 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.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
Title: BioDesign	11.438	11.500	17.500
Description: BioDesign will employ system engineering methods in combination with biotechnology and synthetic chemical technology to create novel beneficial attributes. This thrust area includes designed molecular responses that increase resistance to cellular death signals and improved computational methods for prediction of function based solely on sequence and structure of proteins produced by synthetic biological systems. Development of technologies to genetically tag and/or lock synthesized molecules would provide methods for prevention of manipulation ("tamper proof" synthetic biological systems). This thrust will also 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. ***FY 2014 Accomplishments:*** - Developed genomic security technologies in research microbes and preparing to test functionality in commercially relevant microbes. - Evaluated high-throughput methods that have the potential to map intracellular proteins. - Developed a path to detect intracellular components and events that are present in quantities ranging from fifty to thirty million copies per cell. - Developed a plan to detect intracellular molecules with masses ranging from fifty to two hundred thousand Daltons.			

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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 2014	FY 2015	FY 2016
- Initiated development of high throughput analytical equipment to measure the concentration of >1000 proteins simultaneously. ***FY 2015 Plans:*** - Utilize high throughput approaches to characterize intracellular components and mechanistic interactions that reveal the effects of challenge compounds on intracellular machinery. - Demonstrate high throughput methods using cells of human origin. - Demonstrate the ability to identify intracellular components and events that occur hours after the application of a challenge compound. - Demonstrate the ability to localize relevant molecules and events to one intracellular compartment (membrane, nucleus, or cytoplasm) upon the application of a challenge compound. - Reconstruct and confirm 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. - Research platform technologies to characterize molecular responses between members of a complex microbial community. ***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. - Research advanced bio-based platforms for early detection and mitigation of threats, such as infectious diseases, novel functions, and defense applications.			
Title: Living Foundries ***Description:*** The goal of the Living Foundries program is to create a revolutionary, biologically-based manufacturing platform to provide new materials, capabilities, and manufacturing paradigms 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. However, the DoD's ability to harness this platform is rudimentary. 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. The program will enable the rapid and scalable development of previously unattainable technologies and products (i.e., those that cannot be accessed using known, synthetic mechanisms), leveraging biology to solve challenges associated with production of new materials (e.g., fluoropolymers, enzymes, lubricants, coatings and materials for harsh environments), novel functions (e.g., self-repairing and self-regenerating systems), biological reporting systems, and therapeutics to enable new solutions and	18.155	23.122	30.900

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
enhancements to military needs and capabilities. Ultimately, Living Foundries aims to provide game-changing manufacturing paradigms for the DoD, enabling distributed, adaptable, on-demand production of critical and high-value materials, devices, and capabilities in the field or on base. Such a capability will decrease the DoD's dependence on tenuous material supply chains vulnerable to political change, targeted attack, or environmental accident. Research thrusts will focus on the development and demonstration of open technology platforms, or bioproduction pipelines, that integrate the tools and capabilities developed in PE 0601101E, TRS-01 to prove out capabilities for rapid (months vs. years) design and construction of new bio-production systems for novel materials. 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. Integrated processes developed in this program will translate into significant performance improvements and cost savings for the production of advanced materials, biological reporting systems, and therapeutics. These technologies will ultimately result in on-demand, customizable, and distributed production of strategic materials and systems. 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 and chemical building blocks with complex functionalities, such as synthesis of advanced, functional chemicals, materials precursors, and polymers (e.g., those tolerant of harsh environments). ***FY 2014 Accomplishments:*** - Continued standardization, integration, and automation of the fundamental tools and capabilities developed in PE 0601101E, TRS-01 into a readily adoptable and adaptable biomanufacturing platform. - Began to integrate data streams (using previously developed computation algorithms and software) from fabrication, quality control and characterization tools to provide a comprehensive debugging capability and to enable forward design. - Began to demonstrate, test, and evaluate the extent of design-build-test cycle compression using integrated platforms to engineer new bioproduction systems. - Initiated development of rapid design and prototyping infrastructure pipelines, including initial system integration and process optimization. - Began testing the ability of integrated infrastructure pipelines to demonstrate rapid, improved prototyping of DoD-relevant molecules. ***FY 2015 Plans:*** - Demonstrate the ability of each infrastructure pipeline to rapidly generate DoD-relevant molecules. - Expand the capabilities of the rapid design and prototyping infrastructure to target molecules and chemical building blocks that are currently inaccessible using traditional synthesis mechanisms.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
- Complete proof-of-concept demonstrations of component technologies developed under PE 0601101E, TRS-01 that accelerate the design-build-test cycle. - Expand access and experimental scale to promote the production capabilities of rapid design and prototyping facilities infrastructure. - Begin establishing the efficacy of the integrated design-build-test-learn feedback cycle for forward design and rapid optimization of novel, currently inaccessible molecules via the prototyping facility's established processes. ***FY 2016 Plans:*** - Continue demonstrating infrastructure pipelines capable of rapidly prototyping and generating DoD-relevant molecules. - Demonstrate the rapid design and prototyping of currently inaccessible (not synthesizable by traditional biologic or synthetic chemistry processes) target molecules and materials by the established prototyping facilities. - Continue integrating demonstrated component technologies developed under PE 0601101E, TRS-01 to further enhance the capabilities of the rapid design and prototyping pipelines. - 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.			
Title: Adaptive Immunomodulation-Based Therapeutics ***Description:*** The Adaptive Immunomodulation-Based Therapeutics program will develop platform technologies that can interrogate and define the biological pathways leading to an immune response with the goal of developing and demonstrating new therapeutic interventions. 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 map the bioelectric code that controls the immune response as well as other critical organ functions. This program will also develop capabilities for serial measurements of metabolic state to identify correlates for health and early detection of disease. An additional approach involves characterizing the host response in patients with severe infections, and translating this response into 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 and could later be expanded to track the health of various communities. 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 with no available drugs, such as multiple drug resistant organisms. The ultimate goals for the Adaptive Immunomodulation-Based Therapeutics program are to enable an autonomous and continuous sense and response capability to regulate the human immune response and to develop decision support tools that help manage general health such as tracking and combatting infectious diseases in a community. It is anticipated that these capabilities will ultimately provide	-	12.554	23.000

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
enhanced protection against injury, enable life-saving rescue from hyper-immune activity, and stimulate advances in regenerative medicine. ***FY 2015 Plans:*** - Develop capabilities to characterize the neural-immune interface, including real-time measurement of biomarkers. - Identify novel, actionable targets for neural immune modulation. - Identify 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. - Demonstrate superior specificity of novel interface technologies compared to FDA-approved 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. - Initiate testing of advanced interface technologies.			
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 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. - Explore mechanisms for direct neural interfacing to receive and react to operationally relevant environmental, physiological and neural information. - Begin researching scalable models and algorithms to derive actionable biological signals from multiple users.	-	-	10.500

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B. Accomplishments/Planned Programs ($ in Millions)	**FY 2014**	**FY 2015**	**FY 2016**
- Begin studying approaches to transform neural representations of meaning, content and intentionality to new communications protocols.			
Title: Biological Robustness in Complex Settings (BRICS) ***Description:*** The Biological Robustness in Complex Settings (BRICS) Program will leverage newly developed technologies for engineering biology towards enabling radical new approaches to solving National Security challenges. 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). - Develop analytical tools that allow the simultaneous measurement of relevant parameters, such as gene transcription, protein synthesis, 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. - Integrate promising component technologies that may be readily adapted into a platform for engineering robust, stable, and safe biological communities.	-	-	8.075
Title: Neuroscience Technologies ***Description:*** The Neuroscience Technologies thrust leverages 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 will create modern neuroscientific techniques to develop quantitative models of this impact and explore mechanisms to protect, maintain, complement, or restore physical and cognitive functioning during and after exposure to operational stressors. In addition, new approaches for using physiological and neural signals to make human-machine systems more time efficient and less workload intense will be identified, developed, and evaluated. This thrust area will have far-reaching implications for both current and future	8.075	2.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2014	FY 2015	FY 2016
military operations, with the potential to protect and improve physical and cognitive performance at the individual and group level both prior to and during deployment. ***FY 2014 Accomplishments:*** - Determined genetic, epigenetic, and proteomic changes underlying vulnerability to poor decision making in humans. - Developed tools and metrics for evaluating individual and group performance during close-quarters combat training and other operationally relevant training scenarios. - Exploited advances in predictive models of the brain and investigated new modeling methods to develop tools and techniques that can characterize and improve cognitive performance under stress at the individual level. ***FY 2015 Plans:*** - Investigate 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. - Exploit 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. - Research methods for joint computation and operations between biological systems and traditional digital computing systems.			
Accomplishments/Planned Programs Subtotals	37.668	49.176	89.975

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.