Department of Defense
Fiscal Year (FY) 2022 Budget Estimates

May 2021

Defense Advanced Research Projects Agency

Defense-Wide Justification Book Volume 1 of 5

Research, Development, Test & Evaluation, Defense-Wide

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Footnotes

FY 2020 Actuals

Includes Division A, Title IX and X of the Consolidated Appropriations Act, 2020 (P.L. 116-93), Division F, Title IV and V from the Further Consolidated Appropriations Act, 2020 (P.L. 116-94) and the Coronavirus Aid, Relief, and Economic Security Act (P.L. 116-136).

FY 2021 Enacted

Includes Division C, Title IX and Division J, Title IV of the Consolidated Appropriations Act, 2021 (P.L. 116-260).

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Department of Defense
FY 2022 President's Budget
Exhibit R-1 FY 2022 President's Budget
Total Obligational Authority
(Dollars in Thousands)

04 May 2021

Appropriation	FY 2020 Actual*	FY 2021 Enacted**	FY 2022 Request
Research, Development, Test & Eval, DW	3,571,321	3,500,048	3,528,729
Total Research, Development, Test & Evaluation	3,571,321	3,500,048	3,528,729

Department of Defense
FY 2022 President's Budget
Exhibit R-1 FY 2022 President's Budget
Total Obligational Authority
(Dollars in Thousands)

04 May 2021

Summary Recap of Budget Activities	FY 2020 Actual*	FY 2021 Enacted**	FY 2022 Request
Basic Research	485,558	527,888	471,799
Applied Research	1,448,615	1,360,509	1,447,405
Advanced Technology Development	1,447,580	1,523,883	1,523,640
Management Support	189,568	87,768	85,885
Total Research, Development, Test & Evaluation	3,571,321	3,500,048	3,528,729

Summary Recap of FYDP Programs			
Research and Development	3,571,321	3,500,048	3,528,729
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Defense-Wide
FY 2022 President's Budget
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Defense-Wide
FY 2022 President's Budget
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(Dollars in Thousands)

04 May 2021

Appropriation: 0400D Research, Development, Test & Eval, DW

Line No	Program Element Number	Item	Act	FY 2020 Actual*	FY 2021 Enacted**	FY 2022 Request	Sec
2	0601101E	Defense Research Sciences	01	427,837	474,158	395,781	U
5	0601117E	Basic Operational Medical Research Science	01	57,721	53,730	76,018	U
		Basic Research		485,558	527,888	471,799	
10	0602115E	Biomedical Technology	02	131,017	107,568	108,698	U
15	0602303E	Information & Communications Technology	02	416,935	420,920	430,363	U
16	0602383E	Biological Warfare Defense	02	30,011	26,950	31,421	U
19	0602702E	Tactical Technology	02	300,010	237,271	202,515	U
20	0602715E	Materials and Biological Technology	02	260,831	245,107	317,024	U
21	0602716E	Electronics Technology	02	309,811	322,693	357,384	U
		Applied Research		1,448,615	1,360,509	1,447,405	
36	0603286E	Advanced Aerospace Systems	03	266,646	223,478	174,043	U
37	0603287E	Space Programs and Technology	03	173,839	151,439	101,524	U
57	0603739E	Advanced Electronics Technologies	03	107,259	95,864	116,716	U
58	0603760E	Command, Control and Communications Systems	03	225,917	221,724	251,794	U
59	0603766E	Network-Centric Warfare Technology	03	515,879	641,158	584,771	U
60	0603767E	Sensor Technology	03	158,040	190,220	294,792	U
		Advanced Technology Development		1,447,580	1,523,883	1,523,640	
154	0605001E	Mission Support	06	68,983	74,334	73,145	U
168	0605502E	Small Business Innovative Research	06	107,294			U

Defense-Wide
FY 2022 President's Budget
Exhibit R-1 FY 2022 President's Budget
Total Obligational Authority
(Dollars in Thousands)

04 May 2021

Appropriation: 0400D Research, Development, Test & Eval, DW

Line No	Program Element Number	Item	Act	FY 2020 Actual*	FY 2021 Enacted**	FY 2022 Request	Sec
176	0605898E	Management HQ - R&D	06	13,291	13,434	12,740	U
		Management Support		189,568	87,768	85,885	
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Defense Advanced Research Projects Agency
FY 2022 President's Budget
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Program Element Table of Contents (by Budget Activity then Line Item Number)

Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

Appropriation 0400: Research, Development, Test & Evaluation, Defense-Wide

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Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	427.837	474.158	395.781	-	395.781	-	-	-	-	-	-
CCS-02: *MATH AND COMPUTER SCIENCES*	-	248.978	285.803	265.784	-	265.784	-	-	-	-	-	-
ES-01: *ELECTRONIC SCIENCES*	-	30.393	35.801	16.361	-	16.361	-	-	-	-	-	-
ES-02: *BEYOND SCALING SCIENCES*	-	62.828	59.025	45.145	-	45.145	-	-	-	-	-	-
MS-01: *MATERIALS SCIENCES*	-	41.584	52.560	40.303	-	40.303	-	-	-	-	-	-
TRS-01: *TRANSFORMATIVE SCIENCES*	-	44.054	40.969	28.188	-	28.188	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Defense Research Sciences Program Element is budgeted in the Basic Research Budget Activity because it provides the technical foundation for long-term National Security enhancement through the discovery of new phenomena and the exploration of the potential of such phenomena for Defense applications. It supports the scientific study and experimentation that is the basis for more advanced knowledge and understanding in information, electronic, mathematical, computer, and materials sciences. This Program Element also supports innovation and robust transition planning in the technology cycle by working with entrepreneurs to increase the likelihood that DARPA funded technologies take root in the U.S. and provide new capabilities for national defense.

The Math and Computer Sciences project supports scientific study and experimentation on new mathematical and computational algorithms, models, and mechanisms in support of long-term national security objectives. Modern analytic and information technologies enable important new military capabilities and drive the productivity gains essential to U.S. economic competitiveness. Conversely, new classes of threats, in particular threats that operate in or through the cyber domain, put military systems, critical infrastructure, and the civilian economy at risk. This project aims to magnify these opportunities and mitigate these threats by leveraging emerging mathematical and computational capabilities including computational social science, artificial intelligence, machine learning and reasoning, data science, complex systems modeling and simulation, and theory of computation. The basic research conducted under the Math and Computer Sciences project will produce breakthroughs that enable new capabilities for national and homeland security.

The Electronic Sciences project is for basic exploration of electronic and optoelectronic devices, circuits, and processing concepts to meet the military's need for near real-time information gathering, transmission, and processing. In seeking to continue the phenomenal progress in microelectronics innovation that has characterized the last few decades, the project should provide DoD with new, improved, or potentially revolutionary device options for accomplishing these critical functions. The resulting technologies should help maintain knowledge of the enemy, communicate decisions based on that knowledge, and substantially improve the cost and performance of military systems. Research areas include analog, mixed signal, and photonic circuitry for communications and other applications; alternative computer architectures;

and magnetic components to reduce the size of Electromagnetic (EM) and sensing systems. Other research could support field-portable electronics with reduced power requirements, ultra-high density information storage "on-a-chip", and new approaches to nanometer-scale structures, molecules, and devices.

The Beyond Scaling Sciences project supports investigations into materials, devices, and architectures to provide continued improvements in electronics performance with or without the benefit of Moore's Law (silicon scaling). Within the next ten years, traditional scaling will start to encounter the fundamental physical limits of silicon, requiring fresh approaches to new electronic systems. Over the short term, DoD will therefore need to unleash circuit specialization in order to maximize the benefit of traditional silicon. Over the longer term, DoD and the nation will need to engage the computer, material, and mechanical sciences to explore electronics improvements through new non-volatile memory devices that combine computation, and memory, and new automated design tools using machine learning. Other memory devices could also leverage an emerging understanding of the physics of magnetic states, electron spin properties, topological insulators, or phase-changing materials. Beyond Scaling programs will address fundamental exploration into each of these areas.

The Materials Sciences project provides the fundamental research that underpins the design, development, assembly, and optimization of advanced materials, devices, and systems for DoD applications in areas such as robust diagnostics and therapeutics, novel energetic materials, and complex hybrid systems.

The Transformative Sciences project supports research and analysis that leverages converging technological forces and transformational trends in information-intensive subareas of the social sciences, life sciences, and manufacturing. The project integrates these diverse disciplines to eliminate reliance on foreign sources for critical materials, improve military adaptation to sudden changes in requirements, threats, and emerging/converging trends, especially trends that have the potential to disrupt military operations or threaten National Security. Specific research in this project will investigate technologies to enable detection of novel threat agents (e.g., bacterial pathogens) and maintain warfighter health and improve recovery. This project also includes efforts to create innovative materials of interest to the military (e.g., self-healing materials).

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	432.284	479.958	415.112	-	415.112
Current President's Budget	427.837	474.158	395.781	-	395.781
Total Adjustments	-4.447	-5.800	-19.331	-	-19.331
• Congressional General Reductions	0.000	-13.800			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.304	8.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-0.751	0.000			
• SBIR/STTR Transfer	-4.000	0.000			
• TotalOtherAdjustments	-	-	-19.331	-	-19.331

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2020	FY 2021
Project: CCS-02: *MATH AND COMPUTER SCIENCES*		
Congressional Add: *Foundational Artificial Intelligence - Congressional Add*	-	5.000
Congressional Add: *Alternative Computing - Congressional Add*	-	3.000
Congressional Add Subtotals for Project: CCS-02	-	8.000
Congressional Add Totals for all Projects	-	8.000

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer and reprogrammings offset by COVID response CARES Act add.
FY 2021: Decrease reflects congressional adjustments.
FY 2022: Decrease reflects completion of the Advanced Tools for Modeling and Simulation, Communicating With Computers, Complex Hybrid Systems, Magnetic Miniaturized and Monolithically Integrated Components (M3IC), A MEchanically Based Antenna (AMEBA), Engineered Living Materials (ELM), and Social Simulation (SocialSim) basic research programs in FY 2021.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) CCS-02 / *MATH AND COMPUTER SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
CCS-02: *MATH AND COMPUTER SCIENCES*	-	248.978	285.803	265.784	-	265.784	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Math and Computer Sciences project supports scientific study and experimentation on new mathematical and computational algorithms, models, and mechanisms in support of long-term national security objectives. Modern analytic and information technologies enable important new military capabilities and drive the productivity gains essential to U.S. economic competitiveness. Conversely, new classes of threats, in particular threats that operate in or through the cyber domain, put military systems, critical infrastructure, and the civilian economy at risk. This project aims to magnify these opportunities and mitigate these threats by leveraging emerging mathematical and computational capabilities including artificial intelligence (AI), computational social science, machine learning and reasoning, data science, complex systems modeling and simulation, and theories of computation and programming. The basic research conducted under the Math and Computer Sciences project will produce breakthroughs that enable new capabilities for national and homeland security. This Project includes FY 2020 CARES Act funding in the amount of $.304 million for AI models to rapidly screen, prioritize and test Food and Drug Administration (FDA)-approved therapeutics for new COVID-19 drug candidates.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Foundational Artificial Intelligence (AI) Science	64.845	58.845	58.050
Description: The Foundational Artificial Intelligence (AI) Science thrust is developing a fundamental scientific basis for understanding and quantifying performance expectations and limits of AI technologies. Current AI technologies are challenged in handling uncertainty and incompleteness of training protocols and data. This has prevented the successful integration of AI technology into many transformative DoD applications. To address these limitations, the Foundational AI Science thrust will focus on the development of new learning architectures that enhance AI systems' ability to handle uncertainty, reduce vulnerabilities, and improve robustness for DoD AI systems. One focus area of this thrust is the ability to embed known physics, mathematics, and other prior knowledge to improve performance of AI systems, particularly for problem sets involving incomplete, sparse, and noisy data. Another focus area is the development of a model framework for quantifying performance expectations and limits of AI systems as trusted human partners and collaborators. A third focus area is the development of new tools and methodologies that enable AI approaches for accelerated scientific discovery. The technology advances achieved under the Foundational AI Science thrust will ultimately remove technical barriers to exploiting AI technologies for scientific discovery, human-AI collaboration, and other DoD relevant applications. ***FY 2021 Plans:*** - Develop automated approaches to extract data from electronic lab notebooks, tables, and figures. - Build and demonstrate property prediction models which are informed by and guide automated experimental platforms. - Develop introspective AI systems that are capable of expressing task competencies based on experiences, learned task rules and rule dependencies.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate competency-aware machine learning behaviors and capabilities in machine learning applications. - Develop novelty generators and novelty-robust AI techniques to identify rapidly and respond appropriately to new relationships, representations, and capabilities. - Begin to evaluate novelty generators and novelty-robust AI techniques compared to non-robust methods performing on known tasks. - Demonstrate, in modeling and simulation, non-Von Neumann devices and circuits that have significant benefits over classical computers. - Develop AI-aided capabilities for recovering symbolic mathematical formulas from binary code alone and, more generally, for mathematical comprehension of complex software. - Develop and implement computationally feasible cryptographic techniques for securing the information exchange transactions implicit to cooperative training of Machine Learning (ML) models, and demonstrate their ability to preserve privacy when attacked by a sophisticated adversary. - Develop approaches to automatically identify signatures for the tools used by an adversary in information deception attacks in order to attribute attacks and aid in the formulation of defensive measures. - Develop and apply symbolic and statistical AI techniques to understand collaborative software development activities at scale and to detect patterns of manipulation that have the potential to expose critical information, defeat mitigations even as they are being implemented, or otherwise degrade security. - Assess human pneumothorax ultrasound datasets for AI model training. - Continue efforts to explore frontiers in Artificial Intelligence with a focus on third wave AI.			
FY 2022 Plans: - Continue development of novelty generators and novelty-robust AI techniques to include new environments, goals, and context. - Develop methods to accurately correlate data across multiple sources, such as lab notebooks, tables, figures, and experimental databases. - Develop prediction models across multiple molecular properties of interest. - Demonstrate closed-loop feedback between experimental platforms and AI models to facilitate process optimization and inverse molecular design. - Demonstrate competency-aware machine learning behaviors and capabilities on integrated application platforms. - Develop capabilities for AI systems to learn to compliment and coordinate with humans. Demonstrate potential for enhanced human-machine teaming performance. - Experimentally test small-scale prototype hardware capable of information processing near the theoretical limit of energy efficiency and quantify the utility of quantum information processing systems for tasks related to machine learning. - Demonstrate the accuracy of AI models for pneumothorax classification on a portable device.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Continue efforts to explore frontiers in Artificial Intelligence with a focus on third wave AI. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.			
Title: Alternative Computing	15.580	24.000	36.000
Description: The Alternative Computing thrust is exploring and developing new computational primitives for modeling and simulating complex systems. Despite decades of rapid advancement in electronic computing, there remain important national security relevant challenge problems that do not lend themselves to achieving tractable solutions under size, weight, and power (SWaP) constrained conditions. For example, simulation of complex nonlinear phenomena such as turbulence, fluid flow, and plasma dynamics can be challenging even using currently available high power computing resources. Building on technologies developed under the Advanced Tools for Modeling and Simulation thrust, also in this PE/Project, the goal of the Alternative Computing thrust is to develop novel architectural and algorithmic approaches to enable fast and accurate simulations for problems that are practically intractable using electronic computers. Approaches considered under this thrust include the following: (1) analog computing substrates for efficiently simulating systems governed by complex non-linear phenomena; (2) multi-functional spin-based devices for scalable, efficient neuromorphic computing; (3) computing approaches that exploit the capacity of nonlinear systems to simulate nonlinear dynamical systems; and (4) quantum enabled optimization of complex systems. ***FY 2021 Plans:*** - Complete design of a new scheme capable of coherent control of each individual qubit in a Penning ion trap for ion based quantum computing. - Identify families of instances where near term quantum computers can outperform classical computing in the optimization of complex systems. - Initiate efforts to quantify the speedup achievable with near term quantum computers over classical computing for the optimization of complex systems. - Develop methods for benchmarking quantum processors. - Initiate development of a network architecture that achieves resilience through closed-loop control based on in-network telemetry and verified code executing at line rates on programmable hardware. ***FY 2022 Plans:*** - Demonstrate the use of a near term quantum computer for the optimization of complex systems. - Perform benchmarking of the quantum processor performance against the best classical system. - Initiate efforts to create new hardware agnostic benchmarks for quantum information processing performance that quantitatively measure progress towards specific, transformational computational challenges.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Initiate development of scalable testing techniques for measuring progress in quantum information processing towards addressing specific, transformational computational challenges. - Demonstrate a closed-loop verification system for fine-grained measurement of networks in which every packet is stamped by the forwarding elements to indicate the path it took, the queueing delay it experienced, and the rules it matched. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to a shift from design and planning to demonstration.			
Title: Machine Common Sense (MCS)	12.375	16.500	18.000
Description: The Machine Common Sense (MCS) program is exploring approaches to enable common sense reasoning by machines. Recent advances in machine learning have resulted in new artificial intelligence (AI) capabilities in areas such as image recognition, task-focused natural language processing, and strategy games such as Chess, Go, and Poker. In all of these application domains, the machine reasoning is narrow and highly specialized, and the machine must be carefully trained or programmed for every situation. This program addresses the challenge of general machine reasoning on par with common sense human cognition. MCS is developing computational models that mimic core systems of human cognitive development that are grounded in perceptual, motor, and memory modalities; a simulated interaction and learning environment to support machine manipulation of grounded concept models; and common sense knowledge repositories to support AI system development. AI systems that are capable of human-like reasoning will be able to behave more appropriately in unforeseen situations and to learn with reduced requirements for training data. ***FY 2021 Plans:*** - Enhance core cognitive models with additional capabilities, such as spatial navigation at the cognitive developmental level of nine- to twelve-month old infants, and evaluate model performance on prediction tasks. - Develop core cognitive models with initial experience learning capabilities, and evaluate model performance against experience learning tasks. - Modify the simulation environment for evaluation of additional machine learning methods, cognitive capabilities, prediction tasks, and experience learning tasks. - Enhance common knowledge services to handle common sense phenomena of increased complexity, and assess performance of services against benchmark common sense challenge problem suites. ***FY 2022 Plans:*** - Develop core cognitive models with enhanced experience learning capabilities, and evaluate model performance against experience learning tasks requiring elements of intuitive physics, navigation, and models of intentional agents. - Enhance core cognitive models with additional capabilities, such as models of intentional agents used by twelve- to eighteen-month old infants, and evaluate model performance on prediction tasks.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Augment the simulation environment to enable evaluation of additional machine learning methods, cognitive capabilities, prediction tasks, and experience learning tasks, particularly for problems that require sensemaking, human-machine collaboration, or knowledge transfer. - Enhance common knowledge services to handle common sense phenomena of increased complexity, and assess performance on benchmark common sense challenge problem suites in environments with greater complexity, noise, and novelty. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects continued development of machine common sense technologies and the simulation environment, and additional work to refine techniques and assess of performance against benchmark commonsense challenge problem suites.			
Title: Guaranteeing AI Robustness against Deception (GARD)	14.000	15.400	17.500
Description: The Guaranteeing AI Robustness against Deception (GARD) program is developing techniques to defend against deception and other adversarial attacks on machine learning (ML) and artificial intelligence (AI) systems. GARD addresses the need to defend against deception attacks, whereby an adversary inputs engineered data into an ML system intending to cause the system to produce erroneous results. Deception attacks can enable adversaries to take control of autonomous systems, alter conclusions of ML-based decision support applications, and compromise tools and systems that rely on ML and AI technologies. Current techniques for defending ML and AI have proven brittle due to a focus on individual attack methods and weak methods for testing and evaluation. Techniques developed under the GARD program will address the current limitations of defenses and produce ML and AI systems suitable for use in adversarial environments. ***FY 2021 Plans:*** - Develop a general framework for deception and related attacks on ML, and quantify the vulnerability of ML algorithm classes to an adaptive adversary. - Develop defenses that leverage multiple data sources to reduce vulnerability to adversarial inputs. - Extend evaluation framework for testing ML defenses for multi-sensor scenarios, and evaluate ML defenses in such scenarios. ***FY 2022 Plans:*** - Develop defenses against novel types of adversarial inputs, with particular interest in inputs that can be implemented in the physical world. - Develop and validate novel measures of attack strength, and integrate these measures into the evaluation framework. - Extend evaluation framework for testing ML defenses for adaptive scenarios, and implement and test ML defenses for use against an AI-enabled adversary. ***FY 2021 to FY 2022 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** CCS-02 / *MATH AND COMPUTER SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 increase reflects continued development of ML defenses and an ML defense evaluation framework, and additional work to evaluate the effectiveness of ML defensive techniques against an AI-enabled adversary.			
Title: Young Faculty Award (YFA) ***Description:*** The goal of the Young Faculty Award (YFA) program is to encourage junior faculty at universities and their equivalent at non-profit science and technology research institutions to participate in sponsored research programs that will augment capabilities for future defense systems. This program focuses on cutting-edge technologies for greatly enhancing microsystems technologies, biological technologies, and defense sciences. The long-term goal for this program is to develop the next generation of scientists, engineers, and mathematicians in key disciplines who will focus a significant portion of their careers on DoD and national security issues. The aim is for YFA recipients to receive deep interactions with DARPA program managers, programs, performers, and the user community. Current activities include research in fifteen topic areas spanning from Machine Learning and Many Body Physics, to Wideband Transmitter-Antenna Interfaces and Multi-Scale Models of Infectious Disease Dynamics. A key aspect of the YFA program is DARPA-sponsored military visits; all YFA Principal Investigators are expected to participate in one or more military site visits to help them better understand DoD needs. ***FY 2021 Plans:*** - Award new FY 2021 grants for new two-year research efforts across the topic areas, establishing a new set of appropriate technologies to solve current DoD problems. - Continue FY 2020 research on new concepts for microsystem, biological, strategic, and tactical technologies; information innovation; and defense sciences by exercising second year funding and by providing continued mentorship by program managers. - Award Director's Fellowships for top FY 2019 participants to refine technology further and align to DoD needs. ***FY 2022 Plans:*** - Award new FY 2022 grants for new two-year research efforts across the topic areas, establishing a new set of appropriate technologies to solve current DoD problems. - Continue FY 2021 research on new concepts for microsystem, biological, strategic, and tactical technologies; information innovation; and defense sciences by exercising second year funding and by providing continued mentorship by program managers. - Award Director's Fellowships for top FY 2020 participants to refine technology further and align to DoD needs.	17.000	17.000	17.000
Title: Human Social Systems ***Description:*** The social sciences provide essential theories and models that can enable deeper understanding of human social systems and behaviors relevant to national security such as humanitarian aid, disaster relief, and stability support missions, as well as tactical, operational, strategic, and policy-level decision-making across the DoD. However, current limitations to the speed,	17.500	26.250	15.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
scalability, and reproducibility of empirical social science research continue to hamper its practical use by the DoD. Additionally, current social behavioral models often fail to accurately interpret social behaviors because they do not sufficiently capture diversity of context. The Human Social Systems thrust will address these limitations by focusing on the following technical challenges: (1) developing and validating new methods, models and tools to perform rigorous, reproducible experimental research at scales necessary to understand emergent properties of human social systems; (2) identifying methods to better characterize and quantify properties, dynamics, and behaviors of different social systems to enable better and more confident forecasting of changes in social systems, particularly when under stress; (3) developing an understanding of the complex effect of context and incorporating these effects into social science models; and (4) developing strategic forecasting and operational decision aiding capabilities that account for local contextual and cultural factors to assess the likely effectiveness of and/or responses to actions within an Area of Operations. This research thrust will provide DoD with new, reliable strategies to better understand and respond to social system issues at multiple scales (from small group to cities and/or regions) and will significantly improve DoD stabilization, deterrence, and/or gray zone mission outcomes. ***FY 2021 Plans:*** - Refine, implement, and test algorithms for systematically assigning quantitative confidence scores to social and behavioral science research with focus on logically complete methods that scale broadly across the social science research domain. - Demonstrate interactive meta-analytical algorithmic approaches to quantify social and behavioral science research that situates individual claims within the larger corpus of social science supporting broad generalizability appropriate for decision makers. - Increase efficiency and reduce cost of simulated predictive market algorithms for automatically assigning quantitative confidence scores to social and behavioral science researchers to support more rigorous and reproducible social and behavioral science. - Begin development of methods to semi-automatically create causal understanding of local systems with from participatory modeling with local populations. - Build evidence that cognitive models can be created with a scalable number of touch points. ***FY 2022 Plans:*** - Test algorithms for automatically assigning quantitative confidence scores to social and behavioral science research. - Analyze expert and non-expert usability and explainability of algorithms for automatically assigning quantitative confidence scores. - Validate increased efficiency of algorithms for automatically assigning quantitative confidence scores to social and behavioral science research. - Demonstrate improved prediction accuracy from developed causal models compared to current methods. - Demonstrate that mechanisms developed for engaging local populations are compatible with local infrastructure. - Scope testbed for developing and understanding what metrics are appropriate for measuring the impact of actions such as in Influence Operations.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Explore external and internal validity of social influence metrics within testbed. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from development to demonstration.			
Title: Artificial Social Intelligence for Successful Teams (ASIST)	13.060	17.000	15.000
Description: The Artificial Social Intelligence for Successful Teams (ASIST) program is developing intelligent software agents that can create shared mental models to enable effective teaming with humans. Theory of mind and the ability to create shared mental models are key elements of human social intelligence. Together these skills enable human collaboration and teamwork at all scales, whether the setting is a playing field or a military mission. The ASIST program aims to develop technologies to enable machines to exhibit similar capabilities for collaboration and teamwork with humans, capabilities which can be termed artificial social intelligence. These include the capability to infer the goals and situational knowledge of human partners, to predict what human partners will need, and to formulate context-aware actions having high value to a team. The ASIST program is developing proof-of-concept software agents that demonstrate a machine theory of mind and the capability to participate with humans in an effective team by representing and helping to maintain shared mental models. ASIST aims to provide the basis for machines that can participate effectively with humans on tasks where teamwork is required. ***FY 2021 Plans:*** - Investigate and derive performance predictions for computational agents capable of advising and guiding humans in the performance of complex cognitive and physical tasks. - Develop prototype agents that exhibit machine theory of mind and the ability to contribute to effective human teams. - Enhance virtual testbed and test prototype agents that exhibit machine theory of mind on diverse models of human and human-machine interaction. ***FY 2022 Plans:*** - Demonstrate and test prototype agents that exhibit machine theory of mind and the ability to contribute to effective human teams in specialized environments. - Derive performance, trust, and acceptance predictions for computational agents capable of advising and guiding humans in the performance of complex tasks, thereby reducing the collective cognitive load. - Scale virtual testbed for evaluation of computational agents with artificial social skills in complex environments with teams of humans. ***FY 2021 to FY 2022 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 decrease reflects ramping down of efforts to develop software agents that exhibit machine theory of mind, and focus shifting to experimentation to quantify factors that influence the performance of computational agents and human-machine teams.			
Title: Safe Documents (SafeDocs) ***Description:*** The Safe Documents (SafeDocs) program is developing software technologies that constrain syntactic complexity in data formats, and improve the capability to reject invalid and maliciously crafted data in electronic documents and streaming data. The high complexity and unmanaged evolution of electronic documents and streaming data greatly increases the computational attack surface. The SafeDocs program is focused on rationalizing existing data formats, with attention to compatibility, and advancing the state of the art in the security of document and data format parsers. SafeDocs advances are essential to enabling automated code verification, assuring that the conditions of data validity are enforced, and securing documents and streaming data. ***FY 2021 Plans:*** - Create a safe subset for a very widely used electronic data document format, and show that it supports the same essential functionality as the legacy standard specification. - Construct a program to convert a large majority of legacy format documents to safe format without loss of essential content, and show that the content produced by the program is secure against maliciously crafted data. - Demonstrate the ability to reduce common instances of streaming data formats to safe, simplified subsets that allow the same essential functionality under resource constraints representative of an embedded system. ***FY 2022 Plans:*** - Create methods for comparing multiple distinct classes of analytical information of parsing behaviors and rules, and develop techniques to merge and tag control flow graph blocks with derived semantics for streaming format parsers. - Develop bidirectional machine-readable feedback mechanisms from verification tools to improve system automation. - Automate testing methodologies for a large code base, and demonstrate safe parser construction using the developed tools. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects ramping down of efforts to develop safe formats for electronic documents and streaming data and verified functionally correct, efficient parsers, and focus shifting to demonstration of techniques in representative systems.	12.900	16.500	12.000
Title: Learning with Less Labeling (LwLL) ***Description:*** The Learning with Less Labeling (LwLL) program is developing technology to greatly reduce the amount of labeled data required to train machine learning (ML) systems. In supervised ML, a system learns through the use of labeled training examples to recognize and categorize attributes of images, text, or speech. Humans provide these training-data examples to ML systems and, with enough labeled data, it is generally possible to build useful models. Obtaining large amounts of labeled data	8.000	15.000	12.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
can be costly, particularly for national security applications. LwLL is addressing this problem by creating ML algorithms that learn and adapt more efficiently than current ML approaches, and by formally deriving the limits of machine learning and adaptation. LwLL aims to create ML systems that are easier to train for use in variable, unpredictable, real-world environments where training data is costly or sparse. ***FY 2021 Plans:*** - Develop approaches to label reduction via automated transfer learning that discovers similar problems and learns what is important for a given task. - Develop theoretical limits for transfer learning for problem classes and domains of interest to DoD. - Demonstrate the capability of new ML algorithms to learn with orders of magnitude reduction in labeled data on problems relevant to the DoD. ***FY 2022 Plans:*** - Develop approaches to optimize label reduction in ML algorithms and to simultaneously achieve performance near theoretical limits. - Demonstrate new ML algorithms that retain state-of-the-art performance even with several orders of magnitude reduction in labeled training data. - Demonstrate the generalization capability of new ML algorithms across multiple tasks and domains with datasets relevant to the DoD. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects reduced development of ML techniques that require less labeled data for effective training, and focus shifting to optimization and demonstration of techniques on datasets relevant to the DoD.			
Title: World Modelers	16.300	13.700	12.000
Description: The World Modelers program is creating explanatory models for natural and human-mediated systems at regional and global scales. Because of macro-economic interdependence, widespread consequences can result from the disruption of natural resources, supply chains, and production systems. World Modelers capabilities are focused on regional and global systems with the goal of generating timely indications and warnings. Water and food security are application domains of particular interest, as persistent drought may cause crops to fail, leading to migration and regional conflicts. The World Modelers program aims to develop techniques for automating the creation, maintenance, and validation of large-scale integrated models using publicly available news and analyst reports as a structuring mechanism, and government and commercial data as quantitative inputs. ***FY 2021 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Refine models of acute, high-impact phenomena such as natural disasters that disrupt civilian infrastructure to enable ensemble forecasting and estimation of uncertainty. - Extend technologies to accommodate more complex perturbations and apply to additional use cases such as disease outbreak. - Perform evaluations incorporating new data sources, models, and factors for a diverse set of transition partners. ***FY 2022 Plans:*** - Integrate software capabilities applicable to the diverse data and modeling tasks encountered in high-priority use cases. - Optimize techniques in response to transition partner feedback. - Harden technologies and perform evaluations in collaboration with transition partners. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects conclusion of efforts to develop models for acute high-impact phenomena, and focus shifting to hardening and evaluation of technologies in collaboration with transition partners.			
Title: Perceptually-Enabled Task Guidance (PTG)*	-	7.000	13.234
Description: *Formerly Application-Tailored Artificial Intelligence (APTAI) The Perceptually-Enabled Task Guidance (PTG) program will develop artificial intelligence (AI) technology that guides users in the performance of a wide range of cognitively challenging physical tasks. PTG will leverage recent advances in machine perception, automated reasoning, and augmented reality. The program will connect perception to reasoning and reasoning to augmented reality (AR) so as to create personalized, real-time feedback and contextualized assistance. To connect perception and reasoning, PTG will develop AI technologies for (1) perceptual grounding, to create a shared vocabulary for perception and reasoning, and (2) perceptual attention, to select important information from large volumes of perceptual data. To connect reasoning with AR, PTG will develop AI technologies for (3) knowledge transfer, to derive task models from instructions intended for humans, and (4) user modeling, to determine if, when, and how to best convey task information to the user. Together, the PTG technologies will lay the foundation for perceptually-enabled guidance and a qualitatively new type of AI device that would enable mechanics, medics, and other specialists to perform tasks within and beyond their skillsets with greater accuracy and efficiency. ***FY 2021 Plans:*** - Explore rule-based and statistical AI approaches for perceptual grounding, to create a shared vocabulary for perception and reasoning, and perceptual attention, to select important information from the large volumes of perceptual data. - Formulate approaches for connecting reasoning with AR, focusing on AI technologies for knowledge transfer, to derive task models from instructions intended for humans, and user modeling, to determine if, when, and how to best convey task information to the user. ***FY 2022 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Develop approaches for perceptual grounding as required for perceptually-enabled intelligent agents capable of learning how to recognize task-related terms, including objects, actions, and settings. - Devise new techniques for combining visual and audio examples scraped from multimedia knowledge sources and transferring them into task models, and for inferring model visual and audio properties from the properties of related model classes. - Develop knowledge transfer approaches for taking the knowledge that currently is available only in human-oriented task instructions such as checklists, procedure manuals, and training materials and representing that knowledge in machine-processable form. - Identify and collaborate with military stakeholders on high-priority task use cases, potentially involving repair of mechanical, electrical, or electronic systems or emergency medical care, for demonstration and evaluation of integrated perceptual agent prototype systems. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects continued effort to develop foundational techniques for perceptually-enabled intelligent agents and increased efforts to integrate the techniques for application to high-priority task use cases.			
Title: Knowledge Management at Scale	-	6.000	10.000
Description: The Knowledge Management at Scale thrust is focused on the development of knowledge management tools that can efficiently capture, analyze and reason with expertise, experience and data. The technology development under this thrust will help address a critical need for assimilating and preserving critical national security knowledge and expertise that is currently being lost due to attrition and other factors. Specific objectives include the following: 1) effective, trustworthy, and easily accepted approaches for domain agnostic knowledge acquisition at scale; 2) capabilities to identify correlations or hidden factors relating to knowledge acquired from different sources; and 3) techniques for incorporating domain models and other data sources for more extensive reasoning-based applications. Example approaches towards achieving these objectives include identifying and demonstrating robust knowledge acquisition tools, exploiting Artificial Intelligence (AI) techniques to establish a framework for knowledge analysis and causal reasoning, and developing automation tools that effectively elicit and impart acquired knowledge via user friendly interfaces. ***FY 2021 Plans:*** - Explore novel AI tools with potential to effectively elicit and impart acquired knowledge precisely when useful and applicable via user friendly interfaces. - Demonstrate fine grain knowledge acquisition and dissemination using question and answering system. - Develop novel AI tools capable of recognizing and representing implicit and explicit context of human tasks. ***FY 2022 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Develop automated methods to identify and capture, fuse, and disseminate knowledge across organizations as part of existing workflows. - Design and evaluate comfortable, trusted, and enticing software tools to be used by groups of non-technical people to capture, resolve, and apply effectively and timely different and overlapping aspects of their shared experiences at multiple time scales. - Use context to provide effective and appropriate knowledge from prior experience to current tasks. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects a shift from proof of concept demonstrations to system design and development.			
Title: Analyzing Software to Protect against Evolving Cyber Threats (ASPECT)*	-	4.000	8.500
Description: *Formerly Formal Methods at Scale (FMaS) The Analyzing Software to Protect against Evolving Cyber Threats (ASPECT) program will develop technologies to enable software developers to pose in-depth queries of code under development and sustainment in order to discover negative patterns, capture the semantic features of vulnerability classes, and characterize undesirable behaviors. ASPECT technologies will enable developers to generate the types of evidence required for confident certification, thereby improving software quality and assurance. At present, software faults and vulnerabilities are often unwittingly propagated throughout the software ecosystem because they are not easily discovered in codebases and because developers have strong incentives to re-use code and programming patterns. Moreover, searching for faults and vulnerabilities in software is impractical because these flaws are not manifest through the syntax of the source code but rather through the behaviors encoded in the software, i.e., in the software semantics. ASPECT will develop technologies for querying software at this deeper semantic level by developing modeling languages for the semantics of code and programs; representing code and programs in terms of their semantics; and identifying negative patterns, potential vulnerabilities, and undesirable behaviors. One major impact sought by ASPECT is the capability to efficiently and reliably find all semantically equivalent instances of a vulnerability, as such a capability would make the information that resides in vulnerability databases far more useful to software developers and certifiers. ***FY 2021 Plans:*** - Explore methods to analyze and query codebases across multiple dimensions for the presence or absence of semantic features. - Formulate approaches for querying codebases in a language-agnostic manner while also providing quantifiable metrics of analyzability to drive software improvements. ***FY 2022 Plans:*** - Build automated tools to model vulnerabilities in a manner that protects sensitive intellectual property while allowing for discovered patterns of vulnerability to be searched for in other codebases.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Develop language-agnostic metrics of software quality and evidence management techniques that provide actionable or otherwise useful information for software developers. - Assess the code query and quality measurement capabilities of the tools and demonstrate the capability to identify latent known vulnerabilities including syntactically-distinct but semantically-equivalent instances. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects continued development of techniques and tools to analyze and query codebases and the addition of efforts to assess and demonstrate the capability to identify vulnerabilities including syntactically-distinct but semantically-equivalent instances.			
Title: Agile Artificial Intelligence (AgAI) ***Description:*** The Agile Artificial Intelligence (AgAI) program aims to create capability to rapidly stand-up AI capabilities in domains important to national security. In many significant domains with potentially urgent mission needs, labeled data may be sparse and costly to acquire, sensors and other data sources may be rapidly evolving in their capabilities, and requirements for reliability and traceability may be significant. Building on emerging technical opportunities in machine learning and symbolic reasoning, AgAI will create technological foundations for the agile creation and evolution of AI-based capabilities. Emerging technical areas that are critical to AgAI include explicit domain models, harmonization of statistical and symbolic approaches, hybridization of multiple AI methods with techniques including game theory and optimization, and meta-cognition to support rapid improvement of the AI capabilities themselves. The AgAI program will also combine emerging techniques for mathematical modeling and for explanation to enhance reliability and traceability of the developed AI capabilities. ***FY 2022 Plans:*** - Explore the potential for a flexible, broadly-scoped AI development environment to support and facilitate the agile creation, maintenance, and improvement of AI and machine learning based systems across diverse application domains. - Formulate repeatable approaches for harmonization of statistical and symbolic approaches, hybridization of multiple AI methods with techniques such as game theory and optimization, and meta-cognition to support rapid improvement of the AI capabilities themselves. - Conceptualize approaches for combining emerging techniques for mathematical modeling and for explanation to enhance reliability and traceability of the developed AI capabilities. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.	-	-	21.000
Title: Synergistic Discovery and Design (SD2)	17.000	16.000	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Synergistic Discovery and Design (SD2) program is developing data-driven methods to accelerate scientific discovery and robust design in domains that lack complete models. Engineers regularly use high-fidelity simulations to create robust designs in complex domains such as aeronautics and integrated circuits. In contrast, robust design remains elusive in domains such as synthetic biology, neuro-computation, and synthetic chemistry due to the lack of high-fidelity models. The SD2 program will collect raw experimental data into a data and analysis hub, develop computational techniques that extract scientific knowledge directly from experimental data, and create data sharing tools and metrics that facilitate collaborative design. SD2 application domains include synthetic biology, solar cell chemistry, and protein design, which will impact future DoD capabilities in areas such as chemical and biological defense, and warfighter readiness. ***FY 2021 Plans:*** - Test design and discovery tools in supporting a design-test-build cycle to rapidly produce protein therapeutics, biosensors, and stable solar materials, and demonstrate automated experimental loops that provide rapid improvement in experimental performance. - Develop models of underlying scientific principles for domains such as complex systems design, biosynthesis, computational social science, and information operations. - Extend software to integrate data, experimental protocols, and analysis methods from diverse research groups, and identify resilience strategies for automated experimental bio-cyber-physical laboratories. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Advanced Tools for Modeling and Simulation	19.700	10.765	-
Description: The Advanced Tools for Modeling and Simulation thrust is developing foundational mathematical, computational, and multi-physics theories, approaches, and tools to better represent, quantify, and model complex DoD systems from multimodal data analysis through part/system design and fabrication. One focus area of this thrust is developing a unified mathematical framework to enable better visualization and analysis of massive, complex data sets. Rigorous mathematical theories are also being developed to address uncertainty in the modeling and design of complex multi-scale physical and engineering systems, incorporating capabilities to handle noisy data and model uncertainty that are well beyond the scope of current capabilities. Other work in this thrust focuses on developing the mathematical and computational tools required to generate and better manage the enormous complexity of design, ultimately allowing designers to more easily discover non-intuitive (yet realizable) designs that fully leverage new materials and advanced manufacturing approaches now available. Outcomes from this thrust will improve the speed and accuracy of modeling and simulation, as well as enable management of complexity across DoD devices, parts, and systems. Another focus area of this thrust is multi-physics models for predicting behavior and non-intuitive failure pathways for complex, dynamic physical systems.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: - Integrate and evaluate math and algorithms to generate multi-physics simulators into current simulation processes to assess utility against DoD challenges. - Explore the potential for achieving multi-basis imaging techniques that do not require active illumination. - Utilize image models to understand fundamental tradeoffs in data acquisition, prior knowledge and information resolution. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Communicating With Computers (CWC) ***Description:*** The Communicating With Computers (CWC) program is advancing human-computer interaction by enabling computers to comprehend language, gesture, facial expression, and other communicative modalities in context. Human language is inherently ambiguous, so humans depend on additional communication pathways, including perception of the physical world and shared context, to communicate efficiently. CWC aims to provide computers with analogous capabilities to sense and encode aspects of the physical world in a perceptual structure, and to use this structure to disambiguate language. To accomplish this, CWC will apply and extend research in language, vision, gesture recognition and interpretation, dialog management, cognitive linguistics, and the psychology of visual encoding. CWC also aims to extend the communication techniques developed for physical contexts to nonphysical contexts and virtual constructs. ***FY 2021 Plans:*** - Perform final human-computer interaction technology evaluations on multiple program use cases. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.	10.000	6.543	-
Title: Complex Hybrid Systems ***Description:*** The Complex Hybrid Systems program is focused on exploring fundamental science, mathematics, and computational approaches to collectives, complex hybrid (e.g., human-machine) systems and systems-of-systems across a variety of DoD-relevant domains. Efforts include development of foundational, quantitative theories and algorithms for the analysis and design of complex systems, as well as novel testing capabilities for assessing the value of these theories using experimental verification across multiple problem domains. Results from this thrust will better enable the systematic design of complex hybrid systems that can achieve unprecedented resilience and adaptability in unexpected environments. ***FY 2021 Plans:*** - Characterize hybrid team performance using at least two different mediation approaches.	10.718	7.300	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Characterize dynamics and overall team performance with respect to changes in a single environmental factor. - Implement AI-enabled dynamic mediation scheme and characterize team performance using this scheme. - Demonstrate a static and dynamic AI-mediated mechanism or policy for hybrid teams and characterize impact on team performance in response to environmental change. - Develop and demonstrate techniques and tools for model contextualization, understanding, and comparison, and for rapid automatic construction of executable models from literature sources. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to program completion.			
Accomplishments/Planned Programs Subtotals	248.978	277.803	265.784

	FY 2020	FY 2021
Congressional Add: Foundational Artificial Intelligence - Congressional Add ***FY 2021 Plans:*** Conduct research in Foundational Artificial Intelligence.	-	5.000
Congressional Add: Alternative Computing - Congressional Add ***FY 2021 Plans:*** Conduct research in Alternative Computing.	-	3.000
Congressional Adds Subtotals	-	8.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
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COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
ES-01: *ELECTRONIC SCIENCES*	-	30.393	35.801	16.361	-	16.361	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Electronic Sciences project is for basic exploration of electronic and optoelectronic devices, circuits, and processing concepts to meet the military's need for near real-time information gathering, transmission, and processing. In seeking to continue the phenomenal progress in microelectronics innovation that has characterized the last few decades, the project should provide DoD with new, improved, or potentially revolutionary device options for accomplishing these critical functions. The resulting technologies should help maintain knowledge of the enemy, communicate decisions based on that knowledge, and substantially improve the cost and performance of military systems. Research areas include analog, mixed signal, and photonic circuitry for communications and other applications; alternative computer architectures; and magnetic components to reduce the size of Electromagnetic (EM) and sensing systems. Other research could support field-portable electronics with reduced power requirements, ultra-high density information storage "on-a-chip", and new approaches to nanometer-scale structures, molecules, and devices.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Atomic-Photonic Integration (A-PhI)	14.000	17.000	9.361

Description: The Atomic-Photonic Integration (A-PhI) program is reducing the complexity of atomic clocks and gyroscopes by using integrated photonics for position, navigation, and timing (PNT) applications. A-PhI will demonstrate that a compact photonic integrated chip can replace the optical assembly for trapped atomic gyroscopes and clocks without degrading the performance of the device. PNT is a critical resource for all DoD missions such as communications, navigation, reconnaissance, and electronic warfare. While PNT needs are usually met by using the global positioning system (GPS), GPS signals are vulnerable to a variety of disruption modalities and a fallback from GPS is essential. Currently, in the absence of GPS, tactical grade clocks and tactical/ navigation grade Inertial Measurement Units can provide GPS-like accuracy for the short term. However, longer-term GPS independent strategies are still desirable. A-PhI will enable long-term GPS independence and enable PNT accuracy better than GPS for short durations.

FY 2021 Plans:
- Demonstrate an atomic clock in an integrated photonic integrated circuit physics package.
- Perform critical design of a trapped atomic gyroscope.
- Demonstrate a photonic integrated chip capable of atom trapping and cooling compatible with proposed clock architecture.

FY 2022 Plans:
- Demonstrate an atomic clock physics package meeting size, frequency stability, and phase noise metrics.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-01 / *ELECTRONIC SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate a trapped atom gyroscope with single measurement angle rate resolution and scale factor exceeding commercial gyroscopes. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from fabrication to technology demonstration.			
Title: Ultra-Wide Bandgap Semiconductors (UWBG) ***Description:*** The Ultra-Wide Bandgap Semiconductors (UWBG) program will seek to develop an entirely new class of semiconductor materials that will offer performance breakthroughs for a range of applications when compared to existing compound semiconductors. Electrical bandgap determines a material breakdown voltage, intrinsic charge carrier density, color (wavelength) of light emission, and impacts the maximum output power and operating frequency of a transistor made from the material. Consequently, wide bandgaps have considerable interest for the DoD due to the need for high operating temperatures, currents, voltages, and frequencies often required by emerging high power, agile Radio Frequency (RF) sources for radar, communications, directed energy, and electronic warfare. This program will overcome the fundamental materials and device challenges that currently prevent implementation of UWBG materials into power, RF, and optoelectronic devices and systems. These challenges include reliably manufacturing low-defect substrates, heteroepitaxial material growth, and high concentration p-type and/or n-type doping. ***FY 2021 Plans:*** - Characterize low-defect density substrates and investigate epitaxial material growth. - Develop theoretical models of high-energy performance and avalanche breakdown in UWBG materials. ***FY 2022 Plans:*** - Characterize low-energy heterogeneous epitaxially-grown UWBG devices. - Refine theoretical models with experimental verification of high-energy performance and avalanche breakdown in UWBG materials. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects minor program repricing.	-	6.801	7.000
Title: Magnetic Miniaturized and Monolithically Integrated Components (M3IC) ***Description:*** The Magnetic Miniaturized and Monolithically Integrated Components (M3IC) program aims to integrate magnetic components onto semiconductor materials, improving the size and functionality of Electromagnetic (EM) systems for communications, radar, and electronic warfare (EW). Current EM systems use magnetic components such as circulators, inductors, and isolators that are bulky and cannot be integrated with electronic circuitry. This limits the utility of the magnetic components as well as their ability to impact overall system performance and function. Reducing the size, weight, and power of	7.053	7.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
magnetic components and integrating them onto semiconductor chips, however, could provide new mechanisms for the control and manipulation of EM signals as well as enable broader exploitation of magnetic materials. For instance, tighter integration could yield smaller radar systems, higher bandwidth communication over longer ranges, improved jam resistance, and more resilient EW systems. The M3IC program is divided into three technical areas: integration of magnetic materials and systems with semiconductor technology; accurate and efficient modeling of magnetic phenomena from the molecular to the component system level; and exploitation of magnetic phenomena in innovative component designs relevant to DoD EM systems. ***FY 2021 Plans:*** - Implement and optimize micro-magnetic codes and validate circuit models in industry-standard radio frequency circuit design tools. - Demonstrate improved performance of integrated miniature components by utilizing design tools developed in the M3IC program. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: A MEchanically Based Antenna (AMEBA) ***Description:*** The A MEchanically Based Antenna (AMEBA) program seeks to develop efficient radio frequency (RF) transmitters operating in the Ultra-Low Frequency (ULF) and Very Low Frequency (VLF) ranges, for portable applications in underground and underwater communications. For classical antennas, the minimum antenna size for efficient transmission is related to the wavelength of the RF signal. This fundamental property prevents reducing the size of today's ULF and VLF transmitting antennas, which can be up to a mile in length. Whereas traditional antennas generate electromagnetic waves by driving current through a conductive material, AMEBA takes a novel approach, mechanically moving an electrical charge or magnet to generate electromagnetic waves at ULF and VLF. This mechanical coupling provides unique advantages over traditional approaches at these frequencies, most notably a greater than 1,000-fold reduction in antenna size. AMEBA will focus on developing both the materials and precision-controlled electromechanical systems required for an efficient transmitter system. This new capability would enable a range of applications including wireless communications for use over very long distances and short-range underground and underwater RF links. Other potential applications include terrestrial navigation systems for GPS-denied environments and ground-penetrating radar for detecting unexploded ordnance, underground facilities, and tunnels. ***FY 2021 Plans:*** - Demonstrate high-efficiency mechanical modulation techniques. ***FY 2021 to FY 2022 Increase/Decrease Statement:***	5.990	5.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 decrease reflects program completion.			
Title: SHort Range Independent Microrobotics Program (SHRIMP)	3.350	-	-
Description: The SHort Range Independent Microrobotic Platforms (SHRIMP) program developed efficient and capable actuation mechanisms and power efficient voltage conversion circuits for microrobotic platforms. The primary technical focus areas were the efficiency, robustness, and force output of millimeter-scale actuators, and the power and energy capacity of batteries and chip-level power converters. The program advanced the microrobotics field, allowing future robots to be realized in much smaller form factors than are previously possible. A companion applied research effort was funded in PE 0602716E, Project ELT-01.			
Accomplishments/Planned Programs Subtotals	30.393	35.801	16.361

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) ES-02 / *BEYOND SCALING SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
ES-02: *BEYOND SCALING SCIENCES*	-	62.828	59.025	45.145	-	45.145	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Beyond Scaling Sciences project supports investigations into materials, devices, and architectures to provide continued improvements in electronics performance with or without the benefit of Moore's Law (silicon scaling). Within the next ten years, traditional scaling will start to encounter the fundamental physical limits of silicon, requiring fresh approaches to new electronic systems. Over the short term, DoD will therefore need to unleash circuit specialization in order to maximize the benefit of traditional silicon. Over the longer term, DoD and the nation will need to engage the computer, material, and mechanical sciences to explore electronics improvements through new non-volatile memory devices that combine computation, and memory, and new automated design tools using machine learning. Other memory devices could also leverage an emerging understanding of the physics of magnetic states, electron spin properties, topological insulators, or phase-changing materials. Beyond Scaling programs will address fundamental exploration into each of these areas.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Beyond Scaling - Materials	10.000	11.000	8.000
Description: The Beyond Scaling - Materials program investigates new materials to support next-generation logic and memory components. The program pursues potential enhancements in electronics that do not rely on Moore's Law, i.e. silicon scaling, including research into new materials and into the implications of those materials at the device, algorithm, and packaging levels. These basic explorations include: novel mechanisms for computation based on inherent material properties, innovative processes to vertically integrate these materials with others to realize superior computational mechanisms, and cryogenic computing for 10X improvement in electricity cost or performance. Applied research for this program is funded within PE 0602716E, Project ELT-02. ***FY 2021 Plans:*** - Test memory elements supporting in-memory computation and stochastic computing. - Emulate and design functioning prototype to demonstrate system performance benefit of new computational circuit topologies. - Initiate new memory hardware studies to validate DoD-relevant applications and benefit of program approach. ***FY 2022 Plans:*** - Demonstrate energy efficient in-memory computing processing units with high energy efficiency per operation. - Design and implement advanced compute units for advanced DoD relevant machine learning applications. - Simulate and analyze transistor, memory, and interconnect performance at low temperature for low temperature circuit designs. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the program transitioning to final demonstrations.			
Title: Beyond Scaling - Architectures and Designs	15.000	14.000	13.645

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-02 / *BEYOND SCALING SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Beyond Scaling - Architectures and Designs program investigates circuit architectures and design tools at both the integrated circuit and board level to provide enhanced performance and security with or without the benefit of continued scaling in silicon transistors (Moore's Law). Currently, improvements in electronics largely depend on a regular reduction in the size of silicon components. As Moore's Law slows and the nation loses the benefit of free, exponential improvements in electronics performance, DoD will need to maximize the benefits of available silicon technologies through circuit specialization. This program investigates the potential for lowering the barriers to designing specialized circuits and to incorporating privacy and security protections. Approaches include the use of machine learning and automated design tools to program specialized hardware blocks, integrate them into existing designs, and deploy them in complex systems. The program also explores architecture options for physically protecting sensitive information. Advances under this program will support a new DoD capability to create secure and specialized hardware that does not depend on continued improvements in silicon transistors. Applied research for this program is funded within PE 0602716E, Project ELT-02. ***FY 2021 Plans:*** - Extend research and development of high level languages and novel modeling techniques while reducing transaction overhead on embedded devices. - Collect and curate training data for chip-level layout from published journals to create design tools using machine learning techniques. - Improve accuracy and speed of machine learning based algorithms for chip, package, and board design through incorporation of additional data. ***FY 2022 Plans:*** - Fabricate and test automatically generated digital and analog integrated circuits created using program-developed open source software tools. - Demonstrate the implementation of novel provably secure hardware, with computation overheads that are practical for real-world use. - Develop specialized machine designed hardware, and benchmark against general purpose machine learning chips. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.			
Title: Lifelong Learning Machines (L2M)	19.828	16.025	5.500
Description: The Lifelong Learning Machines (L2M) program is researching and developing fundamentally new machine learning mechanisms, enabling machines that learn continuously as they operate. Current learning machines are fully configured in advance of deployment, meaning that they have difficulty accounting for in-the-field mission changes or for unexpected deviations in the data being processed. To overcome this limitation, L2M will pursue learning approaches inspired by biological systems,			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-02 / *BEYOND SCALING SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
which continuously learn and improve their skills without losing previous knowledge. L2M will explore network structures that improve performance by processing new data seen in the field, learn new tasks without forgetting previous tasks, and incorporate context into their understanding of the environment. These capabilities would impact a broad array of military applications that require processing and understanding data in real-time, often have limited data sets for training, and must be deployed in environments where unpredictable events may occur. ***FY 2021 Plans:*** - Refine the first set of algorithms on the common cross-performer test cases, and add new algorithms to the test cases. - Integrate multiple L2M capabilities into complete systems. - Demonstrate complete set of L2M capabilities. - Evaluate contribution of individual components to L2M capabilities. - Study safety and security in L2M systems. ***FY 2022 Plans:*** - Demonstrate integrated L2M systems in multiple domains. - Transition L2M algorithms into selected applications. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the shift from integration to demonstration of the L2M system.			
Title: Joint University Microelectronics Program (JUMP)	18.000	18.000	18.000
Description: The Joint University Microelectronics Program (JUMP) is a government-industry joint research program to explore computing, sensing, communication, and data storage innovations for applications beyond the 2030 horizon. The program recognizes that the densely interconnected microsystems of the future will be built through the use of groundbreaking materials, revolutionary devices, advanced architectures, and unconventional computing. Therefore, JUMP sponsors academic research teams focused on related key technology areas that will impact future DoD capabilities and national security. The JUMP program will not only push fundamental technology research but also establish long-range microelectronic research themes with greater emphasis on end-application and systems-level computation. By discovering the science underlying new technologies and overcoming engineering challenges, JUMP will enable DoD applications to exploit the entire electromagnetic spectrum from radio frequency (RF) to terahertz (THz) and to employ both distributed and centralized computing with embedded intelligence and memory. ***FY 2021 Plans:*** - Demonstrate promising materials, power efficient RF, THz, digital, and storage devices prototypes.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** ES-02 / *BEYOND SCALING SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Explore next-generation distributed and centralized computing architectures and subsystems to enhance efficiency of information extraction, processing, and autonomous control. - Establish additional multidisciplinary projects across academic research teams to enrich their research agenda for future microsystems. ***FY 2022 Plans:*** - Advance materials, power efficient RF, THz, digital, and storage devices for technology adoption or transition. - Demonstrate next-generation distributed and centralized computing architectures and subsystems with enhanced efficiency of information extraction, processing, and autonomous control.			
Accomplishments/Planned Programs Subtotals	62.828	59.025	45.145

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) MS-01 / *MATERIALS SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
MS-01: *MATERIALS SCIENCES*	-	41.584	52.560	40.303	-	40.303	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Materials Sciences project provides the fundamental research that underpins the design, development, assembly, and optimization of advanced materials, devices, and systems for DoD applications in areas such as robust diagnostics and therapeutics, novel energetic materials, and complex hybrid systems.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Molecular Systems and Materials Assembly	7.000	5.500	5.300
Description: The Molecular Systems and Materials Assembly thrust is exploring new approaches for the synthesis, assembly, and characterization of molecules and materials from the atomic to the product scale. Ultimately, materials and methods developed in this thrust will support a wide range of DoD applications that span therapeutics, energetics, computation and next generation optical materials. Specific approaches include non-traditional synthetic approaches such as the use of extreme pressure and/or temperature conditions, engineering and controlling atomic-scale processing routes for designer microstructures, and the synthesis and rapid screening of many molecules to more quickly identify those with desired functions and/or properties. Efforts in this thrust also include assembly of these and other materials, such as subwavelength engineered shapes, into micro-to-macro-scale objects and devices, exploration of molecules for information storage and processing, and fundamental studies of the properties and function of these molecular ensembles and systems. ***FY 2021 Plans:*** - Establish projections for data access speeds of molecular storage methods with fully automated workflows. - Provide necessary design modifications to molecular computing systems to further improve input/output (I/O) rate, data read error, and computational accuracy. ***FY 2022 Plans:*** - Assess novel approaches to sensing, signal processing, computation, actuation, and energy storage such as structural ionic systems. - Investigate new structural actuation mechanisms such as electrochemical intercalation with combined actuation capability and structural strength and stiffness. - Explore robust local energy harvesting techniques with high structural capability and minimal parasitic mass. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to minor program repricing.			
Title: Fundamental Limits	13.000	19.000	18.903

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: Understanding the Fundamental Limits (i.e., achievable boundaries) of scientific principles, processes and technologies is critical to better anticipate technological surprise for our adversaries and ourselves. This thrust explores boundaries across fields such as physics, chemistry, mathematics, biology, and engineering to address critical questions for national security. This thrust is addressing foundational theory and approaches that include, for example, the fundamental limitations of optical technologies, potential implications for basic biology on national security, and the ability for modeling and simulation to provide a better understanding of complex systems. ***FY 2021 Plans:*** - Complete Engineered Materials Challenge Problems and transition to Government partners. - Demonstrate in simulation the ability of multi-physics models to predict atmospheric perturbations, such as plasma "holes" and acoustic shock waves, associated with small scale meteorological phenomena. - Investigate external modulation of bacteria (biofilm) Radio Frequency (RF) channels, for potential maritime applications; solidify RF channel models via modeling and measurements. - Use experimental methods and parametric models to develop devices that meet challenge problem objectives in the areas of extreme nonlinearities, thermal engineering, and disruptive electrodynamics. - Identify new approaches to improve the range and sensitivity of atmospheric measurements to enable routine characterization of the mesosphere. - Design vapor cell-based vector magnetometers with improved sensitivity and accuracy in a small physics package. - Investigate techniques for improving the sensitivity and reducing the instantaneous bandwidth of vapor cell-based electric field sensors in the mmW frequency range. ***FY 2022 Plans:*** - Experimentally demonstrate challenge problem objectives in areas of extreme nonlinearities, thermal engineering, and disruptive electrodynamics. - Replicate ionospheric total electron content signatures caused by meteorological and geophysical transient disturbances using next generation modeling and simulation. - Discover and characterize the nature of atmospheric background conditions through experimental campaigns in the mesospheric region. - Develop new multimodal whole-of-atmosphere sensors to identify atmospheric transient disturbances produced by meteorological and geophysical sources. - Demonstrate improved sensitivity of atomic vapor-based electric field sensors in the mmW frequency range. - Demonstrate an atomic vapor cell-based vector magnetometer with improved sensitivity and accuracy in a reduced physics package size. - Demonstrate the potential for improving the atom-photon interaction strength and quantum coherence of vapor quantum devices.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Identify DoD relevant applications for room temperature, vapor cell-based electric and magnetic field sensors and quantum atom-light interfaces. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to minor program repricing.			
Title: Non-Equilibrium Materials ***Description:*** The Non-Equilibrium Materials thrust is exploring materials and materials structures that acquire novel properties when driven far from equilibrium. Work in this thrust will examine the physical underpinnings and applications of these systems in areas of interest to the DoD, including next generation electronics, high-performance computing, and sensing. Efforts will include the development of topologically protected excitations in electronic materials and fundamental studies of exotic quantum states of matter in periodically driven solid-state systems. ***FY 2021 Plans:*** - Apply advanced metrology for high-resolution space and time-resolved spin-textures to observe topological spin structures. - Implement braiding operations in topologically protected qubits. - Demonstrate proof of principle topological memory device. - Engage with industry to determine path for implementing topological protection in memory and logic. - Demonstrate many-body localization and increased quantum coherence time to enable high-fidelity multi-qubit logic gates in spin-based quantum information processors. - Advance metrology, particularly atomic clocks, beyond the standard quantum limit via entangled quantum matter stabilization. - Optimize the performance of nitrogen-vacancy diamond-based solid-state magnetometers by improving their optical readout and control protocols. - Demonstrate phase noise reduction and efficiency enhancement in terahertz optical signal generation using microresonator-based Kerr frequency combs (soliton microcombs). ***FY 2022 Plans:*** - Apply developed metrology to skyrmion-host materials. - Test prototype devices for topologically protected memory. - Demonstrate inertial sensors with increased angular sensitivity and bias stability using quantum gyroscopes. - Demonstrate improved multi-qubit logic gate fidelities using engineered periodic control pulses in a highly scalable quantum dot architecture for quantum computing. - Demonstrate overall enhancements in magnetic, temperature, and rotation sensitivities of solid-state quantum sensors by using time-dependent periodic drives. ***FY 2021 to FY 2022 Increase/Decrease Statement:***	15.450	16.000	4.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 decrease is due to transition from development to demonstration.			
Title: Basic Photon Science	6.134	12.060	12.100
Description: The Basic Photon Science thrust is examining the fundamental science of photons and their interactions in integrated devices for potential DoD-applications such as communications, signal processing, spectroscopic sensing and imaging. One focus area is development of novel, chip-scale optical frequency comb sources and associated technologies for spectroscopic sensing, identification, and quantification of multiple trace materials in spectrally cluttered backgrounds. Additional research will explore development of a complex theoretical framework for maximum information extraction from complex scenes to guide development of new imaging technologies. Work in this thrust will establish the first-principles limits of photon detector performance in a variety of detector technologies to enable better, more sensitive detectors. ***FY 2021 Plans:*** - Explore new fundamental techniques with potential to create measurement hyperdiversity. - Develop and demonstrate imaging models to understand fundamental tradeoffs in information gathering and 3-dimensional resolution. ***FY 2022 Plans:*** - Characterize measurement hyperdiversity techniques to generate novel sensor designs. - Create initial predictions of the vehicle speeds that are theoretically supported by completely passive infrared sensors in off-road environments. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to minor program repricing.			
Accomplishments/Planned Programs Subtotals	41.584	52.560	40.303

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 1	R-1 Program Element (Number/Name) PE 0601101E / *DEFENSE RESEARCH SCIENCES*	Project (Number/Name) TRS-01 / *TRANSFORMATIVE SCIENCES*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
TRS-01: *TRANSFORMATIVE SCIENCES*	-	44.054	40.969	28.188	-	28.188	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Transformative Sciences project supports research and analysis that leverages converging technological forces and transformational trends in information-intensive subareas of the social sciences, life sciences, and manufacturing. The project integrates these diverse disciplines to eliminate reliance on foreign sources for critical materials, improve military adaptation to sudden changes in requirements, threats, and emerging/converging trends, especially trends that have the potential to disrupt military operations or threaten National Security. Specific research in this project will investigate technologies to enable detection of novel threat agents (e.g., bacterial pathogens) maintain warfighter health, and improve recovery. This project also includes efforts to create innovative materials of interest to the military (e.g., self-healing, optoelectronic or magnetic materials), as well as biological platforms for fabrication. This Program Element also supports innovation and robust transition planning in the technology cycle by working with entrepreneurs to increase the likelihood that DARPA funded technologies take root in the U.S. and provide new capabilities for national defense.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Biology for Security (BIOSEC)	9.855	11.172	11.601
Description: The Biology for Security (BIOSEC) program seeks to investigate novel approaches to address the DoD need for rapid detection of unknown and/or emerging biological threats from state actors or violent extremist organizations (VEOs). This program will investigate approaches for identifying pathogens based on specific behaviors, or phenotypes, such as niche finding or cell toxicity. Unlike current methods, which rely on a priori knowledge of the pathogen and cannot detect or otherwise analyze unknown threats, this approach will handle scenarios involving engineered or undiscovered bacterial pathogens that do not have known hallmarks. Advances in this area will produce a completely new capability to assess the emergence of pathogens and to detect pathogens that have been specifically engineered to evade detection by traditional methods. Resulting systems may be used to alert deployed military personnel operating around the world to new biothreats, or in response to a U.S.-based discovery, outbreak, or pandemic.			
FY 2021 Plans: - Perform continued platform integration for combined bacterial processing for isolation, integration, and data collection. - Increase isolation and interrogation on complex samples that simulate real environments. - Demonstrate the ability to combine bacterial phenotypes and single-cell omics to support pathogenic trait mapping. - Validate increased algorithmic performance on predicting pathogenicity of unknown bacteria.			
FY 2022 Plans: - Develop isolation and interrogation platforms on sterilized real world samples spiked with 50-100 different types of bacteria.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Develop algorithms that combine trait scoring for predictive threat identification. - Develop decision tree optimization algorithm and demonstrate increased pipeline efficiency. - Demonstrate ability to map pathogenic traits to single bacteria. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects minor program repricing.			
Title: Rapid Healing for Warfighter Injuries*	12.116	17.244	16.587
Description: *Formerly Native Bioelectronic Interfaces The Rapid Healing for Warfighter Injuries effort is addressing the DoD need for improving warfighter recovery from injury by developing technologies that can accelerate the restoration and repair of complex tissues. This program will develop approaches that combine high-resolution biosensors to track the healing process in real-time with bioactuators to stimulate restoration where and when needed. The primary challenge to achieving this is the lack of a closed-loop interface that can manipulate highly complex signaling pathways in wounds and the developmental interdependencies that scale from cell to tissue. The program will develop new methods to convert dense multi-modal information into the body's native repair processes, and will leverage artificial intelligence to guide the delivery of the signals necessary for healing. Advances from this program will produce bioactuators that can release diverse stimuli with high spatial and temporal resolution, and biosensors that provide the requisite in situ measurement to guide the healing process. ***FY 2021 Plans:*** - Incorporate validated sensing data into models and algorithms. - Demonstrate biocompatibility, reliable operation of actuators, and control of at least two physiological processes in animal models. - Demonstrate biocompatibility, reliable operation of sensors, and tracking of at least two physiological processes in animal models. - Demonstrate that the algorithmic model is both descriptive and able to determine the current stage of healing from acquired sensor data. ***FY 2022 Plans:*** - Produce an in vivo sensor system that can accurately report the wound state to be delivered to the independent verification and validation (IV&V) team. - Demonstrate that the model predicts the wound stage from in vivo test data with 80% accuracy. - Demonstrate closed-loop control over at least one physiological process. - Demonstrate improved wound healing for one wound healing stage.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Develop an initial integrated model for multi-systems interventions. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.			
Title: Social Simulation (SocialSim) ***Description:*** The Social Simulation (SocialSim) program is developing a computational capability to simulate the spread and evolution of information in the online environment. The global information environment is radically changing how and at what rate information spreads and evolves. Both nation-state and sub-state actors are incorporating messaging into their operations to great advantage. Existing approaches for understanding online information spread and evolution are largely based on specialized exercises that take considerable time to orchestrate and execute, and have limited accuracy. SocialSim aims to enable a deeper, more quantitative, and better validated understanding of adversaries' messaging campaigns and their likely outcomes, as well as exploration of potential responses. ***FY 2021 Plans:*** - Extend prototype tools using ensemble modeling and meta-modeling techniques, and by incorporating exogenous data sources. - Develop a visualization capability to analyze, assess, and debug the outputs of the multiple simulation models. - Explore the utility of prototype tools for modeling the spread of misinformation/disinformation and for counterfactual simulation in collaboration with operational users. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.	10.008	9.853	-
Title: Engineered Living Materials (ELM) ***Description:*** The Engineered Living Materials (ELM) program is pursuing new approaches to engineer complex, multi-cellular systems for enhanced capabilities and functional materials to improve military infrastructure design and logistics. Complex biological materials and systems have unique properties (e.g., controlled porosity and high strength-to-weight ratios) not only because of the inherent components but also because of how those components are assembled together across length scales. Engineering biology tools and techniques are now at a stage to pursue the organization and function of multi-cellular systems for a new class of improved capabilities. This program is developing underlying technological platforms to enable information-driven assembly of hierarchical multi-cellular systems for the development of advanced materials. Advances in this program will impact military approaches to infrastructure design in austere environments as well as established methods for the manufacture and maintenance of military platforms. ***FY 2021 Plans:*** - Verify stability and scalability of material over a prolonged period under operational conditions.	7.605	2.700	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 1	**R-1 Program Element (Number/Name)** PE 0601101E / *DEFENSE RESEARCH SCIENCES*	**Project (Number/Name)** TRS-01 / *TRANSFORMATIVE SCIENCES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Pressure test self-healing proficiency for deformation, puncture, and tearing resistance under operational conditions. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Biological Complexity (BioCom) ***Description:*** The Biological Complexity (BioCom) program sought to enhance the understanding of the basic processes associated with biological network interactions, communication, and control to enable novel approaches and technology development to improve warfighter readiness and resilience. Key advances delivered from this research included the identification of approaches to create stable, predictable, and dynamic control mechanisms of biological networks. Such information allows the determination of a biosystem's state and enables the prediction of control behavior. Applications range from infectious disease mitigation or prevention, maintaining warfighter health, to leveraging biological systems for optimal production of therapeutics.	4.470	-	-
Accomplishments/Planned Programs Subtotals	44.054	40.969	28.188

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	57.721	53.730	76.018	-	76.018	-	-	-	-	-	-
MED-01: *BASIC OPERATIONAL MEDICAL SCIENCE*	-	57.721	53.730	76.018	-	76.018	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Basic Operational Medical Science Program Element will explore and develop basic research in medical-related information and technology leading to fundamental discoveries, tools, and applications critical to overcoming DoD challenges. Programs in this Program Element address the Department's identified medical gaps in warfighter care related to, restorative function of the body, blood loss, and prevention and treatment of infectious disease. Efforts will draw upon computational modeling and experimental data to discover properties of biological systems that cross multiple scales of biological architecture and function, from the molecular and genetic level through cellular, tissue, organ, and whole organism levels. To enable in-theater continuous monitoring, protection and treatment of warfighters, this Program Element will explore multiple diagnostic and therapeutic approaches, including developing techniques to protect against emerging pathogens; exploring methods to prevent pathological infection or traumatic injury; and leveraging fundamental and engineered biological mechanisms to enhance tolerance to insults such as pain and altitude. This Program Element also supports innovation and robust transition planning in the technology cycle by working with entrepreneurs to increase the likelihood that DARPA funded technologies take root in the U.S. and provide new capabilities for national defense. This Program Element includes FY 2020 CARES Act Funding in the amount of $5.0 million to identify Food and Drug Administration (FDA)-approved drugs that could be repurposed as effective treatments for COVID-19.

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	54.122	53.730	62.181	-	62.181
Current President's Budget	57.721	53.730	76.018	-	76.018
Total Adjustments	3.599	0.000	13.837	-	13.837
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	5.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	4.984	0.000			
• SBIR/STTR Transfer	-6.385	0.000			
• TotalOtherAdjustments	-	-	13.837	-	13.837

Change Summary Explanation

FY 2020: Increase reflects COVID response CARES Act add and reprogrammings offset by the SBIR/STTR transfer.
FY 2021: N/A
FY 2022: Increase reflects scale up of the Combatting Anti-Microbial Resistant Pathogens and Physiological Overmatch programs.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Preventing the Emergence of Disease (PED)	11.848	5.664	5.382
Description: Many emerging infectious disease outbreaks have origins in animal reservoirs and occur in areas where DoD personnel are deployed, putting them at high risk of endemic and emerging diseases. The Preventing the Emergence of Disease (PED) program is investigating how animal pathogens are transmitted to humans and exploring novel approaches to prevent these events. Tools such as detailed molecular analysis and bioinformatics will be leveraged. Researchers will develop models to quantify the probability of pathogen disease transmission from animals to humans. Promising intervention approaches will be developed to prevent viral species jumps from animal reservoirs to humans. Predicting such jumps is a key capability to mitigating outbreaks originating in animal reservoirs. ***FY 2021 Plans:*** - Expand mathematical models to predict when viral shedding from animals will lead to spillover at a spatial and temporal scale relevant for intervention. - Using mathematical models, identify bottlenecks for the optimal timing, delivery, and scaling of countermeasures to ensure efficacy in animal reservoirs. - Demonstrate scalability of preemptive approaches for suppressing virus jump from one species to another in relevant animal models. - Demonstrate broad-spectrum preemptive approaches for suppressing virus transmission from vectors to animal models. ***FY 2022 Plans:*** - Demonstrate safety, efficiency, and efficacy of scalable countermeasure delivery platform in vitro and in animal models. - Adapt phylodynamic and multi-scale modeling to other host species and diseases. - Demonstrate efficacy of a vaccine to prevent Lassa fever virus spillover in controlled laboratory tests. - Demonstrate efficacy of ecological countermeasures to protect against spillover of henipaviruses and coronaviruses from animal reservoirs in controlled laboratory tests. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.			
Title: Early Battlefield Interventions (EBI)	14.348	13.957	17.650
Description: The Early Battlefield Interventions (EBI) program is exploring new methods to slow and limit damage caused by acute trauma, injury, and infection often suffered by warfighters under far-forward conditions. Research efforts will apply advances in molecular and cellular biology, cell signaling, and biomaterials to develop new tools to alter the time course of pathological processes associated with infection and tissue damage. This tactic is a departure from traditional therapeutic approaches that seek to control symptoms associated with active infections or innate physiological responses to tissue trauma. Advances in this			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
area may be applied to the development of both prophylactic and therapeutic medical countermeasures to forward-deployed service members. ***FY 2021 Plans:*** - Evaluate and optimize computational models for molecular design and prediction to achieve biostasis. - Begin evaluation of effects on cell functions and molecular pathways for biostasis-inducing agents. - Demonstrate efficacy of biostasis intervention to reversibly slow processes in biological systems of increasing complexity. - Optimize delivery protocols and formulations of biostasis interventions for biological uptake and distribution, and characterize molecular mechanisms of interventions. ***FY 2022 Plans:*** - Observe the effects of biostasis-inducing agents on cell function (e.g., toxicity, metabolism, DNA damage, etc.), and evaluate mechanisms of biostasis. - Validate intervention approaches to focus on inducing and reversing biostasis in increasingly complex, multicellular systems. - Evaluate biological uptake and distribution of biostasis interventions, and characterize molecular mechanisms of interventions. - Begin to characterize time course of biostasis induction and reversibility of cellular stasis. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the need to demonstrate the ability to preserve a complex biological system (tissue, organoid) with 98% or greater cell survival.			
Title: Outpacing Infectious Disease	13.144	5.850	6.139
Description: Military readiness and national security depend on the health and well-being of military service members. Unfortunately, today's antivirals and vaccines are often circumvented by fast-mutating viruses that evolve to develop drug resistance. Military service members often deploy to areas with such diseases that require new protective measures to maintain readiness. The Outpacing Infectious Disease program is investigating fundamental methods for using biology as a technology to create adaptive therapeutic response mechanisms to outpace viral diseases such as enabling co-evolution and co-transmission of newly developed therapeutics to ultimately outcompete the pathogen. Key advances expected from this research include identifying methods to discover and develop new classes of dynamic therapeutics for fast-mutating viruses. This approach represents a significant departure from conventional antiviral therapies, which typically rely on static solutions and continuous re-formulation and re-development in attempt to keep pace with emerging strains and disease variants. Advances in this area may be applied to the mitigation of known, new, or emerging diseases that impact military readiness and pose a national security risk as a potential pandemic. ***FY 2021 Plans:***			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Prepare and submit pre-Investigational New Drug (IND) regulatory package for clinical trial for therapeutic interfering particles (TIPs). - Demonstrate TIP-based medical countermeasures rapid response platform proof-of-concept. - Prepare Good Manufacturing Practice (GMP) TIP product in quantities sufficient for IND-enabling studies and clinical trial. - Validate predictive mathematical models for viral shedding, symptom severity, and effective interventions. ***FY 2022 Plans:*** - Initiate clinical safety trial for TIPs. - Determine spatial distribution and co-localization of TIPs and viruses in vivo. - Identify alternative methods for discovery and development of prophylactics to increase the longevity of protection for known, new, or emerging diseases. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects minor program repricing.			
Title: Improved Interventions	18.381	13.737	15.733
Description: The Improved Interventions program seeks to develop novel pharmacological interventions to quickly and holistically optimize the performance of the healthy warfighter. The status quo for pharmacological intervention is one drug, one target, which often has many undesirable side effects. This program will create a platform to develop pharmacological interventions capable of modulating multiple targets within biological systems of the body, which will reduce side effects and promote safety. Research will focus on the integration of novel bioinformatics approaches, high-content physiological model systems, and new bio-orthogonal chemical synthesis methods to treat the system in order to achieve desired physiological effects. Progress in this area will lead to new pharmacological discovery and design principles that will lead to products that can be used to augment physical fitness training and maintenance for military populations. ***FY 2021 Plans:*** - Employ a multi-tissue biological system to characterize indications of DoD relevance (e.g., pain/inflammation or metabolic stress under hypoxia). - Predict and optimize drug activity profiles using computational approaches. - Begin synthesis, testing, and exploration of predicted chemical compounds for indications of DoD interest. - Begin validation of computational pipelines to determine highest-value targets without relying on previous knowledge. ***FY 2022 Plans:*** - Begin validation of novel drug target network by predicting and testing drug combinations in a complex model system. - Collect molecular response profiles to target drugs developed for the indications of interest. - Test novel chemical compounds in appropriate animal models and compare to current single drug therapy.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 1: *Basic Research*	**R-1 Program Element (Number/Name)** PE 0601117E / *BASIC OPERATIONAL MEDICAL SCIENCE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Accelerate the timeline to network assembly and drug synthesis platform. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the need for a capability demonstration that establishes the ability to generate a drug target network within 60 days of data collection and validate the proposed network in an appropriate animal model.			
Title: Physiological Overmatch ***Description:*** Warfighters must operate under extreme physiological conditions with limited resources, acclimating quickly to austere environments. The Physiological Overmatch program will investigate innovative approaches to leverage biological systems to adapt to environmental challenges during deployment. The program will initiate work in aiding the deployed soldier's ability to defend against biological pathogens and chemical contaminants, resist fatigue, and receive adequate nutrition and hydration. Advances in engineered cells, bioelectronics, and cellular feedback circuits will enable the controlled, in vivo release of therapies as needed by the warfighter. This approach represents a significant enhancement to warfighter performance by providing internal protection from novel threats. ***FY 2021 Plans:*** - Initiate cell engineering and begin to assess engineered cellular viability in vitro. - Initiate development of ex vivo synthetic biology circuit components to enable the delivery of a beneficial biomolecule at a clinically relevant level (e.g., medical countermeasure). - Initiate development of ex vivo engineered cells that can implement a therapeutic purification or detoxification process, such as removing viral, bacterial, or toxin threats. - Begin development of biocompatible carrier devices that control engineered cells in the body. ***FY 2022 Plans:*** - Demonstrate inducible biosynthesis enabling the delivery of a beneficial biomolecule at a clinically relevant level. - Test biosynthesis of at least one therapy in vivo. - Demonstrate communication with the carrier in vivo or through realistic models (e.g., phantom tissue). - Validate biocompatibility of the carrier device in vivo. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the cost of demonstrating each technical area in small and large animal models.	-	8.817	15.115
Title: Combatting Anti-Microbial Resistant Pathogens ***Description:*** Building upon technologies developed under the Outpacing Infectious Disease program, the Combatting Anti-Microbial Resistant Pathogens program will investigate fundamental methods for using innate host machinery as a technology to create medical countermeasures that degrade or deactivate pathogen targets. The DoD has long recognized the warfighter's	-	5.705	15.999

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
outsized risk of exposure to biological threat agents and to infectious disease, including the increasing prevalence of antimicrobial-resistant (AMR) organisms that are ranked as a Tier 1 threat to the U.S. military. Similarly, the danger posed by bacterial biothreats persists with few countermeasures available. Key advances expected from this research include identifying methods to discover and develop new classes of therapeutics for AMR bacteria and bacterial biothreats. This approach represents a significant departure from conventional antibiotics, which typically rely on a limited number of small molecules with a narrow set of targets and mechanism of action. Advances in this area may be applied to the mitigation of known, new, and emerging bacterial pathogens that impact military readiness and pose a global health threat. ***FY 2021 Plans:*** - Begin development of novel ligands to bind microbial and toxin targets using biochemical and computational discovery methods. - Identify pathways for in-host microbe and toxin degradation or deactivation and begin identification of ligands to engage these pathways. - Begin development of linkers to bridge threat-binding and host-engaging ligands using experimental and computational methods. ***FY 2022 Plans:*** - Investigate the ability of chimeric molecules to inhibit DoD-relevant pathogen threats in vitro. - Develop methods to model the kinetics and outcomes of chimeric molecules against pathogens. - Investigate the mechanism of action for chimeric molecules engaging new host machinery. - Develop rapid ligand identification and screening approaches for pathogen targets and host machinery. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects integration of multiple components of the medical countermeasures required to demonstrate their efficacy for capability demonstrations and development of the rapid response platform that will be required for forthcoming pressure tests.			
Accomplishments/Planned Programs Subtotals	57.721	53.730	76.018

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	131.017	107.568	108.698	-	108.698	-	-	-	-	-	-
BT-01: *BIOMEDICAL TECHNOLOGY*	-	131.017	107.568	108.698	-	108.698	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

This Biomedical Technology Program Element focuses on applied research for medical related technology, information, processes, materials, systems, and devices. Successful battlefield medical and neural interface technologies developed within this Program Element address a broad range of DoD challenges to ensure warfighter readiness, including both resilience to infectious disease and neurotechnology for improved warfighter performance. To maintain warfighter health, battlefield medical technologies research in this project will investigate novel biothreat detection, injury, and therapeutic response. Example programs include the development of a platform for the identification of early infection biomarkers to diagnose and prevent widespread infection in-theater, new methods to rapidly develop medical countermeasures in response to an emerging biothreat, and in-theater manufacturing capabilities for field-relevant pharmaceuticals to reduce the logistical burden and infrastructure requirements. To improve warfighter performance, this project will develop new neural architectures and data processing algorithms to interface the nervous system with multiple devices, facilitating human machine interaction. Additionally, advanced evidence-based techniques will be developed to supplement warfighter healthcare, including the development of shelf stable blood products, and treatment of spinal cord injury. This Program Element also supports innovation and robust transition planning in the technology cycle by working with entrepreneurs to increase the likelihood that DARPA funded technologies take root in the U.S. and provide new capabilities for national defense. This Program Element includes FY 2020 CARES Act funding in the amount of $52.0 million to prevent, diagnose, and treat COVID-19.

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	92.771	107.568	110.953	-	110.953
Current President's Budget	131.017	107.568	108.698	-	108.698
Total Adjustments	38.246	0.000	-2.255	-	-2.255
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	52.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-2.691	0.000			
• SBIR/STTR Transfer	-11.063	0.000			
• TotalOtherAdjustments	-	-	-2.255	-	-2.255

Change Summary Explanation

FY 2020: Increase reflects COVID response CARES Act add offset by reprogrammings and SBIR/STTR transfer.

FY 2021: N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

FY 2022: Decrease reflects minor program repricing.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Neural Signal Interfaces and Applications (NSIA)	17.125	16.924	16.205
Description: As part of their daily duties, many military personnel must handle large volumes of data and interact with complex systems. These tasks could be made less difficult with advanced neurotechnology platforms, but all such devices currently require invasive surgery to implement. The Neural Signal Interfaces and Applications (NSIA) program is developing non-invasive neurotechnologies able to interface with the nervous system with high resolution and precision without surgery. NSIA is utilizing recent advances to transduce neural signals through tissue. Resulting technologies will restore function in wounded warriors and facilitate standard human-machine interfaces for improved workload balance between man and machine. ***FY 2021 Plans:*** - Integrate initial neural read and write subcomponent's functionality into a bidirectional system design. - Optimize neural transducer delivery plan. - Develop algorithms for noninvasive interaction with neural tissue. - Conduct initial testing of integrated record and stimulate capabilities in vivo. ***FY 2022 Plans:*** - Evaluate system ability to input multiple channels of information into a single volume of neural tissue. - Quantify system latency when used in real time. - Assess performance of read and write components on tissue of varying thickness. - Conduct initial in vivo tests evaluating system use for controlling multiple outputs. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.			
Title: Pandemic Prevention	64.954	23.250	8.521
Description: Military personnel are deployed all over the world for traditional operations that can involve exposure to endemic infectious disease, and are often specifically called upon in response to emerging or re-emerging disease outbreaks with pandemic potential (e.g., Ebola). In both instances, the DoD needs effective countermeasures to protect its deployed forces and maintain warfighter readiness. The Pandemic Prevention program is focusing on novel methods to accelerate countermeasure discovery, pre-clinical testing, and manufacturing. This program seeks to advance and integrate newly developed approaches including bioinformatics assessment of genetic sequencing and nucleic acid-based vaccines and to address technology bottlenecks associated with each stage of medical countermeasure development. Additional research will investigate new methods improving the manufacturability, distribution, and delivery of novel therapeutics. Pandemic Prevention will enable an integrated therapeutic development platform that leverages state-of-the-art technologies to prevent disease outbreaks.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: - Demonstrate the ability to manufacture clinical doses of gene-encoded antibody product at scale. - Initiate a Phase I clinical safety study of a gene-encoded antibody. - Conduct a demonstration of integrated technologies identifying, maturing, and delivering a gene-encoded antibody against a virus revealed just prior to demonstration. - Investigate the potential for a link between antibody sequence and level of expression from a nucleic acid construct. - Investigate novel approach to deliver DNA-encoded monoclonal antibodies without electroporation. ***FY 2022 Plans:*** - Complete clinical monitoring of patients in a Phase I clinical safety study. - Investigate antibody medical countermeasure products that bind and neutralize more than one target. - Integrate methodologies for mitigating viral mutant escape from candidate antibodies ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the conclusion of clinical study research and final evaluations of nucleic acid vectors.			
Title: Forensic Indicators of Threat Exposure (FITE)	21.804	13.285	12.957
Description: The Forensic Indicators of Threat Exposure (FITE) program is developing a field-deployable resource for indicators of an individual's exposure history to Weapons of Mass Destruction (WMD) and WMD precursors. FITE will investigate the ability to characterize epigenetic signatures in an individual's genome caused by specific exposures. The program will create the framework for modular technology capable of performing forensic or diagnostic analysis using epigenetic information to provide high specificity of the type of exposure and when it occurred. This novel capability could serve as a field-forward forensic tool for use by the DoD to assist in Chemical, Biological, Radiological, and Nuclear (CBRN) threat detection and response. ***FY 2021 Plans:*** - Perform pressure tests to assess the ability to distinguish viral from bacterial host-based epigenetic signatures in clinical samples. - Generate host-based epigenetic signatures that reveal temporal resolution of exposure events from WMD or WMD precursor exposure events. - Finalize selection of module components and complete system design for deployable platform prototype. ***FY 2022 Plans:*** - Perform pressure tests to assess the ability to identify time since exposure on collected samples. - Expand human exposure signatures based on collected samples. - Finalize bioinformatics algorithms for increased sensitivity and specificity of the epigenetic signatures.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
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C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Build platform prototype and perform initial tests for module integration in field forward device. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.			
Title: Improved Personnel Placement (IPP) ***Description:*** The Improved Personnel Placement (IPP) program aims to improve force lethality and overmatch by identifying and training candidates for specialized military positions in order to maximize performance and resilience, while minimizing attrition. IPP will study the relationships between genotype and phenotype to identify unique physical, cognitive, and behavioral traits associated with a broad spectrum of military specialties. The program will link these phenotypic traits to underlying biological expression circuits driving performance. This knowledge will help individualize training for specialized roles, while providing training cadres greater precision for identifying the correct candidates without bias. Measuring an individual's biological system will ensure that they achieve their maximum potential while facilitating readiness and resilience for the DoD. ***FY 2021 Plans:*** - Implement novel phenotypic detection assays in military cohorts. - Validate the ability to create layered biological data for building gene expression circuits. - Determine correlation of biomarkers across different biological samples (e.g., saliva, blood, urine, stool). - Identify gene expression circuits linked to elite performance. ***FY 2022 Plans:*** - Refine the mathematical and computational tools used to perform in silico analysis of phenotypic and biological variables. - Refine protocols to measure phenotypic traits and biological features. - Validate phenotypes linked to high performance. - Validate expression circuits related to detected phenotypes. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the reduction of phenotypic and biological measurements based on the refinement of protocols that predict military performance.	18.870	21.167	16.866
Title: Deployable Medical Countermeasures for Warfighter Readiness ***Description:*** Maintaining robust protection and treatment against infectious disease threats during stabilization operations (e.g., Humanitarian and Disaster Relief [HADR]) can cause a drug discovery, manufacturing and supply chain burden. A major limitation of our current response to emerging biological and chemical threats is the lack of immediate availability of ideal medical countermeasures (MCMs) for rapid response. The Deployable Medical Countermeasures for Warfighter Readiness program aims to develop an on-demand deployable platform to manufacture nucleic acid drugs at scale, in short timeframes. The platform will be	-	11.728	16.877

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
comprised of a fully contained system capable of selectively manufacturing relevant doses of current Good Manufacturing Process (cGMP) grade nucleic acid therapeutics at or near the point of care. This on-demand platform will enable countermeasures capable of combating novel threats, allowing a small force to prevent regional outbreaks from becoming global emergencies. ***FY 2021 Plans:*** - Initiate development of hardware and software to support production of nucleic acids in a laboratory setting. - Demonstrate the ability to biochemically or chemically synthesize and purify initial nucleic acid constructs. - Initiate studies to determine the efficacy of biochemically or chemically synthesized nucleic acids. - Establish the ability to purify and analyze synthesized nucleic acids in a laboratory setting. ***FY 2022 Plans:*** - Determine the most effective methods for nucleic acid synthesis. - Initiate stability studies for enzymes, intermediate nucleic acid products, and reaction components. - Demonstrate automation of each of the modules for nucleic acid synthesis, purification, and formulation. - Develop schematics for integration of modules for nucleic acid synthesis, purification, and analysis into an alpha prototype. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY2022 increase reflects the culmination of the program's second capability demonstration and beginning of end-to-end integration, prototype development, and FDA engagement.			
Title: Bridging the Gap after Spinal Cord Injury	-	15.997	16.754
Description: The Bridging the Gap after Spinal Cord Injury program will develop and integrate technologies to heal and restore function associated with spinal cord injuries. Building upon foundational work done under the Prosthetic Hand Proprioception & Touch Interfaces program, this program will significantly advance treatment technologies by developing implantable, adaptive devices to address different stages of spinal cord injury (acute, sub-acute, and chronic). For early phases of injury, this program will develop technologies for real-time biomarker tracking and delivery of therapies to stabilize or rebuild nerve connections at the injury site. For final phase of injury, the Bridging the Gap after Spinal Cord Injury program will develop and integrate a network of devices deployed across the body to effectively create a synthetic nervous system and "bridge the gap" of the spinal cord injury to restore function and sensory feedback. The Bridging the Gap after Spinal Cord Injury program will dramatically improve the quality of life for wounded warfighters and veterans suffering from spinal cord injuries. ***FY 2021 Plans:*** - Investigate approaches to design initial prototypes for multiple sensors that will monitor temperature, pressure, blood flow, etc., at the local state of the spinal cord injury. - Initiate assessment of the prototype devices that will stabilize the injury site and restore function.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Establish preliminary design plans for system integration. - Initiate the design of a software development kit that will facilitate system modularity. ***FY 2022 Plans:*** - Complete critical design review for implantable devices for spinal cord injury. - Initiate experiments toward achieving regulatory approval for the system sub-components. - Initiate test of system of systems for spinal cord injury stabilization and restoration of function. - Verify Artificial Intelligence (AI) and machine learning algorithms for each sensor to monitor the spinal cord injury progression and intervene appropriately. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects minor program repricing.			
Title: Distributed Access to Critical Biotherapeutics for Warfighters ***Description:*** The goal of the Distributed Access to Critical Biotherapeutics for Warfighters program is to ensure DoD access to critical medical countermeasures (MCMs) by establishing the foundational technologies needed for fully distributable, on-demand manufacturing of protein-based medical countermeasures. To achieve this, investments will be made in technologies that enable immediate synthesis of bioactive protein MCMs at large yields. This technology will allow the DoD to scale up and scale out MCM production on an immediate time scale, securing access to both protein and nucleic acid based MCMs without reliance on complex supply chains or slow development cycles. ***FY 2022 Plans:*** - Investigate novel biological platforms to produce MCMs. - Investigate processes to ensure the quality of MCMs. - Initiate development of technologies to increase the production yield of MCMs. - Initiate development of hardware designs for high throughput testing and production of candidate MCMs. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.	-	-	10.273
Title: Next-Generation Combat Casualty Care ***Description:*** The Next-Generation Combat Casualty Care program will develop advances in critical efforts to preserve warfighter life and wellbeing in the battlefields of the future. This research will directly address a leading cause of potentially preventable battlefield casualties by investigating new approaches for developing whole blood substitutes for traumatic injury that can be deployed on the battlefield in far forward settings. Additional potential uses apply to disaster relief, mass casualty events, and	-	-	10.245

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
stabilization missions. Advances within this program will ensure that the U.S. remains able to care for servicemembers in peer and near-peer conflict by addressing gaps in combat casualty care. ***FY 2022 Plans:*** - Begin to develop in vitro models for rapid product prototyping, testing, and evaluation. - Begin to investigate approaches for stabilizing the products to enable storage in field conditions. - Begin to investigate key biological functions of a whole blood substitute for trauma settings. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Restoration of Auditory and Visual Function After Injury ***Description:*** The Restoration of Auditory and Visual Function After Injury program is developing neurotechnology to mitigate the effects of physical injury to the auditory and visual systems of military personnel. Research is also focusing on understanding various forms of sensing and actuation to improve outcomes and how biofeedback over time can alter human brain function. Technologies developed through this program will provide foundational neural interface technology for restoring lost capability, improving situational awareness, and enhancing cognitive and physical effectiveness. ***FY 2021 Plans:*** - Submit documentation for regulatory approval of preliminary device evaluation to minimize technical transition risk. - Construct a sensory restoration testbed for the fully integrated input-output platform. - Quantify improvements offered by large-scale (e.g., tens of thousands) recording capabilities. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.	6.676	5.217	-
Title: Prosthetic Hand Proprioception & Touch Interfaces (HAPTIX) ***Description:*** Wounded warriors often suffer from neural injury due to spinal cord injury or amputations. Military personnel with amputated limbs get limited benefit from recent advances in prosthetic-limb technology because the user interface for controlling the limb is low-performance and unreliable. Through investments in the DARPA Reliable Neural-Interface Technology (RE-NET) program, novel interface systems have been developed that overcome these issues and are designed to last for the lifetime of the patient. The goal of the Prosthetic Hand Proprioception & Touch Interfaces (HAPTIX) program was to create the first bi-directional (motor & sensory) peripheral nerve implant for controlling and sensing advanced prosthetic limb systems. With a strong focus on transition, the HAPTIX program created and transitioned clinically relevant technology in support of wounded warriors suffering	1.588	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602115E / *BIOMEDICAL TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
from single or multiple limb loss. Research in this area also addressed similar interface technologies with other nerve pathways such as the spinal cord. Technologies developed in this program transitioned to the Army.			
Accomplishments/Planned Programs Subtotals	131.017	107.568	108.698

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	416.935	420.920	430.363	-	430.363	-	-	-	-	-	-
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	14.250	6.576	0.000	-	0.000	-	-	-	-	-	-
IT-03: *CYBER SECURITY*	-	262.861	236.182	237.089	-	237.089	-	-	-	-	-	-
IT-04: *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*	-	139.824	178.162	193.274	-	193.274	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Information and Communications Technology Program Element is budgeted in the Applied Research budget activity because it is directed toward the application of advanced, innovative computing systems and communications technologies. This Program Element also supports innovation and robust transition planning in the technology cycle by working with entrepreneurs to increase the likelihood that DARPA funded technologies take root in the U.S. and provide new capabilities for national defense.

The High Productivity, High-Performance Responsive Architectures project focuses on developing the computer hardware and associated software technologies required for future computationally- and data-intensive national security applications. Powerful new approaches are needed to manage the rapid growth in available sensor data, to leverage advances in machine learning and artificial intelligence, and to maintain the security of DoD information systems.

The Cyber Security project is developing the computing, networking, and cyber security technologies required to protect DoD, U.S. government, and U.S. civilian information, information infrastructure, and mission-critical information systems. Information technologies enable important new military capabilities and drive the productivity gains essential to U.S. industry.

The Artificial Intelligence and Human-Machine Symbiosis project develops technologies to enable machines to function not only as tools that facilitate human action but as trusted partners to human operators. Of particular interest are systems that can understand human speech and extract information contained in diverse media; answer questions, reach conclusions, and propose explanations; and learn, reason, and apply knowledge gained through experience to respond intelligently to new and unforeseen events. Enabling computing systems with such human-like intelligence is now of critical importance because the tempo of military operations in emerging domains exceeds that at which unaided humans can orient, understand, and act.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602303E *I INFORMATION & COMMUNICATIONS TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	428.556	435.920	454.599	-	454.599
Current President's Budget	416.935	420.920	430.363	-	430.363
Total Adjustments	-11.621	-15.000	-24.236	-	-24.236
• Congressional General Reductions	0.000	-15.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.619	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-4.729	0.000			
• SBIR/STTR Transfer	-7.511	0.000			
• TotalOtherAdjustments	-	-	-24.236	-	-24.236

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2020	FY 2021
Project: IT-03: *CYBER SECURITY*		
Congressional Add: *Distributed Ledger Technology*	1.000	-
Congressional Add Subtotals for Project: IT-03	1.000	-
Congressional Add Totals for all Projects	1.000	-

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer and reprogrammings offset by COVID response CARES Act add.

FY 2021: Decrease reflects congressional adjustments.

FY 2022: Decrease reflects the completion of the IT-02 High Productivity, High Performance Responsive Architectures project, and the Rapid Attack Detection, Isolation and Characterization Systems (RADICS) cyber security program.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	Project (Number/Name) IT-02 / *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
IT-02: *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*	-	14.250	6.576	0.000	-	0.000	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The High Productivity, High-Performance Responsive Architectures project focuses on developing the computer hardware and associated software technologies required for future computationally- and data-intensive national security applications. Powerful new approaches are needed to manage the rapid growth in available sensor data, to leverage advances in machine learning and artificial intelligence, and to maintain the security of DoD information systems. The project therefore aims not only to create larger computing platforms but also to efficiently extract information out of large and chaotic data sets with embedded and low-size, weight, and power systems. Advances in these areas will allow DoD electronic systems to collaboratively manage scarce resources, such as the electromagnetic spectrum, and to adapt to new requirements and situations. Further, the resulting technologies, by being accessible to a wide range of application developers, will support new, sustainable computing systems for a broad spectrum of scientific and engineering applications.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: RF Machine Learning Systems (RFMLS)	14.250	6.576	-
Description: The RF Machine Learning Systems (RFMLS) program is addressing the performance limitations of conventional radio frequency (RF) systems such as radar, signals intelligence, electronic warfare, and communications. The performance of future RF systems in the DoD will be defined by their ability to adapt and respond to their environment in real-time. We currently lack both the algorithms and computational power to manage the volume of data and complexity of decision-making that will be required. RFMLS technology will develop machine learning techniques that are able to help manage this complexity, for example, by recognizing specific emitters or detecting anomalies in a cluttered environment. The objective of the RFMLS program is to both develop these foundational technologies and to apply them to relevant DoD systems. ***FY 2021 Plans:*** - Complete final phase development of machine learning algorithms and architectures for all four of the challenge problems. - Complete a real-time, open-air demonstration of RFMLS capabilities. - Transition technology applications to relevant partners. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	14.250	6.576	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-02 / *HIGH PRODUCTIVITY, HIGH-PERFORMANCE RESPONSIVE ARCHITECTURES*

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	Project (Number/Name) IT-03 / *CYBER SECURITY*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
IT-03: *CYBER SECURITY*	-	262.861	236.182	237.089	-	237.089	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Cyber Security project is developing the computing, networking, and cyber security technologies required to protect DoD, U.S. Government, and U.S. civilian information, information infrastructure, and mission-critical information systems. Information technologies enable important existing and new military capabilities, and drive the productivity gains essential to U.S. industry. Meanwhile, cyber threats grow in sophistication and number, and put sensitive data, classified computer programs, mission-critical information systems, and U.S. economic competitiveness at risk. The technologies developed in this project will enhance the resilience of information systems to current and emerging cyber threats, enable broad situational awareness of the cyber domain, and provide the basis for accurate, calibrated, and safe cyber response.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Intent-Defined Adaptive Software (IDAS)	8.000	14.100	17.350
Description: The Intent-Defined Adaptive Software (IDAS) program is developing technologies to represent the intent of software and its abstract constraints separately from its concrete instantiation, for the purpose of enabling rapid code synthesis and continual adaptation. Modern weapons platforms are increasingly dependent on complex software, increasing the risk of system failures and creating new attack surfaces for adversaries. Software engineers often manage complexity by choosing a particular option that fulfills the immediate needs of the development effort (e.g., by concretization). IDAS will develop techniques for deferring software concretizations until uncertainties are resolved, either at build time or during run time, for complex systems. IDAS technology aims to significantly reduce software development time and maintenance costs, thereby enabling DoD to acquire, sustain, and improve software-based capabilities more cost-effectively.			
FY 2021 Plans: - Develop algorithms for deferring software concretizations until uncertainties are resolved for complex logistics, machine-learning, and cloud software systems. - Develop techniques that permit optimization of multiple implementations, and enable more efficient encoding of quality goals and operational constraints. - Test and evaluate alternative software synthesis algorithms for automated modification by rapidly revising the representation of the intent of the software and measuring software maintenance effort.			
FY 2022 Plans: - Select, scale, optimize, and increase the robustness of the highest performing algorithms for deferring software concretizations in complex logistics, machine-learning, and cloud software systems.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-03 / *CYBER SECURITY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Mature algorithmic techniques that permit verified optimization of multiple implementations, and demonstrate more efficient encoding of quality goals and operational constraints. - Demonstrate initial transitionable capabilities of the highest performing alternative software synthesis algorithms for automated modification of representative military software systems and quantify software maintenance effort. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects continued development and implementation of techniques for deferring software concretization, and increased work to demonstrate and evaluate alternative approaches in the context of representative military software systems.			
Title: Memory Optimization (MemOp)	19.060	18.000	17.000
Description: The Memory Optimization (MemOp) program is developing technology to optimize memory transactions in large scale computing systems. The demand for computing services is growing within both the U.S. Government and commercial industry. In response, new technical approaches are being developed to provide massive computation efficiently and cost effectively. In particular, distributed data centers with high-speed interconnects and customizable hardware, including graphics processing units (GPU) and field programmable gate arrays (FPGAs), are being used by service providers to achieve greater efficiency and improved processing performance. MemOp is exploring new memory architectures that more fully leverage emerging customizable hardware to deliver computing services reliably and at reduced cost. The more promising MemOp memory architectures will be implemented and evaluated in hardware and software. The technologies developed in MemOp will provide enhanced efficiency and improved performance for large scale computing systems. ***FY 2021 Plans:*** - Enhance the scalability of algorithms for task mapping in large scale memory systems, and optimize software implementations. - Implement and test methods to interface to memory and accelerated processing pipelines. - Leverage the testbed to evaluate memory transaction improvements in systems incorporating GPUs and FPGAs. - Optimize algorithms and architectures for memory transaction performance in hardware and software, and evaluate on testbed. ***FY 2022 Plans:*** - Refine and leverage algorithm scaling for task mapping in large scale memory systems, and optimize software implementations. - Evaluate and refine integration of memory and accelerated processing pipelines. - Evaluate memory transaction implementation and develop improvements on program testbed. - Optimize algorithms and architectures for memory transaction performance in hardware and software, and evaluate on testbed. ***FY 2021 to FY 2022 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-03 / *CYBER SECURITY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 decrease reflects ramping down of development of memory interface methods and accelerated processing pipelines, and continued development and use of an enhanced evaluation testbed.			
Title: Securing Information for Encrypted Verification and Evaluation (SIEVE) ***Description:*** The Securing Information for Encrypted Verification and Evaluation (SIEVE) program is developing technology to enable the creation of mathematically verifiable public statements derived from sensitive information that remains hidden. To accomplish this, SIEVE will produce advances in a cryptographic technique known as zero knowledge (ZK) proofs, which simultaneously enable mathematical verification of public statements while provably hiding the sensitive information from which the statement is derived. The advances produced by SIEVE will make it possible to verify statements substantially more complex than the current ZK state of the art supports, for example, statements about a software vulnerability that do not reveal details of how the vulnerability can be exploited. ***FY 2021 Plans:*** - Build efficient ZK proof generation compilers optimized for large and complex problem statements, and that can operate in an efficient manner. - Extend post-quantum analyses to important cases such as non-interactive zero knowledge from post-quantum assumptions, and zero knowledge from symmetric key primitives. - Validate the functionality, information leakage potential, and robustness to attack of developed ZK techniques and software on a set of DoD-relevant applications. ***FY 2022 Plans:*** - Extend ZK proof compilers by adding problem classes as well as reducing representation size of proof statements by orders of magnitude. - Optimize post-quantum analyses to reduce theoretical proof complexity for important use cases. - Enhance techniques to permit optimization for any subset of prover computation, verifier computation, total communication, and total number of communication rounds. - Apply ZK proof techniques to additional DoD and U.S. Government use cases and evaluate their functionality, information leakage potential, and robustness to attack in collaboration with potential transition partners. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects continued development of cryptographic technologies and increased efforts to extend and validate their functionality, information leakage potential, and robustness to attack on applications of interest to the DoD.	7.700	14.500	16.000
Title: Cyber-Hunting at Scale (CHASE)	19.000	16.140	15.100

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-03 / *CYBER SECURITY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Cyber-Hunting at Scale (CHASE) program is developing data-driven tools for real-time cyber threat detection, characterization, and protection within enterprise-scale networks. U.S. computer networks are continually under attack, but at present there are few capabilities to efficiently extract and analyze the right data from the right device at the right time for DoD-scale information networks. For example, analysis of an in-memory exploit requires detailed data from a few devices, while analysis of a global botnet attack requires summary data from a great many devices. CHASE is developing novel algorithms and analysis tools to dynamically collect data from across the network, actively hunt for advanced threats that evade routine security measures, and automatically disseminate protective measures that bolster the collective cyber defense posture. ***FY 2021 Plans:*** - Evaluate threat detection, threat characterization, and data planning feedback loops at enterprise scale, and demonstrate ability to adapt sensor feeds based on threat characterizations. - Evaluate ability for threat detection and characterization to improve detection accuracy and reduce the time analysts require to diagnose alerts. - Evaluate the extent to which novel data retention policies can improve detection accuracy while reducing the amount of historic data stored. - Quantitatively characterize how the accuracy of global cross-enterprise threat detection depends on data policies. ***FY 2022 Plans:*** - Develop an analyst interface to enable automated cyber report generation, evaluate the utility of the interface, and demonstrate foundational protective measures given specific threat detections. - Develop and demonstrate techniques for quantifying the risk of cyber operations. - Identify transition opportunities for validated threat detection, threat characterization, and data planning algorithms. - Integrate threat detection, data retention, and global analysis methods, and harden capabilities for transition to DoD stakeholders. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is the result of development and integration work decreasing, and the focus shifting to demonstration, hardening, and transition to DoD stakeholders.			
Title: Resilient Anonymous Communication for Everyone (RACE)	12.700	13.500	14.700
Description: The Resilient Anonymous Communication for Everyone (RACE) program is developing cryptographic and communication obfuscation technologies to enable anonymous, attack-resilient, mobile communications within a network environment. RACE is developing a mobile phone application and distributed systems that provide a secure message-passing service by combining advances in distributed system tasking with communication protocol encapsulation methods. The RACE system will maintain confidentiality, integrity, and availability of messaging while preventing large-scale compromise of the system.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-03 / *CYBER SECURITY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
RACE security is based on rigorous security arguments or statistical arguments based on realistic simulations, and not on ad hoc security claims. ***FY 2021 Plans:*** - Refine and scale up the secure message-passing system by improving the efficiency of techniques for computing on encrypted routing information. - Integrate components into a secure message-passing system to defeat a cyber adversary with limited ability to observe the network by making the communication protocols statistically indistinguishable from legacy protocols. - Enhance the testbed and demonstrate the integrated secure message-passing system against an active simulated cyber adversary that seeks to discover the obfuscation and cryptographic technologies while possessing limited knowledge of the system. ***FY 2022 Plans:*** - Enable the system to scale to thousands of users by improving the efficiency of techniques for computing on encrypted routing information. - Integrate enhanced components into the secure message-passing system with improved capability to counter a cyber adversary who has access to communication protocol information and communication nodes. - Enhance the testbed and demonstrate the integrated secure message-passing system against a simulated cyber adversary that has full knowledge of the system. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects continued development of obfuscation and encryption technologies, continued implementation of a secure message-passing system and testbed, and expanded work to evaluate the system against a simulated cyber adversary.			
Title: Assured Micropatching (AMP) ***Description:*** The Assured Micropatching (AMP) program is developing technologies to enable the rapid production of targeted micropatches to repair legacy program binaries with strong guarantees. At present, the emergency patching of legacy software, even if all relevant information is available, takes far too long, leaving critical systems with known flaws vulnerable to adversary attack. AMP will create the capability to analyze, modify, and fix legacy software in binary form even when the original source code and/or build process is not fully available. The AMP technical approach involves automatic discovery of known vulnerable components, goal-driven decompilation to isolate and analyze the vulnerable binary components, and minimal-change patching and recompilation to rebuild affected binaries with strong guarantees that the patch will not impair the functions of the system. The technologies developed by AMP aim to enable cyber defenders to quickly and accurately patch legacy binaries in the deployed software systems upon which our military depends.	12.400	16.410	13.500

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-03 / *CYBER SECURITY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: - Develop prototype goal-driven decompilers, and demonstrate feasibility of iteratively guiding decompilation with fitness functions relevant to repairing binary flaws. - Develop prototype recompilers that produce both a micropatch and a formal representation of the effects of the micropatch suitable for use in a proof that the effects of the patch are isolated from other components. - Perform initial tests of decompiler and recompiler prototypes on at-scale system binaries. ***FY 2022 Plans:*** - Develop supergraph generator to infer compiler optimization effects on the call graph structure. - Develop probabilistic graph-matching and inference algorithms to produce candidate matches between the target binary procedures and most likely source code procedures. - Create a Ghidra extension to interactively show the effects of an applied micropatch. - Conduct a challenge event using a commodity Controller Area Network (CAN) controller/data logger based on a widely-used commercial architecture. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects ramping down of work to develop prototype decompilers and recompilers, and focus shifting to work to demonstrate the technology on realistic challenge problems.			
Title: Computers and Humans Exploring Software Security (CHESS)	18.000	14.375	12.400
Description: The Computers and Humans Exploring Software Security (CHESS) program is developing technologies to enable computers and humans to reason collaboratively over software artifacts, such as source code and compiled binaries, with the goal of finding vulnerabilities more rapidly and accurately than unaided human operators. CHESS envisions a future in which high-intensity cyber operations are conducted by computer-human teams. CHESS capabilities will be designed for use by humans of varying skill levels, even those with minimal previous cyber experience or relevant domain knowledge. Achieving the necessary scale and timelines in vulnerability discovery will require innovative combinations of automated program analysis techniques with support for mixed-initiative computer-human collaboration. CHESS aims to enable U.S. operational cyber superiority by combining human-generated insight into the vulnerability discovery process with the speed and scale of computational analysis. ***FY 2021 Plans:*** - Implement and demonstrate techniques for emitting a proof of vulnerability to confirm existence of a vulnerability, and for generating a non-disruptive, specific patch to neutralize the vulnerability. - Expand cyber reasoning techniques to discover additional classes of software vulnerabilities, and enhance representations of information gaps revealed by expanded cyber reasoning techniques.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602303E / *INFORMATION & COMMUNICATIONS TECHNOLOGY*	**Project (Number/Name)** IT-03 / *CYBER SECURITY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate an end-to-end, integrated computer-human software reasoning system to DoD and Intelligence Community (IC) transition partners. ***FY 2022 Plans:*** - Scale techniques for emitting a proof of vulnerability to confirm existence of a vulnerability, and for generating a non-disruptive, specific patch to neutralize the vulnerability, to programs of the size and complexity found in military systems. - Enhance representations of information gaps revealed by expanded cyber reasoning techniques to enable non-experts in vulnerability discovery to approach expert-level efficacy. - Incorporate improved cyber reasoning capabilities and additional operator-requested refinements in an end-to-end, integrated computer-human software reasoning system for the DoD and IC. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects ramping down of work to integrate technologies in a proof-of-concept, computer-human software reasoning system, and focus shifting to enhancement, demonstration, and transition to the DoD and IC.			
Title: Fast Network Interface Cards (FastNICs) ***Description:*** The Fast Network Interface Cards (FastNICs) program is creating new networking technologies to accelerate the computation of distributed applications. Today's network and computing subsystems are badly out of balance with each other, a result of incremental technology advances in networking and computing market silos. This has produced a bottleneck at the network interface used to connect a machine to an external network, severely limiting the input/output capability. FastNICs will develop new input/output technologies based on more realistic models of complex multiprocessor compute, interconnect, and memory subsystems. FastNICs aims to enable a dramatic increase in computational throughput for distributed applications such as iterative training of machine learning systems. ***FY 2021 Plans:*** - Extend the most widely used distributed systems software and operating systems to accommodate massively parallel input data streams. - Implement alternative architectures for the network interface, and quantify achievable communications bandwidth and processing throughput. - Implement distributed computing applications, such as machine learning, that effectively utilize massively parallel data streams. ***FY 2022 Plans:*** - Evaluate network interface architecture alternatives such as busses and parallelism. - Demonstrate versions of widely used distributed systems software and operating systems that accommodate massively parallel input data streams.	6.900	12.000	11.500

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate and evaluate distributed computing applications of interest to the DoD such as training deep learning systems. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects ramping down of work to implement improved network interfaces, and focus shifting to demonstration and evaluation on distributed applications of interest to the DoD.			
Title: Cora ***Description:*** The Cora program is developing technologies to enable machines to read heterogeneous text-based data sources, extract key entities and activities, and characterize cyber threats. Large volumes of text-based data contain scattered clues about the activities of cyber threats. Automated machine reading and analysis capabilities are required due to the extreme rates at which this text-based data is generated. In addition, the connections between extracted entities and their activities can be very subtle and, because they are buried in noise, difficult to detect and correlate. The Cora technologies will benefit cyber analysts by providing them with pre-processed cyber leads that otherwise might not be available. ***FY 2021 Plans:*** - Evaluate cyber analytical technologies on large-scale data, and implement algorithmic improvements to address scalability and performance. - Develop natural language understanding capability in text-based data other than English. - Provide initial software capabilities to transition partners for performance assessments in operational environments. ***FY 2022 Plans:*** - Demonstrate scalability and performance of analytical capabilities on relevant large-scale data sets. - Evaluate machine-learning-based methods for identifying cyber threats across heterogeneous data, in multiple languages. - Harden cyber analytical software technologies and incorporate refinements requested by cyber operators. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects ramping down of efforts to implement and evaluate an integrated cyber analytical system, and transition to operational partners.	12.500	11.000	10.740
Title: Harnessing Autonomy for Countering Cyber-adversary Systems (HACCS) ***Description:*** The Harnessing Autonomy for Countering Cyber-adversary Systems (HACCS) program is developing safe and reliable autonomous software agents that can neutralize botnet implants and similar large-scale malware in networked devices. HACCS is developing technologies to (1) identify and characterize botnet-conscripted networks of devices to determine the types of devices and the software services running on them with sufficient precision to infer the presence of known vulnerabilities; (2) generate software exploits for a large number of known vulnerabilities that can be used to establish initial presence in each botnet-conscripted network without disrupting system functionality; and (3) create high-assurance software agents that can autonomously	18.800	15.400	9.240

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
navigate within botnet-conscripted networks, identify botnet implants, and curtail their ability to operate while minimizing side effects to systems and infrastructure. HACCS technologies aim to enable U.S. agencies possessing the appropriate authorities to safely conduct Internet-scale counter-botnet operations. ***FY 2021 Plans:*** - Enhance botnet-tracking algorithms to enable detection and tracking of additional classes of botnet-conscripted networks, such as peer-to-peer (P2P) botnets. - Expand discovery techniques to address additional platforms and classes of software vulnerabilities. - Evaluate botnet-tracking algorithms for detecting botnet-conscripted networks by characterizing botnet management infrastructure, and evaluate autonomous agent behavior in synthetic environments. - Collaborate with transition partners to evaluate counter-botnet technology in synthetic environments. ***FY 2022 Plans:*** - Enhance botnet-tracking algorithms to provide near-real-time assessment for the global identification and tracking of all major classes of botnet-conscripted networks. - Enhance automated discovery techniques to address software vulnerabilities of increased complexity. - Evaluate botnet-tracking algorithms for detecting botnet-conscripted networks by characterizing botnet management infrastructure, and evaluate autonomous agent behavior in real-world environments. - Collaborate with transition partners to select and evaluate counter-botnet technology in realistic environments. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is the result of reduced counter-botnet technology development and prototype integration work, and focus shifting to demonstrations in collaboration with transition partners.			
Title: Active Social Engineering Defense (ASED) ***Description:*** The Active Social Engineering Defense (ASED) program is developing technologies to automatically identify, disrupt and investigate social engineering attacks via bot-mediated communications. Social engineering attacks, such as phishing and spear-phishing, typically gain user trust via impersonation to induce behaviors or elicit sensitive information that compromise security of an information system. At present, defending against social engineering attacks falls largely to users. ASED aims to prevent social engineering attacks by creating counter-social-engineering bots that act on behalf of users to mediate and aggregate communications and auto-identify attackers. ASED aims to greatly reduce the effectiveness of adversary social engineering attacks and improve the security of DoD information systems. ***FY 2021 Plans:*** - Enhance and refine prototype social engineering attack defense system for use in real-world environments.	12.500	10.800	6.600

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate automated attribution of social engineering attacks across multiple communication platforms. - Assess system performance by quantifying the increased costs to an adversary of conducting a social engineering attack. ***FY 2022 Plans:*** - Demonstrate and evaluate a machine-learning-based social engineering attack detection system, including automated attribution of social engineering attacks against advanced simulated adversaries who disguise their attacks. - Harden a modular social engineering attack detection and attribution system for use by U.S. Government, DoD, and industry. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects ramping down of development of counter-social-engineering bot technologies and focus shifting to demonstration, evaluation and transition to U.S. Government, DoD, and industry.			
Title: Configuration Security ***Description:*** The Configuration Security program is developing technologies to analyze, monitor, and modify the configuration of composed cyber-physical-human systems to identify system vulnerabilities and minimize the attack surface while maintaining functionality and performance. Complex cyber-physical systems, such as ships, airplanes, and critical infrastructure, increasingly make use of multiple commodity information technology components. The manual configuration necessary to enable each component to interoperate introduces exploitable cyber vulnerabilities, as do the standard operating procedures that system operators follow. The Configuration Security program will develop capabilities to automate the appropriate configuration of such systems within the operational context, ensure secure configuration settings, and prevent malicious changes to these settings. ***FY 2021 Plans:*** - Increase automation of best-practice secure configuration generation for operationally relevant, complex cyber-physical-human systems, including the translation of standard operating procedures and figures into machine-understandable formats. - Apply algorithms to automatically reconfigure a civilian critical infrastructure system to a safer and more secure baseline that provides required functionality and supports the new configuration with automatically-generated human-readable explanations. - Test and evaluate a capability to detect and prevent malicious modification of configurations from the system-generated baseline on a shipboard communications system, and to assist system operators in changing between operational contexts. ***FY 2022 Plans:*** - Scale and optimize automatic generation of contextualized secure configurations for operationally relevant, complex cyber-physical-human systems, including the translation of multi-vendor, human-readable artifacts into machine-understandable formats. - Demonstrate algorithms to automatically reconfigure a military operational system to a safer and more secure baseline that provides required functionality and supports the new configuration with automatically-generated human-readable explanations.	14.800	11.400	6.050

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Transition a capability to detect and prevent malicious modification of configurations from the system-generated baseline on multiple DoD-relevant systems, including a shipboard communications system, and to assist system operators in changing between operational contexts. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects ramping down of algorithm and software development, and focus shifting to demonstrations and transition of an automated capability to detect and prevent malicious modification of configurations for military systems.			
Title: Searchlight ***Description:*** The Searchlight program is developing technologies to ensure that quality-of-service (QoS) guarantees are met for distributed applications operating across the Internet. The increasing use of Internet-based distributed applications creates risks as surges in network use can result in resource shortfalls. Searchlight will develop novel approaches for allocating inherently limited network resources to optimize the performance of distributed applications. Searchlight techniques and systems aim to enable organizations to adapt the QoS for their low-priority traffic resulting in improved QoS for their high-priority traffic without affecting traffic from other Internet users. Searchlight technologies will become increasingly important as 5G systems provide advanced capabilities for organizations to adapt their QoS guarantees. ***FY 2021 Plans:*** - Implement a system that integrates automated application inference, network inference, and QoS management for DoD and commercial networks. - Demonstrate the integrated QoS management system and evaluate its capability on heterogeneous distributed applications of interest to the DoD and commercial network service providers. - Formulate transition approaches with DoD and commercial network service providers. ***FY 2022 Plans:*** - Improve integrated QoS management system performance in terms of scale, application identification accuracy, and application responsiveness. - Demonstrate the integrated QoS management system and evaluate its capability on heterogeneous applications distributed across wide area networks of realistic scale and complexity. - Work with transition partners to optimize the QoS management system to relevant use cases, applications, and network characteristics. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.	5.300	4.900	4.809
Title: Enhanced Attribution	18.600	8.600	2.750

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Enhanced Attribution program is developing technologies to associate the malicious actions of cyber adversaries with individual operators, and to publicly reveal these actions without compromising sources and methods. The program focuses on new approaches for identifying malicious cyber operators, analyzing their software tools and actions, and confirming this information with commercial and public sources of data. As the attribution techniques are developed and show promise, they will provide the basis for new cyber capabilities such as indications and warning of adversary cyber actions. These technologies will be implemented in tools for evaluation by potential transition partners. ***FY 2021 Plans:*** - Integrate additional data sources in the attribution platform, and develop techniques for automated and assisted tasking of defensive capabilities. - Adapt tools and techniques to interoperate with existing software frameworks, and extend capabilities of event extraction techniques. - Work with transition partners to evaluate the attribution platform on new commercial and government-provided data sets, and transition attribution technologies to support operational objectives. ***FY 2022 Plans:*** - Harden the attribution platform and transition to operational partners. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects conclusion of development, integration, and evaluation of the attribution platform, and transition to operational partners.			
Title: Dispersed Computing	16.300	4.000	2.300
Description: The Dispersed Computing program is developing techniques to distribute computing tasks across network computing elements to enable more efficient utilization of enterprise and Internet-based storage, processing, and networking resources. At present, enterprises and Internet-based information technology service providers are increasingly adopting the cloud model, with data storage and computer processing concentrated in large data centers. This brings economies of scale and cost savings to storage and processing, but creates problems for the network and for latency-sensitive applications due to the need to backhaul data to (often distant) data centers for processing. The Dispersed Computing program is developing a dispersed computing architecture that results in more efficient utilization of storage, processing, and networking resources. A key enabler is the recent introduction by vendors of network elements that can be dual-purposed as computational elements. These dual-purpose network-compute elements make it possible to eliminate bottlenecks/chokepoints and to mitigate impossible backhaul requirements by opportunistically moving code to data, given network conditions and available network-compute elements. With			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Dispersed Computing technology, the network becomes the cloud, and computation is performed where it is most efficient to do so. ***FY 2021 Plans:*** - Increase the operational scale of integrated network-compute elements to thousands of nodes while automatically redistributing workloads. - Optimize and evaluate integrated capabilities over networks with thousands of network-compute elements in terms of the reduction of network bandwidth consumed and the increase in computational utilization. - Demonstrate integrated network-compute capabilities on realistic workloads to Defense Information Systems Agency (DISA) and commercial network providers. ***FY 2022 Plans:*** - Harden and transition integrated network-compute capabilities to DISA and commercial network providers. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.			
Title: Cyber Assured Systems Engineering (CASE)	15.600	9.780	2.350
Description: The Cyber Assured Systems Engineering (CASE) program is developing the design, analysis and verification tools needed to allow systems engineers to design-in cyber resiliency and manage tradeoffs as they do other quality attributes when designing complex embedded computing systems. The current state of practice for cyber resilience utilizes penetration testing after system construction to drive post-design re-engineering. The CASE technical approach formulates cyber resilience as an explicitly engineered property, similar to other holistic properties such as safety, durability, and reliability now standard in systems engineering. The challenge of resiliency is that it cannot be established through conventional testing methods. CASE will focus on the following technical areas: techniques to derive resilience-related requirements before system design and construction; architectural design and analysis tools to design-in the derived resilience requirements while providing feedback to the human designer to allow for informed tradeoffs between resilience and other system design goals; tools to adapt existing software to support system-level resilience requirements; and inference engines, satisfiability solvers, and provers scalable to complex networked cyber-physical systems. CASE technologies will enable the design of cyber-physical systems that robustly execute their intended function despite the efforts of sophisticated cyber adversaries. ***FY 2021 Plans:*** - Enhance cyber resilience design tools based on the results of integrating into the engineering workflow of a defense system provider. - Evaluate and demonstrate design tools and techniques on defense platforms including a military helicopter.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate the ability of a defense platform provider to use design tools to produce cyber resilient designs. - Demonstrate enhanced platform cyber resiliency in tests coordinated with potential transition partners and other stakeholders. ***FY 2022 Plans:*** - Harden technologies for cyber security systems engineering and transition to DoD stakeholders for demonstration and evaluation in programs of record. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects ramping down of development and demonstration of techniques and software tools to design-in cyber resiliency requirements, and transition of capabilities to programs of record.			
Title: Open, Programmable, Secure 5G (OPS-5G)	-	11.800	21.000
Description: The Open, Programmable, Secure 5G (OPS-5G) program, addressing key technical issues explored in the Searchlight program (also budgeted in this PE and Project), will develop open source, 5G network software that ensures security and stimulates innovation in mobile wireless hardware. Current trends in mobile wireless technology development are unfavorable in that the U.S. and allies are increasingly dependent on proprietary technologies offered by foreign suppliers. OPS-5G will develop standards-compliant software for 5G mobile wireless networks that is open source, programmable, and secure by design. The availability of open source software for 5G will have the additional benefit of opening the mobile wireless hardware market to new participants, stimulating innovation and competition. The OPS-5G program aims to move the mobile wireless market off its current model of opaque, proprietary, and vertically-integrated technology provided by a small number of dominant vendors to a more robust model of transparent, open source technology created by a diverse ecosystem of academic and commercial software and hardware developers. OPS-5G will be coordinated with existing open-source 5G efforts and U.S. Government, DoD, and industry stakeholders. ***FY 2021 Plans:*** - Formulate approaches for addressing 5G security challenges, such as eavesdropping at access points and denial of service. - Formulate approaches for automatically extracting information relevant to software implementations including software structure, service interfaces, timing parameters, flow diagrams, and protocol graphs from 5G standards maintained in electronic documents. - Formulate 5G node and network security architectures, and initiate development of tools for integrity checks, attack prevention, remote diagnosis and service recovery. - Devise in-network sensors and reactive defenses for attack onset detection and scalable resilience against distributed denial of service (DDoS) attacks in 5G networks. ***FY 2022 Plans:*** - Implement and evaluate prototype systems that address 5G security challenges, such as eavesdropping at access points and denial of service.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Implement and evaluate prototype software for automatically extracting information relevant to software implementations including software structure, service interfaces, timing parameters, flow diagrams, and protocol graphs from 5G standards maintained in electronic documents. - Implement and evaluate 5G node and network security technologies and tools for integrity checks, attack prevention, remote diagnosis, and service recovery. - Assess and develop information protection techniques suitable for current and future mobile wireless systems to support DoD operational security needs. - Demonstrate prototype systems to commercial vendors, commercial service providers, the DoD, and other U.S. Government stakeholders. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects ramping up of development and implementation of 5G network security technologies, and initial demonstration and evaluation in collaboration with open-source 5G efforts and U.S. Government, DoD, and industry stakeholders.			
Title: Program Analysis for Capability Excellence (PACE)*	-	10.400	19.250
Description: *Formerly Cyber Course of Action Analysis (C2A2) The Program Analysis for Capability Excellence (PACE) program will develop tools and techniques to autonomously identify adversary compromise of software, mitigate negative effects of adversary capabilities, and restore the integrity of compromised software. PACE will enable rapid, autonomous response to cyber attacks without using source code or requiring recompilation. ***FY 2021 Plans:*** - Develop techniques for autonomously characterizing and identifying software under attack via emergent computation. - Develop attack-specific mitigations that can be rapidly generated and deployed with minimal human assistance. ***FY 2022 Plans:*** - Implement emerging software compromise identification and mitigation techniques in an initial proof-of-concept autonomous system. - Demonstrate techniques for attack-specific mitigations that can be rapidly generated and deployed with minimal human assistance. - Assess autonomous system performance against synthetic attacks representative of real world threats. ***FY 2021 to FY 2022 Increase/Decrease Statement:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 increase reflects continued development of techniques for autonomously identifying and mitigating compromise and expanded efforts related to implementation and assessment.			
Title: Verified Security and Performance Enhancement of Large Legacy Software (V-SPELLS)	-	9.800	14.750
Description: The Verified Security and Performance Enhancement of Large Legacy Software (V-SPELLS) program, addressing issues encountered in the Cyber Assured Systems Engineering (CASE) program, budgeted within this PE and Project, will create methods and tools to recover succinct models of domain data abstractions and logic from source code, add enhancements to the models, and convert them to performant new component implementations verified to be compatible and secure. DoD has a critical need for replacing components of existing software with more secure and more performant code, including cases where a key performance or security benefit comes from moving parts of the software to new hardware, such as utilizing hardware accelerators, isolation enclaves, offload processors, and distributed computation. However, at present, replacing legacy software components with technologically superior ones for improved performance or security faces high risk that the new software, despite being proven correct according to a specification, will not be fully compatible with the existing larger environment. Moreover, verified software is currently written from scratch, starting with a formal specification, rather than incrementally added to a system as provably compatible enhancements. V-SPELLS will address these problems by combining novel concepts in verified programming with recent developments in domain specific languages (DSLs) and systems architecture. V-SPELLS technology will iteratively and interactively leverage automated program understanding to semi-automatically derive a DSL for the targeted component of a large code base, translate the code for the component into this DSL while concurrently inferring its specification within the larger environment, and then generate, optimize, and distribute executable artifacts across the system, creating and validating relevant proofs. V-SPELLS aims to enable piecewise, compatible-by-construction improvement of software components in legacy DoD systems, providing to incremental software (re)engineering the benefits of formal software verification currently available only to clean-slate development efforts. ***FY 2021 Plans:*** - Formulate automated techniques for decomposing legacy code into functional modules with domain data structure and operation definitions. - Design a development environment for convergent DSL programming, including compatibility-centric program analysis techniques. - Explore alternative compilation techniques for DSL virtual machine stacks that are tunable for performance, security, diversity, and verifiability. ***FY 2022 Plans:*** - Implement automated techniques for decomposing legacy code into functional modules with domain data structure and operation definitions, untangling of legacy code into low-level domain operation implementations and higher-level application logic, and lifting of legacy code into an extracted DSL.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Create an initial development environment for convergent DSL programming, including compatibility-centric program analysis techniques that provide efficient, intelligible feedback and refined counterexamples to developers. - Identify DoD software environments that would benefit from recoding selected legacy components using DSLs for packet filtering, data, signal, and image processing, and other latency-sensitive/security-critical functions. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects ramping up of work to develop automated techniques for decomposing legacy code into functional modules, compilation techniques for DSL virtual machine stacks, and an initial development environment.			
Title: Hardware Optimization (HOP) ***Description:*** The Hardware Optimization (HOP) program, addressing technical issues encountered in the Rapid Attack Detection, Isolation and Characterization Systems program, also budgeted within this PE and Project, seeks to develop hardware optimizations for national security purposes. Specifically, HOP will enable new national security workloads in high performance microelectronic hardware. This research will produce end-to-end hardware optimization toolkits to enhance hardware designs. These toolkits will be comprised of algorithms, digital design files, documentation, and binaries. ***FY 2021 Plans:*** - Identify and establish a wide area network (WAN) to support program research and transition efforts. - Begin development of design specifications, architectures, and fabrication. ***FY 2022 Plans:*** - Evaluate hardware optimizations to address algorithmic improvements and address scalability and performance opportunities. - Design and develop initial alternative implementations for hardware optimizations. - Provide initial hardware optimizations to an evaluator for performance assessments and evaluations. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects ramping up of work to develop alternative implementations for hardware optimizations.	-	6.100	13.100
Title: Bio Cyber Security (BCS) ***Description:*** The Bio Cyber Security (BCS) program aims to develop technologies to address the large attack surface of automated experimental bio-cyber-physical laboratories. As biology becomes increasingly an information-driven discipline, and biological experimentation becomes increasingly automated, the attack surface of the integrated bio-cyber-physical infrastructure that enables modern biotech is expanding. The BCS program will use big data technologies, artificial intelligence (AI), machine learning (ML), and advanced bio-informatics to create automated surveillance and defense algorithms that can detect and respond in real-time to high-speed, coordinated attacks on bio-cyber-physical laboratories. The BCS program aims to develop technologies	-	-	6.600

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
to assure the U.S. biotech enterprise and to thwart attempts to compromise the availability, integrity, or safety of U.S. biotech infrastructure. ***FY 2022 Plans:*** - Introduce and refine methods for capturing, organizing, and understanding the information flows, control signaling, and potential vulnerabilities within a bio-cyber-physical laboratory. - Formulate big data, AI, and ML-based approaches for detecting anomalies in the sense-process-actuate loops inherent to automated biotech experimentation. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Rapid Attack Detection, Isolation and Characterization Systems (RADICS) ***Description:*** The Rapid Attack Detection, Isolation and Characterization Systems (RADICS) program is developing automated systems to enable a black start recovery of the U.S. power grid amidst a cyber attack on the energy sector's critical infrastructure. The RADICS program aims to enable skilled cyber and power engineers to rapidly restore electrical service after an attack that challenges the recovery capabilities of the impacted organizations (e.g., utilities, balancing authorities, independent system operators, bulk power markets). The potential for a cyber-enabled attack on the U.S. power grid is a national security issue, as the ability of the military to deploy and project force is dependent on the effective and efficient functioning of civilian logistics and supply systems. The program will develop technologies to monitor heterogeneous distributed networks, detect anomalies that require rapid assessment, isolate compromised system elements, establish secure emergency communications networks, characterize attacks, and detect sensor spoofing. The technology development is coordinated with and will transition to U.S. Government elements responsible for the defense of critical infrastructure. ***FY 2021 Plans:*** - Test inoperability of a utility to utility radio communication network that would facilitate integration and coordination among independent and disparate organizations in a large-scale trans-regional black start scenario. - Collaborate with private industry, DOE, DHS, DoD, and other stakeholders to demonstrate enhanced capabilities for black start restoration of a power grid amidst a cyber-attack. - Harden and transition technology and capabilities to U.S. Government, National Guard, and industry. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.	20.350	3.177	-
Title: Leveraging the Analog Domain for Security (LADS)	10.981	-	-

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Leveraging the Analog Domain for Security (LADS) program developed techniques for defending information systems by advantageously using side channel signals such as radio frequency and acoustic emissions, power consumption, heat generation, differential fault analysis, and timing-based effects. LADS augments standard cybersecurity approaches, which focus on digital effects, with analog techniques. LADS technologies can enable defenders to detect cyber attacks by sensing changes in the analog emissions of computing components, devices, and systems, greatly complicating the task of adversaries who wish to remain hidden.			
Title: Brandeis ***Description:*** The Brandeis program created the capability to dynamically, flexibly, and securely share information while ensuring that private data may be used only for its intended purpose and no other. Brandeis technologies can resolve the tension between maintaining privacy and being able to tap into the huge value of data. In the civilian sphere, there is a recognized need for technologies that enable the controlled sharing of information between commercial entities and U.S. Government agencies. Similarly, the U.S. military is increasingly involved in operations that require highly selective sharing of data with a heterogeneous mix of allies, coalition partners, and other stakeholders. Brandeis technologies are designed to work with the virtualization, cloud computing, and software-defined networking technologies now widely used in both civilian and military environments.	6.620	-	-
Title: Extreme Distributed Denial of Service Defense (XD3) ***Description:*** The Extreme Distributed Denial of Service Defense (XD3) program developed new computer networking architectures that deter, detect, and overcome distributed denial of service (DDoS) attacks. DDoS attacks include both high-volume flooding attacks and more subtle low-volume attacks that evade traditional intrusion detection systems while exhausting server processing and memory. These attacks will accelerate as the Internet of Things (IoT) incorporates new classes of devices that in many cases will be deployed with inadequate security controls: attackers will conscript poorly defended IoT devices into their botnets. XD3 developed defensive architectures that use maneuver, deception, dispersion, and on-host adaptation to increase adversary work factors, boost resilience of mission critical services such as command and control, and thwart DDoS attacks.	5.750	-	-
Accomplishments/Planned Programs Subtotals	261.861	236.182	237.089

	FY 2020	FY 2021
Congressional Add: Distributed Ledger Technology ***FY 2020 Accomplishments:*** - Conducted research in Distributed Ledger Technology.	1.000	-
Congressional Adds Subtotals	1.000	-

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C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
IT-04: *ARTIFICIAL INTELLIGENCE AND HUMAN-MACHINE SYMBIOSIS*	-	139.824	178.162	193.274	-	193.274	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Artificial Intelligence and Human-Machine Symbiosis project develops technologies to enable machines to function not only as tools that facilitate human action but also as trusted partners to human operators. Of particular interest are systems that can understand human language and extract information and reliably categorize content contained in diverse media; answer questions, reach conclusions, and propose explanations; and learn, reason, and apply knowledge gained through experience to respond intelligently to new and unforeseen events. Enabling computing systems with such human-like intelligence is now of critical importance because the tempo of military operations in emerging domains exceeds that at which unaided humans can orient, understand, and act. The technologies developed in the Artificial Intelligence and Human-Machine Symbiosis project will enable warfighters to make better decisions in complex, time-critical, battlefield environments; intelligence analysts to make sense of massive, incomplete, and contradictory information; software developers and certifiers to design, implement, evaluate, and accredit cyber-physical systems and other complex software-reliant systems with greater efficiency and confidence; and unmanned systems and semi-autonomous agents to perform critical missions in contested physical and virtual environments safely and reliably. This Project includes FY 2020 CARES Act funding in the amount of $.619 million to apply artificial intelligence (AI)-based models to rapidly screen, prioritize and test Food and Drug Administration (FDA)-approved therapeutics for new COVID-19 drug candidates.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Accelerating Artificial Intelligence (AAI)	44.575	40.820	35.100
Description: The Accelerating Artificial Intelligence (AAI) program seeks to go beyond commercially-driven advances in AI and to address important national security challenge applications. In particular, this program is focused on improving human-AI collaborations to mitigate current bottlenecks in DoD's ability to rapidly adapt and deploy new technologies and capabilities. If successful, research efforts under this program will significantly accelerate the pace of innovation in many important DoD domains while also reducing the time and cost associated with approval and certification processes needed to transition and deploy new technologies. One technical challenge to be addressed in this program is the need to assess current developmental, approval, and certification processes and identify tasks or sub-tasks amenable to greater automation with minimal human intervention. Other challenges include the need to develop social context aware AI systems and to ensure robustness of AI systems, particularly in novel and/or unanticipated situations. Approaches to addressing these challenges will leverage recent advances at the frontiers of AI research in transfer learning, causal reasoning and associated models. AAI application areas include the following: (1) machine-enabled techniques to efficiently capture, generate, and analyze disparate data sources to accelerate design and development of new materials and chemistries for DoD specific applications; and (2) knowledge management tools that can efficiently capture and disseminate an organization's expertise, experience and data; and (3) social context informed			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
AI approaches to enable reliable and robust forecasting and decision aiding tools for stabilization, deterrence and gray zone operations. ***FY 2021 Plans:*** - Select military application(s) into which to insert and evaluate novelty-aware AI technologies. - Initiate transition of novelty generation technologies from research domains to military application domains. - Evaluate potential for novelty generators and novelty-robust AI techniques in military application domains to rapidly identify and respond appropriately to new classes, attributes, relationships, representations, capabilities, and interactions. - Validate process and property optimization capabilities of molecular design systems through challenges informed by DoD applications. - Develop new time-aware neural network architectures that introduce meta-learning capabilities for time cognition in machine learning. - Implement a reconfigurable kernel toolkit for application development in either a communications or radar based suite to achieve 10x improvement in the system performance of input signal-to-noise sensitivity or signal-to-interference rejection ratio. - Create a comprehensive, automated software framework that can take in a microelectronic system design, train effective machine learning surrogate models of sub-system components and integrate them back into the original design to achieve significant simulation speed-ups while maintaining acceptable levels of accuracy and coverage. - Ingest written doctrine and develop a set of rules and algorithms for adversary brigade offensive operations. - Perform initial demonstrations of artificial intelligence algorithms against a live adversary. - Demonstrate relative effectiveness, extensibility of methodologies for creating empirical measures of game balance state equations. - Demonstrate methodology for effective identification, introduction, and quantification of game/model modifications that create significant imbalance. - Develop and demonstrate automated analysis of electrical and mechanical computer aided design (CAD) documentation datasets to identify notable features and export them in graphs and a human-readable summary format for analysts. - Develop techniques to automatically discover the minimal features needed to distinguish between the members of sets of objects and actions. - Conduct a comprehensive survey of current state-of-the-art in neural net-based computer vision systems, adversarial attack methods and approaches, defenses against adversarial attack methods and approaches, and current research directions in all of the above. - Develop universal attack algorithms that cause misclassification of a single object class. - Demonstrate performance on at least three different deep neural networks. - Begin real-time, in vivo evaluation of AI-enabled neural interface architectures.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Continue efforts to accelerate Artificial Intelligence with a focus on third wave AI. ***FY 2022 Plans:*** - Extend evaluation of novelty generators and novelty-robust AI techniques in military application domains to include new environments, goals, and context. - Initiate transition of molecular design systems from academia and industry to DoD partners for evaluation in DoD applications. - Define and validate parameters for inverse design of molecules with relevance to DoD applications. - Prototype time-aware meta-learning methods and demonstrate novel machine intelligence capabilities. - Initiate efforts to improve human operators' ability to innovate with their AI-enabled platforms. - Explore opportunities for rapid development and test environments for designing interfaces that improve human operation of AI-enabled platforms. - Explore automated approaches for managing language and knowledge encountered in specialized domains, extracting the essential facts in a stream of inputs, and translating between domain-specialized representations and common English. - Describe the technical approach for 1) intelligent array operations, 2) application development in a tensor-based programmable language, and 3) hardware implementation. - Develop a model that demonstrates the combined array and machine learning (ML) algorithms and how the intelligent array algorithms are abstracted to hardware-independent operations. Report on use cases descriptions of the new array-ML architecture. - Develop techniques to automatically discover the new features needed to accommodate differences between newly acquired objects and actions and those previously learned. - Continue efforts to accelerate Artificial Intelligence with a focus on third wave AI. - Quantify competency-aware capabilities with relevance to DoD applications. - Identify DoD experimental platforms and partners to demonstrate competency-aware capabilities. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from development and prototyping to testing.			
Title: Symbiotic Design ***Description:*** The Symbiotic Design program is developing artificial intelligence-based approaches to augment human teams in the design of cyber-physical systems (CPS), and thereby significantly reducing time to deployment and improving the quality of deployed systems. The current generation of DoD systems and platforms integrate cyber and physical subsystems, but the capability of the engineering teams has not scaled with the enormous complexity of modern CPS. Engineering organizations require large teams of engineers that collectively possess the necessary domain knowledge (of component technologies, theories, and tools), but the prolonged timelines of the development process for modern CPS hinders DoD's ability to counter emerging threats. The Symbiotic Design program will address the challenge by transforming the human-focused, model-based design flows	12.809	25.582	28.100

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
used today into a symbiotic process of collaborative analysis by humans and continuously-learning AI-based co-designers. The program will create technologies essential for AI co-design: design space construction, design composition, and design space exploration. The program will demonstrate the approach at realistic scales by a sequence of CPS design challenges of increasing complexity, and quantify the results with respect to development time, system performance, quality, and innovation metrics. ***FY 2021 Plans:*** - Create techniques for defining design spaces and for evaluating design points using domain-specific analysis and simulation tools. - Develop prototype design mining engines and feature extractors to enable query generation from seed designs and to extract heterogeneous model-based design artifacts. - Develop techniques for exploring high-dimensional, multi-domain, combinatorial design spaces and design elaboration methods for automated model completion by an AI co-designer across multiple design domains. ***FY 2022 Plans:*** - Expand scope and domain coverage of design mining engines to allow incremental construction of design spaces. - Develop cross-domain inferencing techniques to automate cross domain reasoning and model learning. - Develop prototype tools to accelerate high fidelity model analysis and simulation, visualize and understand high dimensional design spaces, and shape and guide design exploration. - Produce design challenge problems related to sub-systems and systems of interest to the DoD, and evaluate the effectiveness of symbiotic design technologies. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects continued development and implementation of symbiotic design techniques and expanded evaluation on systems of interest to DoD.			
Title: Automated Rapid Certification Of Software (ARCOS)	16.100	28.860	25.000
Description: The Automated Rapid Certification Of Software (ARCOS) program is developing technologies that automate the evaluation of software assurance evidence to enable certifiers to assess system risks earlier in the process and more rapidly and safely commit to engineering decisions. Current software certification practices do not scale with the extent, complexity, and interconnection of software being developed by the DoD, so certification is becoming a bottleneck to new system deployment. ARCOS technologies address DoD software system certification time and cost. ARCOS technology will automatically and interactively generate strong assurance arguments that incorporate supporting evidence for certification criteria. ARCOS will also develop techniques to compose assurance arguments for pre-evaluated components into consolidated assurance arguments for new systems incorporating those components.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: - Extend assurance-case engineering tools to facilitate the design and implementation of software and associated assurance evidence. - Develop approaches to analyze legacy software assurance evidence and specifications to determine areas of insufficient assurance. - Scale data structure representations to accommodate assurance evidence from complex military platforms such as a military helicopter. - Demonstrate and validate automatically-generated assurance case arguments. ***FY 2022 Plans:*** - Develop approaches to augment assurance evidence for legacy software to provide stronger fitness arguments. - Demonstrate automatically calculated confidence measures for assurance case arguments that are objectively meaningful. - Demonstrate the composability of automatically generated assurance case arguments to support incremental evaluations. - Reduce the computation time necessary to automatically generate assurance case arguments for complex military platforms such as a military helicopter. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from development of assurance case engineering techniques and tools to demonstration of techniques on representative military platforms.			
Title: Knowledge-directed Artificial Intelligence Reasoning Over Schemas (KAIROS)	13.000	21.100	19.000
Description: The Knowledge-directed Artificial Intelligence (AI) Reasoning Over Schemas (KAIROS) program is developing AI and machine learning technologies to aid a human operator in understanding complex sequences of events in the world. For the purposes of KAIROS, an event is an occurrence that results in an observable and recognizable change in either the physical world or human activity. Events of particular interest to KAIROS are those that create changes that have significant impact on national or homeland security. The KAIROS program will develop automated systems that codify existing event-representation schemas and, when needed, create and codify new schemas to bring structure to complex event sequences and present these structured representations to operators. Given multi-media inputs, operators will use KAIROS technologies to identify subsidiary event elements, determine their temporal order, recognize complex event sequences, and link disparate events. KAIROS technologies aim to enable analysts and warfighters to understand unfolding events rapidly and accurately. ***FY 2021 Plans:*** - Develop and assess the capability for machine learning of complex schemas from large multimedia data sets. - Develop and evaluate the capability for matching unfiltered simple events from unconstrained large data sets to an initial schema library.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Develop and assess machine learning classifiers for categorizing the temporal and causal relationship between two simple events that are part of a complex event sequence. - Collaborate with transition partners to establish thresholds for mission utility for anticipating future events that are part of partially-observed complex events in operational data. ***FY 2022 Plans:*** - Develop capability for machine learning of the similarities and differences in the structural features of various complex event schemas. - Develop the means to curate the schema library and methods for identifying intermediate levels in the structure of the library. - Develop a user interface to probe input sources for missing information and to provide interactive feedback. - Collaborate with transition partners to evaluate systems on complex real-world event sequences and identify necessary adjustments. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the shift from development of techniques for learning complex schemas to assessment of techniques on operational data.			
Title: Active Interpretation of Disparate Alternatives (AIDA)	14.790	22.300	16.950
Description: The Active Interpretation of Disparate Alternatives (AIDA) program is developing a multi-hypothesis semantic engine that generates alternative interpretations of events, situations, and trends from a variety of unstructured sources where there are noisy, conflicting, and potentially deceptive data. At present, information from each medium is often analyzed independently, without the context provided by information from other media, with only informal comparison among competing hypotheses. The consequence of this can be inadequate interpretations, because alternatives are eliminated due to lack of evidence even in the absence of contradictory evidence. AIDA seeks to develop and demonstrate technology to automatically map information derived from diverse media into a common semantic representation, aggregate information, resolve ambiguities, discover conflicting information, and generate and explore multiple interpretations of events, situations, and trends. AIDA aims to provide decision makers a capability to understand alternative explanations for available information and to make contingency plans accordingly. ***FY 2021 Plans:*** - Develop the means to rank hypotheses according to relevance and confidence, and the capability to verify and explore hypotheses developed by users. - Enhance the capability of the system to infer components of hypotheses not explicit in the input. - Enhance the interface to facilitate the capability of the user to refine the extracted semantic elements and the generated hypotheses.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Collaborate with transition partners to conduct experiments to evaluate performance on operational data. ***FY 2022 Plans:*** - Develop the means to detect seemingly minor but important changes in otherwise similar documents to enable discovery and analysis of different hypotheses. - Develop the means to change statistical priors for new sources to reflect known biases and reliability, and thereby enable more accurate computation of coherence measures. - Enhance interface capabilities to facilitate exploration of user-generated conjectures and other models of human-computer interaction. - Collaborate with transition partners to conduct experiments to evaluate extraction and hypothesis generation performance on operational data. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the shift from development of techniques for generating multiple alternative interpretations from multimedia data to evaluations of techniques on real-world data.			
Title: Assured Autonomy	16.000	15.000	13.000
Description: The Assured Autonomy program is developing rigorous design and analysis technologies for continual assurance of learning-enabled autonomous systems to enhance system safety in uncertain environments. Currently, the state of the art for test, evaluation, verification, and validation is only applicable to non-learning systems operating in well-characterized environments. As a result, autonomous systems enabled by machine learning (e.g., deep neural nets for perception, reinforcement learning for control policies, and online model learning) lack rigorous safety assurance. Assured Autonomy is developing new techniques for modeling and system design, formal verification, simulation-based testing, and safety-assured learning to provide continual assurance of learning-enabled autonomous systems. The technologies being developed in Assured Autonomy will enable the DoD to more rapidly and efficiently deploy learning-enabled autonomous systems that can be trusted to operate safely in uncertain environments. ***FY 2021 Plans:*** - Integrate learning-enabled components with examples of formally verified safety properties into autonomous systems, and implement scalable algorithms for dynamic evaluation of assurance cases. - Develop and evaluate scalable monitoring techniques to detect data-distribution shifts on simulated and real-world data in which the operating environment diverges from the training environment.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Develop scalable techniques for runtime verification of learning-enabled systems, and integrate safety constraints in online learning algorithms to allow safe operation of autonomous systems in proximity to humans in unknown and unstructured environments. ***FY 2022 Plans:*** - Evaluate the impact of safety-constraints incorporated in online learning algorithms on the performance of autonomous systems operating in unknown and unstructured environments. - Demonstrate technologies on assurance challenge problems for several learning-enabled autonomous platforms of interest to the DoD. - Perform improvements to formal verification tools and monitoring techniques, and transition technologies to industry and DoD. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the shift from development efforts to demonstrations on several learning-enabled autonomous platforms, and transition to industry and DoD.			
Title: Explainable Artificial Intelligence (XAI)	18.550	17.200	9.324
Description: The Explainable Artificial Intelligence (XAI) program is developing a new generation of machine learning techniques that are able to explain their rationale, characterize their strengths and weaknesses, and convey an understanding of how they will behave in the future. AI is a critical enabler for U.S. military systems that will perform increasingly complex and sensitive missions. However, in order for developers, users, and senior leaders to feel confident enough to deploy and use AI-enabled systems, these systems must be able to explain their rationale, and their recommendations, decisions, and actions must be delivered in a way that military users can understand and trust. Today, most machine learning systems provide no explanations, or provide explanations that are at the wrong level of abstraction, not meaningful to a human user, or inconsistent with the full range of behaviors of the AI system. XAI is developing the tools necessary to build explainable AI systems, specifically with: (1) new machine learning techniques that produce human-interpretable models and (2) user interfaces that generate explanations from those models that are meaningful to end-users, using natural language, saliency maps, and other representations. XAI implementations will be developed and demonstrated in next-generation data analytics and autonomous systems. ***FY 2021 Plans:*** - Enhance explainable systems for robustness to increased machine learning task complexity. - Expand the cognitive model of explanation based on task performance evaluations. - Measure system explainability, accuracy, and learning performance against additional datasets and scenarios. - Select and integrate subsets of explainable model techniques in prototype systems for capability demonstrations coordinated with DoD and Intelligence Community (IC) partners. ***FY 2022 Plans:***			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Refine the cognitive model of explanation based on the results of prototype system capability demonstrations. - Optimize integrated explainable AI prototypes and quantify system explainability, accuracy, and learning performance against additional datasets and scenarios in capability demonstrations coordinated with DoD and IC partners. - Create an explainable AI toolkit, and transition datasets and code. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the shift from development and integration of explainable machine learning techniques and systems to testing, performance assessment, and transition.			
Title: Engineering Artificial Intelligence Systems Implementations (EAISI)	-	7.300	9.800
Description: The Engineering Artificial Intelligence Systems Implementations (EAISI) program will create technologies and tools to support the development of viable and trusted systems that include AI and machine learning (ML) capabilities. Modern AI-dependent systems may include multiple AI components, drawing on a diverse set of AI-related techniques, ranging from ML to knowledge representation, search, planning, game theory, and optimization. Current methods for development of such systems remains primarily based on trial-and-error designs, with limited abstractions, architectures, and patterns. These developments can be costly, risky, and demanding of very high levels of expertise. To address this, EAISI will develop abstractions, patterns, architectures, assurance techniques, and iterative processes that facilitate the analysis and synthesis of complex systems that must rely on AI-based components and associated training data. One of the more difficult engineering challenges with AI is evaluation and assurance, since AI-based systems tend to resist traditional approaches to testing, inspection, and analysis. It is not possible to fully test an AI-based system for every situation it will ever encounter, so new techniques are needed for verifying and validating AI-based systems. EAISI aims to create software and systems engineering techniques, tools, and practices to facilitate the development of AI-based systems that are capable, trustworthy, affordable, and timely. ***FY 2021 Plans:*** - Formulate rigorous approaches for managing training data for AI-based systems, including provenance, security, and quality in the engineering of an AI-based system. - Devise approaches for testing, analyzing, and evaluating AI-based systems as means for gaining confidence in and validating those systems. ***FY 2022 Plans:*** - Develop prototype tools for managing training data for AI-based systems, including provenance, security, and quality in the engineering of an AI-based system. - Develop prototype tools for testing, analyzing, and evaluating AI-based systems including intuitive visualization techniques that give users a realistic understanding of the confidence that is warranted when validating those systems.			

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Devise a framework and associated interfaces for integrating prototype tools in an AI systems engineering development environment for use by developers and evaluators who are not experts in AI. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects ramping up of the development of AI systems engineering technologies and their integration in an AI systems engineering development environment for use by developers and evaluators who are not experts in AI.			
Title: Counter Adversarial Artificial Intelligence ***Description:*** The Counter Adversarial Artificial Intelligence program aims to enhance the capability to detect, deflect, and diminish the effects of adversarial attacks on AI-based systems. Defense systems increasingly incorporate artificial intelligence (AI) capabilities such as machine learning and automated reasoning. These AI-enabled systems are typically engineered and optimized for environments where adversary systems are either static or strictly limited in terms of adaptive behaviors. Engagements between sophisticated AI-enabled systems are likely to become increasingly common going forward. Maintaining AI-superiority for the U.S. will require systems with higher levels of capability. Specific capabilities to be developed include recognizing when an adversary system is AI-enabled, identifying and modeling adversary AI capabilities based on empirical data, and creating counter-AI strategies including techniques to render adversary AI capabilities ineffective and/or deleterious. ***FY 2022 Plans:*** - Begin modeling the range of potential adversarial AI behaviors, including the nature of vulnerabilities in machine learning components and symbolic AI components. - Conceptualize AI systems with capabilities to detect, deflect, and diminish the effects of adversarial attacks. - Formulate approaches for recognizing when an adversary system is AI-enabled, identifying and modeling adversary AI capabilities based on empirical data, and countering adversary AI strategies including techniques to render AI capabilities ineffective and/or deleterious. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.	-	-	12.000
Title: Artificial Intelligence Reliability and Traceability (AIRT) ***Description:*** The Artificial Intelligence Reliability and Traceability (AIRT) program will develop design-time and run-time technologies to ensure the correct functioning of AI-enabled systems. As AI deployment scales up, it becomes more important for machine learning (ML) systems to be explainable, which means providing rationale for classifications, characterizing confidence level of the classifications, and, as a consequence, conveying understanding of how the system will behave with similar inputs. Explainability, however, is not sufficient to ensure that ML systems meet reliability requirements, in the sense that the ML operates consistently with domain-focused predictive models, nor traceable, in the sense that there are mappings between the models and	-	-	15.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
the ML behaviors. AIRT will develop the test, evaluation, verification, and validation (TEVV) technologies that system developers need to ensure that AI-enabled systems will correctly perform their intended functions. The AIRT TEVV technologies will address the challenge of how to specify AI-related behaviors and then how to verify the specified behaviors using both analytic formal approaches, which emphasize mathematical modeling and reasoning, and traditional statistical-sampling based approaches. AIRT will also develop design principles for machine learning and related systems that enhance reliability and traceability without appreciable compromise to reasoning capability. Additionally, AIRT will develop traceability approaches that model the learning behavior of an AI component to enable developers, testers, and operators to gain detailed knowledge of how the AI system reached a computational state. The AIRT program aims to make the design and operation of AI systems more scientific and safe. ***FY 2022 Plans:*** - Formulate approaches for TEVV of AI-enabled systems to increase confidence in correct performance of intended functions. - Explore TEVV approaches that include means to specify intended AI-related behaviors and that combine analytic formal approaches, which emphasize mathematical modeling and reasoning, with traditional statistical-sampling based approaches. - Introduce traceability approaches akin to check-pointing and other roll-back techniques that can enhance knowledge of how an AI system reached a computational state. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Control System Introspection ***Description:*** The Control System Introspection program seeks to develop machine introspection and learning technologies to characterize a damaged or modified military platform from its behavior, and update the control law to maintain stability and control. A platform equipped with Control System Introspection technologies will continually compare the real-time behavior of the platform as measured by on-board sensors with a learned model, determine if the current observed behavior of the platform differs from that model in ways that might compromise stability and control, and implement an updated control law when required. The current approach to handling platform damage or modification places the burden of recovery and control on the operator, whether the operator is human or an autonomous controller. In contrast, the Control System Introspection capability would aid operators in maintaining effective control of military platforms that suffer damage in battle or have been modified in the field to address emergent requirements identified during operations. ***FY 2022 Plans:*** - Explore machine introspection and learning approaches for identifying the behavioral characteristics of a platform in terms of the transfer function and related control-theoretic models in real time. - Architect machine introspection and learning algorithms that can run in the background on platforms for which the available computational resources are limited.	-	-	10.000

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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Design and implement an operator-in-the-loop testbed for assessing integrated machine introspection and learning approaches for recovery and control of military platforms that suffer damage in battle or are modified in the field. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Low Resource Languages for Emergent Incidents (LORELEI) ***Description:*** The Low Resource Languages for Emergent Incidents (LORELEI) program developed technology to rapidly field machine translation and other language processing capabilities for low-resource foreign languages. The U.S. military operates globally, and frequently encounters low-resource languages, which are languages for which few linguists are available and automated human language technologies do not exist. Processing foreign language materials requires protracted effort, and current systems rely on huge, manually-translated, manually-transcribed, or manually-annotated data sets. As a result, systems currently exist only for languages in widespread use and in high demand. LORELEI took a different approach by leveraging language-universal resources, projecting from related-language resources, and fully exploiting a broad range of language-specific resources. The resulting capabilities can rapidly provide situational awareness based on information from low resource languages encountered during emergent missions such as humanitarian assistance/disaster relief, terrorist attack response, peacekeeping, and infectious disease response.	4.000	-	-
Accomplishments/Planned Programs Subtotals	139.824	178.162	193.274

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602383E / *BIOLOGICAL WARFARE DEFENSE*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	30.011	26.950	31.421	-	31.421	-	-	-	-	-	-
BW-01: *BIOLOGICAL WARFARE DEFENSE*	-	30.011	26.950	31.421	-	31.421	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Biological Warfare Defense project is budgeted in the Applied Research Budget Activity because its focus is on the underlying technologies associated with the detection, prevention, treatment and remediation of biological, chemical, and radionuclide threats.

Efforts to counter existing and emerging biological, chemical and radiological threats include: countermeasures to stop the pathophysiologic processes that occur as a consequence of an attack; collection of environmental trace constituents to support chemical mapping, tactical and strategic biological, chemical, and radiological sensors; and integrated defense systems. This Project includes FY 2020 CARES Act funding in the amount of $2.0 million to rapidly develop and field a potential capability to detect airborne Severe Acute Respiratory Syndrome Coronavirus 2 (SARS-CoV-2) and enable persistent, broad-scale environmental screening for contagion, such as in airports, mass transportation hubs and public areas where community transmission control is critical.

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	34.588	26.950	25.071	-	25.071
Current President's Budget	30.011	26.950	31.421	-	31.421
Total Adjustments	-4.577	0.000	6.350	-	6.350
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	2.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-2.534	0.000			
• SBIR/STTR Transfer	-4.043	0.000			
• TotalOtherAdjustments	-	-	6.350	-	6.350

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer and reprogrammings offset by COVID response CARES Act add.
FY 2021: N/A
FY 2022: Increase is due to a shift in focus from laboratory demonstrations to operational demonstrations and transition of the Defense Against Mass Terror Threats program.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602383E / *BIOLOGICAL WARFARE DEFENSE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Defense Against Mass Terror Threats	30.011	26.950	31.421

Description: The objective of the Defense Against Mass Terror Threats program is to identify and develop technologies that have the potential to significantly improve the United States' ability to reduce the risk of mass casualties in the wake of a Weapons of Mass Terror (WMT) attack. Challenges in reducing U.S. vulnerability to these attacks include developing new sensors and systems that afford early warning and opportunities to interdict these threats before they can be employed in urban areas and other population centers. A major goal of this program is to develop new sensors and sensing networks that can economically and reliably provide these wide-area monitoring capabilities for WMT threat signatures.

FY 2021 Plans:
- Continue spiral development of chemical and biological sensors with emphasis on algorithm development for sensor maturity, and initiate independent government testing of performance and suitability.
- Conduct initial operational demonstrations of new chemical and biological sensor systems with local, state and Federal stakeholders.
- Assess utility of worn physiological sensors to augment a biological sensor network and adjust research to support application to infectious disease detection.
- Continue spiral development of a network backbone and operating system supporting sensor, contextual and transactional data ingestion, to include initial examination of unstructured data, and assemblage of world graphs from this data.
- Assess and validate an approach for an automated adversary attack template generation process.
- Develop initial end-to-end alpha build of the network, including data model, pipeline and analytics engine capable of ingestion and automated analytics of heterogeneous sensor, contextual, and transactional data sets.
- Develop initial test strategies for sensor and network technologies that support eventual transition strategies, including into a possible Joint Concept Technology Demonstration or Program of Record.

FY 2022 Plans:
- Continue spiral development of chemical and biological sensors, with emphasis on algorithm development, to include follow-on independent Government testing of performance and suitability.
- Conduct follow-on operational demonstrations of new and augmented, commercial-off-the-shelf chemical and biological sensor systems with local and Federal Government stakeholders.
- Expand on utility assessment of worn physiological sensors building on developments associated with infectious disease detection.
- Continue spiral development of a network backbone and operating system supporting sensor, contextual and transactional data ingestion with a focus on capabilities for unstructured data via natural language processing and assemblage of world graphs.
- Work with Federal Government partners to develop and mature methods for automated adversary attack template generation.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602383E / *BIOLOGICAL WARFARE DEFENSE*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Mature end-to-end beta build of the network, including data model, pipeline and analytics engine capable of ingestion and automated analytics of heterogeneous sensor data, with contextual and law enforcement transactional data. - Develop transition strategies for sensor and network technologies with local municipalities and Federal Government partners such as the Department of Homeland Security (DHS), Countering Weapons of Mass Destruction (CWMD) Office and Immigration and Customs Enforcement (ICE). ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to a shift in focus from laboratory demonstrations to operational demonstrations and transition.			
Accomplishments/Planned Programs Subtotals	30.011	26.950	31.421

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

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Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	300.010	237.271	202.515	-	202.515	-	-	-	-	-	-
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	49.652	14.890	11.059	-	11.059	-	-	-	-	-	-
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	93.547	73.883	57.460	-	57.460	-	-	-	-	-	-
TT-07: *AERONAUTICS TECHNOLOGY*	-	59.434	56.119	47.607	-	47.607	-	-	-	-	-	-
TT-13: *INFORMATION ANALYTICS TECHNOLOGY*	-	97.377	92.379	86.389	-	86.389	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Tactical Technology Program Element is budgeted in the Applied Research Budget Activity because it supports the advancement of concepts and technologies to enhance the next generation of tactical systems. The Tactical Technology Program Element funds a number of projects in the areas of Naval Warfare, Advanced Land Systems, Aeronautics Technology and Information Analytics Technology.

The Naval Warfare Technology project develops advanced technologies for application to a broad range of naval requirements. Enabling and novel technologies include concepts for expanding the envelope of operational naval capabilities to include the entire sea column such as improved situational awareness over large maritime environments, ship self-defense techniques, novel underwater propulsion modalities, vessels for estuary and riverine operations, high speed underwater vessels, improved techniques for underwater object detection and discrimination, long endurance unmanned surface vehicles, methods and techniques for servicing assets throughout the sea column, and high bandwidth communications.

The Advanced Land Systems Technology project is developing technologies for enhancing U.S. military effectiveness and survivability in operations ranging from traditional threats to military operations against irregular forces that can employ disruptive or catastrophic capabilities, or disrupt stabilization operations. Programs seek to break the relative symmetry of land combat to give U.S. forces a decided advantage in the current and future ground battlefield. The emphasis is on developing affordable technologies that reduce reliance on consolidated forward-operating bases and required lines of communication, and provide small units and individual warfighters with hyper-mobility and hyper-lethality.

Aeronautics Technology efforts will address high payoff opportunities that dramatically reduce costs associated with advanced aeronautical and aerospace systems and/or provide revolutionary new system capabilities for satisfying current and projected military mission requirements. This includes advanced technology studies of revolutionary propulsion, vehicle, and launch concepts, sophisticated fabrication methods, and examination of novel materials and enabling technologies for aeronautic and aerospace system applications.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*

The Information Analytics Technology project develops technology for analyzing data and information arising from: 1) intelligence networks; 2) open, media, and other external sources; 3) sensors and signal/image processors; and 4) collection platforms and weapon systems. Technical challenges include the need to: 1) process huge volumes of diverse, incomplete, and uncertain data in tactically-relevant timeframes and 2) counter the information operations of sophisticated adversaries who seek to deceive, degrade, deny, and disrupt the U.S. information enterprise. Benefits sought include deeper understanding of the evolving operational environment tailored to the needs of commanders at every echelon; an enhanced capability to plan, monitor, and control diverse military operations ranging from stabilization and information operations to combat engagements; and improvements to the efficiency of core military functions such as national and homeland security, warfighter health and readiness, and defense support of law enforcement and civil authorities.

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	313.002	233.271	199.803	-	199.803
Current President's Budget	300.010	237.271	202.515	-	202.515
Total Adjustments	-12.992	4.000	2.712	-	2.712
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	4.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	3.950	0.000			
• SBIR/STTR Transfer	-16.942	0.000			
• TotalOtherAdjustments	-	-	2.712	-	2.712

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2020	FY 2021
Project: TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*		
Congressional Add: *Counter Directed Energy Laser Eye Protection Research*	-	4.000
Congressional Add Subtotals for Project: TT-04	-	4.000
Congressional Add Totals for all Projects	-	4.000

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.
FY 2021: Increase reflects congressional adjustments.
FY 2022: Increase reflects minor program repricing.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602702E / *TACTICAL TECHNOLOGY*	Project (Number/Name) TT-03 / *NAVAL WARFARE TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
TT-03: *NAVAL WARFARE TECHNOLOGY*	-	49.652	14.890	11.059	-	11.059	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Naval Warfare Technology project develops advanced technologies for application to a broad range of naval requirements. Enabling and novel technologies include concepts for expanding the envelope of operational naval capabilities to include the entire sea column such as improved situational awareness over large maritime environments, ship self-defense techniques, novel underwater propulsion modalities, vessels for estuary and riverine operations, high speed underwater vessels, improved techniques for underwater object detection and discrimination, long endurance unmanned surface vehicles, methods and techniques for servicing assets throughout the sea column, and high bandwidth communications. This project will also examine methods and architectures for distributing maritime operations to enable a more agile, survivable, and cost-effective fleet.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES)	34.980	7.534	7.157

Description: The Multi-Azimuth Defense Fast Intercept Round Engagement (MAD-FIRES) program seeks to develop a point defense system against today's most stressing threats by developing a highly maneuverable, medium caliber, guided projectile, fire sequencing and control system capable of neutralizing large threat raids of high speed, highly maneuverable targets. Leveraging recent advancements in gun hardening, miniaturization of guided munition components, and long-range sensors, MAD-FIRES advances fire control technologies, medium caliber gun technologies, and guided projectile technologies enabling the multiple, simultaneous target, kinetic engagement mission at greatly reduced costs. MAD-FIRES seeks to achieve lethality overmatch through accuracy rather than size, thus expanding the role of smaller combat platforms into missions where they have been traditionally outgunned. MAD-FIRES, sized as a medium caliber system, enhances flexibility for installment as a new ship self-defense system. This phase of the project will end with testing against subsonic targets. The final phase of supersonic testing is funded in PE 0603766E, Project NET-02.

FY 2021 Plans:
- Verify fire control system ability to guide rounds to simulated target.
- Verify projectile compatibility with gun feed system.
- Verify fire control system ability to acquire and track surrogate threats.
- Perform end-to-end demonstration of gun launched guided flight.

FY 2022 Plans:
- Conduct end-to-end tests leading up to demonstrations against subsonic flying targets.

FY 2021 to FY 2022 Increase/Decrease Statement:

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-03 / *NAVAL WARFARE TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 decrease reflects minor program repricing.			
Title: Maritime Defense* ***Description:*** *Formerly Port Defense/Mine Counter Measures The Maritime Defense program will explore novel technologies and concepts of operations to mature capabilities to extend freedom of access and operations in all parts of the maritime domain, including waterways, arctic areas, and the seabed. The program will investigate and mature technologies necessary for unmanned underwater vehicle (UUV) concepts for defense against large volumes of low-cost expendable platforms, including compressing the detect-to-engage sequence by exploiting localized networked sensors to rapidly detect, identify, and neutralize threats. Enabling technologies for advanced undersea systems, including a revolutionary propulsion concept, and novel approaches for submarine self-defense will be investigated. Novel technologies and concepts required for arctic and seabed operations, such as distributed sensing, navigation, and communications architectures, as well as including new technologies to enable long duration UUV platforms, will also be investigated. ***FY 2021 Plans:*** - Begin developing advanced underwater propulsion subsystems. - Begin conceptual development of underwater networked sensors for artic environment. - Conduct a trade space analysis of advanced self-defense concepts, payloads, and employment Concept of Operations (CONOPS). - Begin conceptual design and component risk reduction to advance novel technologies for seabed operations. ***FY 2022 Plans:*** - Continue conceptual design and risk reduction activities to advance novel technologies and CONOPS. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects focus on design and risk reduction completion of conceptual design activities.	-	7.356	3.902
Title: Angler ***Description:*** The undersea domain has significant importance to national security and military operations. Yet it is a challenging domain in which to operate due to extreme water pressures, restricted communications, ever changing bottom environments, marine fouling and corrosion. The Angler program seeks to improve U.S. operations in this domain by enabling underwater robotic systems significantly ahead of the state of the art. These robotic systems would be able to search and manipulate objects autonomously, even in dark, turbulent, and semi-opaque sea conditions without the need for human control and without reliance on the Global Positioning System (GPS). Key Angler technical challenges include sensing techniques that provide high-resolution navigation without GPS, perception and manipulation strategies for objects with unknown parameters, long duration autonomy	14.672	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-03 / *NAVAL WARFARE TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
approaches to support mission execution, and autonomy approaches that do not rely on human intervention. From FY 2021 onward, this program is funded in PE 0603766E, Project NET-02. The anticipated transition is to the Navy.			
Accomplishments/Planned Programs Subtotals	49.652	14.890	11.059

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602702E / *TACTICAL TECHNOLOGY*	Project (Number/Name) TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
TT-04: *ADVANCED LAND SYSTEMS TECHNOLOGY*	-	93.547	73.883	57.460	-	57.460	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Advanced Land Systems Technology project is developing technologies for enhancing U.S. military effectiveness and survivability in operations ranging from traditional threats to military operations against irregular forces that can employ disruptive or catastrophic capabilities, or disrupt stabilization operations, including competing in undergoverned spaces. Programs seek to break the relative symmetry of land combat to give U.S. forces a decided advantage in the current and future ground battlefield. The emphasis is on developing affordable technologies that reduce reliance on consolidated forward-operating bases and required lines of communication, and provide small units and individual warfighters with hyper-mobility and hyper-lethality. This project will develop methods and technologies to expand the maneuver trade space to include the vertical dimension, including subterranean environments, as well as undergoverned spaces. It will leverage advances in artificial intelligence to enable integrated manned-unmanned operations and decrease warfighter exposure through the use of autonomous agents.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Subterranean (SubT) Challenge	24.757	21.800	4.000
Description: The DARPA Subterranean (SubT) Challenge is developing novel integrated solutions capable of mapping, navigating, and searching complex and dynamic terrains (tunnel systems, urban underground and cave networks); sensors and computation for perception in austere conditions; distributed information sharing in degraded communications environments; and collaborative autonomy enabling extended operations with minimal human intervention. The core objective of the SubT Challenge is to discover the solution(s) which best outperforms current approaches for manually and laboriously mapping and searching subterranean environments. Newly developed capabilities will span across four technology focus areas in autonomy, perception, networking, and mobility technologies. The program will increase the diversity, versatility, and robustness of relevant system technologies, capable of addressing the multi-faceted needs of a wide range of environments. Innovations are being explored in the context of a public-facing, broadly inclusive DARPA Challenge.			
FY 2021 Plans: - Begin final competition efforts in the combined subdomains of tunnel systems, urban underground, and cave networks. - Continue development and refinement of the virtual test bed. - Host final event encompassing all three domains including tunnels, urban underground, and cave networks.			
FY 2022 Plans: - Facilitate deep tech commercialization and transfer opportunities. - Complete technology assessments, reference data collection, and prize award execution from the Final Event.			
FY 2021 to FY 2022 Increase/Decrease Statement:			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2022 decrease reflects completion of program with live capstone field demonstration.			
Title: Urban Reconnaissance through Supervised Autonomy (URSA)	20.000	19.000	8.000
Description: The Urban Reconnaissance through Supervised Autonomy (URSA) program is developing and demonstrating new autonomous agents and techniques that support a Blue Force Commander in managing the complexity and ambiguity of urban spaces by rapidly identifying and discriminating among potential threats during missions ranging from minutes to hours. The program uses perception-enabled autonomous vehicles to manage complexity and interactions with populations to drive down the ambiguity between peaceful civilians and threats. The program seeks to create a system of autonomous ground and air platforms operating in conjunction with U.S. ground forces that monitor an area overtly to detect hostile forces and establish Positive Identification (PID) before any U.S. troops come into contact. Military units follow strict rules of engagement (ROEs) that prescribe an escalation of force appropriate with the level of hostilities and confidence that an individual is engaged in nefarious behavior. This program will establish a Legal, Moral, Ethical (LME) working group comprising multiple individuals (technologists, military, university professors, ethicists, legal experts) to develop an understanding of how escalation and/or de-escalation of force can and should be appropriately applied in the context of supervised autonomous systems. URSA is exploring scenarios and probing behaviors that will enable identifying innocent civilians and individuals who pose a threat to U.S. Forces, allies, or non-combat civilians. This mission requires the integration and maturation of novel sensors, and unmanned ground and air vehicles which leverage current techniques in perspective and reactive autonomy to navigate cluttered urban environments. URSA is developing new search and engagement behaviors to disambiguate human actions and serve as evidence that a potential target is a threat. It is implementing new dimensions of evidence such as the human reactions to these engagements to improve confidence in its decisions, and building a novel framework for escalating and de-escalating nonlethal force. ***FY 2021 Plans:*** - Continue to develop and increase the fidelity of the URSA Integrated Testbed (UIT) for iterative evaluation of expanding URSA system capability. - Develop test infrastructure for live URSA field demonstrations. - Begin evaluating system performance with incremental field demonstrations in increasingly complex and varying urban environments. ***FY 2022 Plans:*** - Conduct the final system end-to-end performance evaluation in a live environment. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** FY 2022 decrease reflects completion of program with live capstone field demonstration.			
Title: Robotic Autonomy in Complex Environments with Resiliency (RACER)*	7.500	11.000	35.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022

Description: *Formerly Sustained Combat Operations in Undefined Terrain (SCOUT)

Multi-domain operations (MDO) environments present complex and challenging environments to ground combat platforms. Ground combat platforms must operate in a more distributed manner in these environments to gain a sustained tactical advantage and enhance Warfighter survivability. The Army intends to deploy autonomous robotic combat vehicles and optionally manned fighting vehicles to accomplish this objective. In order to meet the demands of an MDO environment, significant advances in perception, planning, and control algorithms are required to autonomously maneuver faster and more resiliently in complex and novel off-road environments. Maneuver environments are characterized by three-dimensional surfaces of highly compliant soils and vegetation, hundreds of positive and negative obstacle classes, no defined road networks or driving rules, and where use of terrain for survivability is critical. In order to achieve operationally relevant speeds and resilience to novel situations on the future battlefield, while simultaneously reducing the Soldier cognitive and communications burden and increasing battle space awareness, RACER will demonstrate game-changing autonomous ground combat vehicle mobility using a combination of simulation and advanced platforms. RACER will deliver autonomy algorithms using the latest in Artificial Intelligence (AI) and machine-learning techniques, a code repository, an off-road simulation environment tailored for military off-road autonomy development, tactical route planning methods and field-demonstrated off-road autonomous capabilities. The culmination of the RACER program will be to demonstrate fully autonomous maneuver on a military Unmanned Ground Vehicle (UGV) in a variety of militarily relevant environments.

FY 2021 Plans:
- Complete assessment of sensors and detection techniques, size weight and power for demonstration vehicles.
- Initiate assessments of off-road autonomy simulation technologies.
- Initiate testing of off-road autonomy algorithms using subscale vehicles.
- Conduct testing of autonomy algorithms on surrogate vehicles.
- Initiate code repository of AI-based autonomy algorithms.

FY 2022 Plans:
- Initiate Government-hosted field experiments.
- Initiate large-scale combat vehicle platform preparations.
- Demonstrate off-road autonomy simulation technologies.
- Demonstrate off-road speeds and interventions comparable to best human driver capability.
- Increase the complexity of capability demonstrations.

FY 2021 to FY 2022 Increase/Decrease Statement:

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 increase reflects the initiation of field demonstrations and large-scale platform preparations.			
Title: Proportional Weapons	-	2.000	-
Description: The Proportional Weapons program will pursue a real-time capability to analyze and apply proportional effects for families of weapons that suppress or breach any external structure to neutralize threats, clear spaces at range, keep them intact, and minimize collateral damage. Novel approaches are needed that are effective from the air or ground against several scales of threats while not being catastrophically destructive. Current approaches to identifying, engaging, and assessing effects against evasive ground targets requires significant human oversight combined with human semantic reasoning tied to rules of execution, resulting in slow and methodical engagements. Proportional weapons will study systems that provide extended range and tunable effects. Proposed technical approaches will be scalable for application to dismounted warfighters, vehicle-borne (air and ground) systems, or as human-in-the-loop payloads for future autonomous platforms. ***FY 2021 Plans:*** - Conduct performance trade studies of air and ground systems and conduct effects analysis that support concepts development leading to a future platform. - Translate performance trade studies of air and ground systems and effects analysis into prototype concepts development leading to a future platform. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects completion of program studies.			
Title: Competing in Undergoverned Spaces	-	-	10.460
Description: A vast majority of U.S. technology is focused on gaining competitive advantage against near peer adversaries in kinetic engagements where there are known rules and players, concrete timelines and clear winners and losers. While these finite games are important, many critical engagements are actually infinite contests, where activities occur over long periods, often involving third parties with an ultimate goal of resetting the regional power and influence equilibrium. Competing in these contests is critical for successful stabilization and Humanitarian Assistance Disaster Relief (HADR) missions, as well as operations in undergoverned spaces, where local governance is sufficiently weak such that internal or external parties can compete for influence over the local population (e.g., Syria). This program will develop technologies that are focused on successfully competing in infinite contests by developing tools for constant acting, assessing and adapting (i.e., iterative Hypothesis A/B testing). Specific areas of interest include information, influence or economic tools that rapidly adapt to the environment to yield specific, effects that can be sensed. This includes developing new options to engage friendly/non-friendly local populations while minimizing the social impact of stabilization. Other areas of interest include sensing tools designed to update pre-existing models to support decision making, and decision tools designed to adapt to changing population or adversary actions.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2022 Plans: - Initiate efforts to develop techniques for measuring and characterizing changes to structure and operation of an exemplar global system (e.g., food) at multiple time scales. - Identify potential approaches for bridging the gap between static risk analysis and real time monitoring for an exemplar global system (e.g., food). - Develop initial requirements for economic, social, informational, and controlled force concepts that positively engage local populations while providing security for U.S. forces amidst regional conflicts. - Explore decision tools (e.g., wargames) that are specifically tuned to infinite contests in undergoverned spaces. - Leverage commercial cloud computing systems and petabyte-scale computer networks to extend advanced anomaly detection mathematics and algorithms to analyze an exemplar, previously computationally intractable global system (e.g., food). - Employ novel multiscale anomaly detection algorithms to detect non-linear, divergent regions for an exemplar global system (e.g., food). - Initiate development of automated red team analytics with "what-if" analysis to enable the continuous discovery, testing and challenging of risks and resilience in critical global systems. - Explore approaches to link diverse spectroscopy techniques to quantifiable local activity (e.g., economic, social). - Initiate the development of models to anticipate community dynamics through studies of how terrain, social structure, environment, etc. shape activity. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to program initiation.			
Title: Mobile Force Protection (MFP)	12.050	4.320	-
Description: The goal of the Mobile Force Protection (MFP) program is to develop and demonstrate an integrated system capable of defeating a raid of self-guided small unmanned aircraft systems (sUAS) attacking a high value convoy on the move. By focusing on protecting mobile assets, the program is emphasizing low footprint solutions, in terms of size, weight, power (SWaP), and manning, which will benefit other counter-UAS missions and result in more affordable systems. Defending in a variety of operating environments against these sUAS threats and associated concept of operations requires several breakthroughs in affordable technology to sense, decide and act on a compressed timeline while mitigating collateral damage. The program is developing solutions applicable to the defense of mobile ground and naval forces that can also potentially defeat more conventional threats. The solution will be scalable and modular such that it can be deployed in multiple defense applications and does not become obsolete with evolving threat capability. ***FY 2021 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-04 / *ADVANCED LAND SYSTEMS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Conduct additional open-air demonstrations that include realistic threats, performance models, signatures, networks, and environmental factors. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Underminer ***Description:*** The Underminer effort, an outgrowth of the Subterranean Challenge program, is exploring the development and integration of technologies that drill/bore and build the underground environment for tactical operations. Underminer is exploring creation and utilization of tunneling, drilling, and boring capabilities for systems at multiple scales. The program is examining multiple concepts of operation and considering creation and use of both temporary tunnels as well as rapid creation of tunnel networks. ***FY 2021 Plans:*** - Finalize concept of operation, system architecture, and demonstration test plans. - Integrate enabling technologies and test system performance. - Verify technologies meet required speed and accuracy threshold. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.	9.000	8.763	-
Title: Squad X ***Description:*** The U.S. military achieves overmatch against its adversaries in certain regimes; however, this level of overmatch is not realized at the squad to individual dismounted warfighter level. The goal of the Squad X program was to leverage advances in real-time situational awareness and mission command; organic three-dimensional dismount mobility; extended range tracking, targeting, and response; and unmanned mobility and perception in order to create a squad with substantial combat overmatch. The concept of overmatch at the squad level included increased human stand-off, a smaller force density, and adaptive sensing to allow for responses at multiple scales. Squad X explored advanced wearable force protection, advanced organic squad level direct and indirect trajectory precision weaponry, and non-kinetic precision capabilities. The end result of the Squad X program was an individual dismount unit outfitted with sensors, weaponry, and supporting technology to achieve unit level overmatch as well as the overall integration of unmanned assets alongside the dismounts to create an advanced, dismounted small unit. ***FY 2021 Plans:*** - Demonstrate artificial intelligence decision aids and autonomous behaviors to augment small unit tactics with significant increase in situational awareness and tactical advantage.	16.240	3.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Conduct system-level experimentation in operational deployments to evaluate with transition partners. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Rapunzel ***Description:*** Urban combat demands that riflemen also serve as combat engineers manipulating their local environment to gain tactical advantage. The urban environment creates unique challenges in providing solutions for mobility, counter-mobility, survivability, and concealment. Every pound that a warfighter wears or carries reduces their mobility and mission effectiveness, and, particularly in urban combat, reduced mobility paradoxically reduces their survivability. The Rapunzel program sought to enable warfighters to manipulate the urban environment through the application of novel materials research. Rapunzel envisioned soldier-borne or vehicle-borne utility-belt style packaged containers, reels, and spools of material that can perform urban engineering tasks such as create bridges between building rooftops, pull down enemy barriers, or provide false targets and concealment. The program identified those mass-manufactured materials, such as extremely high-tensile strength monofilament that can both provide novel mobility between buildings but also provide novel counter-mobility to enemy vehicles due to their electrical conductance properties. The Rapunzel program leveraged extensive existing research into early developmental materials and invest in the task-based development and packing to provide these materials at appropriate length and size scales for immediate tactical use.	4.000	-	-
Accomplishments/Planned Programs Subtotals	93.547	69.883	57.460

	FY 2020	FY 2021
Congressional Add: Counter Directed Energy Laser Eye Protection Research	-	4.000
FY 2021 Plans: - Conduct research in Counter Directed Energy Laser Eye Protection.		
Congressional Adds Subtotals	-	4.000

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602702E / *TACTICAL TECHNOLOGY*	Project (Number/Name) TT-07 / *AERONAUTICS TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
TT-07: *AERONAUTICS TECHNOLOGY*	-	59.434	56.119	47.607	-	47.607	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

Aeronautics Technology efforts will address high payoff opportunities that dramatically reduce costs associated with advanced aeronautical and aerospace systems and/or provide revolutionary new system capabilities for satisfying current and projected military mission requirements. This includes advanced technology studies of revolutionary propulsion, vehicle, and launch concepts, sophisticated fabrication methods, and examination of novel materials and enabling technologies for aeronautic and aerospace system applications. Studies that also fundamentally change the calculus of battle including consideration of a mix of assets, potentially disposable or with limited lifespans, with increased levels of autonomy are included.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Control of Revolutionary Aircraft with Novel Effectors (CRANE)	23.573	26.000	31.607

Description: The Control of Revolutionary Aircraft with Novel Effectors (CRANE) program is demonstrating revolutionary improvements in aircraft controls technology. The program will design, build, and flight test an aircraft that is able to fly and maneuver at altitude relying on state of the art Active Flow Control (AFC) technology. AFC is a broad term that encompasses a range of technology approaches; it includes a number of control mechanism which alter the aerodynamic flow field thru ejection or suction of fluid via an orifice on a lifting body. An emphasis of the program will be on assessing AFC component technologies, risk reduction and experimentation, integrated testing, fabrication and demonstration of a relevant scale novel and innovative aircraft. Technologies, design tools and models developed and demonstrated under this program will be made available to all Services as well as the civilian aerospace sector for application to future air systems development.

FY 2021 Plans:
- Complete development of conceptual design tools for AFC enabled aircraft.
- Continue experimentation and test of AFC technologies.
- Conduct design and analysis activities resulting in conceptual design review.

FY 2022 Plans:
- Complete analysis and test activities resulting in preliminary design review.
- Conduct system critical design review.
- Conduct detailed design, flight software and control law development.
- Begin subsystems integration leading to the fabrication of a demonstration aircraft.
- Initiate airworthiness and ground/flight test approvals supporting testing of the X-Plane.

FY 2021 to FY 2022 Increase/Decrease Statement:

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 increase reflects program focus on detailed design and component testing.			
Title: Gremlins	12.361	14.119	12.500
Description: The goal of the Gremlins program is to develop platform technologies that enable a new class of distributed warfare. The Gremlins concept envisions small air-launched unmanned systems that can be responsively dispatched in volley quantity from commodity platforms, fly into contested airspace, conduct a moderate duration mission, and ultimately be recovered. Key enabling technologies for the concept include smaller developmental payloads that benefit from multiple collaborating host platforms. The Gremlins program will conduct risk reduction and development of the host platform launch and recovery capability and develop and demonstrate a recoverable Unmanned Air Vehicle (UAV) platform concept. Enabling platform technologies will include precision relative navigation, advanced computational modeling, small form factor payloads, compact propulsion systems, and high speed digital flight control. The program will leverage these technologies, perform analytic trade studies, conduct incremental development, and ultimately demonstrate the potential for an integrated air-launched Gremlins unmanned platform capable of conducting distributed air operations. ***FY 2021 Plans:*** - Conduct final flight test demonstrating full recovery capability. - Conduct flight analysis and reporting of airborne launch and recovery. - Perform design work for Intelligence Surveillance and Reconnaissance (ISR) payload integration. - Integrate autonomy architecture into Gremlins system. ***FY 2022 Plans:*** - Integrate ISR payload into Gremlins system. - Conduct preliminary flight test demonstrating autonomy capability. - Demonstrate ISR Gremlins capability. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects completion of full recovery demonstrations and shift to final ISR demonstrations.			
Title: Advanced Aeronautics Technologies	4.000	3.000	3.500
Description: The Advanced Aeronautics Technologies program is examining and evaluating aeronautical technologies and concepts through applied research. These may include the feasibility studies of novel or emergent materials, devices and tactics for both fixed and rotary wing air vehicle applications, launch vehicles, as well as manufacturing and implementation approaches. The areas of interest range from propulsion and power to control techniques to solutions for aerospace mission requirements. The result of these studies may lead to the development of new programs, components or subsystems to enhance future aerospace platforms, or improvement of existing systems. ***FY 2021 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Initiate conceptual design studies. - Demonstrate emerging technologies to support maturation plans and risk reduction strategies. - Perform modeling and simulation that support future concepts and novel architectures. ***FY 2022 Plans:*** - Continue conceptual design studies and demonstrate emerging technologies. - Perform modeling and simulation that support future concepts and novel architectures. - Identify and demonstrate feasible technologies for air platform defense. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** FY 2022 increase reflects minor program repricing.			
Title: OFFensive Swarm-Enabled Tactics (OFFSET) ***Description:*** The OFFensive Swarm-Enabled Tactics (OFFSET) program is designing, developing, and demonstrating a swarm system architecture to advance the innovation, interaction, and integration of novel swarm tactics. The program will examine enabling technologies for collaborative autonomy for large teams of unmanned systems, including unmanned ground and air capabilities through the use of both virtual, game-based and physical, live-fly testbeds. Key research thrusts include the development of advanced swarm tactics-centered autonomy and development of human-swarm teaming interface technologies. These combined enhancements will facilitate insights and enable employment of these collective systems to address current needs and defeat future threats. The program will consider technologies supporting U.S. ground and air operations, extensible to other operating environments, requiring organic and/or tactical swarm capabilities, and leveraging low-cost, rapidly deploy-able, autonomous system technologies. ***FY 2021 Plans:*** - Integrate advanced swarm tactics and physical testbed enhanced for capability-based field experimentation. - Perform capability-based demonstration at scaled missions of relevance. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.	14.500	8.000	-
Title: CounterSwarmAI ***Description:*** The objective of the CounterSwarmAI program is to develop systems for anticipating and defeating autonomous systems threats of the future. These adversary systems will likely employ advanced artificial intelligence (AI) and machine learning techniques which will inevitably lead to increased complexity and unpredictability of these advanced threats. CounterSwarmAI envisions the development of disruptive technologies across the engagement kill chain, themselves AI-empowered, which directly combat these challenges. CounterSwarmAI decision software will directly interface with future and legacy defensive systems (kinetic and non-kinetic) to rapidly assess, optimally exploit, and efficiently defeat enemy autonomous	5.000	5.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
systems threats. Innovative solutions will enable (a) autonomous systems which provide understanding and vulnerability exploitation through machine learning, (b) an integrated AI-equipped open architecture for multi-faceted swarm defense, and (c) integration and experimentation with live surrogate swarm threats against current fielded defensive systems. ***FY 2021 Plans:*** - Develop understanding of swarm behaviors, techniques and vulnerabilities to underpin possible mechanisms for disruption of swarm behaviors or goals. - Collect and curate operationally relevant swarm data sets captured at field experiment events that highlight swarm threat behaviors. - Document possible swarm defeat or mitigation approaches to inform future program approaches. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	59.434	56.119	47.607

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602702E / *TACTICAL TECHNOLOGY*	Project (Number/Name) TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
TT-13: *INFORMATION ANALYTICS TECHNOLOGY*	-	97.377	92.379	86.389	-	86.389	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Information Analytics Technology project develops technology for analyzing data and information arising from: 1) intelligence networks; 2) open sources, social and broadcast media, and other external sources; 3) sensors and signal/image processors; and 4) collection platforms and weapon systems. Technical challenges include processing huge volumes of diverse, incomplete, and uncertain data in tactically-relevant timeframes, and countering the information operations of sophisticated adversaries who seek to deceive, degrade, deny, and disrupt the U.S. information enterprise. Benefits sought include a deeper understanding of the evolving operational environment tailored to the needs of commanders at every echelon; an enhanced capability to plan, monitor, and control diverse military operations ranging from stabilization and information operations to combat engagements; and increased efficiency of core military functions such as national and homeland security, warfighter health and readiness, and defense support of law enforcement and civil authorities.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Semantic Forensics (SemaFor)	10.450	19.700	23.421
Description: The Semantic Forensics (SemaFor) program is developing technologies to defend against the falsification of multimedia and disinformation campaigns. Statistical detection techniques have been successful, but media generation and manipulation technology is advancing rapidly, including imagery, voice, video, text, and other modalities. Purely statistical detection methods are now insufficient to detect these manipulations, especially when multiple modalities are involved. Existing media generation and manipulation algorithms are data driven and are prone to making semantic errors that provide defenders an opportunity for asymmetric advantage. SemaFor is developing semantic and statistical analysis algorithms that determine if media is generated or manipulated, attribution algorithms that infer if media originates from a particular organization or individual, and characterization algorithms that reason about whether media was falsified (generated or manipulated) for malicious purposes. SemaFor aims to create technologies to identify, deter, and understand adversary media falsification. ***FY 2021 Plans:*** - Create techniques for using multi-source semantic information to detect, attribute, and characterize inconsistent and potentially falsified media, such as news articles or social media posts, and to develop mechanisms for explaining algorithmically-generated semantic inferences on multimedia. - Develop an initial semantic forensics system prototype, and evaluate performance on existing and purpose-built text, image, video, and audio datasets.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Develop challenge problems that emphasize threat scenarios in collaboration with DoD and Intelligence Community (IC) partners. ***FY 2022 Plans:*** - Implement algorithmic approaches for analyzing inconsistencies across complex, multi-modal social media posts and technical information. - Develop machine learning and other artificial intelligence techniques to attribute falsified media to particular adversarial elements. - Enhance the semantic forensics prototype with the capability to reason about inconsistencies across multiple media instances, such as news articles, to detect falsification, and to explain its reasoning. - Collaborate with DoD and IC partners to assess prototype semantic forensics capabilities on challenge problems informed by threat scenarios, and identify areas for additional research effort based on the assessment. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to ramping up of development of semantic techniques for reasoning about inconsistencies in multimedia, and initiation of prototyping and evaluation work.			
Title: Adapting Cross-domain Kill-Webs (ACK)	15.000	14.400	11.700
Description: The Adapting Cross-domain Kill-Webs (ACK) program is assisting military decision makers with rapidly identifying and selecting options for tasking and re-tasking assets within and across organizational boundaries. Based on technologies developed in the Resilient Synchronized Planning and Assessment for the Contest Environment (RSPACE) program (budgeted in PE 0603766E, Project NET-01), ACK will assist users with selecting sensors, effectors, and support elements across military domains (space, air, land, surface, subsurface, and cyber) to form and adapt kill chains to deliver desired effects on targets. Today's Command and Control (C2) organizations and processes cannot support multi-domain warfighting concepts, especially during joint operations. ACK will address this challenge by utilizing a decentralized approach to allocating resources to tasks and assigning mission orders to assets, motivated by ideas developed in online commerce, sourcing, and supply chain management, such as bid requests and offers. The impact of ACK will be to accelerate asset re-allocation and assignment decision timelines to be on the order of minutes, and the output of ACK will be automated tools and decision aids to support the selection of the elements of a kill-chain and assignment of roles and responsibilities to each of the elements. Technology developed under this program will be transitioned to the Services. ***FY 2021 Plans:*** - Complete development of evaluation test-bed. - Assess the ability of virtual liaisons to quickly adapt mission plans in the test bed environment. - Assess the ability of C2 node software to adjudicate offers and support rapid user assessment in visual interfaces.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Identify Service partners and develop plans for demonstration of cross-domain mission adaptation. ***FY 2022 Plans:*** - Execute evaluation scenario to exercise algorithm cross-domain reasoning capabilities. - Evaluate cross-domain solution recommendations and user interface presentation. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to a transition from software development to integration and software deployment and testing.			
Title: Data-Driven Discovery of Models (D3M) ***Description:*** The Data-Driven Discovery of Models (D3M) program is developing automated model discovery techniques and tools that enable non-expert users to create empirical models of real, complex processes and phenomena. The ability to understand the battlespace is driven increasingly by expert analysis of sensor and open source data. The DoD and the Intelligence Community (IC) are fundamentally limited by a shortage of domain-focused subject matter expert data scientists to construct empirical models that predict behaviors and anticipate contingencies during tactical and strategic planning. D3M is addressing this need by creating technologies that automate the construction of complex empirical models. D3M technologies include a library of data modeling primitives that are automatically selectable, automated approaches for composition of complex models from modeling primitives, and intuitive mechanisms for human-model interaction that enable curation of models by non-experts. D3M is focused on the types of empirical modeling problems commonly encountered by the DoD and IC. ***FY 2021 Plans:*** - Enhance the library of modeling primitives with support for unsupervised and semi-supervised machine learning, and extend automated data collection to support discovery and augmentation of datasets with limited or no human-in-the-loop. - Develop scalable techniques to extract information from contractual databases to enable situational awareness and vulnerability analysis of markets and supply chains. - Refine modeling tools with respect to interoperability to enable transition and deployment of end-to-end empirical modeling software systems. ***FY 2022 Plans:*** - Demonstrate automated surveillance algorithms that respond in real-time to high-speed, coordinated attacks against global supply chains and markets to enable early warning, damage mitigation, and active protection measures. - Harden software modeling tools and systems, and transition to operational users. ***FY 2021 to FY 2022 Increase/Decrease Statement:***	16.000	12.650	11.700

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 decrease is the result of development work ramping down and the focus shifting to hardening of modeling tools for transition.			
Title: Warfighter Analytics using Smartphones for Health (WASH) ***Description:*** The Warfighter Analytics using Smartphones for Health (WASH) program is developing analytic techniques for continuous and real-time assessment of warfighter physiological health and cognitive state based on the multiple sensor data streams generated by modern smartphones. Recent research in the area of smartphone biometrics has shown the feasibility of measuring user physiological and behavioral parameters for purposes of user authentication. WASH will extend these smartphone biometrics to reliably measure additional user physiological and behavioral parameters relevant to health assessment and the diagnosis of disease. WASH aims to enable the remote assessment of warfighter health and mission readiness. ***FY 2021 Plans:*** - Continue to enhance periodic audits of the security and privacy controls of the cloud-based data ingest and storage infrastructure, and perform upgrades as appropriate. - Evaluate privacy-preserving contact tracing techniques as an adjunct to digital biomarkers as a means for predicting physiological disease. - Demonstrate technology suitable for a privacy-preserving military mobile app, and scale cloud-based back-end infrastructure for a large study with a military service partner. ***FY 2022 Plans:*** - Evaluate algorithms to associate digital biomarkers with physiological and cognitive state across a diverse set of relevant ambient contexts. - Conduct demonstrations of the capability to track and predict service member physiological health status in collaboration with DoD stakeholders, and harden technology for transition. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to ramping down of work to develop and integrate techniques to analyze user smartphone data, and focus shifting to demonstration and evaluation of the performance of techniques to assess user physiological health and cognitive state.	17.000	15.500	7.000
Title: Causal Exploration of Complex Operational Environments ***Description:*** The Causal Exploration of Complex Operational Environments program is developing advanced modeling, analysis, simulation, and visualization tools to enable command staffs to rapidly and effectively design, plan, and manage missions in complex operational environments. The U.S. military increasingly operates in remote and unstable parts of the world where mission success depends heavily on cooperation with a wide variety of stakeholder groups on civil, economic, and military	20.500	13.400	5.468

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
matters. These groups typically include host nation government organizations, local civilian groups, and non-governmental organizations, each of which has priorities, sensitivities, and concerns that may differ significantly. Current mission design and planning technologies do not adequately model the range of options or the inherent uncertainties. This program is developing tools to create causal, computational models that represent the most significant relationships, dynamics, interactions, and uncertainties of the operational environment including political, military, economic, and social factors. These tools will enable command staffs to design and quantitatively assess potential courses of action in complex operational environments. ***FY 2021 Plans:*** - Develop war gaming and red teaming capabilities to account for adversary activities, and assess effectiveness of countermeasures. - Fully integrate and transition system into the School of Advanced Military Studies (SAMS) curriculum, tailor system to meet key functional and performance needs of transition partners, and conduct operational evaluation to measure military utility of the system. - Harden system and transition new operational design capability to operational users. ***FY 2022 Plans:*** - Explore the utility of the technology for the planning and conduct of multi-domain operations and related joint force concepts for countering and defeating a near-peer adversary, with emphasis on non-kinetic domains and phases of conflict. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to ramping down of work to develop, evaluate, and refine causal modeling technologies, and focus shifting to exploration of technical utility and transition to military users.			
Title: Modeling Adversarial Activity (MAA) ***Description:*** The Modeling Adversarial Activity (MAA) program is developing technologies for generating high-confidence indications and warnings for weapons of mass terror (WMT) activities. WMT pathways consist of networks or links among individuals, groups, organizations, and other entities that act to promote or enable the development, procurement, possession, transportation, or proliferation of WMTs and related capabilities. Monitoring and controlling WMT pathways is essential to denying access to WMT technology, knowledge, materials, expertise, and weapons. MAA will create template graph models reflecting prototypical WMT pathways, develop methods for creating merged activity graphs by aligning entities across multiple intelligence modalities, develop algorithms to match large-scale empirical activity graphs with pathway models, and create synthetic data sets at scale to support development and testing of WMT activity detection techniques. MAA technology development is being coordinated with operational partners. ***FY 2021 Plans:***	14.000	10.729	5.100

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Evaluate the scalability of techniques for construction of large, semantically-rich graphs and for approximate matching of activity graphs with rich semantics on real world data. - Extend real-time graph alignment capabilities to environments with frequent information updates and explore methods to tune the end-to-end system to maximize detection and graph matching performance. - Collaborate with transition partners to implement techniques in their environments and to optimize techniques for efficient and timely execution on their computational infrastructure. ***FY 2022 Plans:*** - Harden graph analysis techniques and transition software capabilities to operational partners. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects ramping down of work to develop and evaluate techniques and software for WMT pathway discovery, and the focus shifting to hardening of software capabilities and transition.			
Title: Influence Campaign Awareness and Sensemaking (INCAS)	-	6.000	14.500
Description: The Influence Campaign Awareness and Sensemaking (INCAS) program, building upon research conducted in the Causal Exploration of Complex Operational Environments program in this PE/Project, will develop techniques, tools, and platforms for the DoD to detect and understand information operations in a rigorous, quantitative manner. Increasingly, competitors and adversaries are using information operations to project soft power. Competitor and adversary influence campaigns can be overt in the form of anti-U.S. messaging, or they can be disguised in the form of complex narratives that seek to advance agendas harmful to U.S. interests. The USG and DoD need the capability to rapidly detect and understand competitor and adversary messaging campaigns and narratives within the context of the populations and groups for whom they are intended. To accomplish this, the program will develop and operationalize natural language processing, semantic analysis, social network analysis, psychographics, and behavioral science-based technologies, and integrate these into a unified information operations modeling framework and sensemaking platform. INCAS aims to produce a suite of largely automated digital tools to enable analysts to better understand how information is being used by competitors and adversaries, and to quantitatively assess in real time and at scale the effects of influence campaigns and of countermeasures. ***FY 2021 Plans:*** - Formulate influence indicators that can be used to detect competitor and adversary influence campaigns from messages and narratives. - Explore the potential for natural language processing and semantic analysis techniques to extract an agenda from influence indicators and context, and for psychographic and behavioral science-based techniques to measure the receptivity of populations and groups to influence messages and narratives. ***FY 2022 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Implement influence indicators in scalable algorithms and conduct initial assessments of their effectiveness in detecting competitor and adversary influence campaigns from messages and narratives. - Develop and implement natural language processing and semantic analysis techniques to extract an agenda from influence indicators and context, and for psychographic and behavioral science-based techniques to measure the receptivity of populations and groups to influence messages and narratives, and initiate efforts to quantify the contribution of these capabilities to analyst sensemaking. - Develop, refine, and extend a modeling framework and sensemaking platform in response to operator assessments of its contribution to their ability to understand and anticipate the likely reaction of populations and groups to influence campaigns. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to ramping up of work to develop natural language processing and semantic analysis techniques, to extract an agenda, to measure the receptivity of populations and groups, and to implement a modeling framework and sensemaking platform.			
Title: Culturally-aware IO Defense (CLAID) ***Description:*** The Culturally-aware IO Defense (CLAID) program aims to create human language technology capabilities to enable machines to understand cultural background and social and emotional context in order to deepen situational awareness of emergent incidents. Speakers produce and consume language within a social and cultural context that influences cognition, beliefs, and intents through shared values, and social norms. Therefore, for a natural language processing (NLP) system to fully understand a language and its speakers, it must understand culture and social context. Specific sociocultural NLP capabilities to be developed in CLAID include understanding localized references to entities, assessing emotion and urgency, and interpreting the cultural significance of narratives and events. CLAID will develop technologies to enable local commanders to better understand rapidly changing tactical environments, and to more effectively plan and conduct stabilization operations in all phases of conflict. ***FY 2022 Plans:*** - Introduce a modeling framework for social and cultural context that includes shared values, social norms, and variations in cross-cultural affective expressions. - Formulate approaches for new NLP capabilities such as interpreting localized references to entities, emotion, and urgency, and the cultural significance of narratives and events. - Create culturally-specialized capabilities for understanding the types of emergent incidents typically encountered during the conduct of stabilization operations. ***FY 2021 to FY 2022 Increase/Decrease Statement:***	-	-	7.500

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602702E / *TACTICAL TECHNOLOGY*	**Project (Number/Name)** TT-13 / *INFORMATION ANALYTICS TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 increase reflects program initiation.			
Title: Media Forensics (MediFor)	4.427	-	-
Description: The Media Forensics (MediFor) program created technologies for analyzing media content to determine trustworthiness for military and intelligence purposes. Prior to MediFor, approaches to media forensics were labor intensive, requiring analysts and investigators to undertake painstaking analyses to establish context and provenance. The program developed, integrated, and extended image and video analytics to provide forensic information that can be used by analysts and automated systems to quickly determine the integrity of open source and captured images and video. Technologies were transitioned to operational commands, the Intelligence Community (IC), and Law Enforcement.			
Accomplishments/Planned Programs Subtotals	97.377	92.379	86.389

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	260.831	245.107	317.024	-	317.024	-	-	-	-	-	-
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	111.417	98.041	137.326	-	137.326	-	-	-	-	-	-
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	149.414	147.066	179.698	-	179.698	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Materials and Biological Technology Program Element is budgeted in the Applied Research Budget Activity because its objective is to develop materials and biological technologies that make possible a wide range of new military capabilities. This Program Element also supports innovation and robust transition planning in the technology cycle by working with entrepreneurs to increase the likelihood that DARPA funded technologies take root in the U.S. and provide new capabilities for national defense.

The major goal of the Materials Processing Technology project is to develop novel materials, fabrication and processing techniques, models, 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 technology areas including manufacturing, electronics, sensors, optics, and complex and autonomous systems.

The Biologically Based Materials and Devices project will leverage the growing application space of the biological sciences for the development of new DoD capabilities in materials development, threat detection, and warfighter performance. Contained in this project are thrusts that apply biology's unique synthesis capabilities to source DoD-relevant materials and overcome current limitations in accessing, scaling, and distributing critical resources to achieve overmatch. Programs in this project also enable in situ and stand-off detection and mitigation of biological, chemical, traditional, and emerging threats against the warfighter, the food supply, and other targets. This project also includes efforts to develop novel biological technologies for maintaining human combat performance.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	214.976	250.107	245.748	-	245.748
Current President's Budget	260.831	245.107	317.024	-	317.024
Total Adjustments	45.855	-5.000	71.276	-	71.276
• Congressional General Reductions	0.000	-5.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	53.077	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-0.923	0.000			
• SBIR/STTR Transfer	-6.299	0.000			
• TotalOtherAdjustments	-	-	71.276	-	71.276

Change Summary Explanation

FY 2020: Increase reflects COVID response CARES Act add offset by reprogrammings and SBIR/STTR transfer.

FY 2021: Decrease reflects congressional adjustments.

FY 2022: Increase reflects initiation of the Bio-Inspired Coastal Defense program in the Biologically Based Materials and Devices project, as well as, transition from design and initial development to prototype development and testing in the Functional Materials and Devices thrust in the Materials Processing and Technology project.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
MBT-01: *MATERIALS PROCESSING TECHNOLOGY*	-	111.417	98.041	137.326	-	137.326	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The major goal of the Materials Processing Technology project is to develop novel materials, fabrication and processing techniques, models, 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 technology areas including manufacturing, electronics, sensors, optics, and complex and autonomous systems. This Project includes FY 2020 CARES Act funding in the amount of $29.077 million to develop U.S. sourced production capabilities for chemical precursors needed to produce pharmaceuticals critical to SARS-CoV-2/ COVID-19, and assess the efficacy of Food and Drug Administration (FDA)-approved therapeutic drug candidates for treatment of COVID-19 patients.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Materials for Extreme Environments	20.006	42.041	56.094

Description: The Materials for Extreme Environments thrust is exploring new materials, innovative architectures, and development processes that will significantly enhance the performance and persistence of DoD platforms operating in extremely harsh environments. Materials with superior strength, functionality, and resiliency are critical for enabling DoD platforms, weapons and other components to operate and persist under conditions including, but not limited to, extremely high or low temperatures, turbulence, ionizing radiation, and/or corrosive environments. Recent developments in materials such as high entropy alloys, infiltrated carbon fiber composites, and synergistic processing hold promise for achieving material solutions for improved survivability in a wide range of harsh environment conditions. Similarly, advancements in material design, processing and manufacturing are enabling novel material architectures that can further enhance performance and resilience in structures such as leading edges, windows and apertures, propulsion systems, and space structures. Exemplar areas of research within the Materials for Extreme Environments thrust include the following: 1) high temperature materials for hypersonic platforms; 2) high temperature window and aperture materials; 3) radiation and/or electromagnetic pulse (EMP) hardened electronics for space platforms; and 4) coatings for platform survivability in corrosive environments.

FY 2021 Plans:

- Investigate mechanical/physical/chemical properties of high entropy alloys for applications in extreme environments.
- Conduct arc-jet testing on architected material coupons to quantify material performance.
- Identify and integrate advanced diagnostic capabilities into relevant test facilities to monitor material response in real time.
- Demonstrate scalable manufacturing processes to enable multifunctional structural/thermal leading edge structures for hypersonic vehicles, including scaled leading edge coupons with microscale features for heat pipe, transpiration and phase-change functionality.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
- Identify material approaches to enable operational Infrared/Radio Frequency (IR/RF) performance at temperatures characteristic of hypersonic flight. - Develop models to predict operational impact of improved radome materials. - Identify materials that are amenable to manufacture in the space environment. - Identify technologies such as robotic self-assembly and low power curing that can be modified for zero gravity operation. ***FY 2022 Plans:*** - Validate component level models for scaled cooled leading edge structures under high aerothermal conditions. - Conduct integration studies for scaled cooled leading edge components to facilitate technology transition. - Manufacture scaled architected leading edge structures with integrated cooling and demonstrate under high heat flux conditions. - Develop new test capabilities for testing IR/RF performance under high temperature oxidative conditions. - Demonstrate novel sensing capabilities suitable for hypersonic platforms under high temperature conditions. - Identify new designs and stabilization techniques for ultra-low mass density structures suitable for on-orbit applications such as solar arrays, antennas and optical surfaces. - Laboratory demonstration of critical materials manufacturing steps to enable ultra-low mass density structures. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to the shift from initial design to development and testing.			
Title: Functional Materials and Devices	11.060	20.500	46.204
Description: The Functional Materials and Devices thrust is developing advanced materials, components and systems to improve device performance for DoD sensing, imaging and communication applications. One focus of this thrust involves development of advanced transductional materials that convert one form of energy to another for DoD-relevant applications in areas such as thermoelectrics. While promising transduction materials are known for a variety of applications, integration into devices has not been realized. Another focus area is the development of physics based models that predict material behavior when illuminated by high peak power electromagnetic interference. A third focus area involves development of new multi-functional materials and device designs that will radically decrease the size, weight and power requirements of neutron and gamma sources for high-resolution neutron, gamma and x-ray imaging. Such devices should enable fieldable detection units for non-destructive evaluation of parts, detection of explosives and other DoD-relevant targets. ***FY 2021 Plans:*** - Refine compact gamma ray source component technology designs and plan for integration of component technologies into compact, mono-energetic gamma ray source prototypes. - Mature component and system modeling efforts to support realization of prototype test beds for intense, compact, mono-energetic gamma ray sources.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
- Explore novel algorithms and sensors for passive 3D night vision. - Create a preliminary ground-truth database of the ambient infrared light present in off-road environments. - Develop understanding of the fundamental trade-space between night vision system field of view, bandwidth, efficiency, and overall system length/weight using planar optics and novel materials for transduction. - Develop fundamental understanding of photon upconversion bandwidth and efficiency; identifying methods of achieving high-efficiency upconversion across the infrared to the visible. - Define system requirements for a compact ruggedized linear accelerator. ***FY 2022 Plans:*** - Complete initial prototype test beds for compact gamma ray sources that feature high intensity, tunability, and narrow bandwidth. - Conduct initial demonstrations of prototype test beds for compact gamma ray sources that are capable of meeting base phase performance goals for intensity and bandwidth. - Design novel techniques to extract 3-dimensional information from infrared data. - Perform spectral analysis of passive thermal emissions to mathematically determine object structures. - Perform co-optimization of planar optics and materials for transduction to identify paths towards low torque (less than 0.2 nanometers) night vision systems providing visual access to at least 1,550 nanometers with a greater-than 60 degree field-of-view. - Develop and verify a system design for a compact ruggedized linear accelerator system. - Complete testing of critical compact ruggedized linear accelerator components to validate they can provide the required performance. - Investigate limits of microscale architecture for achieving high performance active acoustic materials such as piezoelectric, magnetostrictive and multiferroic materials for deep water operation. - Explore opportunities for adapting advances in energy harvesting and recovery for applications in austere locations. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to the transition from initial component design to integrated system design.			
Title: Chemical Processing for Force Protection	37.684	13.000	19.028
Description: Research in the Chemical Processing for Force Protection thrust is focused on the development of new chemical approaches and technologies across a broad spectrum of DoD needs. One area involves development of innovative approaches for scalable small molecule synthesis coupled with predictive tools for route design, possibly offering a new strategy to discover how to make new molecules such as pharmaceuticals and explosives. Another focus leverages advances in automation to develop safe, reproducible experimental approaches for systematic development of energetic materials. In addition, investments in this thrust will advance chemical characterization, information management and analysis, and automation.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
FY 2021 Plans: - Develop standardized protocols for conducting energetic-relevant experimentation using minimal quantities of energetic compounds. - Design and begin constructing semi-automated experimental capabilities that integrate energetic ingredient synthesis with formulation development and testing to enable a safer, more rapid, systematized design of experiments approach to energetics development. - Leverage new energetic synthesis pathways to initiate development of advanced energetic formulations for one or more DoD-relevant applications. ***FY 2022 Plans:*** - Demonstrate semi-automated, reproducible experimental systems that integrate more than three explosive ingredients at scales over 10 grams per formulation with on-board sensitivity tests. - Extend semi-automated experimental systems to handle materials for propellant development, with automated integration of more than six propellant ingredients at scales over 25 grams per formulation. - Demonstrate accurate and safe determination of explosive and propellant metrics using gram-scale quantities. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to the transition from initial design to system development and demonstration.			
Title: Multi-Scale Modeling	16.000	15.000	9.000
Description: The Multi-Scale Modeling thrust is developing advanced, multi-physics models that can predict the effect of disturbances and/or perturbations in the space environment in order to inform operational decisions based on current space environment conditions. Current space environment models are limited to predicting long term climatic averages or regularly occurring phenomena and do not fully account for coupling effects where perturbations in one region of the space environment may produce disturbances in another region. Approaches for addressing these limitations under the Multi-Scale Modeling thrust include the following: (1) development of observation driven/first-principles theory of magnetosphere-ionosphere-thermosphere coupling; (2) creation of an extensible assimilation framework for unifying space environment monitoring systems and data; and (3) non-traditional space environment measurement approaches. These developments will ensure the accuracy and spatiotemporal resolution of space weather models and is sufficient to enable prediction of operationally relevant perturbations and disturbances in the space environment. ***FY 2021 Plans:*** - Demonstrate in simulation the ability to predict and track phenomenon with scale lengths as small as one hundred kilometers. - Demonstrate the extensible data assimilation frameworks ability to process all data sources in less than fifteen minutes with a minimum of two major observation networks integrated and one synthetic source of data.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
- Demonstrate the capability of plasma physics models to simulate wave/particle interactions necessary to inform understanding of electron depletion by electromagnetic (EM) waves. ***FY 2022 Plans:*** - Demonstrate and field test an integrated space environment forecasting capability to predict perturbation and disturbances within scale lengths as small as one hundred kilometers, every hour, within a seventy-two-hour window, and over an area representative of an operation area of responsibility. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to the transition from heavy system development to demonstration.			
Title: Reconfigurable Systems ***Description:*** In the Reconfigurable Systems thrust, new approaches are being developed to enable more rapid and robust adaptation of defense systems and systems-of-systems to changing mission requirements and unpredictable environments. This includes development of capabilities across sensing, perception, planning and control for autonomous, high-speed operation in cluttered environments without Global Positioning System (GPS) information. This also includes development of capabilities to manipulate and control adversary sensory perception and/or situational awareness. Additional work in this thrust focuses on how sensing systems and military systems-of-systems are designed for real-time resilient response to dynamic, unexpected signals and contingencies. Research is developing a more unified view of system behavior that allows better understanding and exploitation of complex interactions among components, including development of formal mathematical approaches to complex adaptive system composition and design. These capabilities will impact autonomous systems and systems-of-systems, including those that involve humans, in a variety of DoD-relevant contexts. ***FY 2021 Plans:*** - Explore designs for a portable optical clock physics package capable of demonstrating stability of fifty femtoseconds at one second maintained over a day. ***FY 2022 Plans:*** - Initiate efforts to demonstrate sub-picosecond optical time transfer over a range of greater than fifty kilometers. - Finalize design for a portable optical clock with a frequency comb capable of demonstrating precise (picosecond) two-way optical time transfer. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to the transition from initial component demonstration to integrated system demonstration.	9.650	3.000	7.000
Title: Accelerating Discovery and Innovation	15.017	4.500	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
Description: The Accelerating Discovery and Innovation thrust is developing new approaches, tools and technologies to speed the pace of scientific discoveries and technological innovations from idea generation and fundamental research through integration of technologies into fieldable products and systems in production. The path from idea generation to a discovery is a lengthy, complex process involving many unpredictable steps, cycles and stages across fundamental and applied research and development. Research in this thrust is focused on developing and implementing strategies to address many of the challenges and bottlenecks inherent along this path and to speed the rate at which an idea can be advanced into a concrete capability. Specific approaches include advanced multiplayer gaming technologies to catalyze development of new technology concepts, development of tools for data collection and visualization to accelerate fundamental and applied research, and strategies to understand how seemingly benign commercially available technologies may be converted or combined into threats to military operations, equipment or personnel. ***FY 2021 Plans:*** - Apply and evaluate online, multi-platform structured conversation tools for rapidly identifying evidence-based development opportunities. - Employ and evaluate online conversation tools to expedite the identification and vetting of research ideas. - Evaluate the success of research projects developed via online structured conversation tools. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to program completion.			
Title: Materials Processing and Manufacturing ***Description:*** The Materials Processing and Manufacturing thrust explored new manufacturing and processing approaches that dramatically lowered the cost and decreased the time required to fabricate DoD parts and systems. Constantly changing specifications for DoD platforms combined with recent manufacturing advances, such as 3D printing and manufacture on demand, drive a need for greater efficiency in development and design cycles as well as scalable and reconfigurable manufacturing processes that incorporate advanced materials with superior properties. Research within the Materials Processing and Manufacturing thrust focused on achieving the following capability objectives: (1) scalable processes to assemble fully 3D devices that include nanometer- to micron-scale components; (2) processes that yield new materials, materials capabilities and parts that cannot be made through conventional processing approaches; (3) efficient, low volume manufacturing; (4) approaches that reduce manufacturing complexity through new material feedstock formats with reconfigurable processing techniques; and (5) material processing that enhances platform survivability in extreme environments.	2.000	-	-
Accomplishments/Planned Programs Subtotals	111.417	98.041	137.326

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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*

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
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 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
MBT-02: *BIOLOGICALLY BASED MATERIALS AND DEVICES*	-	149.414	147.066	179.698	-	179.698	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Biologically Based Materials and Devices project will leverage the growing application space of the biological sciences for the development of new DoD capabilities in materials development, threat detection, and warfighter performance. Contained in this project are thrusts that apply biology's unique synthesis capabilities to source DoD-relevant materials and overcome current limitations in accessing, scaling, and distributing critical resources to achieve overmatch. Programs in this project also enable in situ and stand-off detection and mitigation of biological, chemical, traditional, and emerging threats against the warfighter, the food supply, and other targets. This Project also includes efforts to develop novel biological technologies for maintaining human combat performance. This Project also supports innovation and robust transition planning in the technology cycle by working with entrepreneurs to increase the likelihood that DARPA funded technologies take root in the U.S. and provide new capabilities for national defense. This Project includes FY 2020 CARES Act funding in the amount of $24.0 million to test ultra-sensitive methods for diagnosing COVID-19, discover completely novel clustered regularly interspaced short palindromic repeats (CRISPR)-based therapies against COVID-19, and assess the efficacy of Food and Drug Administration (FDA)-approved therapeutic drug candidates for treatment of COVID-19.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Persistent Terrestrial Living Sensors	15.790	15.832	18.672
Description: The Persistent Terrestrial Living Sensors program is developing engineered biological sensor platforms capable of detecting land-based threats (e.g., chemicals, radiation, explosives, biologics) and relaying unique signals to existing DoD ground, air, and space assets. Unlike conventional methods that monitor threats and are limited by sensor energy needs, these biological sensors are effectively energy independent, increasing the potential for wide distribution and environmental robustness. Resulting platforms developed within this program will enable a variety of remote, persistent monitoring and reporting capabilities to address threat scenarios relevant for national security, including passively detecting improvised explosive devices (IEDs) and presence of biological pathogens in indoor and outdoor environments. These sensors will provide a flexible suite to complement conventional sensor systems within the DoD.			
FY 2021 Plans: - Integrate plant platforms to align threat detection with plant resource and ecology traits. - Develop a simulated environment containing co-occurring plant, insect, and microbial species representing realistic competitive, predator, parasitic, and mutualistic interactions. - Demonstrate the ability of engineered plants to sense and report exposure to threats in multiple simulated environments. - Examine molecular mechanisms of protein production in mature plants.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
- Assess plant protein production outcomes and determine relevant phenotype characteristics. ***FY 2022 Plans:*** - Confirm plant sensor reporting phenotypes are detectable from stand-off post stimulus exposure. - Perform phenotyping of plant sensors under prescribed simulated biosecurity threat scenario. - Quantify plant sensor functionality by applying trace stimuli and evaluating response for high sensor sensitivity and specificity. - Evaluate altered plant physiological properties based on understood molecular mechanisms for desired outcomes. - Demonstrate protein production outcomes and analyze system for potential undesired effects. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects initiation of large-scale experimental simulation for integrated plant sensor testing.			
Title: Preemptive Expression of Protective Alleles and Response Elements (PREPARE)	30.097	16.899	14.585
Description: The Preemptive Expression of Protective Alleles and Response Elements (PREPARE) program is creating a transient, near immediate prophylaxis and treatment to protect military personnel and civilians against public health and national security threats. Currently, protection against Chemical, Biological, Radiological, and Nuclear (CBRN) threats relies on physical barrier technology. This program includes research to develop novel transient and reversible gene modulator therapies to bolster intrinsic host defenses. Work within this program will provide novel solutions that extend beyond the DoD's capabilities to respond to re-emerging, newly emerging, or engineered threats. ***FY 2021 Plans:*** - Refine Target Product Profile (TPP) to guide initial regulatory discussions and inform pre-clinical studies to determine efficacy of programmable gene modulator based medical countermeasures. - Determine optimal formulations to deliver programmable gene modulators to appropriate cells and tissues with high specificity and for threat-relevant periods of time. - Demonstrate and optimize specificity to targets, duration, and magnitude of programmable gene modulator activity in vivo. - Perform capability demonstration of programmable gene modulator platform to assess protection against a chemical, biological, or radiological threat in small animal models. ***FY 2022 Plans:*** - Refine formulations to deliver programmable gene modulators to appropriate cells and tissues with high specificity and for threat-relevant periods of time. - Refine specificity to targets, duration, and magnitude of programmable gene modulator activity in vivo. - Perform capability demonstration of programmable gene modulator platform to assess protection against a chemical, biological, or radiological threat in large animal models.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
- Begin drafting pre-Investigational New Drug (IND) or Emergency Use Authorization (EUA) package for submission to the FDA. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects reduction in research efforts associated with identifying effective gene targets for clustered regularly interspaced short palindromic repeats (CRISPR)-based medical countermeasures.			
Title: Persistent Aquatic Living Sensors ***Description:*** The Persistent Aquatic Living Sensors program is developing novel capabilities to sense and surveil submersibles (e.g., submarines, unmanned underwater vehicles) and divers in littoral waters using living organisms present in the environment. This effort focuses on characterizing marine biological behavior in response to targets of interest and developing the hardware, software, and algorithms that will translate organism behavior into DoD actionable information. By harnessing the unique capabilities of biology, including adaptation, response, and replication, work in this program will enable persistent dominance in contested waters. Results from this research will enhance security for maritime activities and provide DoD naval operations with new sensing paradigms to complement current sensor technologies used in traditionally challenging regions across the world. ***FY 2021 Plans:*** - Demonstrate approaches to evoke biological responses in marine organisms. - Characterize operational utility of biological responses in multiple environments. - Demonstrate biological responses to targets and confounders in more realistic environments, with greater discrimination fidelity. - Perform field experiments to characterize maximum sensory and response propagation distances of biological organisms. - Demonstrate full end-to-end system capability in near shore environments for detection, processing, and near real-time alerting to presence of manned or unmanned vehicles via seaworthy prototype. ***FY 2022 Plans:*** - Demonstrate improvements in approaches to evoke and characterize biological responses in marine organisms. - Test the accuracy of biological systems at various propagation distances in multiple environments. - Refine system improvements and validate performance in the presence of noise and surface vessel traffic. - Demonstrate the ability of second-generation prototype to detect, process, characterize and alert the presence of manned or unmanned underwater vehicles in near shore or open water environments. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects minor program repricing.	27.066	25.720	26.541
Title: Expanding Human Resiliency ***Description:*** The Expanding Human Resiliency program aims to maximize warfighter resiliency by leveraging the signals of the human microbiome to improve physiology. This program will develop new technologies to control and manipulate the microbiome	13.425	13.500	17.773

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
(e.g., to reduce attraction and feeding of disease vectors such as mosquitoes). Current state-of-the-art approaches are focused on metagenomics to inventory and categorize the microbes in a given sample. In order to have more precise and on-demand control of microbiomes, technologies will be developed to elucidate the complex interactions between the microorganisms and their host as well as the interactions between consortia of adapted and evolved microorganisms. Advances in this area will both develop novel technologies to interrogate complex microbial communities in human systems and discover ways to beneficially harness microbiomes to expand warfighter resiliency. ***FY 2021 Plans:*** - Optimize testing methods to alter chemical production by microbiomes. - Initiate testing using in vitro model communities to alter chemical production by microbiomes. - Validate alterations to chemical production to reduce attraction and feeding of mosquitoes or other disease vectors. - Investigate methods to improve physical and computational models of microbiomes. ***FY 2022 Plans:*** - Test integration and stability of altered microbial strains in vivo. - Investigate methods to deliver interventions to skin to alter chemical production by the microbiome. - Down select and refine targets for chemical production by microbiomes. - Validate alterations to chemical production to reduce attraction and feeding of mosquitoes or other disease vectors within in vitro model communities. - Refine and validate physical and computational models of microbiomes based on empirical data. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects initiation of efficacy and stability studies using animal models and initial studies toward development of topical (skin) formulations.			
Title: Restoring Cognitive Capability ***Description:*** The Restoring Cognitive Capability program is developing novel drugs to provide rapid therapy for neuropsychiatric disorders experienced by warfighters and veterans. Active duty military personnel face increased risk of acute and chronic neuropsychiatric dysfunction, limiting day-to-day function and return to duty. Current therapeutic approaches for many neuropsychiatric disorders (e.g., Post Traumatic Stress Disorder [PTSD], mood disorders, and substance abuse) rely on individual management with integrated psychiatric therapy and medication. However, most interventions approved for use in these conditions lack long-term efficacy, involve a logistical burden of treatment and/or carry a risk of serious adverse side effects. The Restoring Cognitive Capability program is developing and testing novel drug chemotypes designed to functionally interact with neuronal receptor subtypes known to play a role in these neuropsychiatric conditions, with the aim of enabling fast-acting and effective alleviation of neuropsychiatric dysfunction with single or minimal doses.	8.498	11.178	11.423

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
FY 2021 Plans: - Continue in vitro functional testing of novel molecules. - Develop novel biosensors for assessment of drug uptake and distribution. - Continue assembly and validation in vivo of behavioral assays. ***FY 2022 Plans:*** - Evaluate in vitro signaling effects of novel molecules. - Develop animal models with humanized neuronal receptor subtype. - Validate biosensors for assessment of drug uptake and distribution in vivo. - Test novel molecules for therapeutic actions and side effects in vivo. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects minor program repricing.			
Title: Food and Feedstocks on Demand	9.693	13.053	18.642
Description: The Food and Feedstocks on Demand program is developing biological technologies to support the DoD need to strengthen local resource security for the warfighter. Currently, operators in the field are burdened with transport and disposal of single-use materials. This program is using these burdensome materials as inputs and re-form the molecules for nutrition or other strategic applications. Research in this program will provide a versatile system that delivers food, water, and petroleum/ oils/lubricants (POLs) so that warfighters can independently produce material support to extend mission duration and/or expand operational flexibility in resource-limited environments. ***FY 2021 Plans:*** - Design a prototype system to maximize the use of military waste for desired products. - Design chemical, biochemical, and biological treatments, and combinatorial processes to complement the deconstruction of waste in military operation scenarios. - Design extraction techniques to obtain purified chemical compounds from contaminated waste mixtures. ***FY 2022 Plans:*** - Breakdown plastic waste material into a biodegradable, detoxified environmentally compatible formulation. - Scale purification techniques to obtain desired products free from contaminants. - Optimize the process for product generation from increasingly complex plastic waste mixtures. - Demonstrate the capability to convert waste into usable materials for 24 hours. - Investigate methods to develop computational tools for alternate approaches to develop critical molecules and materials. ***FY 2021 to FY 2022 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
The FY 2022 increase reflects addition of systems engineering and design deliverable to proof-of-concept.			
Title: Gene Editing Enabled Diagnostics & Biosurveillance	10.000	13.550	19.923
Description: The Gene Editing Enabled Diagnostics & Biosurveillance program is developing fieldable, low-cost gene editing-based diagnostics capabilities for rapid, specific, sensitive, and multiplexed detection of biological threats in military and public health scenarios. This program will investigate the design rules for diagnostic and biosurveillance targets to achieve broad-spectrum detection with high confidence diagnostic results. These design rules will inform advanced computational and machine learning approaches to scan genome data and algorithmically design probes and guides for optimal assay results. Additional work will develop assay architectures, reagents, and detection platforms to enable field-forward diagnostics at the point-of-care with the same sensitivity, and reliability tests conducted in hospital/central laboratories. ***FY 2021 Plans:*** - Begin to develop assays with multiplexed, clinically or environmentally relevant levels of detection sensitivity. - Investigate robust and reproducible detection in clinically or environmentally relevant sample matrices. - Refine computational design tools to inform the design and function of optimal diagnostic and biosurveillance assays. - Characterize failure modes of design and detection technologies. ***FY 2022 Plans:*** - Establish computational tools to create diagnostic and biosurveillance assays for a target biological signature. - Demonstrate assay utility for detection of targets in relevant clinical or environmental samples. - Develop prototype handheld devices for point-of-care and demonstrate detection of targets. - Develop prototype benchtop modules for highly multiplexed diagnostic and biosurveillance assays and demonstrate detection of targets. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects systems-level integration of components into a biosensor for disease detection and surveillance.			
Title: Unburdening the Warfighter from Chemical/Biological (CB) Defense	-	9.040	17.198
Description: The Unburdening the Warfighter from Chemical/Biological (CB) Defense program aims to increase warfighter survivability by developing improved personal protective equipment (PPE) and medical countermeasure (MCM) technologies to protect against CB threats. Current methods of CB protection require significant logistical burdens, including suits that are bulky and hot, which limit operational capability. These burdens increase if an increased level of protection is required. The Unburdening the Warfighter from CB Defense program will investigate and design novel biological and material approaches that provide rapid protection against multiple CB agents for the warfighter. This research will innovate PPE through the discovery of compounds			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
and lightweight, durable systems designed to capture, neutralize, or repel CB agents. This novel approach will provide almost immediate and lasting protection even in austere operational settings. ***FY 2021 Plans:*** - Coordinate with Independent Validation and Verification (IV&V) support teams to establish study designs, testing infrastructure, and standards compatible with FDA regulatory guidance. - Investigate approaches (e.g., special coatings, enzymes, biological) to neutralize or decontaminate Chemical or Biological agents. - Initiate development of novel system components to provide protection to vulnerable tissue barriers (e.g., skin, airway, and ocular). - Initiate platform component design in concert with regulatory and IV&V guidance for developing warfighter technologies. ***FY 2022 Plans:*** - Investigate formulations and delivery methods required to provide the warfighter with biological systems capable of mitigating threats. - Begin testing the ability of the system components to protect against exposure to CB threats using special coatings, enzymes and biological approaches. - Validate system components safety design in a simulated environment. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the initiation of testing and safety validation of system components.			
Title: Atmospheric Water Extraction (AWE)	-	9.500	14.687
Description: The Atmospheric Water Extraction program aims to enable water harvesting directly from the atmosphere by leveraging new materials and advanced engineering and manufacturing techniques to alleviate the logistical and tactical burden of the water supply chain. Currently, the DoD relies on purification of existing water sources and/or distribution of bottled or treated water to provide the warfighter with sufficient daily hydration. State-of-the-art water-from-air generation systems are not suitable for military applications because the systems do not operate in a range of atmospheric conditions needed by our soldiers, from arid conditions (<40% relative humidity) to extremely humid, and are too energy-intensive (<7 gallons of water output per gallon of fuel). This program will deliver systems with extraordinarily low size, weight, and power (SWaP) characteristics to provide potable water to individual warfighters, and expeditionary units. Technologies developed under this program will provide strategic and tactical advantages aligned with the DoD's vision of future combat operations carried out by distributed and self-sustaining forces. ***FY 2021 Plans:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
- Begin development and optimization of sorbent materials with properties tailored to low-powered and rapid water capture and release. - Develop a component-level system model for an engineered water extraction device. - Initiate fabrication of components of modeled water extraction device. ***FY 2022 Plans:*** - Optimize and refine water capture and release with developed sorbent materials. - Integrate sorbent materials with components of modeled water extraction device. - Test and evaluate fabricated components of modeled water extraction device. - Demonstrate initial prototype water extraction device under program test conditions. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects development of system components and optimization for prototype integration.			
Title: Bio-Inspired Coastal Defense ***Description:*** Building upon technologies discovered in the Persistent Aquatic Living Sensors (PALS) program, the Bio-Inspired Coastal Defense program will develop self-sustaining, hybrid man-made and biological reef structures to fortify and defend DoD bases in low-lying coastal regions. Military assets in these coastal regions are vulnerable to storm surges, wave action, and sea-level rise that cause erosion, degrade infrastructure, and impede operations. Innovative coastal defense will require major technological advances in (1) design, construction, and placement of manufactured reef primers, (2) accelerated recruitment and/or growth of reef species, and (3) sustained, zero-cost natural maintenance and improvement (e.g., increased durability after challenge) of the defensive reef. The primary benefit of such structures is to attenuate wave height during storm events for both established and under construction coastal facilities. This approach could also mitigate ongoing threats posed by state and non-state actors that seek to penetrate, mine, or damage harbors using unmanned underwater vehicles as delivery mechanisms. ***FY 2022 Plans:*** - Design and fabricate structural components to achieve target wave energy attenuation in wave tank simulations. - Demonstrate the efficacy of reef-building approaches under laboratory conditions. - Conduct laboratory experiments to promote improved temperature tolerance for reef-building organisms. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.	-	-	11.490
Title: Environmental Microbes as a Bioengineering Resource (EMBER) ***Description:*** The Environmental Microbes as a Bioengineering Resource (EMBER) program will seek to leverage microbial processes to enable new methods of discovery, design, and/or production of critical materials used by the DoD. This program	-	-	8.764

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
will leverage capabilities of microbes from extreme environments for processing inorganic materials not typically associated with biology to serve as platforms for discovery, engineering, and production. Efforts will elucidate and exploit biomolecular mechanisms for binding and biomineralization of inorganic elements (e.g., rare earth elements, metals) and utilize computational and high-throughput experimental methods to accelerate prototyping of microbe-assembled functional inorganic nanomaterials (e.g., optoelectronic, magnetic materials). Advances in this area will deliver capabilities to assure access to DoD-critical materials domestically or in operational settings. ***FY 2022 Plans:*** - Identify novel organisms, gene pathways, and microbial chemistries required for biomineralization of rare earth elements. - Begin development of synthetic biology tools to engineer organisms or adapt current chassis to rare earth elements. - Initiate studies of microbes that operate in high temperature and acidic conditions. - Initiate studies of microbial extraction of specific rare earth elements from simulated source materials at relevant concentrations. - Explore ability to genetically engineer microbes to assemble functional inorganic nanomaterial architectures. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Genome Protection Technologies ***Description:*** The Genome Protection Technologies program is developing advances in critical efforts to generate a biodefense capability to control, counter, and reverse the effects of accidental or malicious misuse of gene editing technologies. This research is investigating new approaches for developing tunable controls to enable the safe and predictable use of synthetic genes and pathways. Additional work will develop protecting measures to prevent or limit unintended genome editing or engineering and develop new tools to recall or reverse engineered changes. Advances within this program will ensure that the U.S. remains at the vanguard of this now widespread, rapidly advancing field that poses potential national security threats due to the large-scale democratization of gene editing technologies. ***FY 2021 Plans:*** - Demonstrate efficient and specific target gene removal in vivo within a simulated natural environment. - Demonstrate safe, specific, stable, and highly-efficient genome editors and controllers in vivo for therapeutic applications. - Demonstrate effective and safe application of genome editing inhibitors in vivo. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.	13.584	10.296	-
Title: Defend Against Crop System Attack	12.718	8.498	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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 2020	FY 2021	FY 2022
Description: The Defend Against Crop System Attack program is developing a platform technology aimed at increasing the speed of DoD response to state or non-state actor release of biological threats directed at our crop systems. Conventional methods to defend against these threats are generally slow and ineffective. This program will leverage recent advances in molecular and synthetic biology to enable rapid delivery of gene therapies to plants for large-scale trait modification, improving resilience against adversary attack or emerging natural threats. Research within this program will develop an agnostic, scalable capability for protecting entire crop systems from emerging threats posed to food security by U.S. adversaries. ***FY 2021 Plans:*** - Demonstrate successful insect delivery of a virus to targeted plants in a diverse plant community, without off-target effects, in a contained environment. - Employ and validate conditional lethal approach restricts viral delivery and limits propagation of virus, insect, and plant trait acquisition. - Verify protective traits delivered to a diverse plant community results in mitigation of an environmental stressor. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Enhancing Neuroplasticity ***Description:*** The DoD needs tools to rapidly and effectively train military personnel in multifaceted and complex tasks. The Enhancing Neuroplasticity program explored and developed peripheral nerve stimulation methods and non-invasive devices to promote synaptic plasticity for improved learning paradigms. Key advances from this research include an anatomical and functional map of the underlying biological circuitry that mediates plasticity, as well as successful stimulation and training protocols to enable long-term retention for military personnel. Underlying mechanisms of targeted plasticity training were successfully identified and leveraged to inform intervention parameters that have been applied to a broad range of cognitive skill training within the DoD, including foreign language learning and intelligence analysis.	8.543	-	-
Accomplishments/Planned Programs Subtotals	149.414	147.066	179.698

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	309.811	322.693	357.384	-	357.384	-	-	-	-	-	-
ELT-01: *ELECTRONIC TECHNOLOGY*	-	116.520	122.986	160.891	-	160.891	-	-	-	-	-	-
ELT-02: *BEYOND SCALING TECHNOLOGY*	-	193.291	199.707	196.493	-	196.493	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Electronics Technology Program Element is budgeted in the Applied Research Budget Activity because its objective is to develop electronics that make a wide range of military applications possible. The Electronics Technology Project focuses on turning basic advancements into the underpinning technologies required to address critical national security issues and to enable an information-driven warfighter. This Program Element also supports innovation and robust transition planning in the technology cycle by working with entrepreneurs to increase the likelihood that DARPA funded technologies take root in the U.S. and provide new capabilities for national defense.

Advances in microelectronic device technologies continue to significantly benefit improved weapons effectiveness, intelligence capabilities, and information superiority. The Electronic Technology project supports continued advancement in microelectronics, including electronic and optoelectronic devices, Microelectromechanical Systems (MEMS), semiconductor device design and fabrication, and new materials and material structures. Particular focuses of this work include reducing the barriers to designing and fabricating custom electronics and exploiting improved manufacturing techniques to provide low-cost, high-performance sensors. Programs in this project will also greatly improve the size, weight, power, and performance characteristics of electronic systems; support positioning, navigation, and timing in GPS-denied environments; and develop sensors more sensitive and robust than today's standards. This project has six major focus areas: Electronics, Photonics, MicroElectroMechanical Systems, Architectures, Algorithms, and other Electronic Technology research.

The Beyond Scaling Technology project recognizes that, within the next decade, the continuous pace of improvements in electronics performance will face the fundamental limits of silicon technology. This project will therefore pursue electronics performance advancements that do not rely on Moore's Law but instead exploit new concepts in circuit specialization, by the optimization of materials, architectures, and designs to achieve specific circuit function at high performance. Because electronics advancements must simultaneously make progress in performance and secure the foundation on which our digital infrastructure relies, this envisioned electronics specialization will require incorporation of security safeguards. Accordingly, programs within the Beyond Scaling project will reduce barriers to making specialized circuits in today's silicon hardware and significantly increase the ease with which DoD can design, deliver, and eventually upgrade critical, customized electronics. Programs also explore alternatives to traditional circuit architectures, for instance by exploiting vertical circuit integration to optimize electronic devices and by incorporating novel materials, and new techniques for securing DoD and commercial data and hardware.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 2: *Applied Research*	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	317.192	322.693	357.162	-	357.162
Current President's Budget	309.811	322.693	357.384	-	357.384
Total Adjustments	-7.381	0.000	0.222	-	0.222
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	2.171	0.000			
• SBIR/STTR Transfer	-9.552	0.000			
• TotalOtherAdjustments	-	-	0.222	-	0.222

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.

FY 2021: N/A

FY 2022: Increase reflects minor program repricing.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 2	R-1 Program Element (Number/Name) PE 0602716E / *ELECTRONICS TECHNOLOGY*	Project (Number/Name) ELT-01 / *ELECTRONIC TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
ELT-01: *ELECTRONIC TECHNOLOGY*	-	116.520	122.986	160.891	-	160.891	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

Advances in microelectronic device technologies continue to significantly benefit improved weapons effectiveness, intelligence capabilities, and information superiority. The Electronic Technology project supports continued advancement in microelectronics, including electronic and optoelectronic devices, Microelectromechanical Systems (MEMS), semiconductor device design and fabrication, and new materials and material structures. Areas of particular emphasis of this work include reducing the barriers to designing and fabricating custom electronics and exploiting improved manufacturing techniques to provide low-cost, high-performance sensors. Programs in this project will also greatly improve the size, weight, power, and performance characteristics of electronic systems; support positioning, navigation, and timing in GPS-denied environments; and develop sensors more sensitive and robust than today's standards. This project has six major focus areas: Electronics, Photonics, Microelectromechanical Systems, Architectures, Algorithms, and other Electronic Technology research.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Atomic Magnetometry for Biological Imaging In Earth's Native Terrain (AMBIIENT)	10.000	9.000	4.000
Description: The Atomic Magnetometry for Biological Imaging In Earth's Native Terrain (AMBIIENT) program is developing novel magnetic sensors capable of providing high-sensitivity signal measurements in the presence of ambient magnetic fields. The AMBIIENT program will exploit novel physical architectures that are resistant to the impact of common noise sources. The AMBIIENT sensor itself must be able to detect the gradient of a local magnetic field while subtracting the much larger ambient signal. This would enable low-cost, portable, high-sensitivity measurements for in-the-field applications. In addition to medical research and clinical diagnosis, AMBIIENT sensors promise to enable diverse sensing applications including magnetic gradient navigation, anomaly detection, perimeter monitoring, and ultralow frequency communications. ***FY 2021 Plans:*** - Design sensor package array architecture meeting AMBIIENT size weight and power, and sensitivity goals. - Integrate control electronics for direct gradient sensing of magnetic fields. ***FY 2022 Plans:*** - Demonstrate AMBIIENT array's medical effectiveness using simulated neural signals. - Test AMBIIENT sensor's sensitivity and dynamic range in government owned and operated facility. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the shift from final design to testing the AMBIIENT sensor's sensitivity and dynamic range architecture.			
Title: Focal Arrays for Curved Infrared Imagers (FOCII)	13.000	19.000	19.750

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-01 / *ELECTRONIC TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Focal Arrays for Curved Infrared Imagers (FOCII) program is developing curved focal plane arrays for broadband infrared (IR) imagers to enhance battlefield detection and discrimination while maintaining situational awareness. FOCII will leverage curving strategies for state of the art focal plane arrays combined with advances in designing and manufacturing stress relief features to demonstrate hardware that simultaneously provides maximum resolution and illumination. This program will develop novel designs for IR imagers that enable minimal size, weight and cost for size-constrained applications. This will enable new applications in passive seeker technology for missiles, overhead persistent infrared imaging, 360-degree situational awareness, infrared search and track, and long-range targeting. ***FY 2021 Plans:*** - Measure baseline spectral uniformity of curved large area focal arrays. - Measure mechanical stress of curved large area focal arrays to validate mechanical stress models. - Measure seam width and deviation from sphericity. ***FY 2022 Plans:*** - Measure operability of large area focal arrays curved to program specified objective radius. - Design and fabricate readout integrated circuits for structured focal arrays. - Measure initial effects of thermal cycling and baking. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects minor program repricing.			
Title: Wideband Adaptive RF Protection (WARP) ***Description:*** The Wideband Adaptive RF Protection (WARP) program is developing radio frequency (RF) front-end technology that can protect wideband digital radios against external electromagnetic threats and self-interference through tunable filtering, limiting, and/or signal cancellation. The ability to create tunable and reconfigurable bandpass and bandstop filters in the range of 2-18 gigahertz will be important for implementing transmit/receive modules in next-generation multi-function arrays. Another important area of interference mitigation is self-interference. WARP will develop the signal cancellation technology that will listen to the transmitted interfering signal and subtract it from the input of the receiver so faint signals near the noise floor can still be detected. Program research will provide feedback mechanisms that intelligently correct these problems. Whether for self-induced interference or external interference jamming, WARP will develop intelligent filtering and self-interference cancellation technologies to protect wideband DoD receivers. ***FY 2021 Plans:*** - Demonstrate new materials, devices and/or circuit architectures that will enable frequency tuning of band pass and band stop filters in chip-scale size for use in next generation wideband receivers for DoD systems.	11.200	19.845	19.141

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-01 / *ELECTRONIC TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate new materials, devices and/or circuit architectures that will enable cancellation of signal leakage between two adjacent antennas for simultaneous transmit and receive electronic warfare applications on small platforms. ***FY 2022 Plans:*** - Demonstrate a 2:1 center frequency tuning range and 3:1 bandwidth tuning range of band pass and band stop filters for use in next generation wideband receivers for DoD systems. - Demonstrate analog signal cancellers covering 0.1-1 gigahertz with 100 megahertz of cancellation bandwidth over a 25 nanosecond leakage path delay spread. - Demonstrate analog signal cancellers covering 1-6 gigahertz with 400 megahertz of cancellation bandwidth over a 5 nanosecond leakage path delay spread. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.			
Title: Quantum Imaging of Vector Electromagnetic Radiation (QuIVER)	12.000	20.000	21.000
Description: The Quantum Imaging of Vector Electromagnetic Radiation (QuIVER) program is developing full tensor magnetic field sensors and will demonstrate them in DoD-relevant applications and concept of operations. In addition to being diagnostically relevant, such sensitive magnetometers could enable future human-machine/brain-machine interfaces. The DoD and industry also use magnetometers for magnetic anomaly detection, which may allow for the discovery of mineral/oil deposits, discovery of old wellheads, or the detection of improvised explosive devices. In addition, magnetometers offer the possibility of magnetic navigation, which may operate in GPS-denied environments. Recent developments have resulted in the potential to develop highly sensitive vector magnetometers, which would enable the consequent development of sensitive full tensor gradient sensors. Such tensors offer more degrees of freedom than their scalar or vector counterparts and potentially provide additional information about the source. ***FY 2021 Plans:*** - Build preliminary magnetic or electric field tensor gradiometer. - Develop tensor-based algorithms for DoD relevant applications. - Initiate research into building a magnetic or electric field tensor sensor. ***FY 2022 Plans:*** - Demonstrate sensitivity and functionality of tensor magnetometer. - Design portable tensor magnetometer system for field testing. - Initiate construction of tensor magnetometer system for field testing. ***FY 2021 to FY 2022 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-01 / *ELECTRONIC TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 increase reflects a shift from designing to initiating construction of tensor magnetometer system.			
Title: Fast Event-based Neuromorphic Camera and Electronics (FENCE)	-	16.000	24.000
Description: The Fast Event-based Neuromorphic Camera and Electronics (FENCE) program, building upon technologies developed in the FOCII program (budgeted within this PE and Project) will develop and demonstrate a low latency, low power event-based infrared (IR) camera to enable intelligent sensors for tactical DoD applications. Event-based imagers are an emerging class of sensors with major demonstrated advantages relative to traditional cameras. State of the art visible event-based cameras have been shown to produce over two orders of magnitude less data in optimal conditions relative to traditional framing cameras, because they only transmit data from pixels that have changed. This leads directly to two orders of magnitude lower data latency and a commensurate reduction in power consumption. Despite their inherent advantages, existing event-based cameras are not compatible with DoD applications because DoD applications regularly face conditions that are not naturally sparse, where issues such as clutter and noise would cause a large percentage of the event-based pixels to change simultaneously. When this happens event-based cameras do not perform significantly better than traditional cameras. FENCE will develop an infrared event-based imager consistent with military requirements. FENCE will develop a four megapixel asynchronous read-out integrated circuit (ROIC), co-designed with a 3D integrated processor that will intelligently remove noise and clutter to maintain low power and latency operation even when faced with all of the pixels firing simultaneously. If successful, this new class of sensors enabled by FENCE will be capable of responding to fast moving targets and discriminating dim targets in noisy conditions. ***FY 2021 Plans:*** - Conduct advanced design review for the ROIC. - Develop preliminary design of the processor layer. ***FY 2022 Plans:*** - Conduct ROIC preliminary design review. - Simulate timing accuracy and power of the ROIC. - Conduct processor layer preliminary design review. - Perform initial analysis of relevant system parameters including power and latency. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the shift from concept to design for the ROIC.			
Title: Quantum Apertures (QA)	-	10.000	19.000
Description: The Quantum Apertures (QA) program, building upon technologies developed in the QuIVER program (budgeted within this PE and Project) will develop novel radio receiver and aperture systems utilizing quantum sensors as the receiving			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-01 / *ELECTRONIC TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
elements. These receiver systems will be portable, programmable over a very large frequency range, and more sensitive than classical systems at similar size and temperature. This will be achieved by exploiting quantum-based receiving elements composed of atomic vapor cells in highly excited "Rydberg" states that have programmable sensitivity over a large range of frequencies and amplitudes. The program will require quantum engineering and traditional electro-mechanical-systems engineering to overcome technical and application challenges that impede rapid adoption of a quantum aperture receiver by the defense industrial base. In this program, the receiver systems enhanced capabilities will also be leveraged to develop novel waveforms while also being compatible with constraints imposed by real-world defense applications. The final receiver system will comprise a phase-sensitive array of quantum "Rydberg" receiving elements, lasers to program the sensor and read out radio signals, and processing electronics. ***FY 2021 Plans:*** - Design quantum aperture sensor for improved sensitivity and frequency range. - Develop government-owned model of quantum aperture receiver for complex signal inputs. - Initiate DoD-relevant application studies that utilize single-element or phased array quantum aperture receiver system. ***FY 2022 Plans:*** - Demonstrate quantum aperture sensor for sensitivity and frequency tunability. - Complete DoD-relevant application studies that utilize single-element or phased array quantum aperture receiver system. - Complete government-owned model of quantum aperture receiver for complex signal inputs. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the shift from initial design to demonstrate quantum aperture sensor for sensitivity and frequency tunability.			
Title: Waveform Agile Radio-frequency Directed Energy (WARDEN)	-	6.000	15.000
Description: The Waveform Agile Radio-frequency Directed Energy (WARDEN) program, building upon technologies developed in the DREaM program (budgeted within this PE and Project) aims to extend the range and lethality of high power microwave (HPM) systems by introducing flexible waveform techniques that use combinations of frequency-, amplitude-, and pulse-width modulations to significantly improve electromagnetic coupling into complex target enclosures and increase the probability of disruption or damage to internal electronic components and circuits. Applications for HPM systems include counter-unmanned aerial systems (C-UAS), vehicle and vessel disruption, electronic strike, and guided missile defense. Current HPM systems use oscillators to produce electromagnetic radiation. These systems are inherently narrowband and lack the frequency agility to support waveforms to maximize electromagnetic coupling and to optimally exploit electronic system vulnerabilities. Lacking the capability to use optimized waveforms, HPM oscillators have been pushed close to the physical limits of peak power generation. To develop a more efficient, lower power, waveform agile approach, the WARDEN program will develop and demonstrate the first			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
broadband HPM amplifier; create new theory and simulation tools to predict electromagnetic coupling into complex enclosures and the effects on electronics; and develop novel agile waveform techniques capable of reducing the susceptibility threshold of targeted electronics systems to HPM attack. ***FY 2021 Plans:*** - Perform analysis of existing methods of electromagnetic coupling theory and relevant computational models. ***FY 2022 Plans:*** - Finalize broadband amplifier design confirmed through 3D simulation. - Develop time-domain electromagnetic coupling theory and demonstrate early concept computational models. - Fabricate broadband amplifier. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 program increase is due to increased amplifier fabrication activities.			
Title: Generating RF with Photonics for low Noise (GRYPHON) ***Description:*** The Generating RF with Photonics for low Noise (GRYPHON) program will develop compact sources of microwaves and millimeter waves with extremely low noise. Compact signal sources used today, such as crystal oscillators, are too noisy to support advanced military radar and communications functions. Conversely, best-in-class oscillators which use optical techniques to synthesize extremely pure microwaves are too large and expensive to deploy on the airborne systems, munitions, and other size-constrained platforms where the DoD requires high-performance capabilities. The GRYPHON program will draw on recent advances in miniature optical components in order to replicate best-in-class optical synthesis techniques in microchip form factors. ***FY 2022 Plans:*** - Develop optical synthesis theoretical models. - Perform initial demonstration of chip-scale component functionality. - Fabricate chip-scale optical components. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.	-	-	13.000
Title: COmpact Front-end Filters at the ElEment-level (COFFEE) ***Description:*** The COmpact Front-end Filters at the ElEment-level (COFFEE) program will develop and demonstrate compact, high frequency radio frequency (RF) filter technology without compromising low insertion loss and high-power handling. The new filtering technology will enable interference rejection capability, efficient spectral management, and coexistence with commercial 5G applications. It is projected that COFFEE filter technology will enhance the resilience of military microwave and mm-wave	-	-	14.000

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
radar and communication systems for DoD spectral dominance into the future. For commercial applications, COFFEE will result in more efficient use of mm-wave frequency allocations for 5G networks. ***FY 2022 Plans:*** - Design new high frequency resonator technologies significantly smaller than current state of the art electromagnetic resonators. - Demonstrate, through modeling and simulation, the feasibility of high-performance filters using resonators developed in the program. - Initiate fabrication of high frequency resonators. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Compact High Intensity Radiating Photonics (CHIRP) ***Description:*** The Compact High Intensity Radiating Photonics (CHIRP) program will develop compact, high-power lasers. Current high-power lasers are capable of providing the high optical intensities required to achieve directed energy effects, but the size of these lasers limits their ability to be used on or against highly mobile platforms. CHIRP will decrease the size, weight and power (SWaP) of high-power laser sources by employing emerging integrated photonics and amplification techniques. Additionally, CHIRP will develop high-performance components and package these elements employing innovative thermal management strategies. ***FY 2022 Plans:*** - Analyze designs for high peak-power laser systems with reduced SWaP. - Initiate development of high efficiency ultra-fast laser components. - Perform initial thermal management analysis for compact, high peak-power laser systems. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.	-	-	12.000
Title: Modular Optical Aperture Building Blocks (MOABB) ***Description:*** The Modular Optical Aperture Building Blocks (MOABB) program aims to greatly improve the cost, size, weight, and performance of free-space optical systems. These systems enable applications such as Light Detection And Ranging (LIDAR), laser communications, laser illumination, navigation, and 3D imaging. Specifically, MOABB will construct millimeter-scale optical building blocks that can be coherently arrayed to form larger, higher power devices. These building blocks would replace the traditional large and expensive precision lenses and mirrors, which require slow mechanical steering, that form conventional optical systems. MOABB will develop scalable optical phased arrays that can steer light waves without the use of mechanical	19.000	13.141	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
components. These advances would allow for a 100-fold reduction in size and weight and a 1,000-fold increase in the steering rate of optical systems. ***FY 2021 Plans:*** - Improve optical phased array LIDAR range. - Demonstrate optical phased array LIDAR on unmanned ground and air vehicles. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Dynamic Range-enhanced Electronics and Materials (DREaM) ***Description:*** The Dynamic Range-enhanced Electronics and Materials (DREaM) program aims to develop intrinsically linear (ideal) radio frequency (RF) transistors with improved power efficiency and extremely high dynamic range. Linearity, power efficiency, and dynamic range are fundamental characteristics that allow RF systems to reliably transmit clear signals. Improving these characteristics is essential to operating in a crowded RF environment and to enabling next-generation communication, sensing, and electronic warfare systems. Traditional RF transistor designs typically require a trade-off between linearity and broadcast power, and poor linearity results in undesired interference. DREAM will overcome this tradeoff by employing new transistor materials, architectures, and designs. The resulting DREAM-enabled technologies will allow future RF electronics to increase their operating range without polluting the already-congested RF spectrum and while consuming less system power. ***FY 2021 Plans:*** - Optimize novel transistor topology and fabrication processes to enable an output power density five times higher than the state-of-the-art at 94 gigahertz, and identify thermal solutions for high power operation. - Explore new channel materials, device topology and modeling to enable scaling to achieve linearity-to-DC-power ratios ten times better than state-of-the-art at 94 gigahertz. - Design, simulate, fabricate and characterize wideband high power and low noise amplifier integrated circuits to deliver 10 Watts of output power with a factor of four times improvement in the DC-to-millimeter wave power-added efficiency, or a factor of ten better low noise linear amplification over the state-of-the-art between 20 to 40 gigahertz. - Optimize novel transistor topologies and fabrication processes to demonstrate a factor of five improvement in output power density over the state-of-the-art at 94 gigahertz with good DC-to-millimeter wave conversion efficiency. - Explore and demonstrate new channel materials, device topologies, and modeling techniques to enable scaling to linearity-to-DC-power ratio by a factor of ten over than the state-of-the-art at 94 gigahertz. ***FY 2021 to FY 2022 Increase/Decrease Statement:***	17.000	10.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 decrease reflects program completion.			
Title: SHort Range Independent Microrobotic Platforms (SHRIMP) ***Description:*** The SHort Range Independent Microrobotic Platforms (SHRIMP) program developed multi-functional millimeter-to-centimeter scale robotic platforms with a focus on untethered mobility, maneuverability, and dexterity. To achieve this goal, SHRIMP conducted foundational research in the area of micro-actuator materials and energy efficient power systems for extremely size, weight, and power constrained microrobotic systems. The program's platform development activities leveraged recent advances in low power, application specific integrated circuit electronics and low power sensors from the internet of things community to increase the functionality of microrobotic platforms while increasing platform mobility, maneuverability, and dexterity. The future microrobotic platform capabilities enabled by SHRIMP will provide the DoD with capability to operate in small spaces that are practically inaccessible to today's state-of-the-art robotic platforms. Foundational research efforts are funded in PE 0601101E, Project ES-01.	9.000	-	-
Title: High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) ***Description:*** The High power Amplifier using Vacuum electronics for Overmatch Capability (HAVOC) program developed compact radio frequency signal amplifiers for air, ground, and ship-based communications and sensing systems. HAVOC amplifiers enabled these systems to access the high-frequency millimeter-wave portion of the electromagnetic spectrum, facilitating increased range and other performance improvements. Operating at higher frequencies, such as the millimeter-wave, offers numerous tactical advantages such as high data-rate communications and high resolution and sensitivity for radar and sensors.	6.000	-	-
Title: Precise Robust Inertial Guidance for Munitions (PRIGM) ***Description:*** The Precise Robust Inertial Guidance for Munitions (PRIGM) program developed inertial sensor technologies for positioning, navigation, and timing (PNT) in GPS-denied environments. These inertial sensors can provide autonomous PNT information when GPS is unavailable. PRIGM developed and plans to transition a Navigation-Grade Inertial Measurement Unit (NGIMU), a state-of-the-art Microelectromechanical Systems (MEMS) device, to DoD platforms in 2022. These advances should enable navigation applications, such as smart munitions, that require low-cost, size, weight, and power inertial sensors with high bandwidth, precision, and shock tolerance. PRIGM advanced state-of-the-art MEMS gyros from Technology Readiness Level (TRL) 3 devices to a TRL 6 transition platform. Advanced technology development for the program is budgeted in PE 0603739E, Project MT-15.	3.000	-	-
Title: Wafer-scale Infrared Detectors (WIRED)	3.320	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Wafer-scale Infrared Detectors (WIRED) program addressed the need for low-cost, high-performance imaging sensors in the short-wave and mid-wave infrared (SWIR/MWIR) bands. These sensors provided increased standoff distances for small unmanned aerial vehicles, low-cost missiles, handheld weapon sights and surveillance systems, helmet-mounted systems, and ground-vehicle-mounted threat warning systems. WIRED manufactured these sensors at the wafer scale, which reduces costs by processing dozens to hundreds of camera imaging arrays at a time. The program significantly reduced the weight and volume of MWIR detectors, which today require heavy cryogenic cooling systems, and increased the resolution of SWIR detectors by dramatically reducing their pixel size relative to the state-of-the-art.			
Title: Atomic Clock with Enhanced Stability (ACES) ***Description:*** The Atomic Clock with Enhanced Stability (ACES) program developed extremely stable chip-scale atomic clocks for unmanned aerial vehicles and other low size, weight, and power (SWaP) platforms with extended mission durations. ACES developed the component technologies necessary for low-cost manufacturing and for deployment in harsh DoD-relevant environments. Among its many benefits, the program helped reduce the risk posed by a growing national dependence on GPS, allowing systems to maintain their timing accuracy in the event of temporary GPS unavailability.	6.000	-	-
Title: Limits of Thermal Sensors (LOTS) ***Description:*** The Limits of Thermal Sensors (LOTS) program demonstrated long-wave infrared (LWIR) detector technologies with both high performance and low size, weight, power, and cost (SWaP-C). The resulting technologies will enable improvements in imaging systems such as night-vision goggles, infrared-guided missiles, and missile threat warning systems. LOTS developed microbolometers that can compete with larger cameras in terms of higher sensitivity required to detect signals over long ranges and lower response time required to avoid image blur. These technologies will allow DoD to deploy smaller, lighter, and cheaper sensors on critical, high-value assets while maintaining or improving their ability to engage fast-moving or distant targets.	7.000	-	-
Accomplishments/Planned Programs Subtotals	116.520	122.986	160.891

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
ELT-02: *BEYOND SCALING TECHNOLOGY*	-	193.291	199.707	196.493	-	196.493	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Beyond Scaling Technology project recognizes that, within the next decade, the continuous pace of improvements in electronics performance will face the fundamental limits of silicon technology. This project pursues electronics performance advancements that do not rely on Moore's Law but instead exploit new concepts in circuit specialization, by the optimization of materials, architectures, and designs to achieve specific circuit function at high performance. Because electronics advancements must simultaneously make progress in performance and secure the foundation on which our digital infrastructure relies, this envisioned electronics specialization will require incorporation of security safeguards. Accordingly, programs within the Beyond Scaling project will reduce barriers to making specialized circuits in today's silicon hardware and significantly increase the ease with which DoD can design, deliver, and eventually upgrade critical, customized electronics. Programs also explore alternatives to traditional circuit architectures, for instance by exploiting vertical circuit integration to optimize electronic devices and by incorporating novel materials and new techniques for securing DoD and commercial data and hardware.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Beyond Scaling - Materials	42.981	32.000	16.000
Description: The Beyond Scaling - Materials program is demonstrating the integration of novel materials into next-generation logic and memory components. This program is pursuing potential enhancements in electronics that do not rely on Moore's Law, i.e. silicon scaling, including research into new materials and the implications of those materials at the device, algorithm, and packaging levels. Research areas include heterogeneous integration of multiple materials, "sticky logic" and novel transistor devices that combine elements of computation and memory, and leveraging three-dimensional vertical circuit integration to demonstrate dramatic performance improvements with older silicon technologies. Further research supports innovation in the technology cycle by working with entrepreneurs focused on DoD-relevant businesses. Basic research for this program is funded within PE 0601101E, Project ES-02.			
FY 2021 Plans: - Test critical mixed-mode demonstration circuit blocks fabricated at a commercial foundry. - Improve switching speed of transistors with enhanced fabrication processes in a commercial foundry. - Release final design tools to be utilized for design of 3D monolithic circuits. - Expand access to the Federally Funded Research and Development Centers (FFRDC) infrastructure to include additional academic researchers, leading to new technology prototypes with a validated path to deployment by U.S. suppliers. - Analyze relevant magnetic materials and perform initial spin wave device design.			
FY 2022 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate the manufacturability of a large-scale fully integrated 3D monolithic system-on-chip, and share design with DoD and commercial end users. - Demonstrate broadband low noise mixed-mode integrated circuits with enhanced transistors in a commercial foundry. - Integrate advanced transistor processing technology and models in a commercial foundry. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the shift towards demonstrating the ability to take alternative materials through a full commercial process flow.			
Title: Beyond Scaling - Architectures	35.000	31.707	26.000
Description: The Beyond Scaling - Architectures program is demonstrating a new DoD capability to create and utilize specialized hardware by enabling the writing of a common code base on top of customized hardware. The program is exploring technologies and techniques such as new domain-specific circuit architectures, co-design of electronics hardware and software, intelligent edge sensors, hardware security architectures, and tight integration of chip-scale processing blocks and artificial intelligence-enabled processing controllers. Further research will enable significant improvements in programming productivity for massively parallel heterogeneous processing systems (e.g., data centers). Basic research for this program is funded within PE 0601101E, Project ES-02. ***FY 2021 Plans:*** - Produce, test and demonstrate a specialized processor design executing two simultaneous applications. - Advance the software tools, development technologies, and design methodologies for a system-on-chip with heterogeneous components that can be easily reprogrammed for specialized applications. - Demonstrate field-programmable gate array-based full architecture emulation environments and fully functional software development environments. - Prototype a compiler that demonstrates the feasibility of achieving high levels of productivity, efficiency, portability, and execution speed on a DoD-relevant workload. ***FY 2022 Plans:*** - Prototype reconfigurable software defined hardware and associated software. - Demonstrate a system-on-chip executing five simultaneous applications utilizing multiple heterogeneous processing elements. - Demonstrate a prototype test bench that can detect anomalous system behavior due to hardware Trojans in complex systems. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from software enhancement to testing and demonstration.			
Title: Beyond Scaling - Design	22.000	25.000	15.493

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Beyond Scaling - Design program is developing and demonstrating the tools required for rapidly designing and deploying specialized circuits. Research efforts are exploring technologies and techniques for rapid, specialized design such as intelligent design tools, automated physical layout generation, and open-source circuit design. The goal of this program is to reduce the barrier to entry for complex system-on-chip (SoC) designs and to provide a secure pathway for the rapid upgrade of electronics. Advances under this program demonstrate a new DoD capability to create specialized hardware and provide electronics improvements that do not depend on continued, rapid silicon scaling. Rapid design and deployment techniques developed also consider the need to incorporate security into DoD hardware. Basic research for this program is funded within PE 0601101E, Project ES-02. ***FY 2021 Plans:*** - Optimize algorithms and the physical design platform to demonstrate a path to improvement of power, performance, and area for performance equivalent to traditional best in-class techniques. - Extend physical design platform applicability to support large circuits at leading-edge complementary metal oxide semiconductor (CMOS) technology nodes. - Develop initial system-on-chip design leveraging open source Intellectual Property (IP) building blocks verified for correctness with open source simulation technologies. ***FY 2022 Plans:*** - Optimize algorithms and the physical design platform to demonstrate path to improvement of power, performance, and area for performance beyond existing state-of-the-art techniques. - Further develop open source tools to enhance interoperability and integration between tools and move toward a unified chip development infrastructure. - Fabricate and test initial system-on-chip design using open source IP building blocks verified for correctness with open source simulation technologies. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the transition from development to the delivery of functional tools, software, intellectual property, and fabricated hardware.			
Title: Digital RF Battlespace Emulator (DRBE)	15.000	24.000	23.000
Description: The Digital RF Battlespace Emulator (DRBE) program is developing a large-scale, interactive, emulated radio frequency (RF) environment, providing the DoD with the capability to cost-effectively evaluate adaptive, intelligent, and spatially distributed next-generation RF systems. DRBE is leveraging advances in massively multi-core computing hardware and high-bandwidth digital cross-connects to emulate realistic RF environments accounting for RF platform movement, signal propagation effects and delays, signal interference, and interactions between RF systems. An electronics architecture supporting the power			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
and latency requirements demanded by these emulation environments does not currently exist. DRBE is pursuing three technical thrust areas: architecture, massively multi-core computing, and scenario modeling. The resulting test environment will allow plug-and-play connections for hundreds of RF systems in a battlespace test. Multi-system exercises will then be quickly executed through many different combat scenarios and variations. DRBE is serving to develop concept of operations (CONOPS), inform battle plans, and fine-tune the performance of both individual and large groups of RF systems. ***FY 2021 Plans:*** - Complete DRBE real-time High Performance Computer (HPC) design to the level of a Concept Design Review (CoDR). - Complete DRBE system design to the level of a Preliminary Design Review (PDR). ***FY 2022 Plans:*** - Complete DRBE real-time HPC design to the level of a PDR. - Complete DRBE system design to the level of a Critical Design Review. - Design first-spin computational accelerator chips to the level of tape-out. - Fabricate and test first-spin computational accelerator chips. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor program repricing.			
Title: Automatic Implementation of Secure Silicon (AISS)	12.000	18.000	19.000
Description: The Automatic Implementation of Secure Silicon (AISS) program is enabling a design tool and Intellectual Property (IP) ecosystem where security is pervasive and can be naturally incorporated into chip design with minimal effort and expense. The program will enable rapid evaluation of architectural alternatives in platform integration where security is considered with conventional design economics, together being power, area, speed, and security. The program will advance multi-level provenance and integrity validation techniques for design through advances in current methods or invention of novel technical approaches, and will demonstrate new capabilities in the context of reduced instruction set computing (RISC) architectures or computer processors. AISS aims to automate inclusion of scalable defense mechanisms into chip designs to enable optimization of the security versus economics trade space. It will protect advanced chips from known attack strategies by incorporating security into a highly automated system aimed at reducing design time while maximizing exploration of architectural alternatives. As a result, DoD applications will benefit from more secure chips becoming pervasive whether procured commercially or designed specifically for defense systems. ***FY 2021 Plans:*** - Demonstrate a static implementation of the on-chip Security Engine capable of protecting common attack surfaces. - Demonstrate three proof-of-concept (PoC) systems on the cloud infrastructure.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate high-level synthesis generating register-transfer level design code instrumented with security features, encapsulated in an extensible markup language and accompanied by a corresponding high-speed simulation model. ***FY 2022 Plans:*** - Demonstrate automatic generation of the on-chip Security Engine, adjustable to different cost points and defense intensities. - Demonstrate rapid power and security estimation models executed on the auto-integrated PoC systems and accurately grade their relative attack resistivity. - Finalize design and demonstrate that the three selected PoC designs can be semi-automatically built out of AISS IP. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects a shift from PoC to demonstrating the AISS IP.			
Title: Guaranteed Architectures for Physical Security (GAPS)	7.000	12.000	8.000
Description: The Guaranteed Architectures for Physical Security (GAPS) program is developing hardware security and software architectures with provable security interfaces. These interfaces will physically isolate high-risk transactions during both system design and system build, and will track that such protections are enforced at run-time. GAPS will reduce the inherent complexity through the development of hardware and software that is open, extendible, and compatible with size, weight, and power constrained environments to enable security across DoD and commercial systems. The program will substantially lower the barrier to safely enabling high-risk transactions, thus allowing for fast computer-to-computer transactions, physical spatial isolation reducing the need for unreliable software partitioning solutions, and more complex missions without putting sensitive data at risk. ***FY 2021 Plans:*** - Continue research and development of verifiable bus standards and board support packages (BSPs) while increasing the number of protocol layers. - Extend research and development of high-level languages and novel modeling techniques while reducing transaction overhead on embedded devices. - Demonstrate GAPS techniques on platforms representative of DoD systems. ***FY 2022 Plans:*** - Implement interconnect architectures and BSPs for a single common embedded bus while increasing the number of protocol layers. - Demonstrate a reduction in transaction overhead on embedded busses when implementing GAPS extensions for multilevel security. - Permit at least one gigabit per second sustained throughput across multiple security level architectures.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Integrate GAPS isolation techniques to a research application associated with an ongoing DoD platform. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from demonstration to implementing the GAPS techniques on DoD platforms.			
Title: Lasers for Universal Microscale Optical Systems (LUMOS) ***Description:*** The Lasers for Universal Microscale Optical Systems (LUMOS) program is integrating high-performance light sources into integrated silicon photonics enabling compact, rugged, high-performance systems for positioning, navigation, communications, 3D imaging, and quantum technologies. Silicon photonics today enables microscale integration of complex optical systems, but the platform's lack of optical gain precludes the creation of lasers and amplifiers through foundry processes. LUMOS will deliver the missing capability to provide compact optical sources at wavelengths from the visible to the infrared, and will create a universal manufacturing platform that builds upon the current photonics ecosystem. To drive innovation and maintain DoD access to leading-edge deployable photonic solutions, LUMOS will establish a technology pathway connecting government, academic, commercial, and defense users of integrated photonics, and will provide multi-project wafer runs through an open-access foundry. ***FY 2021 Plans:*** - Complete a process development evaluation of heterogeneous integration approaches including a discussion of potential risks and component specifications. - Investigate new materials and components for high-performance lasers at unique wavelengths on emerging platforms. ***FY 2022 Plans:*** - Develop heterogeneous integration technology for optical gain and nonlinear photonics components in a complementary metal-oxide semiconductor (CMOS) compatible photonics process. - Create initial process design rules and design methodologies to enable early foundry users to fabricate integrated photonics circuits leveraging novel gain mediums and nonlinear photonic components. - Demonstrate active platform components, including modulators and detectors, with high performance. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the shift from initial design to demonstrating active platform components.	8.000	21.000	23.000
Title: System Security Integrated Through Hardware and firmware (SSITH) ***Description:*** The System Security Integrated Through Hardware and firmware (SSITH) program seeks to secure DoD and commercial electronic systems against cybersecurity threats by developing novel hardware/firmware security architectures and hardware design methodologies. Current responses to cybersecurity attacks typically consist of developing and deploying software patches to address specific vulnerabilities in a software firewall without addressing potential vulnerabilities in the	17.000	9.000	4.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
underlying hardware architecture. To address this challenge, SSITH is driving new research in electronics hardware security and exploiting current research in areas such as cryptographic-based computing and hardware verification. Implementation of these advanced ideas has been enabled by the extremely capable semiconductor technology driven by Moore's Law. The program is also investigating flexible hardware architectures that adapt to and limit the impact of new cybersecurity attacks. Finally, SSITH is mitigating the potential negative impact of new security protection architectures on system performance and power usage. Once developed, SSITH capabilities will be applicable to both commercial and military electronic systems. ***FY 2021 Plans:*** - Utilize hardware demonstrations to evaluate the tradeoffs between security, power, and performance of hardware. - Organize a second, open, crowd-sourced red team event to evaluate revised security capabilities. - Begin manufacturing of a high-performance, secure SSITH application-specific integrated circuit. ***FY 2022 Plans:*** - Deliver a high-performance, secure SSITH application-specific integrated circuit (ASIC) for transition and demonstration purposes. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the shift from testing hardware to transitioning fully secure SSITH ASIC.			
Title: Hierarchical Identify Verify Exploit (HIVE) ***Description:*** The Hierarchical Identify Verify Exploit (HIVE) program is pursuing new hardware architectures and algorithms for improving the efficiency of graph and sparse data analytics. When developing operationally significant intelligence, human analysts today are forced to reduce the scope of the problems they can address and the tempo of their analyses due to the limitations of currently deployed hardware. Because of these limitations, the amount of information gathered is quickly outstripping the human ability to review, process, fuse, and interpret. To resolve this challenge, HIVE is leveraging improvements in computational efficiency to augment the analyst's ability to integrate large streams of data. The program is investigating advances in chip architecture and data analytics algorithms that can allow machines to infer meaning out of data based on the information needs of the warfighter. This program will enable the warfighter to understand far more of the battlespace in real time. ***FY 2021 Plans:*** - Fabricate functional HIVE architecture prototype. - Deliver graph analytic tool set and software stack for use with HIVE architecture. - Deliver single-node HIVE architecture platform. ***FY 2022 Plans:*** - Evaluate transition of HIVE architectures defense applications.	16.510	10.000	7.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Initiate design of HIVE platform for specific high performance computing application. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift to transition activities.			
Title: Data Privacy for Virtual Environments (DPRIVE) ***Description:*** The Data Privacy in Virtual Environments (DPRIVE) program will enable data privacy at the user and application level, through the development of new hardware accelerators to achieve acceptable computational times. The program plans to provide strong privacy protections at the tactical edge with no more than one order of magnitude penalty in computation time and enable very strong privacy at the enterprise level with no more than three orders of magnitude penalty over unencrypted processing. DPRIVE will build hardware to accelerate the computation of homomorphic encryption, which enables mathematical operations to execute on encrypted data such that the data is never unencrypted. The program will enable the development and deployment of these hardware accelerators to edge computing devices where power and time are a premium as well as enterprise computing facilities where the amount and sensitivity of the data requires increased protection. The DPRIVE program was originally funded within PE 0602716E, ELT-01. ***FY 2021 Plans:*** - Develop algorithms and simulate performance for both edge and enterprise mission sets. - Create a hardware design model. - Prove the ability to compute deep neural networks on encrypted data. ***FY 2022 Plans:*** - Design an accelerator that is ready for fabrication. - Emulate integrated accelerator design for relevant workloads. - Verify accelerator design through appropriate testing. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY2022 increase reflects the shift from concept development to designing an accelerator for fabrication.	-	10.000	18.000
Title: Ferroelectric Computing (FC) ***Description:*** The Ferroelectric Computing (FC) program will develop low energy ferroelectric technology for dense and scalable computing performance. Current state of the art silicon devices are not capable of scaling to the performance and efficiency levels necessary for future data-centric architectures and applications in high performance computing. This program addresses this need by developing ferroelectric transistor technology for next-generation power-efficient and scalable computing that is readily integrated into current complementary metal oxide semiconductor (CMOS) fabrication process flows.	-	-	10.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2022 Plans: - Perform initial designs of novel ferroelectric transistors that are fast, dense, and energy efficient. - Initiate plans to integrate novel ferroelectric transistors into state of the art silicon technology. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Low Temperature Logic Technology (LTLT) ***Description:*** The Low Temperature Logic Technology (LTLT) program will exploit the unique device and material performance characteristics of state-of-the-art silicon transistors at cryogenic temperatures. Current silicon transistors are performance and power limited when operating at room temperature or higher. This program removes these limitations through modifying the design of existing silicon transistors to optimize their performance at cryogenic temperatures. These devices will be compatible with current complementary metal-oxide-semiconductor (CMOS) fabrication process flows and will offer significant increases in performance and power efficiency over room temperature devices. ***FY 2022 Plans:*** - Perform initial design of transistor, memory, and interconnect technologies that are optimized for low temperature operation. - Initiate plans to modify the fabrication flow for state of the art silicon technology for transistors with optimized cryogenic performance. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.	-	-	15.000
Title: Quantum Inspired Classical Computing (QuICC) ***Description:*** The Quantum Inspired Classical Computing (QuICC) program will implement quantum-inspired algorithms using classical dynamic systems in novel computing architectures for the efficient solving of complex optimization problems. Currently, too much computational energy is required to solve mission-scale optimization problems leading to sub-optimal solutions and excessive computation times. This program will create frameworks for analyzing the computational advantage provided by quantum-inspired algorithms and perform the hardware and algorithm co-design needed to reduce the required energy to optimally solve mission-scale problems. ***FY 2022 Plans:*** - Initiate development of quantum inspired algorithms for scalable optimization problems on classical hardware. - Perform initial hardware and algorithm co-design analysis for representative mission-scale optimization problems. ***FY 2021 to FY 2022 Increase/Decrease Statement:***	-	-	12.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 2	**R-1 Program Element (Number/Name)** PE 0602716E / *ELECTRONICS TECHNOLOGY*	**Project (Number/Name)** ELT-02 / *BEYOND SCALING TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 increase reflects program initiation.			
Title: Common Heterogeneous integration and IP reuse Strategies (CHIPS)	17.800	7.000	-
Description: The Common Heterogeneous integration and IP reuse Strategies (CHIPS) program is developing the design tools and integration standards required to better leverage leading-edge commercial sector technologies in DoD systems. The program aims to realize modular Integrated Circuits (ICs) that integrate designs using different commercial suppliers and silicon technologies. CHIPS is pursuing standardized interfaces for integrating a variety of Intellectual Property (IP) blocks in the form of prefabricated chiplets. The chiplets can be reused across applications, manufacturers, and transistor types, allowing DoD to amortize IC design costs across programs, better align electronics design and fabrication with military performance goals, and expand beyond its traditional reliance on the proprietary capabilities of a few on-shore manufacturers. ***FY 2021 Plans:*** - Demonstrate IP re-use of commercial off-the-shelf circuit designs for integration into the CHIPS platform. - Demonstrate functionality of the CHIPS interface and chiplets in representative defense applications. - Continue work with transition partners to evaluate the system-level impact of CHIPS in DoD applications. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	193.291	199.707	196.493

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	266.646	223.478	174.043	-	174.043	-	-	-	-	-	-
AIR-01: *ADVANCED AEROSPACE SYSTEMS*	-	266.646	223.478	174.043	-	174.043	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Advanced Aerospace Systems program element, budgeted in the Advanced Technology Budget Activity, is focused on exploiting high pay-off opportunities to provide revolutionary new system capabilities, as opposed to incremental or evolutionary advancements, in order to achieve undeterrable air presence at dramatically reduced costs. Rapid prototyping and experimentation of integrated system concepts, as well as enabling vehicle subsystems will be conducted. Programs will explore new architectural concepts that employ a mix of weapon technologies that achieve lethality through a combination of overwhelming performance and overwhelming numbers rather than through the use of singular and costly high value assets. Studies conducted under this program element include examination and evaluation of emerging aerospace threats, technologies, concepts, use of autonomy to minimize risk, and applications for missiles, munitions, and vehicle systems.

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	279.741	230.978	191.443	-	191.443
Current President's Budget	266.646	223.478	174.043	-	174.043
Total Adjustments	-13.095	-7.500	-17.400	-	-17.400
• Congressional General Reductions	0.000	-10.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	2.500			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.454	0.000			
• SBIR/STTR Transfer	-13.549	0.000			
• TotalOtherAdjustments	-	-	-17.400	-	-17.400

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2020	FY 2021
Project: AIR-01: *ADVANCED AEROSPACE SYSTEMS*		
Congressional Add: *Advanced Full Range Engine (AFRE) Congressional Add*	-	2.500
Congressional Add Subtotals for Project: AIR-01	-	2.500
Congressional Add Totals for all Projects	-	2.500

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.
FY 2021: Decrease reflects congressional adjustments.
FY 2022: Decrease reflects completion of the Advanced Full Range Engine (AFRE) program.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Tactical Boost Glide	152.100	81.858	50.043

Description: The Tactical Boost Glide (TBG) program is a Joint DARPA / Air Force effort that is developing and demonstrating technologies to enable air-launched tactical range hypersonic boost glide systems, including flight demonstration of a vehicle that is traceable to an operationally relevant weapon that can be launched from current platforms. The program will also consider traceability, compatibility, and integration with the Navy Vertical Launch System (VLS). The metrics associated with this objective include total range, time of flight, payload, accuracy, and impact velocity. The program will address the system and technology issues required to enable development of a hypersonic boost glide system considering (1) vehicle concepts possessing the required aerodynamic and aero-thermal performance, controllability and robustness for a wide operational envelope, (2) the system attributes and subsystems required to be effective in relevant operational environments, and (3) approaches to reducing cost and improving affordability for both the demonstration system and future operational systems. TBG capabilities are planned for transition to the Air Force and the Navy.

FY 2021 Plans:

- Continue detailed planning and execution of additional tests for expanded risk reduction.
- Complete Assembly, Integration, and Test (AI&T) of first and second flight-test vehicles.
- Conduct test readiness reviews (TRRs) for first and second flight, conduct two flight tests, and complete post-flight analyses.
- Continue AI&T of third flight vehicle.
- Complete materials arc-jet testing.
- Complete Static Test Article aeroshell thermo-structural testing.
- Complete test of Engineering Development Unit.
- Continue procurement of hardware for additional tests and continue AI&T of test articles.
- Continue second TBG performer's aerodynamic and aero-thermodynamic risk reduction testing.
- Continue second TBG performer's material and thermo-structural risk reduction testing.
- Continue second TBG performer's materials arc-jet testing.
- Complete second TBG performer's engineering component and system-level testing and design verification testing.
- Complete second TBG performer's material and thermo-structural risk reduction testing, including structural model validation test, and full-scale hot structure test.
- Conduct static firing of Navy variant rocket motor.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Derive Navy variant guidance electronic unit (GEU) system requirements, and complete GEU preliminary and critical designs. - Derive Navy variant weapon datalink (WDL) system requirements, and complete WDL preliminary and critical designs. ***FY 2022 Plans:*** - Complete AI&T of third flight-test vehicle. - Conduct TRR for third flight, conduct flight test, and complete post-flight analysis. - Conduct Navy variant WDL lab verification test. - Conduct two Navy variant GEU captive flight tests and complete post-test analysis. - Conduct Navy variant WDL over-the-air field test and complete post-test analysis. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program progression from risk reduction activities, hardware procurements, and vehicle builds across both TBG performers to: completion of flight vehicle build and execution of two flight tests, execution of two Navy variant GEU flight tests and Navy variant WDL over-the-air field test.			
Title: Operational Fires	50.000	47.575	45.000
Description: The goal of the Operational Fires (OpFires) program is to develop and demonstrate a novel ground-launched system enabling advanced tactical weapons to penetrate modern enemy air defenses, and rapidly and precisely engage critical time sensitive targets. This program seeks to develop an advanced booster capable of delivering a variety of payloads at a variety of ranges. Additional considerations include the need for compatible mobile ground launch platforms enabling integration with existing ground forces and infrastructure, and specific system attributes required for rapid deployment and redeployment. The program will conduct an engineering flight test to demonstrate the critical technologies in a relevant environment. Those lessons will be captured in an integrated weapon system critical design review for a potential follow-on effort developing a full prototype. OpFires will leverage and integrate ongoing investments in hypersonics to achieve these objectives. ***FY 2021 Plans:*** - Develop integrated weapon system technology maturation plan and initial flight test plan. - Conduct integrated weapon system risk reduction testing. - Complete integrated weapon system Preliminary Design Review (PDR). - Begin Engineering Test (ET-1) Test Readiness Review for canister egress test. - Conduct full-scale propulsion system static hot-fire testing. ***FY 2022 Plans:*** - Complete booster separation, and missile control system testing. - Complete flight test configuration assembly, integration, and test plans. - Complete ET-1 Test Readiness Review and flight (canister egress) test.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Complete integrated weapon system Critical Design Review (CDR). ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to completion of static hot fire testing and ramping down to finish Critical Design Review.			
Title: Glide Breaker ***Description:*** Glide Breaker is developing a critical component technology to support a lightweight vehicle designed for precise engagement of hypersonic threats at very long range. Glide Breaker focuses on a single, critical, long-lead technology with applicability to a variety of interceptor concepts and designs. ***FY 2021 Plans:*** - Complete critical design review for technology demonstration. - Begin materials and component level bench testing. - Complete component level bench testing. - Complete test readiness review and procurement for critical, long-lead technology demonstration. - Complete feasibility study for Sounding Rocket Flight Test. ***FY 2022 Plans:*** - Conduct critical, long-lead technology demonstration.	10.000	7.000	7.000
Title: Series Hybrid Electric Propulsion AircRaft Demonstrator (SHEPARD)* ***Description:*** *Formerly Air-Ground Autonomous VEhicles (AGAVE) The result of efforts conducted under AGAVE evolved into more focused research in novel approaches to hybrid-electric propulsion (HEP) systems. The Series Hybrid Electric Propulsion AircRaft Demonstrator (SHEPARD) program will design and develop an efficient HEP system and integrate it into a unique military aircraft application. The innovative aircraft design will include essential operational considerations and mission system components. The program employs a rapid development framework that capitalizes on maturing mission-enabling technologies to quickly meet emergent mission needs while overcoming significant system-level technical challenges. The result will be a flight-demonstrated system with a minimal viable mission capability that is developed quickly and at relatively low cost. ***FY 2021 Plans:*** - Define systems requirements. - Conduct conceptual design activities. - Conduct preliminary design activities.	4.000	16.770	23.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Order long-lead items. ***FY 2022 Plans:*** - Conduct propulsion component testing. - Execute aircraft fabrication. - Integrate and test platform. - Conduct a flight test series. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects a shift from design activities to fabrication and system testing.			
Title: Advanced Aerospace System Concepts ***Description:*** Studies conducted under this program examine and evaluate emerging aerospace technologies and system concepts for applicability to military use. This includes the degree and scope of potential impact and improvements to military operations, mission utility, and warfighter capability. Studies are also conducted to analyze emerging aerospace threats along with possible methods and technologies to counter them. The feasibility of achieving potential improvements, in terms of resources, schedule, and technological risk, is also evaluated. The results from these studies are used, in part, to formulate future prototype development programs or refocus ongoing work. Topics include: methods of defeating enemy anti-aircraft attacks; munition technologies to increase precision, range, endurance, and lethality of weapons for a variety of mission sets; novel launch systems; air vehicle control, power, propulsion, materials, and architectures; and payload and cargo handling systems. ***FY 2021 Plans:*** - Conduct modeling of concept system designs. - Perform sub-system viability experiments. - Demonstrate enabling technologies that support sub-system components. ***FY 2022 Plans:*** - Examine operational utility of novel aerospace system concepts. - Assess feasibility and practicality of developmental aerospace subsystems. - Perform modeling and simulation that support future concepts and novel architectures.	3.000	3.000	3.000
Title: Hypersonic Air-breathing Weapon Concept (HAWC) ***Description:*** The Hypersonic Air-breathing Weapon Concept (HAWC) program is a Joint DARPA / Air Force effort that is developing and demonstrating technologies for an effective and affordable air-launched hypersonic cruise missile. These technologies include advanced air vehicle configurations capable of efficient hypersonic flight, hydrocarbon scramjet-powered propulsion to enable sustained hypersonic cruise, thermal management approaches designed for high-temperature cruise,	19.900	30.880	10.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E *I ADVANCED AEROSPACE SYSTEMS*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
and affordable system designs and manufacturing approaches. Investments may lead into developments in aerodynamics, propulsion, and payload capacity, and algorithms that support maneuvering and target recognition. This is a joint program with the Air Force, and HAWC technologies are planned for transition to the Air Force after flight-testing is complete. ***FY 2021 Plans:*** - Conduct flight tests. - Conduct flight test data analysis. ***FY 2022 Plans:*** - Conduct flight tests. - Complete flight test data analysis and final program review. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects completion of flight tests and program completion.			
Title: LongShot ***Description:*** The goal of the LongShot program is to develop and flight demonstrate a weapon system using multi-mode propulsion that significantly increases engagement range and weapon effectiveness against adversary air threats. LongShot will explore new engagement concepts for multi-modal, multi-kill systems that can engage more than one target. LongShot can be deployed either externally from existing fighters or internally from existing bombers. An air system using multi-modal propulsion could capitalize on a slower speed, higher fuel-efficient air vehicle for ingress, while retaining highly energetic air-to-air missiles for end-game target engagements. This approach provides several key benefits, which ultimately increase weapon effectiveness. First, the weapon system will have a much-increased range over their legacy counterparts for transit to an engagement zone. Second, launching air-to-air missiles closer to the adversary increases energy in terminal flight, reduces reaction time, and increases probability of kill. The program will also evaluate other applications of multi-mode propulsion. Potential transition partners include the Navy and Air Force. ***FY 2021 Plans:*** - Initiate conceptual design of vehicle and begin operational analysis showing mission utility of performer design approaches. - Complete conceptual design of the Objective System and derived Demonstration System and conduct conceptual design review. - Conduct system requirements review of the Demonstration System. - Conduct risk reduction studies in support of design activity.	-	24.000	36.000

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E / *ADVANCED AEROSPACE SYSTEMS*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Mature operational analysis showing mission utility of performer design approaches and conduct independent Government operational analysis. ***FY 2022 Plans:*** - Complete preliminary design of the Demonstration System and conduct preliminary design review. - Complete Wind Tunnel Testing of a Demonstration Air Vehicle. - Conduct missile separation test. - Initiate System Integration Laboratory setup and testing. - Complete critical design of the demonstration system and conduct critical design review. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to completion of preliminary design and increasing efforts on testing of a Demonstration System.			
Title: Advanced Full Range Engine (AFRE) ***Description:*** The Advanced Full Range Engine (AFRE) program is demonstrating turbine-based combined cycle (TBCC) technologies to establish the feasibility of a hypersonic reusable propulsion system. Specifically, AFRE will demonstrate key components of the TBCC propulsion system at low speed where turbine propulsion is used, at high speed where a dual-mode ramjet (DMRJ) is used, and at turbine-to-DMRJ transition conditions. Large-scale components of this complex propulsion system will be developed and demonstrated independently and experimentation will focus on regimes where the propulsion system smoothly transitions from low-speed turbine only operation to high-speed DMRJ only operation. AFRE will enable future airfield-based hypersonic systems to operate without special logistics considerations, resulting in transformational changes in long-range strike, high-speed Intelligence, Surveillance and Reconnaissance (ISR) and Two-Stage-To-Orbit (TSTO) operations. The anticipated transition partner for this effort is the Air Force. ***FY 2021 Plans:*** - Complete ignitor and combustor ignition risk reduction test. - Complete testing of common inlet aerodynamic model. - Complete full-scale combustor (DMRJ) ground test demonstrations at transition and high Mach conditions. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease is due to program completion.	27.646	9.895	-
Accomplishments/Planned Programs Subtotals	266.646	220.978	174.043

	FY 2020	FY 2021
Congressional Add: Advanced Full Range Engine (AFRE) Congressional Add	-	2.500

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603286E *I ADVANCED AEROSPACE SYSTEMS*

	FY 2020	FY 2021
FY 2021 Plans: - Complete ignitor and combustor ignition risk reduction test. - Complete testing of common inlet aerodynamic model. - Complete full-scale combustor (DMRJ) ground test demonstrations at transition and high Mach conditions.		
Congressional Adds Subtotals	-	2.500

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	173.839	151.439	101.524	-	101.524	-	-	-	-	-	-
SPC-01: *SPACE PROGRAMS AND TECHNOLOGY*	-	173.839	151.439	101.524	-	101.524	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Space Programs and Technology program element is budgeted in the Advanced Technology Development budget activity because it addresses high payoff opportunities to dramatically reduce costs associated with advanced space systems and provides revolutionary new system capabilities for satisfying current and projected military missions.

A space force structure that is robust against attack represents a stabilizing deterrent against adversary attacks on space assets. This program element will examine concepts and architectures that move the U.S. away from a dependence on monolithic, ultra-capable, vulnerable, and unsustainably costly assets; replacing them with disaggregated assets that are agile, affordable, and easily replaced/maintained. Ready access to space requires the delivery of capabilities, replenishment of supplies into orbit, and rapid manufacturing of affordable space capabilities. Development of smaller, simpler, and more agile launch vehicles and infrastructure will be pursued. In addition, developing space access and spacecraft servicing technologies will lead to reduced ownership costs of space systems and new opportunities for introducing technologies for the exploitation of space.

Systems development is also required to increase the interactivity and functionality of space systems, space-derived information, and services with terrestrial users. Studies under this program element include technologies and systems that will enable satellites and microsatellites to operate more effectively by increasing maneuverability, survivability, and situational awareness, and precision control of multi-payload systems. Studies will actively seek to take advantage of new commercial developments which may enable both rapid constitution/reconstitution of assets, and agility/functionality not previously available for military systems.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	190.306	158.439	108.126	-	108.126
Current President's Budget	173.839	151.439	101.524	-	101.524
Total Adjustments	-16.467	-7.000	-6.602	-	-6.602
• Congressional General Reductions	0.000	-7.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-9.954	0.000			
• SBIR/STTR Transfer	-6.513	0.000			
• TotalOtherAdjustments	-	-	-6.602	-	-6.602

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer and reprogrammings.

FY 2021: Decrease reflects congressional adjustments.

FY 2022: Decrease reflects completion of the Robotic Servicing of Geosynchronous Satellites (RSGS) systems builds, and transition to early operations of the Blackjack program.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Robotic Servicing of Geosynchronous Satellites (RSGS)	51.580	46.329	19.005
Description: A large number of national security and commercial space systems operate at geosynchronous earth orbit (GEO), providing persistence and enabling ground station antennas to point in a fixed direction. Technologies for servicing of GEO spacecraft would involve a mix of highly automated and remotely operated (from Earth) robotic systems. The Robotic Servicing of Geosynchronous Satellites (RSGS) program seeks to establish the capability to provide robotic services in GEO suitable for a variety of potential servicing tasks, in full collaboration and cooperation with existing satellite owners and national security space operators, and with sufficient propellant for several years of follow-on capability. Key RSGS challenges include robotic tool/end effector requirements, efficient orbital maneuvering of a servicing vehicle, robotic arm systems, automation of certain spacecraft operations, and development of the infrastructure for coordinated control between the servicer and client spacecraft operations teams. The anticipated transition is to a commercial partner who will provide the satellite to carry the robotic payload and who will operate the robotic servicer. To support the development of a broadly accepted satellite servicing capability, DARPA is using the Consortium for Execution of Rendezvous and Servicing operations (CONFERS) approach to bring together experts from the private sector and Government to research, develop and publish nonbinding, consensus-based standards for safe operational approaches to on-orbit servicing.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: - Complete flight software for integration. - Complete build and test of robotic arms and tool changers. - Complete build and test of robotic tools and tool holders. - Complete payload structures fabrication. - Continue integration of robotic payload. - Publication of CONFERS Standard Operational Principles and Practices by International Standards Organization. ***FY 2022 Plans:*** - Test and complete space qualification of integrated robotic payload. - Deliver integrated and tested robotic payload for integration to spacecraft. - Initiate partner training and detailed demonstration planning. - Convene CONFERS fourth general assembly and Global Satellite Servicing Forum. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects completion of system builds.			
Title: Blackjack	79.762	68.610	42.019
Description: The Blackjack program is developing space technologies demonstrating a proliferated smallsat constellation capability in Low Earth Orbit (LEO). Capabilities demonstrated will provide constant custody of very large numbers of concurrent targets; target identification, tracking, and characterization; tactical communications; architectural resilience via massive proliferation; and rapid on-orbit technology refresh and experimentation. Blackjack will leverage commercial industry plans to build constellations in LEO to provide global commercial broadband internet service. Key efforts include low size, weight, power, and cost (SWaP-C) multi-modality smallsat sensor payloads, algorithms for autonomous payload and architecture command and control, algorithms for satellite on-board processing and data fusion, and advanced manufacturing for military payload mass production. A MOA documents the partnership with U.S. Space Force and Air Force. The anticipated transition partners are the U.S. Space Force, Air Force and Space Development Agency. Blackjack will progress through design and build of 2 satellites with missile warning/defense payloads, then an additional 2 satellites with tactical communications and Intelligence, Surveillance, and Reconnaissance (ISR) payloads, and then build and launch 2 additional missile warning/defense and 8 additional tactical communications/ISR satellites for the full Blackjack demonstration of a proliferated LEO constellation. ***FY 2021 Plans:*** - Complete Critical Design Review (CDR) for commoditized satellite bus. - Complete CDR for sensor payloads. - Complete CDR for autonomous control element.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Initiate autonomous control element manufacturing. - Complete CDR for satellite integrator. - Procure missile tracking payload sensor for in-space experiments. - Procure tactical communications and ISR payloads for in-space experiments. - Initiate assembly, integration, and testing for initial two satellites. - Initiate full demonstration spacecraft bus manufacturing. - Initiate full demonstration sensor payload manufacturing. ***FY 2022 Plans:*** - Conduct operations of first demonstration satellites. - Complete assembly, integration, and testing of full demonstration satellites. - Launch full demonstration satellites to support autonomous constellation control. - Initiate procurement of two additional OPIR (Overhead Persistent Infrared) missile warning/defense payloads. - Launch and conduct check-out and early operations of first two ISR/Radio Frequency (RF) satellites. - Launch and conduct check-out and early operations of first two OPIR satellites. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from spacecraft procurement to assembly integration and testing and early operations.			
Title: Demonstration Rocket for Agile Cislunar Operations (DRACO)	10.000	33.000	37.000
Description: Maintaining U.S. interests in cislunar space will require leap-ahead propulsion technology. Current space propulsion includes electric (high efficiency but low thrust) and chemical (high thrust but low efficiency). The Demonstration Rocket for Agile Cislunar Operations (DRACO) program seeks to develop and demonstrate a High-Assay Low-Enriched Uranium (HALEU) nuclear thermal propulsion (NTP) system on orbit by 2025. The NTP technology demonstrated by DRACO can achieve thrust similar to chemical systems, but with 2-5 times the efficiency. The enhanced performance afforded by NTP will allow the U.S. to lead operations in the cislunar volume, a volume that is in danger of being defined by the adversary. The anticipated transition partner is the Air Force. ***FY 2021 Plans:*** - Initiate preliminary design of an NTP demonstration reactor. - Initiate conceptual design of demonstration system (DS) and operational system (OS) NTP spacecraft. - Complete system requirements review for OS spacecraft concept. - Complete subsystem requirements review for NTP demonstration reactor. - Demonstrate designs of NTP fuel elements in representative test environments. - Complete system requirements review for DS spacecraft concept.			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Complete baseline design review for NTP demonstration reactor. - Complete technology maturation plan review for DS spacecraft concept. ***FY 2022 Plans:*** - Begin detailed design of the NTP demonstration reactor. - Begin preliminary design of the demonstration system NTP spacecraft. - Begin fabrication of long lead components for both the NTP demonstration reactor and demonstration system NTP spacecraft. - Complete preliminary design review (PDR) for the demonstration system. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program focus shift from feasibility studies to design and initial demonstration.			
Title: Advanced Space Technology Concepts ***Description:*** Studies conducted under this program will examine and evaluate emerging technologies and concepts with the potential to provide substantial improvement in efficiency and effectiveness of operations in space. This includes the degree and scope of potential impact and improvements to military operations, mission utility, and warfighter capability. Studies are also conducted to analyze emerging threats along with possible methods and technologies for countermeasures. The feasibility of achieving potential improvements, in terms of resources, schedule, and technological risk, is also evaluated. The results from these studies are used, in part, to formulate future programs or refocus ongoing work. Topics of consideration include advanced or novel power and propulsion systems, novel sensors, advanced lightweight structures, advanced miniature radio frequency (RF) technology, navigation technologies, avionics, structures, advanced communications, autonomous constellation operations, and on-orbit software environments. ***FY 2021 Plans:*** - Explore options for high-thrust, high-efficiency propulsion, and autonomous collaboration within satellite constellations. - Examine the use of new technologies to provide responsive, resilient space system capabilities. ***FY 2022 Plans:*** - Initiate studies of new concepts and novel approaches for global navigation and timing systems. - Examine the use of new technologies to enable operation in novel orbital domains.	3.500	3.500	3.500
Title: DARPA Launch Challenge ***Description:*** Advances in technology, including networking and computing, have significantly increased the utility of small (<300kg) spacecraft that would previously have been of limited military value. For the simultaneous purposes of responsiveness and resiliency, these spacecraft are envisioned to be built on dramatically faster timelines (weeks instead of years) than are executed today. The current practice for space launch generally favors large launch vehicles with complex, one-of-a-kind	11.500	-	-

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
infrastructure. This architecture has been matched to the large, heavy spacecraft, which compose most of DoD's space architecture today. Small spacecraft, which offer large potential value for resiliency and tactical employment, are typically required to rideshare for access to space, which requires programmatic, technical, and schedule entanglement with other programs. The U.S. commercial sector has promising developments for small launch vehicles that are designed for launch on rapid timescales with minimal fixed infrastructure. To incentivize industry to deliver capability that can meet emerging DoD needs for rapid, responsive launch of small payloads, the DARPA Launch Challenge was designed to reward competitors who could demonstrate the ability to launch a payload to orbit with minimal notification time and unknown pre-conditions regarding the payload configuration, required orbit, and launch site.			
Title: Experimental Spaceplane (XSP) ***Description:*** The goal of the Experimental Spaceplane (XSP) program was to design a scalable, responsive, prototype reusable launch system capable of inserting commercially and militarily relevant payloads (greater than 3,000 lbs.) into low earth orbit and suborbital trajectories. There was a $5M/launch cost goal to drive down the expense of space access by an order of magnitude versus traditional expendable launch vehicles. This was to be accomplished by designing for high velocity staging which dramatically reduces the amount of costly expendable hardware. The ability to fly 10 times in 10 days and designing the system to launch a payload into orbit within 24 hours was traceable to the responsiveness necessary in a military system. The system had design goals to fly greater than Mach 6.5 multiple times.	12.497	-	-
Title: Planar Imager ***Description:*** The Planar Imager program evaluated the feasibility of a lightweight, compact, affordable optical payload to be integrated into a ride-share compatible satellite bus with equivalent imaging performance of current commercial conventional optical imaging satellites. This technology has the potential to significantly lower the size, weight, power, and cost (SWaP-C) of high-resolution intelligence, surveillance, and reconnaissance (ISR) satellites enabling persistent coverage by an affordable satellite constellation and enabling a rapid reconstitution ability. To achieve this goal, Planar Imager explored recent developments in materials science and nanofabrication and matured small-scale ultra-thin optics demonstrated in the laboratory to larger sizes. Reducing optical payload SWaP-C enables multiple ISR satellites to be packaged into a single launch vehicle fairing, dramatically reducing launch costs and improving reconstitution rate. A more persistent and pervasive space-based ISR architecture will increase warfighter readiness and lethality. These planar optics also have possible applications in optical imaging systems where SWaP-C is a constraint, impacting all areas of optical remote sensing and imaging as well as any system that requires optical components. The anticipated primary transition partners are the Air Force and Space Force.	5.000	-	-
Accomplishments/Planned Programs Subtotals	173.839	151.439	101.524

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603287E / *SPACE PROGRAMS AND TECHNOLOGY*

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

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Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	107.259	95.864	116.716	-	116.716	-	-	-	-	-	-
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	35.108	36.131	27.854	-	27.854	-	-	-	-	-	-
MT-16: *BEYOND SCALING ADVANCED TECHNOLOGIES*	-	72.151	59.733	88.862	-	88.862	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Advanced Electronics Technologies Program Element is budgeted in the Advanced Technology Development Budget Activity because it seeks to design and demonstrate state-of-the-art manufacturing and processing technologies for the production of various electronics and microelectronic devices, sensor systems, integrated photonic-electronic components that have military applications and potential commercial utility. Introduction of advanced product design capability and flexible, scalable manufacturing techniques will enable the commercial sector to rapidly and cost-effectively satisfy military requirements.

The Mixed Technology Integration project funds the advanced development and demonstration of selected basic and applied electronics research programs. Examples of technologies with funded development and demonstration activities include, but are not limited to: (1) reducing the size, weight, and power (SWaP) of components for laser weapon systems that will protect airborne platforms from emerging surface-to-air missiles; integrated photonic-electronic components for positioning, navigation and timing in GPS-denied environments; flexible, software-defined cameras that enable real-time image analysis of complex scenes to provide more actionable information; and optical communications systems that rely on no moving parts enabling their use on SWaP-restricted platforms. Funding under this project is intended to advance transitioning novel technologies to use, providing advanced components compatible with mid-term and other future warfighting requirements.

The Beyond Scaling Advanced Technologies Project is a continuation of DARPA's basic and applied research in this area and will support activities in large scale co-development with leading industry players to enable and accelerate transformative computing interactions with industry. Funding under this project will include developing new technologies and capabilities in commercial settings, establishing access to these new processes and commercial state-of-the-art (SOTA) foundries, developing manufacturable processes for integrated photonics, new architectures and integration technologies for advanced field programmable gate arrays (FPGAs), and innovating back end of line technologies for wide bandgap semiconductors.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603739E *I ADVANCED ELECTRONICS TECHNOLOGIES*

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	123.616	95.864	142.412	-	142.412
Current President's Budget	107.259	95.864	116.716	-	116.716
Total Adjustments	-16.357	0.000	-25.696	-	-25.696
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-4.407	0.000			
• SBIR/STTR Transfer	-11.950	0.000			
• TotalOtherAdjustments	-	-	-25.696	-	-25.696

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer and reprogrammings.

FY 2021: N/A

FY 2022: Decrease reflects completion of the Precise Robust Inertial Guidance for Munitions (PRIGM) program in FY 2021, as well as, the transition from prototype development to final demonstrations in the Reconfigurable Imaging (ReImagine) program.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	Project (Number/Name) MT-15 / *MIXED TECHNOLOGY INTEGRATION*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
MT-15: *MIXED TECHNOLOGY INTEGRATION*	-	35.108	36.131	27.854	-	27.854	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Mixed Technology Integration project funds the advanced development and demonstration of selected basic and applied electronics research programs. Examples of technologies with funded development and demonstration activities include, but are not limited to: (1) reducing the size, weight, and power (SWaP) of components for laser weapon systems that will protect airborne platforms from emerging surface-to-air missiles; integrated photonic-electronic components for positioning, navigation and timing in GPS-denied environments; flexible, software-defined cameras that enable real-time image analysis of complex scenes to provide more actionable information; and optical communications systems that rely on no moving parts enabling their use on SWaP-restricted platforms. Funding under this project is intended to advance transitioning novel technologies to use, providing advanced components compatible with mid-term and other future warfighting requirements.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Reconfigurable Imaging (ReImagine)	14.000	12.000	6.000
Description: The Reconfigurable Imaging (ReImagine) program aims to create multi-functional readout integrated circuits (ROICs) that fundamentally change the way camera systems collect, process and relay image information. This is accomplished by adding multifunctional flexibility in the ROIC. Today, most cameras are designed to capture high quality imagery at standard frame rates. These traditional camera architectures collect a single type of data across the full image frame. Specialty cameras can be used to capture different spatial, spectral or temporal data but are rarely deployed because of the cost and complexity of adding imaging subsystems for niche measurements. Although these measurements are typically only desired for specific features or regions of interest (ROIs) in a scene, the cameras collect specialized data over the full image frame. The ReImagine architecture, conversely, would enable a single, real-time reconfigurable, software-defined camera system with the ability to collect different data in different ROIs. Depending on the need, a ReImagine imager would be able to selectively collect and simultaneously process data from a specific ROI, for example, at a higher resolution (i.e., foveated imaging), at a higher frame rate, or with 3-D depth information. The system would interface with virtually any sensor and could therefore be used in any spectral band. By demonstrating more efficient data collection and computation across ROIs, ReImagine ROICs will enable real-time analysis of much more complex scenes and provide more actionable information than has ever been possible. Technologies from this program are intended for transition to the Air Force, Navy and Army.			
FY 2021 Plans:			
- Complete functional verification testing of second-generation (Gen-2) ROIC tier 1.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Complete the design and build of the Gen-2 prototype camera that integrates the Gen-2 ROIC. ***FY 2022 Plans:*** - Fully demonstrate the updated ReImagine reconfigurable sensing system concept. - Engage with potential transition partners for relevant applications. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from development of a multi-functional digital ROIC camera prototype to conducting final demonstrations.			
Title: Wideband Secured and Protected Emitter and Receiver (WiSPER)	9.000	20.131	21.854
Description: The Wideband Secured and Protected Emitter and Receiver (WiSPER) program aims to develop an ultra-broadband technology platform to demonstrate a robust, secure and protected communication link. WiSPER technology provides high signal coding gain to deliver a secured and protected link with significantly enhanced capacity for next generation DoD communications. Current terrestrial tactical radios operate with limited bandwidth at prescribed low frequency bands, which are unable to support high capacity with multiple users, and are vulnerable to interference and jamming. WiSPER technology addresses military needs for assured communications, throughput, security, and size, weight, and power limitations of future command, control, communications, computers, intelligence, surveillance and reconnaissance missions. The program will develop an ultra-broadband compact antenna, radio frequency front end electronics, mixed signal circuits, and waveform technologies. The WiSPER program will culminate with the integration and demonstration of a secured communication link. Technologies developed under the WiSPER program are planned for transition to the Services. ***FY 2021 Plans:*** - Complete first-generation architecture study of the ultra-broadband, secure communication system. - Implement proof-of-concept designs of antenna, integrated circuits, and waveform for system demonstration. - Simulate and optimize the secured radio transceiver design. ***FY 2022 Plans:*** - Integrate first-generation functional test prototype of the secured radio transceiver. - Prepare laboratory environment for prototype secured radio transceiver testing. - Test prototype secured radio transceiver in laboratory environment. - Prepare to implement second-generation functional test prototype of the secured radio transceiver. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the program shifting from study and design to demonstrating and testing secured radio transceiver.			
Title: Precise Robust Inertial Guidance for Munitions (PRIGM)	9.000	4.000	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Precise Robust Inertial Guidance for Munitions (PRIGM) program is developing inertial sensor technologies for positioning, navigation, and timing (PNT) in GPS-denied environments. These inertial sensors can provide autonomous PNT information when GPS is unavailable. The program exploits recent advances in integrating photonic (light-manipulating) components into electronics and in employing microelectromechanical systems (MEMS) as high-performance inertial sensors for use in extreme environments. Whereas conventional MEMS inertial sensors suffer from inaccuracies due to factors such as temperature sensitivity, photonics-based PNT techniques have demonstrated the ability to mitigate these inaccuracies. PRIGM is focused on developing and transitioning a Navigation-Grade Inertial Measurement Unit (NGIMU), a state-of-the-art MEMS device, to DoD platforms in 2022. PRIGM will advance state-of-the-art MEMS gyros from TRL 3 devices to a TRL 6 transition platform. The ultimate goal is to develop a complete MEMS-based NGIMU with a mechanical/electronic interface identical to existing DoD-standard tactical-grade MEMS IMUs, providing a drop-in replacement for existing DoD systems. Service laboratories have been actively involved throughout program development and remain engaged to facilitate transition of NGIMU prototypes, which will be delivered at the program conclusion. This program has applied research efforts funded in PE 0602716E, Project ELT-01. ***FY 2021 Plans:*** - Develop initial designs and simulations for millimeter-scale two-chip, low-power, near tactical grade Inertial Measurement Unit (IMU). - Deliver NGIMU prototypes to Service transition partners. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Rapid Array Development (RAD) ***Description:*** The Rapid Array Development (RAD) program investigated utilizing an immersive electromagnetic environment to understand the effects of electronic maneuvers and develop new electronic maneuver warfare (EMW) techniques for warfighter training. The program leveraged developments in flexible and adaptive radio frequency (RF) hardware, access to a larger variety of more powerful computing platforms, and advances in software virtualization to allow radical change to the development and deployment cycle for EMW techniques. Technologies developed under the RAD program were transitioned to the Services.	3.108	-	-
Accomplishments/Planned Programs Subtotals	35.108	36.131	27.854

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-15 / *MIXED TECHNOLOGY INTEGRATION*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	Project (Number/Name) MT-16 / *BEYOND SCALING ADVANCED TECHNOLOGIES*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
MT-16: *BEYOND SCALING ADVANCED TECHNOLOGIES*	-	72.151	59.733	88.862	-	88.862	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Beyond Scaling Advanced Technologies Project supports activities to enable and accelerate the transition of disruptive microelectronics advancement, including those developed under the Beyond Scaling Sciences (ES-02) and Beyond Scaling Technology (ELT-02) projects. Funding under this project will include developing new technologies and capabilities in commercial settings, establishing access to these new processes and to commercial state-of-the-art (SOTA) foundries, enabling prototyping, developing manufacturable processes for integrated photonics, advancing new architectures and integration technologies for advanced field programmable gate arrays (FPGAs), and innovating back end of line technologies for wide bandgap semiconductors.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Beyond Scaling - Access	12.137	7.733	5.000
Description: The Beyond Scaling - Access program demonstrates design and fabrication of advanced electronics, including through collaborations with leading industry players. Although the United States has led the development of advanced electronics and is home to three of the five leading-edge silicon foundries, recent investments by foreign competitors are threatening this leadership. Additionally, the fabrication cost of next-generation microelectronics has increased at an alarming rate. While the commercial sector is able to spread these costs over a large volume of products, the low volumes used by the DoD creates a cost barrier to meeting its future technology needs. The Beyond Scaling - Access program forges forward-looking collaborations among the commercial electronics community, defense industrial base, university researchers, and the DoD to address domestic and DoD-available microelectronics capabilities. Activities include establishing design capabilities for advanced digital logic in state-of-the-art foundries; enabling domestic production of millimeter wave circuits for 5G applications, military communication systems, and DoD radar sensors; initializing prototyping facilities and other activities to enhance the likelihood for domestic production and implementation of leading edge technologies; and exploring microelectronics development and manufacturing capabilities aligned to DoD-specific environments.			
FY 2021 Plans: - Demonstrate application of Electronics Resurgence Initiative technologies in DoD-relevant applications. - Engage with relevant transition partners in the Services. - Produce prototype millimeter wave transmitter chips with high reliability and low cycle time.			
FY 2022 Plans:			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-16 / *BEYOND SCALING ADVANCED TECHNOLOGIES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Explore the development of a domestic microelectronics prototyping infrastructure, to enable the rapid transition of advanced microelectronics technologies out of the laboratory and into systems. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects shift from developing technologies to supporting opportunities for domestic production of the technologies.			
Title: Millimeter Wave Digital Arrays (MIDAS)	17.200	12.000	8.050
Description: The Millimeter Wave Digital Arrays (MIDAS) program is developing a common millimeter wave phased array tile that is scalable to large arrays to provide wideband frequency agility from 18-50 gigahertz with element-level digital beamforming. Millimeter wave systems are used today to achieve physical security through the use of narrow antenna beams in a small form-factor. We see this applied to satellite communications and tactical line-of-sight communications such as in the F-22 and F-35. One of the challenges of using directional communications in mobile applications is the problem of knowing where to point the antenna when both platforms are mobile. This can be solved with digital beamforming to enable a mobile platform to listen in all directions with many antenna beams to facilitate neighbor discovery when transmitting. Digital beamforming also enables multiple beams to communicate with several neighbors simultaneously. This capability will increase the network throughput and robustness that will be tolerant to unexpected outages. To achieve these goals, MIDAS is developing a common digital phased array tile that can be used to build large arrays from this common block. The program is executed in two primary technical areas. First, advanced complementary metal oxide semiconductor (CMOS) technology is used to develop the core transceiver elements at a size and power consumption that is required to fit in the small size required by current millimeter wave systems. Second, a combination of advanced packaging and high-performance compound semiconductors is used to build the wideband antenna and front-end amplifiers necessary to make a complete system. Technologies from this program are intended for transition through commercial industry to the Services. ***FY 2021 Plans:*** - Finalize designs, fabricate, and test millimeter wave 64-element digital phased arrays in advanced CMOS co-integrated with compound semiconductor power amplifiers and wideband apertures. - Begin designs of millimeter wave 256-element digital phased arrays in advanced CMOS co-integrated with compound semiconductor power amplifiers and wideband apertures. - Finalize advancements in the fundamental technologies relevant to millimeter wave digital arrays in the areas of converters, filters, oscillators, and broadband apertures. ***FY 2022 Plans:*** - Begin fabrication of 256-element digital phased arrays in advanced CMOS co-integrated with compound semiconductor power amplifiers and wideband apertures.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-16 / *BEYOND SCALING ADVANCED TECHNOLOGIES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate 256-element digital phased arrays for communications or remoting sensing applications. - Engage with transition partners for relevant applications. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the shift from finalizing design and fabrication to demonstration.			
Title: Photonics in the Package for Extreme Scalability (PIPES)	7.000	10.000	10.000
Description: The Photonics in the Package for Extreme Scalability (PIPES) program aims to develop optical signaling technologies for digital microelectronics. Distributed and parallel computing architectures are now pervasive across all size scales, from personal-scale multicore processing units to enterprise-scale high performance computing systems, and span application domains from consumer electronics to DoD systems. Increasingly, however, the benefits of parallelism are constrained not by the limits of computation at individual nodes but by the movement of data between nodes. PIPES will advance microelectronics capabilities by intimately integrating photonics with advanced integrated electronics to yield system connectivity with an unprecedented combination of high aggregate bandwidth, power efficiency, channel density, and link reach. Specifically, PIPES will develop photonic input/output (I/O) capability for application-specific integrated circuits and Field-Programmable Gate Arrays (FPGAs) that are widely used in advanced DoD sensors and radio frequency systems. The goal of the program is improving I/O bandwidth density, efficiency, and reach by more than a factor of 100 to enable disruptive DoD system parallelism and performance scaling. As PIPES technologies mature, they are anticipated to proliferate into central processing units, graphical processing units, and emerging tensor-flow processing units that will impact a wide range of dual-use applications including artificial intelligence, machine learning, large scale emulation, and high performance computing. Technologies from this program are intended for transition to larger scale commercial performers and the Services. ***FY 2021 Plans:*** - Integrate silicon photonics and electronic drive circuitry, and characterize packaged photonic interconnect demonstrator performance to enable FPGAs with photonic interfaces. - Define system integration concepts that leverage PIPES photonic connectivity for defense applications. - Integrate and demonstrate innovative component technologies and characterize link performance of next-generation photonic interconnect capabilities. ***FY 2022 Plans:*** - Mature FPGAs with optical interfaces for transition to commercial and DoD applications. - Develop domestic photonics interconnect capabilities to facilitate DoD access to key silicon photonics fabrication and packaging resources. - Engage with relevant transition partners from the Services.			
Title: Technologies for Mixed-mode Ultra Scaled Integrated Circuits (T-MUSIC)	20.814	13.000	17.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Technologies for Mixed-mode Ultra Scaled Integrated Circuits (T-MUSIC) program is developing an on-shore ultra-broadband radio frequency (RF) mixed-mode semiconductor integrated circuits foundry platform for the critical interface to convert high speed analog signals to a digital representation for commercial and military systems. Mixed-mode circuits take analog and RF signals and transform them to digital data for processing in computing systems. As defense and commercial wireless applications move to higher frequencies in order to carry more data traffic, integrating the broadband mixed-mode circuitry with high speed digital processing logic onto one chip becomes imperative to avoid data transfer bottlenecks. T-MUSIC seeks to integrate high-speed, high-performance analog and digital electronics together in highly-scaled silicon complementary metal-oxide semiconductor (CMOS) foundries on-shore. Such processes will enable the high integration and performance needed for DoD-relevant and commercial 5G/6G applications. A goal of the T-MUSIC program is to enable wireless operations beyond 100 gigahertz with very wide bandwidth with low noise and high dynamic range. In addition, T-MUSIC aims to develop next-generation terahertz mixed-mode devices based on the advanced digital CMOS fabrication platform. The T-MUSIC program will establish advanced on-shore foundry capabilities to establish a long-term domestic world-class RF mixed-mode system-on-chip technology for intended transition to DoD and commercial applications. ***FY 2021 Plans:*** - Fabricate and demonstrate foundational mixed-mode analog/digital circuit building blocks in domestic foundries. - Develop the processes and specifications for next-generation 400 gigahertz high speed mixed-mode device technology. - Demonstrate advanced materials, preliminary device structures, and integration process for terahertz transistors based on domestic CMOS process platform. ***FY 2022 Plans:*** - Fabricate and demonstrate foundational mixed-mode analog/digital circuit building blocks based on the developed 400 gigahertz processes in domestic foundries. - Develop the processes and specifications for next-generation 600 gigahertz high speed mixed-mode device technology. - Optimize and demonstrate advanced materials, scaled terahertz device structures, and integration process based on domestic CMOS process platform. - Work with potential transition partners on applications of T-MUSIC technologies. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the shift to fabricating and demonstrating foundational mixed-mode analog/digital building blocks in domestic foundries.			
Title: Programmable Logic for Applications In Defense (PLAID)* ***Description:*** *Previously part of Beyond Scaling - Access	15.000	17.000	35.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-16 / *BEYOND SCALING ADVANCED TECHNOLOGIES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The Programmable Logic for Applications In Defense (PLAID) program is developing a heterogeneous compute platform that can support processing of large data arrays. Current computing architectures are subject to scaling, bandwidth, and memory limitations and the large size of today's chips limits the movement of data resulting in a fundamental trade-off between circuit size and data throughput. The PLAID program will break this paradigm with new architecture development and achieve more than a 10X bandwidth increase on-chip. In addition to the development of this new device, the PLAID program will expedite deployment into DoD systems by engaging the defense industrial base to map DoD-relevant radio frequency (RF) processing problems onto the new architecture. These RF problems may include element-level digital beamforming, multi-target tracking radar applications and synthetic aperture radar processing. Once applications are mapped onto the new processor, the implementation will be programmed and tested with the intent that the use of the new device developed by commercial industry will directly transition into an asymmetric advantage for the DoD and used by the defense industrial base in emerging applications. ***FY 2021 Plans:*** - Demonstrate direct current power delivery, thermal management, and signal integrity solutions for the proposed device. - Finalize architecture for the new heterogeneous computing platform. - Identify key DoD algorithms for mapping into the new device. ***FY 2022 Plans:*** - Demonstrate five wafer stack with a complete reliability assessment. - Freeze device definition in preparation for completion of physical design. - Demonstrate full-chip model with fabric place and route in Vivado design environment. - Quantify DoD system applications trade-offs with respect to how algorithms map into the device programming. - Engage with transition partners to identify relevant applications. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects a shift from initial concept to fabrication.			
Title: Dense Electronic Packaging for Heterogeneous Integration (DELPHI)	-	-	13.812
Description: The Dense Electronic Packaging for Heterogeneous Integration (DELPHI) program will address the inherent limits of conventional two-dimensional (2D) electronics. Typically, electronics consisted of either single materials such as silicon or of compound semiconductors such as gallium arsenide (GaAs), indium phosphide (InP) or gallium nitride and featured device and circuit architectures in 2D. However, recent developments in the heterogenous integration of different materials systems and advancements in 3D fabrication establish the path to achieving electronic devices and circuits with dramatic increases in performance. This program will harness these advancements and expand on them by developing new semiconductor interconnect materials, heterogeneous integration approaches, and 3D fabrication techniques for advanced devices and circuits. This program will also create robust, compact, low loss passive components and combining networks necessary to realize efficient power			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603739E / *ADVANCED ELECTRONICS TECHNOLOGIES*	**Project (Number/Name)** MT-16 / *BEYOND SCALING ADVANCED TECHNOLOGIES*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
amplifiers with heterogeneous integration. The technologies developed will support transitions including enabling emerging satellite communication and sensing missions to provide enhanced situational awareness. ***FY 2022 Plans:*** - Perform initial development of process flows for scaled transistor and interconnect technology for complex, heterogeneously integrated circuits. - Develop and refine approaches that facilitate integration of compound semiconductor devices/circuits with silicon technologies. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Accomplishments/Planned Programs Subtotals	72.151	59.733	88.862

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	225.917	221.724	251.794	-	251.794	-	-	-	-	-	-
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	108.541	110.555	122.057	-	122.057	-	-	-	-	-	-
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	117.376	111.169	129.737	-	129.737	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Command, Control and Communications Systems Program Element is budgeted in the Advanced Technology Development Budget Activity because its purpose is to demonstrate and evaluate advanced information systems research and development concepts.

The success of military operations depends on timely, reliable, secure, and synchronized dissemination of command and control and relevant situational awareness information to every military echelon. While wired communications and networks are fairly well developed, providing assured high-bandwidth mobile wireless capabilities that match or exceed commercial wired infrastructure is needed to meet the demands of military users. The goal of the Information Integration Systems project is to develop and demonstrate technologies that will provide effective communications to U.S. forces. Approaches to this goal include developing technologies in these areas:

- High-Capacity Links technologies - enables greater back-haul capability.
- Advanced Networking technologies - supports resilience, adaptability, scalability, and composable systems to enable adaptive effects webs.
- Low Probability of Detection and Anti-Jam (LPD/AJ) technologies - provides assured communications in very high-threat environments.
- Novel Radio Frequency and Spectral Sensing (RF/SS) - supports efficient spectrum management in congested environments and detection of electromagnetic threats.

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	229.134	221.724	283.864	-	283.864
Current President's Budget	225.917	221.724	251.794	-	251.794
Total Adjustments	-3.217	0.000	-32.070	-	-32.070
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	-2.217	0.000			
• SBIR/STTR Transfer	-1.000	0.000			
• TotalOtherAdjustments	-	-	-32.070	-	-32.070

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603760E *I COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*

Congressional Add Details ($ in Millions, and Includes General Reductions)	FY 2020	FY 2021
Project: CCC-02: *INFORMATION INTEGRATION SYSTEMS*		
Congressional Add: *Satellite Antenna Technology*	7.000	-
Congressional Add Subtotals for Project: CCC-02	7.000	-
Congressional Add Totals for all Projects	7.000	-

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer and reprogrammings.

FY 2021: N/A

FY 2022: Decrease reflects the completion of the Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE), Dynamic Network Adaptation for Mission Optimization (DyNAMO), and Geospatial Cloud Analytics (GCA) programs.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	Project (Number/Name) CCC-02 / *INFORMATION INTEGRATION SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
CCC-02: *INFORMATION INTEGRATION SYSTEMS*	-	108.541	110.555	122.057	-	122.057	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The success of military operations depends on timely, reliable, secure, and synchronized dissemination of command and control and relevant situational awareness information to every military echelon. While wired communications and networks are fairly well developed, providing assured high-bandwidth mobile wireless capabilities that match or exceed commercial wired infrastructure is needed to meet the demands of military users. The goal of the Information Integration Systems project is to develop and demonstrate technologies that will provide effective communications to U.S. forces. Approaches to this goal include developing technologies in these areas:

- High-Capacity Links technologies - enables greater back-haul capability.
- Advanced Networking technologies - supports resilience, adaptability, scalability, and composable systems to enable adaptive effects webs.
- Low Probability of Detection and Anti-Jam (LPD/AJ) technologies - provides assured communications in very high-threat environments.
- Novel Radio Frequency and Spectral Sensing (RF/SS) - supports efficient spectrum management in congested environments and detection of electromagnetic threats.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Network Universal Persistence (Network UP)	19.934	16.829	10.998
Description: Current radios send network control information and data using the same wireless link. This produces a common failure mode when that wireless link degrades. In many of today's military wireless networks, even brief wireless link outages create a loss of network connectivity that can take more than two minutes to recover once the wireless link is re-established. During these network outages, data transmission is not possible. The Network UP program will develop and demonstrate radio technology that maintains network reliability through periods of frequent signal degradation that routinely occur in military operational environments. Isolation of critical control channel information in a separate, robust wireless link will allow creation of a protected control channel that can maintain network reliability even when the data channel is lost. The Network UP program will develop technology and a prototype system that enables military wireless networks to send data over dynamic, unstable wireless links. The program will develop approaches to separate the control and data planes across different wireless links and design and implement mechanisms to maintain synchronization across those separate links. Technologies developed under this program will transition to the Services.			
FY 2021 Plans: - Design and build a wireless hardware and software demonstration platform. - Complete integration of network control algorithms onto multi-band or multiple radio platforms.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Conduct critical design review of integrated hardware and software. ***FY 2022 Plans:*** - Test and verify that the operation of the integrated hardware and software meet program goals. - Demonstrate network connectivity and data throughput on wireless channels in the presence of high levels of interference. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from development and integration to demonstrations and testing.			
Title: Protected Forward Communications (PFC)	19.924	15.951	13.325
Description: The collaborative application of combat power in ground tactical operations demands reliable exchange of rich information and precise coordination of actions across various echelons. These operations take place over three critical conversations: (1) to coordinate the actions of a local group, (2) to coordinate group and airborne assets, and (3) to interact with rear echelon command. The communication links over which these three conversations take place are at risk from jamming and geolocation operations conducted with increasingly sophisticated exploitation and denial technology employed by our adversaries. This problem is compounded by demands for ever-increasing capacity of these links. The Protected Forward Communications (PFC) program will build on technical advances in resilient, efficient, and aware communications technology to design a single communication architecture to protect all three conversations from jamming and geolocation. PFC is generally applicable to small unit operations and is particularly relevant to the close air support (CAS) function typically executed by the Joint Terminal Attack Controller (JTAC) or Forward Air Controller (FAC). The PFC program will transition to the Services. ***FY 2021 Plans:*** - Demonstrate bread board implementations designed to performance goals established for the program and conduct lab bench testing. - Develop brass board implementations of a subset of the communications links. - Conduct experimentation with brass board implementations in a realistic environment with real operators and assess performance against realistic threat systems. - Produce complete objective system design of PFC communication system with data artifacts. ***FY 2022 Plans:*** - Conduct engineering over the air test of system prototype to verify updates and modifications. - Conduct over the air testing of system prototype with service transition partner in an emulated anti-access, area denied environment. ***FY 2021 to FY 2022 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 decrease reflects transitioning from design and development to test and evaluation.			
Title: Composable Logistics and Information Omniscience (LogX)	18.401	27.552	24.965
Description: The Composable Logistics and Information Omniscience (LogX) program is developing and demonstrating software for real-time logistics and supply chain system situational awareness (diagnosis), future state prediction (prognosis) and resilience at unprecedented scale and speed. The software will integrate a range of technical innovations spanning human-machine interface, dynamic data visualization, and distributed/collaborative software design. Based upon technologies developed in the Prototype Resilient Operations Testbed for Expeditionary Urban Systems of Systems (PROTEUS) program (budgeted in PE 0603766E, Project NET-01), the LogX capability will allow users to achieve a more distributed and resilient logistics command and control (C2) system utilizing planned cloud-based data environments. The new capability will be tested in an experimental environment tied to current logistics datasets. Technologies from this program will be transitioned to the Services, Combatant Commands, including U.S. Transportation Command, and the Defense Logistics Agency (DLA). ***FY 2021 Plans:*** - Demonstrate capabilities to detect and mitigate supply chain fluctuations and disruptions. - Demonstrate capability to address multiple operational applications simultaneously. - Produce systems for use by actual logistics and operations planners. - Begin to prepare systems for deployment to operational settings. ***FY 2022 Plans:*** - Demonstrate an integrated system ready for deployment to operational settings. - Demonstrate ability to assess resilience within the logistics enterprise. - Characterize the effect of supply chain fluctuations or disruptions. - Demonstrate dynamic adaptation of the system to mitigate disruptions and improve outcomes. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects shift in focus from system development to testing and documentation in support of transition.			
Title: Air Space Total Awareness for Rapid Tactical Execution (ASTARTE)*	-	15.693	24.616
Description: *Formerly Dynamic Airspace Control The Air Space Total Awareness for Rapid Tactical Execution (ASTARTE) program will develop and demonstrate innovative approaches to create a joint, regional (covering the span of an Army division) airspace picture and dynamically managing local airspace operations in an Anti-Access/Area Denial (A2/AD) environment without requiring conventional high power radars or communications. This capability will support airspace dynamic planning and real-time re-planning and deconfliction of a wide array			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
of airborne systems and long-range fires. ASTARTE will identify and deconflict operational missions in a complicated environment filled with ground and airborne threats, friendly fires, precision guided munitions, manned and unmanned aircraft, and civilian aviation. Based on technologies developed in the Systems of Systems-Enhanced Small Units (SESU) program (budgeted in PE 0603766E/Project NET-01), ASTARTE will develop a virtual and live testbed for airspace management systems, a series of algorithms for airspace planning and operations, and a collection of sensors, leveraging existing and novel sensors for real-time spatial and temporal tracking of airborne platforms. ASTARTE will be compatible with legacy command and control (C2) airspace management tools to take advantage of prior investments in technologies, such as human-machine interfaces, and to minimize costs and the impact on training. Technologies from this program will transition to the Army and the Air Force. ***FY 2021 Plans:*** - Develop representative airspace vignettes and identify performance metrics. - Design and develop the software architecture, development environment (DEVSECOPS), and interface specifications to host program software technology and interoperate with legacy airspace management tools. - Define required algorithm training data sets. - Identify non-traditional sensor options and develop performance models. ***FY 2022 Plans:*** - Develop understanding and decision algorithms. - Conduct critical design review of algorithms and sensor systems. - Establish Army and Air Force testbeds that will interface to legacy test and training infrastructure. - Integrate understanding and decision algorithms and sensor models into testbed. - Conduct constructive and virtual integration experiments to evaluate technology performance. - Conduct virtual and live experimentation to assess operational use of ASTARTE technology in joint live exercises. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects transition from modelling and software development to constructive and virtual experimentation.			
Title: Resilient Networked Distributed Mosaic Communications (RNDMC)*	-	10.965	22.153
Description: *Formerly Resilient Networked Distributed Multi Transceiver Communications (RNDMC) Resilient Networked Distributed Mosaic Communications (RNDMC) aims to provide Beyond-Line-Of-Sight (BLOS) tactical communications for an Anti-Access/Area Denial (A2/AD) environment by developing low-cost expendable transceivers that may be hosted on ground platforms, including hand-carried, autonomous air vehicles, high altitude platforms, and low-cost/low earth orbit satellites. RNDMC plans to use a combination of synchronized transceivers and tactical radios to enhance desired signals and reject intentional and unintentional interference. Based on technologies developed in the Protected Forward Communications			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
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B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
(PFC) program (budgeted in this PE/Project), RNDMC will design, develop, and demonstrate a distributed field of expendable transceivers, providing a robust, low-cost, BLOS tactical communications system that degrades gracefully as transceiver nodes become unavailable. The ultimate RNDMC goal is a demonstration on ground and air platforms and will not be reliant on Global Positioning System (GPS). Technologies from this program will transition to the Services. ***FY 2021 Plans:*** - Develop representative communication vignettes and identify performance metrics for ground, air, high altitude, and space RNDMC configurations. - Begin development of tactical terminals and transceiver nodes. - Verify designs using modeling and simulation in ground and air vignettes. ***FY 2022 Plans:*** - Conduct system-level design review of multiple-hop RNDMC system. - Build prototypes for low size, weight, power, and cost (SWaP-C) transceiver nodes. - Begin unit testing of transceiver nodes including tactical waveform augmentation and channel sounding. - Conduct lab testing of prototype system including gain enhancements from distributed coherent beamforming and interference suppression through distributed coherent beam-nulling. - Conduct long link air-to-ground test to validate RNDMC approach in a multipoint to point configuration. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects transition from modelling and simulation to unit and system level testing.			
Title: Mobile Advanced-network Laboratory for Tactics and Applications (MALTA) ***Description:*** MALTA will develop technology that enables tactical and expeditionary operations to quickly integrate and rapidly deploy tactical, resilient networks in hostile environments. Based on technologies developed under the Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE) program, also budgeted in this PE/Project, MALTA solves long-standing problems of rapidly setting up forward-deployed expeditionary networks through the use of advanced commercial wireless networking technologies (e.g., 5G and 5G+) to replace current siloed, outdated, and hard to manage systems. Instead of recreating datalinks, waveforms, or networking technology, MALTA will bring to the tactical and operational setting fully authenticated core network capabilities that, shortly after deployment, enable operators to move and process information and interact with coalition partners without the need for weeks of planning and configuration time. Technologies from MALTA will transition to the Services. ***FY 2022 Plans:*** - Design initial tactical radio integration capabilities.	-	-	11.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Investigate commercial technology opportunities and complete initial network management reference design. - Establish regular user interaction to assess overall system performance and inform dynamic network reconfiguration tools. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Mission Integrated Network Control (MINC) ***Description:*** The goal of the Mission Integrated Network Control (MINC) program is to develop networking resource management technology to enable agile, self-healing, heterogeneous communications that adapt autonomously to battlefield situations and information needs. Technology developed by MINC will translate warfighter information needs and mission applications into requests for communication services and will autonomously discover and configure communications nodes and pathways to form and execute adaptive kill-webs and move information where it is needed the most. Building on technologies developed in the Dynamic Network Adaptation for Mission Optimization (DyNAMO) program, budgeted in this PE/Project, MINC supports applications that will provide up-to-date information to support warfighter situational awareness, a customized common operating picture, and adaptive kill chains across joint all-domain operations in a highly contested environment. Technology from this program will transition to the Services. ***FY 2022 Plans:*** - Design a secure control overlay network that provides resilient discovery and control of network resources and mission services across heterogeneous networks. - Design network orchestration approaches and interfaces that provide semi-autonomous network and information management in support of mission objectives and information needs. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.	-	-	15.000
Title: Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE) ***Description:*** The goal of the Secure Handhelds on Assured Resilient networks at the tactical Edge (SHARE) program is to develop innovative networking and information sharing approaches that enable U.S. and coalition forces to coordinate tactical operations effectively, efficiently, and securely by eliminating today's prohibitive security cost and complexity barriers. SHARE will provide the level of security provided by today's communications systems, while managing trust at the tactical edge, and provide new opportunities for U.S. and coalition forces to gain and maintain a tactical advantage on the battlefield. Coordination includes providing all the information required to enable the command and control necessary to plan and execute operations in all phases of warfare. Technology from this program will transition to the Services and DoD Agencies that work with coalition partners. ***FY 2021 Plans:***	19.963	11.687	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Complete integration of SHARE security and networking capabilities onto DoD handheld devices and conduct final prototype testing to include automated network configuration software. - Conduct testing of SHARE security and networking capabilities integrated onto operational airborne and ground networks that support larger DoD Command and Control (C2) enterprise systems. - Continue co-development of SHARE software with DoD partners for follow-on software configuration management and begin accreditation for use on approved DoD handheld systems. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Dynamic Network Adaptation for Mission Optimization (DyNAMO) ***Description:*** Wireless networks have evolved into complex systems having many configurable parameters and features, including link data rates, power settings, inter-network gateways, and security associations. The optimal settings for these features vary greatly depending on the mission for which the network is deployed and the environment in which it is operating. Currently, the majority of these features are optimized off-line for specific scenarios and assumptions and are pre-set before use in a mission. There is no capability for the settings to adapt if the actual mission or environment differs from the original assumptions used to configure the network. The problem is exacerbated in scenarios in which intelligent adversaries can affect the topology and operation of the network unpredictably and on short timescales. Furthermore, future operations will include multiple, different radios interconnected on the same platform, and those existing networks lack a common standard for interoperability. The DyNAMO program will develop software that addresses the incompatibilities preventing information sharing across independent airborne and ground networks and develop new approaches to configure and control networks and networks of networks for operation in dynamic and contested environments. The program will address optimization within legacy and future military networks, interactions between networks, and availability of necessary network services to support mission success. Technologies developed under this program will transition to the Services. ***FY 2021 Plans:*** - Integrate advanced security elements into DyNAMO in order to operate over multiple security enclaves. - Demonstrate the integrated DyNAMO system to military Service partners to support transition. - Provide DyNAMO software in government controlled repository for use by the Services. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.	11.331	5.989	-
Title: Geospatial Cloud Analytics (GCA)	11.988	5.889	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Description: The Geospatial Cloud Analytics (GCA) program is developing technology to access and analyze global-scale, multimodal geospatial data and pilot an analytics-as-a-service business model. Exploiting multiple sources and modalities at a global scale requires the development of technologies and systems that provide common access points to commercial data, computational power to preprocess data and make it exploitable by analytical tools, and new models supporting sensing and analytics as services, including sharing of tools and results between individuals and consortiums. GCA creates a capability for near real time monitoring of global events and change detection across various environments and warfighting domains. By exploiting the vast amounts of geospatial information from new commercial satellite constellations and other sources, GCA will create the technology foundations needed to provide global awareness of gray zone activities for DoD military mission planning and execution. It will do so by augmenting commercial capabilities with defense assets, not vice versa, and thereby will improve speed, agility, and scalability. Technology from this program will transition to the National Geospatial-Intelligence Agency (NGA). ***FY 2021 Plans:*** - Transition analytics services to National Geospatial-Intelligence Agency. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Accomplishments/Planned Programs Subtotals	101.541	110.555	122.057

	FY 2020	FY 2021
Congressional Add: Satellite Antenna Technology	7.000	-
FY 2020 Accomplishments: - Evaluated the current SoA in Free Space Optical Communications (FSOC). - Identified cost-effective technical approach leveraging existing system. - Initiated preliminary design for 2-D chip. - Converted existing automotive Light Detection and Ranging (LIDAR) chip to operation in conventional FSOC bands. - Demonstrated 2-D beam steering. - Increased range to meet requirements for satellite-to-satellite FSOC.		
Congressional Adds Subtotals	7.000	-

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*	**Project (Number/Name)** CCC-02 / *INFORMATION INTEGRATION SYSTEMS*

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency											Date: May 2021	
Appropriation/Budget Activity 0400 / 3					R-1 Program Element (Number/Name) PE 0603760E / *COMMAND, CONTROL AND COMMUNICATIONS SYSTEMS*				Project (Number/Name) CCC-06 / *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*			
COST ($ in Millions)	**Prior Years**	**FY 2020**	**FY 2021**	**FY 2022 Base**	**FY 2022 OCO**	**FY 2022 Total**	**FY 2023**	**FY 2024**	**FY 2025**	**FY 2026**	**Cost To Complete**	**Total Cost**
CCC-06: *COMMAND, CONTROL AND COMMUNICATION SYSTEMS*	-	117.376	111.169	129.737	-	129.737	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

This project funds classified DARPA programs that are reported in accordance with Title 10, United States Code, Section 119(a)(1) in the Special Access Program Annual Report to Congress.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Classified DARPA Program	117.376	111.169	129.737
Description: This project funds Classified DARPA Programs. Details of this submission are classified.			
FY 2021 Plans: Details will be provided under separate cover.			
FY 2022 Plans: Details will be provided under separate cover.			
FY 2021 to FY 2022 Increase/Decrease Statement: Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	117.376	111.169	129.737

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	515.879	641.158	584.771	-	584.771	-	-	-	-	-	-
NET-01: *JOINT WARFARE SYSTEMS*	-	130.222	143.199	111.089	-	111.089	-	-	-	-	-	-
NET-02: *MARITIME SYSTEMS*	-	112.421	148.459	149.127	-	149.127	-	-	-	-	-	-
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	273.236	349.500	324.555	-	324.555	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Network-Centric Warfare Technology Program Element is budgeted in the Advanced Technology Development budget activity because it addresses high payoff opportunities to develop and rapidly mature advanced technologies and systems required for today's network-centric warfare concepts. It is imperative for the future of the U.S. forces to operate flawlessly with each other, regardless of which services and systems are involved in any particular mission. The overarching goal of this program element is to enable technologies at all levels, regardless of service component, to operate as one system.

The objective of the Joint Warfare Systems project is to create enabling technologies for seamless joint operations, from strategic planning to tactical and urban operations. Joint Warfare Systems leverage current and emerging network, robotic, and information technology and provide next generation U.S. forces with greatly increased capability, lethality, and rapid responsiveness. Critical issues facing this project are: (1) U.S. opponents using systems that are flexible, robust, and difficult to neutralize; and (2) U.S. doctrine that limits the use of firepower to lessen the impact of operations on noncombatants. These problems are magnified in urban and semi-urban areas where combatants and civilians are often co-located and in peacekeeping operations where combatants and civilians are often indistinguishable. Meeting these challenges places a heavy burden on joint war planning. Understanding opponent networks is essential so that creative options can be developed to counter their strategies. Synchronization of air and ground operations to apply force only where needed and with specific effects is required. This project supports all levels of the force structure including: (1) the strategic/operational level by generating targeting options against opponents' centers of gravity that have complex networked relationships; (2) the tactical/operational level by managing highly automated forces with tight coupling between air and ground platforms; and (3) the focused tactical level by developing platforms and tools, which acquire targets of opportunity and cue network-based analysis of likely enemy operations thus maximizing the effectiveness of ground forces in stability and support operations.

The Maritime Systems project is identifying, developing and rapidly maturing critical advanced technologies and system concepts for the naval forces' role in today's network centric warfare concept. Improvements in communications between and among submarines, surface ships and naval aircraft have allowed these forces to operate seamlessly with each other and with other Service's network centric systems. Naval forces will play an ever-increasing role in network centric warfare because of their forward deployed nature, their unique capability to operate simultaneously in the air, on the sea and under the sea, and their versatile ability to provide both rapid strike and project-sustained force. The technologies developed under this project will capitalize on these attributes, improve them and enable them to operate with other network centric forces.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603766E *I NETWORK-CENTRIC WARFARE TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	507.424	661.158	647.113	-	647.113
Current President's Budget	515.879	641.158	584.771	-	584.771
Total Adjustments	8.455	-20.000	-62.342	-	-62.342
• Congressional General Reductions	0.000	-20.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	9.327	0.000			
• SBIR/STTR Transfer	-0.872	0.000			
• TotalOtherAdjustments	-	-	-62.342	-	-62.342

Change Summary Explanation

FY 2020: Increase reflects reprogrammings offset by SBIR/STTR transfer.

FY 2021: Decrease reflects congressional adjustments.

FY 2022: Decrease reflects a shift from standing up a development and operations environment to demonstrating and modeling the Assault Breaker II (ABII) capability, as well as, completion of classified efforts.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	Project (Number/Name) NET-01 / *JOINT WARFARE SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
NET-01: *JOINT WARFARE SYSTEMS*	-	130.222	143.199	111.089	-	111.089	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The objective of the Joint Warfare Systems project is to create enabling technologies for seamless joint operations, from strategic planning to tactical and urban operations. Joint Warfare Systems leverage current and emerging network, robotic, and information technology and provide next generation U.S. forces with greatly increased capability, lethality, and rapid responsiveness. Critical issues facing this project are: (1) U.S. opponents using systems that are flexible, robust, and difficult to neutralize; and (2) U.S. doctrine that limits the use of firepower to lessen the impact of operations on noncombatants. These problems are magnified in urban and semi-urban areas where combatants and civilians are often co-located and in peacekeeping operations where combatants and civilians are often indistinguishable. Meeting these challenges places a heavy burden on joint war planning. Understanding opponent networks is essential so that creative options can be developed to counter their strategies. Synchronization of air and ground operations to apply force only where needed and with specific effects is required. This project supports all levels of the force structure including: (1) the strategic/operational level by generating targeting options against opponents' centers of gravity that have complex networked relationships; (2) the tactical/operational level by managing highly automated forces with tight coupling between air and ground platforms; and (3) the focused tactical level by developing platforms and tools, which acquire targets of opportunity and cue network-based analysis of likely enemy operations thus maximizing the effectiveness of ground forces in stability and support operations.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Prototype Resilient Operations Testbed for Expeditionary Urban Systems of Systems (PROTEUS)	15.960	13.136	8.030
Description: The Prototype Resilient Operations Testbed for Expeditionary Urban Systems of Systems (PROTEUS) program is demonstrating that a dynamically composable Mosaic warfare approach provides superior performance and adaptability in the dynamic, uncertain environment imposed on U.S. warfighters by urban combat operations. PROTEUS will be adaptive to an inherently dynamic and fluid environment that will account for the environmental influence of non-combatants in urban combat as well as kinetic warfighting. Technologies will be integrated using systems of systems principles developed under the System of Systems Integration Technology and Experimentation (SoSITE) program, budgeted in this PE/Project. To support concept development, testing, and warfighter interaction, the program will also develop a supporting virtual testbed. Technologies from this program will be transitioned to the Services.			
FY 2021 Plans: - Expand development of planning and force composition tools for multi-echelon operations. - Enhance features for logistics plan management and considerations for operational impacts. - Demonstrate integration of virtual testbed and composition tool using complex multi-domain scenario against near peer threat.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-01 / *JOINT WARFARE SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate system integration with Service participants executing multi-domain operations at Marine Corps Air Ground Combat Center (MGACC). ***FY 2022 Plans:*** - Demonstrate system integration with Service participants executing multi-echelon, multi-domain operations. - Document and transition software to hosting on Navy and/or Marine Corps IT systems. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a continuation of demonstration and documentation, after initial testing and refinement activities.			
Title: Systems of Systems-Enhanced Small Units (SESU)	20.185	18.487	16.239
Description: The System of Systems-Enhanced Small Unit (SESU) program is developing and demonstrating adaptive kill-web capabilities based on a system-of-systems architecture that enables a small unit of U.S. forces to prevail against a much larger near-peer adversary force in a contested environment. SESU-developed capabilities will provide the small unit with improved awareness of enemy force composition, disposition, and intent. It will also provide the means to deter escalation of threat, and, if deterrence fails, the ability to degrade, disrupt, and/or destroy enemy anti-access/area denial (A2/AD) and combat systems. Technologies to accomplish this include command and control (C2) that operates in a contested environment; distributed sensing, including the ability to leverage indigenous information sources; hybrid effects that include a mix of kinetic, non-kinetic, and information operations capabilities; and autonomous systems to deliver effects and conduct sensing. A Campaign of Learning (CoL) will be conducted in partnership with the Army, and technologies produced by this program will be transitioned to the Services. ***FY 2021 Plans:*** - Demonstrate impact of advanced technology suites in constructive and virtual simulations. - Integrate sensors and effectors in autonomous ground and air platforms and demonstrate real-time operation in hardware-in-the-loop or live environment. - Evaluate prototype distributed C2 software and hardware operating speeds. - Conduct live and virtual experiments to demonstrate and evaluate prototype architectures with distributed C2, sensors, and effectors. - Conduct live and virtual demonstrations of full SESU capabilities of autonomous platforms, sensors, and effectors. - Finalize plans for integration of government furnished third party sensors, effectors, and autonomous platforms. ***FY 2022 Plans:*** - Conduct live, virtual, constructive experiments for government-provided missions in realistic environments to demonstrate the ability of the system to support new missions and transition. - Apply SESU technologies to new threats and geographies in live, virtual, and constructive experiments.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-01 / *JOINT WARFARE SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Conduct independent SESU system overall performance and operational analysis in SESU's ability to destroy, disrupt, degrade, and/or delay aspects of an adversary's A2/AD capabilities. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from development to live, virtual, and constructive demonstrations and testing.			
Title: Assault Breaker II (ABII)	67.358	71.350	51.154
Description: Assault Breaker II (ABII) seeks to change the current warfighting paradigm of reliance on a Service-specific and platform centric force that executes prescribed kill chains to a highly adaptable and capability-based force. This new paradigm operates as a disaggregated kill web able to execute rapidly composable, joint, and all domain kill chains. Building upon technologies developed in the Cross Domain Maritime Surveillance and Targeting (CDMaST) program, budgeted in PE 0603766E, Project NET-02, ABII will exploit both existing and emerging technologies across the Services to address known capability gaps, opportunities, and threats. ABII will conduct mission-centric, multi-Service and multi-domain analyses, modeling & simulation (M&S), and experimentation to inform research and development and program of record recommendations. ABII will build an enduring, multi-service M&S environment to support complex mission level kill web analysis. ABII will also design and develop a Vanguard Force DevOps Environment (VFDE) and battle management enclave with physical nodes that will enable the transition of ABII technologies, concepts and architectures to the Services. ***FY 2021 Plans:*** - Perform scenario focused studies of kill web architecture and effects. - Demonstrate completed modules for the modeling and simulation environment compatibility. - Initiate detailed design of multi-domain and multi-level security environment. - Begin experimentation efforts within the Distributed Experimentation Environment (DE2). - Design early user evaluations and field trial of technologies matured through ABII. - Demonstrate completed modules for VFDE and related facilities. - Develop modules and battle management capabilities of the VFDE. ***FY 2022 Plans:*** - Initiate studies for the finalization of kill web architectures and effects. - Execute model development for the M&S environment. - Demonstrate model and simulation initial operating capability. - Demonstrate completed modules for the multi-domain, multi-level security environment. - Execute experimentation campaign utilizing VFDE and DE2 capabilities. - Perform preliminary design for large scale exercise based experiment. - Demonstrate completed modules of battle management command and control tool sets.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-01 / *JOINT WARFARE SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Demonstrate operational capability of VFDE and execute initial integration of battle management tools. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the completion of the Vanguard Force DevOps Environment infrastructure, and the completion of critical software and toolset modules associated with Advanced Battle Management and modeling & simulation.			
Title: Air Combat Evolution (ACE) ***Description:*** As the Services develop new Joint Multi-Domain Battle warfighting concepts, there is a strong demand for innovative ways to assess architectures, advance technology, and support operators developing advanced multi-domain tactics. Based upon technologies developed in the System of Systems Integration Technology and Experimentation (SoSITE) program, budgeted in this PE/Project, the Air Combat Evolution (ACE) program will apply technologies and principles of distributed autonomy and artificial intelligence (AI) to aerial within-visual-range (WVR) maneuvering, colloquially known as a dogfight, in modeling and simulation (M&S), sub-scale, and ultimately full-scale vehicles. The program will deliver an initial instantiation of a scalable AI controller enabling aircraft autonomy at levels ranging from an advanced tactical autopilot for dynamic maneuver to a form of multi-domain mosaic battle management controller. Experiments will explore both augmentation of existing manned platforms and enhanced future unmanned systems. ACE will provide an early opportunity to build operator trust in combat autonomy and demonstrate adaptive human-machine teaming tools and architectures. Technology developed by this program will transition to the Services. ***FY 2021 Plans:*** - Refine and implement WVR algorithms onto sub-scale commercial unmanned aerial vehicle (UAV) aircraft and test 1v1 scenarios in a live experiment. - Develop Human Machine Interfaces (HMIs) for sub-scale trust assessments. - Conduct trust assessment events in sub-scale aircraft environment. - Conduct extension of combat autonomy to initial campaign scenarios. - Prepare aircraft for testing with final 1v1 flight certification demonstrations. ***FY 2022 Plans:*** - Refine and implement WVR algorithms onto sub-scale commercial UAV aircraft progression to 2v1, 2v2 scenarios. - Implement HMIs for full scale aircraft trust assessments. - Conduct trust assessment events in M&S environment in more complex 2v1, 2v2 scenarios. - Conduct extension of combat autonomy to more complex campaign scenarios. - Prepare for full-scale aircraft testing of combat autonomy. ***FY 2021 to FY 2022 Increase/Decrease Statement:***	12.838	28.601	26.666

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-01 / *JOINT WARFARE SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 decrease reflects a continuation of multiple live testing events and a shift from system development to testing.			
Title: System of Systems Integration Technology and Experimentation (SoSITE)	12.536	11.625	-
Description: The System of Systems Integration Technology and Experimentation (SoSITE) program seeks to implement an architecture framework capable of assessing and demonstrating potential operational benefits of integrating various system capabilities to improve mission success in contested environments. Such assessments would optimize system-level trades of requirements and architectures to leverage an integrated set of system characteristics and capabilities. The demonstration assessment metrics will measure individual and combined system performance to streamline resource allocation to maximize operational impact. In addition, providing a modeling and simulation (M&S) environment to assess complex systems will enable greater utility of emerging system technologies, since they can be assessed in near-real-world simulations without the real-world costs of testing fully integrated systems. The program will also develop system synthesis and integration technologies that enable rapid assimilation of new and off-the-shelf technologies into the system of systems architecture. These technologies will break down current barriers to entry that new technologies face in system of systems using formal methods, compositional reasoning, and automated design space exploration. Technologies from this program will be transitioned to the Services. ***FY 2021 Plans:*** - Perform live flight experiments for USAF and USN partners. - Conduct integration events to characterize long-range fires sub-systems digitally to enable rapid integration into systems of systems. - Create and deploy System of Systems Technology Integration Tool Chain for Heterogeneous Electronic Systems (STITCHES) training software. - Establish Air Force STITCHES Warfighter Application Team (SWAT) effort to transition the SoSITE STITCHES toolchain to the USAF and USN. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects program completion.			
Title: Critical Infrastructure Defense (CID)	-	-	9.000
Description: The goal of the Critical Infrastructure Defense (CID) program is to develop a holistic framework by which DoD can measure its dependencies on civil infrastructure domestically and overseas as well as resulting vulnerabilities. CID will build on technologies developed in the Rapid Attack Detection, Isolation, and Characterization Systems (RADICS) program, budgeted in PE 0602303E, Project IT-03. The creation of CID will mitigate or decrease the impact of adversary attacks on civilian infrastructure. CID will also examine the ability for alternative capabilities that can rapidly take the place of civilian infrastructure on an interim basis. Technologies from CID will transition to the Services.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-01 / *JOINT WARFARE SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2022 Plans: - Design a modeling framework that examines critical infrastructure dependencies across all sectors. - Develop prototypes for capabilities that mitigate vulnerabilities that may be exploited by an adversary ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Resilient Synchronized Planning and Assessment for the Contested Environment (RSPACE) ***Description:*** Currently, Command and Control (C2) of air platforms is a highly centralized process operating largely independently across planning domains (Intelligence, Surveillance, and Reconnaissance (ISR), strike, and spectrum management) and is optimized for a permissive environment. To address the challenges faced in today's increasingly contested environments, the Resilient Synchronized Planning and Assessment for the Contested Environment (RSPACE) program developed tools and models to enable distribution of planning functions across the C2 hierarchy for resilience (e.g., loss of communications), while synchronizing strike, ISR, and spectrum planning to maximize the contribution of all assets through increased utilization and exploitation of synergies. The program developed tools supporting a mixed initiative planning approach, maximizing automation according to operator's choice, and enabling human-in-the-loop intervention and modification. RSPACE also developed tactical decision aids for maritime commanders and planners to build and assess courses of action (COAs) for fleet and ship movements and the employment of counter-ISR techniques. During execution, the tools provided lifecycle tracking of targeting and information needs and supported assessment of progress towards achieving the commander's intent. The tools dynamically responded as directed to ad hoc requests and significant plan deviations via a real-time dynamic re-planning capability and easily adapted to technology refreshes. RSPACE tools transitioned to the Air Force's Kessel Run Experimentation Lab as part of the Air Operations Center Weapon System Program of Record modernization effort and the Navy.	1.345	-	-
Accomplishments/Planned Programs Subtotals	130.222	143.199	111.089

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	Project (Number/Name) NET-02 / *MARITIME SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
NET-02: *MARITIME SYSTEMS*	-	112.421	148.459	149.127	-	149.127	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Maritime Systems project is identifying, developing and rapidly maturing critical advanced technologies and system concepts for the naval forces' role in today's network centric warfare concept. Improvements in communications between and among submarines, surface ships and naval aircraft have allowed these forces to operate seamlessly with each other and with other Service's network centric systems. Naval forces will play an ever-increasing role in network centric warfare because of their forward deployed nature, their unique capability to operate simultaneously in the air, on the sea and under the sea, and their versatile ability to provide both rapid strike and project-sustained force. The technologies developed under this project will capitalize on these attributes, improve them and enable them to operate with other network centric forces.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Cross Domain Maritime Surveillance and Targeting (CDMaST)	15.397	11.326	3.000

Description: The Cross Domain Maritime Surveillance and Targeting (CDMaST) program seeks to identify and implement architectures consisting of novel combinations of manned and unmanned systems to execute long-range kill chains and develop a robust "kill web" against submarines and ships over large contested maritime areas. By exploiting promising new developments in unmanned platforms, seafloor systems, and emerging long-range weapon systems, the program will develop an advanced, integrated undersea and above sea warfighting capability. The CDMaST program will establish an analytical and experimental environment to explore architecture combinations in terms of operational effectiveness as well as engineering feasibility and robustness. The program will leverage enabling technologies needed for command, control, and communication (C3) between physical domains in order to support the architecture constructs. Through experimentation, the program will not only demonstrate integrated system performance, but also develop new tactics that capitalize on features created by the heterogeneous architecture. The CDMaST program will invest in technologies that will reduce cost, manage complexity, and improve reliability. Technologies from this program will transition to the Navy.

FY 2021 Plans:
- Conduct additional at-sea and in-lab demonstrations, document results, and deliver test results report.
- Execute engineering tests to support the final experimentation event.
- Collaborate with the Navy on CDMaST experimentation events based on previously executed transition documentation (e.g., Memorandums of Agreement).

FY 2022 Plans:
- Perform final CDMaST experimentation event.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Complete transition of hardware, software, and reports to the Navy. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the completion of design and integration activities and transition to final experimentation events.			
Title: Hunter ***Description:*** The Hunter program seeks to develop novel concepts for Extra Large Unmanned Undersea Vehicles (XLUUVs) to deliver complex payloads. The program will explore efficient encapsulation and buoyancy control concepts to be implemented with advanced fiber handling capabilities for high bandwidth communications in order to create a highly modular and adaptable ocean interface. This interface will give XLUUVs significantly increased payload handling ability and allow them to deliver completely new capabilities previously delivered only by manned platforms. Building upon research conducted under the Cross Domain Maritime Surveillance and Targeting (CDMaST) program budgeted in this PE/Project, the Hunter program will establish a new capability for integration into maritime system of systems warfare architectures. Technologies developed under the Hunter program will transition to the Navy. ***FY 2021 Plans:*** - Commence carriage integration with the XLUUV to include engineering testing of integrated subcomponents. - Conduct pool testing of entire payload system, which includes the Hunter carriage and the XLUUV payload module. - Conduct studies to upgrade XLUUV autonomy and ability to deploy alternate payloads. - Complete coordinated in-water systems-of-systems testing. ***FY 2022 Plans:*** - Upgrade Hunter carriage and XLUUV communications capability. - Conduct end-to-end mission demonstration. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the transition from system integration and test to mission demonstrations.	15.242	11.863	6.924
Title: Ocean of Things ***Description:*** The goal of the Ocean of Things program is to advance oceanographic sensing and maritime awareness using low-power microelectronics and advanced data analytics. Ocean of Things builds upon advances made in the Cross Domain Maritime Surveillance and Targeting (CDMaST) program, budgeted in this PE/Project. Ocean of Things will develop large numbers of heterogeneous sensing floats to cover large ocean areas, while incorporating environmentally friendly construction materials. These platforms will leverage satellite communications to populate a large data repository with sensor outputs for shared processing. Ocean of Things will apply advanced analysis techniques to the stored data to synthesize and discover new signals and behaviors in the ocean environment. The program will research the spatio-temporal composability of sensors and	25.933	13.011	5.403

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
develop applications for distributed platform behavior using an internet of things (IoT) architecture deployed across the world's oceans. Further research will examine additional platform capabilities and system impacts of communication rate and edge processing. The Ocean of Things program will improve ocean awareness and provide persistent coverage to areas between existing platforms. Technologies developed in Ocean of Things will transition to the Navy. ***FY 2021 Plans:*** - Develop large data test results for Navy ingestion and application. - Develop advanced data analysis and control algorithms. - Evaluate test data to determine optimal deployment and test for Navy involvement. - Develop updated ocean models with improved resolution for Navy employment. ***FY 2022 Plans:*** - Develop advanced algorithms and automated performance. - Integrate analytic and ocean modeling products into Navy applications. - Test advanced algorithms on large-scale data. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from design and development to integration and testing.			
Title: Timely Information for Maritime Engagements (TIMEly)	11.778	20.259	16.500
Description: Integration of undersea elements for joint cross-domain operations is critical for developing the most effective distributed kill webs. The Timely Information for Maritime Engagements (TIMEly) program is creating a heterogeneous underwater network architecture that will span the ocean and bridge to other operating domains. Building upon technologies learned in the Positioning System for Deep Ocean Navigation (POSYDON) program, budgeted in this PE/Project, TIMEly will provide an adaptive, heterogeneous, scalable communications capability to link undersea and cross-domain assets together into kill webs with minimal operator burden. The program will focus on developing architectures with the capability to transfer the right information to its intended purpose. TIMEly will work within commonly understood limitations, with a focus on protocols, quality of service, and information exchange. The program will leverage developments demonstrating short-range and long-range acoustic communications at higher bandwidth and greater reliability, while minimizing detectability. The program will also leverage recent developments in network interoperability to manage heterogeneous undersea and cross-domain networks. Technology developed by this program will transition to the Navy. ***FY 2021 Plans:*** - Conduct hardware in-the-loop simulation and testing. - Conduct limited in-water risk reduction testing for high risk technology areas specific to individual TIMEly architectures.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Develop analytically based architecture performance predictions to evaluate TIMEly performance across a range of mission scenarios. - Commence hardware design and fabrication efforts for TIMEly nodes. - Begin development of hardware control logic and integration with hardware nodes. ***FY 2022 Plans:*** - Fabricate prototype TIMEly nodes for in-water demonstration. - Refine data management architecture and TIMEly communication protocols. - Develop networking and node autonomy behaviors. - Conduct end-to-end testing of TIMEly architectures to evaluate performance. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from fabrication and integration efforts to testing.			
Title: Manta Ray	11.415	22.000	29.500
Description: The Manta Ray program seeks to develop a new class of long-duration, long-range, payload-capable unmanned underwater vehicles (UUVs) at an acquisition and lifecycle cost significantly less than current payload-capable UUVs. This new class of UUV will give the combatant commander an amplification of capacity without disrupting current operations by remaining independent of manned vessels and ports once deployed. The primary goal of the Manta Ray program is to open a design space for future UUVs that are capable of both long duration missions and large payload capacity. A secondary goal of the program is to advance key technologies that will benefit other naval designs such as low lifecycle cost UUV operations, energy management technologies to enable long-duration operations, biofouling reduction technologies, and long-duration navigational enablers. The anticipated transition partner is the Navy. ***FY 2021 Plans:*** - Conduct preliminary and critical design review. - Develop platform subsystems. - Demonstrate and test subsystems in a controlled maritime environment. ***FY 2022 Plans:*** - Continue demonstration and testing of subsystems in controlled maritime environment. - Complete subsystem development and integration. - Begin fabrication of integrated vehicle. - Conduct preliminary integrated platform tests. ***FY 2021 to FY 2022 Increase/Decrease Statement:***			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The FY 2022 increase reflects a shift from technology demonstrations to integrated platform fabrication and testing.			
Title: No Manning Required Ship (NOMARS) ***Description:*** No Manning Required Ship (NOMARS) seeks to develop small, low-cost, disaggregated naval platforms to demonstrate the ability to perform persistent power projection and force application combat missions currently conducted from large, high-value capital ships. The NOMARS program seeks to design a ship that can operate autonomously for long durations at sea, enabling a ship design process that eliminates considerations associated with crew. NOMARS focuses on exploring novel approaches to the design of the sea frame (the ship without mission systems) while accommodating representative payload size, weight, and power. The goal of the program is to demonstrate the feasibility of Unmanned Surface Vessels (USVs) that can operate autonomously for months to years without human intervention, in large numbers, with only periodic, depot-based maintenance. This capability will enable disaggregated persistent USVs, which allows the surface fleet to credibly threaten peer adversaries and negate their investments in high-cost weapon systems designed to counter large naval targets such as aircraft carriers. A successful NOMARS program will prove feasibility of a small unmanned ship with significantly improved reliability and functional performance over current USVs providing a pathway to allow a distributed lethality concept to become viable: small ships, in large numbers, each of which is individually low-cost and low-value, but in aggregate presents a significant deterrent. ***FY 2021 Plans:*** - Complete Conceptual Design Review. - Complete system requirements review. - Conduct preliminary system design of multiple concept vessels. ***FY 2022 Plans:*** - Conduct detailed design of selected concept vessels and complete critical design review. - Initiate NOMARS demonstrator vessel development. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to detailed design of the selected concept vessel(s) and beginning development of the demonstrator vessel.	13.000	24.000	30.600
Title: Angler ***Description:*** The undersea domain has significant importance to national security and military operations. Yet it is a challenging domain in which to operate due to extreme water pressures, restricted communications, ever changing bottom environments, and marine fouling and corrosion. The Angler program seeks to improve U.S. operations in this domain by enabling underwater robotic systems significantly ahead of the state-of-the-art. These robotic systems would be able to search and manipulate objects autonomously, even in dark, turbulent, and semi-opaque sea conditions without the need for human control and without reliance	14.937	26.000	4.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
on the Global Positioning System (GPS). Key Angler technical challenges include sensing techniques that provide high-resolution navigation without GPS, perception and manipulation strategies for objects with unknown parameters, long duration autonomy approaches to support mission execution, and autonomy approaches that do not rely on human intervention. This program was initiated in an applied research effort budgeted in FY 2020 PE 0602702E, Project TT-03. The anticipated transition is to the Navy. ***FY 2021 Plans:*** - Conduct Post-Preliminary Design Review (PDR) activities to identify and transition autonomy and manipulation technologies to Navy partners. - Develop fully integrated robot subsystems. - Demonstrate Phase 1 objectives in a representative maritime environment. ***FY 2022 Plans:*** - Complete program closeout activities. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects completion of Phase 1 activities.			
Title: Sea Train ***Description:*** The Sea Train program will support the delivery of masses of unmanned surface vessels into theater, without reliance on large, manned capital assets. The Sea Train program will develop and demonstrate approaches to exploit the efficiencies of longer slender hulls, while enabling a distributed fleet of tactical Unmanned Surface Vessels (USVs). The Sea Train concept enables vessels that are efficient for transoceanic transport while enabling dispersed operations as individual vessels. The Sea Train program will develop and demonstrate connector approaches to couple the vessels, the control laws required to drive the vessel in open ocean conditions, sensor approaches to understand the wave environment to efficiently navigate the vessel, and the autonomy required to connect and disconnect the vessels without human intervention. The goal of this effort is to improve transport efficiency over what can be achieved with current monohull designs. This allows for the efficient transport of smaller vessels into and out of theater, an operation that is normally accomplished today by carrying smaller vessels on board larger vessels or reliance on at-sea refueling of smaller vessels. ***FY 2021 Plans:*** - Perform Conceptual Design Review of the Objective System. - Conduct Systems Requirements Review of the Phase 1 Demonstration System. - Perform subsystem integration and test. ***FY 2022 Plans:*** - Conduct scaled model testing, analysis, and simulation to inform demonstrator system Preliminary Design Review.	-	20.000	33.000

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Conduct objective system Concept Design Review. - Begin development of a one-quarter scale demonstrator system to support towing tank and in-water testing of the fully assembled, self-powered vehicle. - Initiate demonstrations to evaluate control laws and autonomy behaviors in high sea-state conditions. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase is due to development of large-scale demonstration system.			
Title: Multi-Azimuth Defense Fast Intercept Round Engagement System (MAD-FIRES) ***Description:*** The Multi-Azimuth Defense Fast Intercept Round Engagement (MAD-FIRES) program seeks to develop and demonstrate a point defense system against today's most stressing threats by developing a highly maneuverable, medium caliber, guided supersonic projectiles, fire sequencing and control system capable of neutralizing large threat raids of high speed, highly maneuverable threats. Leveraging recent advancements in gun hardening, miniaturization of guided munition components, and long-range sensors, MAD-FIRES advances fire control technologies, medium caliber gun technologies, and guided projectile technologies enabling the multiple, simultaneous target, kinetic engagement mission at greatly reduced costs. MAD-FIRES seeks to achieve lethality overmatch through accuracy rather than size, thus expanding the role of smaller combat platforms into missions where they have been traditionally outgunned. MAD-FIRES, sized as a medium caliber system, enhances flexibility for installment as a new ship self-defense system. The final phase of the project will end with testing against supersonic targets. Prior to FY 2022, this program was funded in PE 0602702E, Project TT-03. ***FY 2022 Plans:*** - Begin design effort for tactically sized radar illuminator. - Begin design cycle for supersonic threat engagement demonstration. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects initiation of MAD-FIRES advanced technology efforts to complete the final phase of supersonic testing.	-	-	6.000
Title: Goblin ***Description:*** The undersea domain has significant importance to national security and military operations, however, manned missions are restricted in their operational ranges. The Goblin program seeks to enhance U.S. autonomous capabilities in the challenging undersea domain by enabling complex underwater systems able to search, locate, and execute mission objectives without the need for human control. Navigation approaches will focus on the use of commercial, low-cost navigation hardware combined with environmental feature-based algorithm approaches to eliminate reliance on GPS for long duration missions. Key Goblin technical challenges include sensing techniques that provide high-resolution navigation without GPS, perception and	-	-	14.200

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	**Project (Number/Name)** NET-02 / *MARITIME SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
effector strategies for objects with unknown parameters, long-duration autonomy approaches to support mission execution, and autonomy approaches that do not rely on human interaction. The anticipated transition is to the U.S. Navy. ***FY 2022 Plans:*** - Begin subsystems design, long-lead purchase items, and initial subsystems integration. - Test subsystems in a representative maritime environment. - Risk reduction activities supporting preliminary development of fully integrated test system. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Positioning System for Deep Ocean Navigation (POSYDON) ***Description:*** The Positioning System for Deep Ocean Navigation (POSYDON) program provided continuous, Global Positioning System (GPS)-level positioning accuracy to submarines and autonomous undersea vehicles (AUVs) in the ocean over extended periods of time. Undersea navigation cannot use GPS because the water blocks its signals. At shallower depths, masts can be raised to receive GPS signals, but masts present a detection risk. Typically, the alternative to GPS for undersea navigation has been inertial navigation systems (INS), but INS accuracy can degrade unacceptably over time. The POSYDON program distributed a small number of acoustic sources, analogous to GPS satellites, around an ocean basin at known locations. Undersea platforms equipped with a passive acoustic receiver and appropriate processing software are capable of obtaining and maintaining location. By transmitting specific acoustic waveforms and developing accurate acoustic propagation models to predict and interpret the complex arrival structure of the acoustic sources, the submarine or AUV could determine its range from each source and thus calculate its position. Technologies developed under this program transitioned to the Navy's Maritime Surveillance Systems Program Office for fleet experimentation and future Office of Naval Research (ONR) research as endorsed by the Undersea Rapid Capabilities Insertion effort.	4.719	-	-
Accomplishments/Planned Programs Subtotals	112.421	148.459	149.127

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603766E / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	Project (Number/Name) NET-06 / *NETWORK-CENTRIC WARFARE TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
NET-06: *NETWORK-CENTRIC WARFARE TECHNOLOGY*	-	273.236	349.500	324.555	-	324.555	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

This project funds classified DARPA programs that are reported in accordance with Title 10, United States Code, Section 119(a)(1) in the Special Access Program Annual Report to Congress.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Classified DARPA Program	273.236	349.500	324.555
Description: This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2021 Plans:*** Details will be provided under separate cover. ***FY 2022 Plans:*** Details will be provided under separate cover. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	273.236	349.500	324.555

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

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Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	158.040	190.220	294.792	-	294.792	-	-	-	-	-	-
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	24.413	28.281	36.785	-	36.785	-	-	-	-	-	-
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	47.350	64.414	84.248	-	84.248	-	-	-	-	-	-
SEN-06: *SENSOR TECHNOLOGY*	-	86.277	97.525	173.759	-	173.759	-	-	-	-	-	-

A. Mission Description and Budget Item Justification

The Sensor Technology program element is budgeted in the Advanced Technology Development Budget Activity because it funds sensor efforts that will improve the accuracy and timeliness of our surveillance and targeting systems for improved battlefield awareness, strike capability and battle damage assessment.

The Surveillance and Countermeasures Technology project funds sensor efforts that will improve the accuracy and timeliness of our surveillance and targeting systems for improved battlefield awareness, strike capability, and battle damage assessment. Timely surveillance of enemy territory under all weather conditions is critical to providing our forces with the tactical information needed to succeed in future wars. This operational surveillance capability must continue to perform during enemy efforts to deny and deceive the sensor systems, and operate, at times, in a clandestine manner. This project will exploit recent advances in multispectral target phenomenology, signal processing, low-power high-performance computing, and low-cost microelectronics to develop advanced surveillance and targeting systems. In addition, this project encompasses several advanced technologies related to the development of techniques to counter advanced battlefield threats.

The Sensors and Processing Systems project develops and demonstrates the advanced sensor and processing technologies and systems necessary for Intelligence, Surveillance, and Reconnaissance (ISR) missions. Future battlefields will continue to be populated with targets that use mobility and concealment as key survival tactics, and high-value targets will range from specific individual insurgents and vehicles to groups of individuals and large platforms such as mobile missile launchers and artillery. The Sensors and Processing Systems project is primarily driven by four needs: (a) providing day-night ISR capabilities against the entire range of potential targets; (b) countering camouflage, concealment, and deception of mobile ground targets; (c) detecting and identifying objects of interest/targets across wide geographic areas in near-real-time; and (d) enabling reliable identification, precision fire control tracking, timely engagement, and accurate battle damage assessment of ground targets.

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 3: *Advanced Technology Development (ATD)*	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	158.903	200.220	189.258	-	189.258
Current President's Budget	158.040	190.220	294.792	-	294.792
Total Adjustments	-0.863	-10.000	105.534	-	105.534
• Congressional General Reductions	0.000	-10.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	6.752	0.000			
• SBIR/STTR Transfer	-7.615	0.000			
• TotalOtherAdjustments	-	-	105.534	-	105.534

Change Summary Explanation

FY 2020: Decrease reflects the SBIR/STTR transfer offset by reprogrammings.

FY 2021: Decrease reflects congressional adjustments.

FY 2022: Increase reflects initiation of the Painter program, as well as, increased scope of classified programs.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603767E / *SENSOR TECHNOLOGY*	Project (Number/Name) SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
SEN-01: *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*	-	24.413	28.281	36.785	-	36.785	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Surveillance and Countermeasures Technology project funds sensor efforts that will improve the accuracy and timeliness of our surveillance and targeting systems for improved battlefield awareness, strike capability, and battle damage assessment. Timely surveillance of enemy territory under all weather conditions is critical to providing our forces with the tactical information needed to succeed in future wars. This operational surveillance capability must continue to perform during enemy efforts to deny and deceive the sensor systems, and operate, at times, in a clandestine manner. This project will exploit recent advances in multispectral target phenomenology, signal processing, low-power high-performance computing, and low-cost microelectronics to develop advanced surveillance and targeting systems. In addition, this project encompasses several advanced technologies related to the development of techniques to counter advanced battlefield threats.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: All Source Combat Operations and Targeting (ASCOT)	9.943	12.856	13.300

Description: The All Source Combat Operations and Targeting (ASCOT) program will allow maritime platforms to maintain robust battlespace awareness and survivability by combining data and coordinating operations using all available sensors. The program will create methods for optimal balancing of battlespace awareness and survivability by leveraging existing networked sensors and local platform sensors. The program builds upon technology developed as a part of the Resilient Synchronized Planning and Assessment Contested Environment (RSPACE) program, budgeted in PE 0603766E/Project NET-01. Key attributes of this program are survivability, information latency, reliability, and endurance. Demonstrations on relevant platforms in relevant environments will be used to validate the technology. Technologies from this program will transition to the Services.

FY 2021 Plans:
- Conduct field testing with prototype payload.
- Conduct performance review of payload design and sensor fusion/data analysis tools.
- Initiate development of full payload and advanced targeting architecture.
- Conduct initial sensor fusion and data analysis tests in support of an at-sea demonstration.

FY 2022 Plans:
- Complete development of final payload and advanced targeting architecture.
- Conduct performance evaluation and flight testing with final payload.

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Perform sensor fusion, data analysis, and system integration tests in support of an at-sea demonstration. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects the movement from development and integration activities to system testing.			
Title: Aerial Dragnet ***Description:*** Aerial Dragnet seeks to detect multiple small Unmanned Aerial Systems (UAS) in complex and/or urban terrain before they are within Line-Of-Sight (LOS) of friendly assets. Unlike traditional air targets, small UASs pose a special threat in urban terrain for several reasons: they can fly at low altitudes between buildings, they are small making them difficult to sense, and they move at slow speeds making them difficult to differentiate from other moving objects. Moreover, the development of small UASs is driven by commercial technologies, which make them rapidly adaptable and very easy to use. Building upon research conducted in the System of Systems Integration Technology and Experimentation (SoSITE) program (budgeted in PE 0603766E, Project NET-01), Aerial Dragnet will perform surveillance using an architecture consisting of networked sensor payloads deployed on buildings, masts and aerial platforms. The ability to see over and into urban terrain allows Aerial Dragnet to detect, track, and classify UAS incursions rapidly, thus enabling multiple defeat options. Aerial Dragnet sensor payloads are low-cost and comprised of signal processing software, sensor hardware, and networking for distributed, autonomous operation. The system will be scalable to provide cost-effective surveillance coverage from neighborhood to city-sized areas. Aerial Dragnet technologies are expected to transition to the Army, Marine Corps, and Department of State. ***FY 2021 Plans:*** - Develop and test new and enhanced sensor payloads that complement the current sensor suite, building from experience gained during FY 2020 large urban experiment. ***FY 2022 Plans:*** - Evaluate system performance, mission planning and modeling tools of the sensors in a persistent deployment (more than 30 days) within a dense urban environment. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from development and testing of new sensors to evaluation of overall system performance.	7.125	3.847	3.568
Title: Shosty ***Description:*** Shosty seeks to develop and demonstrate enhanced capabilities for high frequency (HF) over-the-horizon-radar (OTHR) systems. This program will develop techniques to characterize distributed skywave HF radar propagation channels and measure radar backscatter from the surface. System signal processing, modeling, analysis, and over-the-air experimentation will be conducted to assess performance. Technologies developed under the Shosty program will transition to the Services.	7.345	7.078	6.055

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: - Design and procure multi-site receive system capable of handling advanced waveform design. - Develop signal processing algorithms for coordinated, multi-site receive system. - Perform end-to-end multi-site, multi-static over-the-horizon radar demonstration. ***FY 2022 Plans:*** - Update algorithms based on testing and needs of identified transition partners, and verify with modeling and simulation. - Perform end-to-end multi-site, multi-static over-the-horizon radar demonstration incorporating advanced waveforms. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from algorithm development to testing of over-the-horizon radar.			
Title: Moving Target Recognition (MTR)	-	4.500	13.862
Description: Based on technologies developed under the Automatic Target Recognition (ATR) Technology program (previously budgeted in 0603767E, SEN-02), the Moving Target Recognition (MTR) program seeks to enable the use of synthetic aperture radar (SAR) sensors to detect, track, image, and automatically recognize moving ground targets within an area of interest. SAR sensors provide the capability to detect and identify high-value targets in all weather conditions but only when the targets are stationary due to limitations in traditional SAR processing. Ground moving target indicator (GMTI) radars are capable of detecting and tracking moving targets, but they cannot form recognizable images of targets. MTR will overcome the limitations of traditional SAR and improve the operational utility of widely deployed SAR sensors on many different types of platforms. The recognition capability will enable new concepts of operation for maintaining persistent custody of high-value targets on the move. Unlike GMTI which loses custody if the track is broken due to terrain or other factors, MTR-enabled SAR sensors will be able to tolerate coverage gaps by reacquiring and reestablishing identification of the moving targets. Technology developed under MTR will transition to the Services. ***FY 2021 Plans:*** - Modify airborne research radar hardware in preparation for data collect experiments. - Develop software to enable novel MTR collection techniques in preparation for data collect experiments. ***FY 2022 Plans:*** - Develop novel MTR algorithms for ground moving target detection, tracking, and imaging with SAR sensors. - Plan and conduct airborne data collect experiments involving ground-truthed moving military vehicles to test the MTR algorithms and collection techniques. - Analyze MTR algorithm performance using the airborne experiment data.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-01 / *SURVEILLANCE AND COUNTERMEASURES TECHNOLOGY*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Determine system requirements for objective SAR sensors to support the MTR algorithms. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects a shift from data collection planning to algorithm creation and airborne data collection.			
Accomplishments/Planned Programs Subtotals	24.413	28.281	36.785

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603767E / *SENSOR TECHNOLOGY*	Project (Number/Name) SEN-02 / *SENSORS AND PROCESSING SYSTEMS*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
SEN-02: *SENSORS AND PROCESSING SYSTEMS*	-	47.350	64.414	84.248	-	84.248	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Sensors and Processing Systems project develops and demonstrates the advanced sensor and processing technologies and systems necessary for Intelligence, Surveillance, and Reconnaissance (ISR) missions. Future battlefields will continue to be populated with targets that use mobility and concealment as key survival tactics, and high-value targets will range from specific individual insurgents and vehicles to groups of individuals and large platforms such as mobile missile launchers and artillery. The Sensors and Processing Systems project is primarily driven by four needs: (a) providing day-night ISR capabilities against the entire range of potential targets; (b) countering camouflage, concealment, and deception of mobile ground targets; (c) detecting and identifying objects of interest/targets across wide geographic areas in near-real-time; and (d) enabling reliable identification, precision fire control tracking, timely engagement, and accurate battle damage assessment of ground targets. The Sensors and Processing Systems project develops and demonstrates technologies and system concepts that combine novel approaches to sensing with emerging sensor technologies and advanced sensor and image processing algorithms, software, and hardware to enable comprehensive knowledge of the battlespace and detection, identification, tracking, engagement, and battle damage assessment for high-value targets in all weather conditions and combat environments.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Military Tactical Means (MTM)	13.806	28.335	23.718
Description: The Military Tactical Means (MTM) program is developing sensors and exploitation techniques capable of performing wide-area search to detect high-value targets in order to task engagement systems to close effects-chains. Finding and prosecuting targets with distributed effects-chains requires the ability to detect, track, and maintain custody of targets across sensors with different modalities residing in various domains. This program will examine both the sensors and the exploitation needed to perform this wide-area search for missions in denied territories and maintain positive chain of custody hand-offs to one or more targeting sensors. The sensors developed under this program will concentrate on sensor modalities that are mostly geometry-invariant and have the potential to be used in highly proliferated systems, such as small satellite constellations and small terrestrial platforms (e.g., class-I or II unmanned aerial system). The exploitation portion of this program will develop algorithms to ensure consistency when passing chain of custody between sensors in different domains where there is the possibility of different sensing modalities and will also be designed to increase confidence and accuracy as targets are passed between sensors. Technology developed by this program will transition to the Services and other government agencies.			
FY 2021 Plans: - Complete development of initial multi-mode exploitation algorithms. - Complete multi-mode sensor module design based on size, weight, power, and modality requirements.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Conduct preliminary and critical design reviews of the sensor modules to determine viability of the designs. - Begin building sensor modules and integration efforts for brassboard demonstration. - Continue development of exploitation algorithms to further refine the effectiveness of the modalities. ***FY 2022 Plans:*** - Integrate algorithms and sensors compatible with field experimentation. - Execute experiments to measure sensor and algorithm performance and effectiveness. - Evaluate both sensor and processor compatibility for objective platform size, weight, and power (SWAP). - Continue modeling and simulation of MTM capabilities against real world use cases developed jointly with operational stakeholders. - Perform objective system modeling to validate performance and effectiveness in military utilization. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects a shift from module design and development to system integration.			
Title: Dynamically Composed RF Systems	7.960	13.158	6.900
Description: Dominance of the Radio Frequency (RF) spectrum is critical to successful U.S. military operations. Radar systems, electronic warfare (EW) systems, and communication systems require custom software and hardware that is costly and time-consuming to build and integrate onto platforms. The Dynamically Composed RF Systems program addresses these challenges by developing adaptive, converged RF array systems. This enables enhanced operational capability by dynamically adapting the system for tasks to support radar, communications, and EW in a converged manner. This program will design and develop: (1) a modular architecture for collaborative, agile RF systems; (2) advanced techniques for RF apertures and airframe integration and the associated wide-band agile electronics to support converged missions over those apertures; (3) a heterogeneous signal processing complex implementing hardware-agnostic RF operating modes (the RF Virtual Machine); (4) software tools for the control, coordination, and scheduling of RF functions and payloads at the element level to maximize overall task performance (a System and Sensor Resource Manager (SSRM)). This capability can be adapted to address diverse missions. Technology developed under this program will transition to the Services. ***FY 2021 Plans:*** - Conduct laboratory testing of the SSRM installed on the two payloads to demonstrate the SSRM's ability to control the two payloads in concert. - Install SSRM and a second payload on the testbed aircraft. ***FY 2022 Plans:*** - Conduct ground testing of SSRM on testbed aircraft and demonstrate ability to control both payloads on the ground.			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Conduct flight tests of the SSRM controlling two third-party payloads and demonstrate ability to control those payloads in flight. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects the transition from development and testing of the SSRM software and integration of the payloads to a focus on flight demonstration.			
Title: Coho ***Description:*** The Coho program will develop advanced signal processing technologies and techniques for future Radio Frequency (RF) systems. These systems will create an asymmetric advantage for tactical operations in anti-access/area-denial environments by extending the real-time operating bandwidth of tactical signal processing, underpinning the ability of U.S. and Allied Forces to accurately orient and beneficially maneuver in the electromagnetic spectrum. Based on technologies developed under the All-Signal Tactical Real-time Analyzer (ASTRAL) program, budgeted in this PE and Project, the objective of Coho is to provide ultra wide-band RF signal detection and recognition capabilities in a form factor suitable for tactical platforms. Coho seeks to provide capabilities for multiple mission areas. These capabilities include (1) surveillance: combining wide operating bandwidth with noise isolation for background electromagnetic search in the low signal to noise ratio environment, (2) filtering: isolating signals based on modulation features to process signals in the presence of co-channel interference, and (3) localization: supporting low-latency execution of multi-aperture processing for discrimination of signals based on angle of bearing. Technology from Coho will transition to the Services. ***FY 2021 Plans:*** - Define concept of employment for Coho signal detection and recognition. - Begin development of algorithms for signal recognition. - Simulate performance of Coho in the contested electromagnetic environment. ***FY 2022 Plans:*** - Conduct Conceptual Design Review for the Coho system. - Continue development of algorithms for signal recognition. - Develop brassboard Coho system. - Conduct initial testing of the brassboard system to determine efficacy of the technology. - Conduct Critical Design Review for final prototype system. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program brassboard hardware instantiation and testing.	-	11.985	16.534
Title: Thermal Imaging Technology Experiment-Recon (TITE-R)* ***Description:*** *Formerly Military Tactical Means (MTM) Demo	-	10.936	21.742

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
The Thermal Imaging Technology Experiment-Recon (TITE-R) leverages and expands upon the successful technology demonstrations associated with Small Satellite Sensors program, budgeted in this PE/Project. TITE-R will develop and demonstrate complimentary sensing modalities, advanced processing, and low swap cross and downlinks which will more closely represent an objective tactical capability. TITE-R will develop sensors and software automation capable of supporting future tactical Intelligence, Surveillance, and Reconnaissance (ISR) operations implemented on small (< 250 kg) satellites. This scalable multi-modal ISR approach will allow tactical users to rapidly characterize, quantify and report battlespace environments and conditions. TITE-R will also expand upon the utility of small satellites to enable access to the world-wide data necessary to optimize machine learning (ML) automation. In addition, this world-wide access will enable discovery of new sources of false positives which is a key factor in using proliferated Low Orbit Earth (pLOE) to support tactical operations. Such broad accesses are not possible through traditional R&D airborne testing. TITE-R aims to rapidly develop and demonstrate an early-to-space prototype system, the data from which will be used to optimize signature discovery and target discrimination algorithms. Technology developed by this program will transition to the Services and other government agencies. ***FY 2021 Plans:*** - Develop concepts of operation with military partners. - Develop demonstration plans for tactical scenarios. ***FY 2022 Plans:*** - Complete payload design and build. - Conduct system-level preliminary design review (PDR) and critical design review (CDR). - Complete payload space qualification and testing of all hardware components. - Implement a baseline set of mission software demonstrating mission feasibility. - Establish a software integration laboratory consisting of an integrated framework of hardware emulators to enable testing and evaluation. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects a shift from design and planning activities to prototype development, validation, and experimentation efforts.			
Title: Painter	-	-	15.354
Description: The Painter program seeks to create revolutionary advancements in laser technologies for future active optical systems. Building on technologies developed in the Efficient Ultra-Compact Laser Integrated Devices (EUCLID) program, previously budgeted in PE 0603739E, Project MT-15, Painter will translate efficiency benefits from critical laser components into compact optical sources. The objective of Painter is to simultaneously increase the power and decrease the size of laser sources			

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
compared to state of the art. Aggressive packaging objectives will be met by overcoming the thermal management challenges of state-of-the-art lasers. Painter development is guided and constrained by spectral properties required to support multiple mission applications. Technologies from Painter will transition to the Services. ***FY 2022 Plans:*** - Conduct application studies for Painter-enabled active optical systems. - Perform architectural studies for critical Painter components and sub-systems. - Model Painter effectiveness over multiple concepts of employment. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects program initiation.			
Title: Small Satellite Sensors ***Description:*** The Small Satellite Sensors program developed and space-qualified an Electro-Optical Infrared (EO/IR) sensor and an inter-satellite communications approach establishing feasibility for new DoD tactical capabilities to be implemented on small (< 100 kg) satellites. Experimental payloads were flown on small satellites, and data was collected to validate new operational concepts. Small satellites provide a low-cost and quick-turnaround capability for testing new technologies and experimental payloads. Operationally, small and low-cost satellites enable the deployment of larger constellations, which can provide greater coverage, persistence, and survivability compared to a small number of more expensive satellites, as well as the possibility for launch-on-demand. This program successfully leveraged the rapid progress being made by the commercial sector on small satellite bus technology, as well as investments being made by DoD and industry on low-cost launch and launch-on-demand capabilities for small satellites. The program focused on developing, demonstrating, and validating key payload technologies needed by DoD that are not currently being developed for commercial space applications. Technologies developed under this program transitioned to the Services.	12.848	-	-
Title: All-Signal Tactical Real-Time Analyzer (ASTRAL) ***Description:*** The All-Signal Tactical Real-time Analyzer (ASTRAL) program developed and demonstrated a system for radio frequency and optical electromagnetic signal surveillance and environment understanding. Built on technologies explored under the Dynamically Composed RF Systems program, also budgeted in this PE/Project, the objective of ASTRAL was to provide a factor of at least 1,000 times improvement over current signal awareness processing speed over broad spectral coverage. The program used technology that supports a development path leading to a mobile, tactical capability. The development objectives of the ASTRAL program were to (1) develop a hybrid processor that provides real-time processing of the most challenging Low-Probability-of-Intercept (LPI) threat signals across a wide bandwidth, and (2) identify exploitation algorithms for military applications that are well-suited to this type of hybrid processor. Several strategic and tactical spectrum awareness applications	3.832	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
that were addressed include, but are not limited to: (a) real-time exploitation of optical communications, (b) city-wide wireless device geo-location, (c) broadband LPI radar warning, and (d) theater-wide spread-spectrum LPI radio geo-location. ASTRAL transitioned to the Navy.			
Title: Collection and Monitoring via Planning for Active Situational Scenarios (COMPASS) ***Description:*** The goal of the Collection and Monitoring via Planning for Active Situational Scenarios (COMPASS) program was to build decision aids for gray zone scenarios, where adversaries attempt to manipulate a U.S.-allied nation through the use of both kinetic and non-kinetic means. Based on research performed under the Resilient Synchronized Planning and Assessment Contested Environment (RSPACE) program, budgeted in PE 0603766E, Project NET-01, the purpose of the COMPASS program was to reduce ambiguity and reveal intent of gray zone actors who use techniques such as misinformation and intimidation to destabilize host nations and possibly produce advantageous conditions for military engagements. COMPASS produced tools to automate gray zone information operations and help U.S. forces adapt to changing conditions and adversary responses. Instead of relying on passive collection of sensory data, COMPASS employed active sensing and recommended actions that U.S. Forces and allied partners can take to stimulate the environment and elicit a response from the adversary that reveals its strategies. To achieve this goal, COMPASS sought to build and demonstrate tools to: 1) discover the structure of the operating environment that includes the goals and objectives of the adversary as it engages in illicit and subversive activities, 2) develop models that capture the dynamics of the situations including the actors, relationships, timings, and dependencies of the adversary campaigns, and 3) integrate the various algorithms into a comprehensive gaming architecture that allows operators to assess the decision space, recommend sensing actions, and monitor progress towards reducing the ambiguity of the operating environment and suggest adjustments. Models and a planning technology prototype were provided to INDOPACOM.	5.278	-	-
Title: Seeker Cost Transformation (SECTR) ***Description:*** The Seeker Cost Transformation (SECTR) program developed novel weapon terminal sensing and guidance technologies and systems for air-launched and air-delivered weapons that can: (1) find and acquire fixed and moving targets with only minimal external support, (2) achieve high navigation accuracy in a GPS-denied environment, and (3) be very small in size and weight and potentially low cost. SECTR-developed systems and technologies are small size, weight and power (SWaP), low recurring cost, and applicable to a wide range of weapons and missions, such as small unit lethality, suppression of enemy air defenses, precision strike, and strike of time-sensitive targets. Hardware technology leveraged passive Electro-Optical and Infrared (EO/IR) sensors, which have evolved into very small and inexpensive devices in the commercial market, and a reconfigurable processing architecture. SECTR also developed a Government-owned open system architecture for the seeker with standardized interfaces between components (both hardware and software). The technical approach to target recognition started from "deep learning" and machine vision algorithms pioneered for facial recognition and the identification of critical image features. Technologies developed under this program transitioned to the Services.	3.626	-	-

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency		Date: May 2021
Appropriation/Budget Activity 0400 / 3	**R-1 Program Element (Number/Name)** PE 0603767E / *SENSOR TECHNOLOGY*	**Project (Number/Name)** SEN-02 / *SENSORS AND PROCESSING SYSTEMS*

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Accomplishments/Planned Programs Subtotals	47.350	64.414	84.248

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2A, RDT&E Project Justification: PB 2022 Defense Advanced Research Projects Agency			Date: May 2021
Appropriation/Budget Activity 0400 / 3	R-1 Program Element (Number/Name) PE 0603767E / *SENSOR TECHNOLOGY*	Project (Number/Name) SEN-06 / *SENSOR TECHNOLOGY*	

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
SEN-06: *SENSOR TECHNOLOGY*	-	86.277	97.525	173.759	-	173.759	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

This project funds classified DARPA programs that are reported in accordance with Title 10, United States Code, Section 119(a)(1) in the Special Access Program Annual Report to Congress.

B. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Classified DARPA Program	86.277	97.525	173.759
Description: This project funds Classified DARPA Programs. Details of this submission are classified. ***FY 2021 Plans:*** Details will be provided under separate cover. ***FY 2022 Plans:*** Details will be provided under separate cover. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** Details will be provided under separate cover.			
Accomplishments/Planned Programs Subtotals	86.277	97.525	173.759

C. Other Program Funding Summary ($ in Millions)

N/A

Remarks

D. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605001E / *MISSION SUPPORT*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	68.983	74.334	73.145	-	73.145	-	-	-	-	-	-
MST-01: *MISSION SUPPORT*	-	68.983	74.334	73.145	-	73.145	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Mission Support Program Element provides funding for the costs of mission support activities for the Defense Advanced Research Projects Agency. The funds provide personnel compensation for mission support civilians as well as costs for building rent, physical security, travel, supplies and equipment, communications, printing and reproduction.

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	68.498	74.334	74.770	-	74.770
Current President's Budget	68.983	74.334	73.145	-	73.145
Total Adjustments	0.485	0.000	-1.625	-	-1.625
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.485	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• TotalOtherAdjustments	-	-	-1.625	-	-1.625

Change Summary Explanation

FY 2020: Increase reflects reprogrammings.
FY 2021: N/A
FY 2022: Decrease reflects travel reduction offset by repricing of civilian personnel costs.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Mission Support	68.983	74.334	73.145
Description: Mission Support			
FY 2021 Plans:			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605001E / *MISSION SUPPORT*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
- Fund mission support civilian salaries and benefits, and administrative support costs. - Fund travel, rent and other infrastructure support costs. - Fund security costs to continue access controls, uniformed guards, and building security requirements. ***FY 2022 Plans:*** - Fund mission support civilian salaries and benefits, and administrative support costs. - Fund travel, rent and other infrastructure support costs. - Fund security costs to continue access controls, uniformed guards, and building security requirements. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 increase reflects minor repricing of civilian personnel costs.			
Accomplishments/Planned Programs Subtotals	68.983	74.334	73.145

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605502E / *SMALL BUSINESS INNOVATION RESEARCH*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	107.294	0.000	0.000	-	0.000	-	-	-	-	-	-
SB-01: *SMALL BUSINESS INNOVATION RESEARCH*	-	107.294	0.000	0.000	-	0.000	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

In accordance with Public Law No: 116-92 (National Defense Authorization Act 2020) and the Small Business Act (15 U.S.C. 638), the DARPA Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are designed to provide small, high-tech businesses and academic institutions the opportunity to propose radical, innovative, high-risk approaches to address existing and emerging national security threats, thereby supporting DARPA's overall strategy to enable fundamental discoveries and technological breakthroughs that provide new military capabilities.

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	0.000	0.000	0.000	-	0.000
Current President's Budget	107.294	0.000	0.000	-	0.000
Total Adjustments	107.294	0.000	0.000	-	0.000
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.000	0.000			
• SBIR/STTR Transfer	107.294	0.000			

Change Summary Explanation

FY 2020: Increase reflects SBIR/STTR transfer.
FY 2021: N/A
FY 2022: N/A

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Small Business Innovation Research	107.294	-	-
Description: The Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs are designed to provide small, high-tech businesses and academic institutions the opportunity to propose radical, innovative, high-risk			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605502E / *SMALL BUSINESS INNOVATION RESEARCH*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
approaches to address existing and emerging national security threats; thereby supporting DARPA's overall strategy to enable fundamental discoveries and technological breakthroughs that provide new military capabilities.			
Accomplishments/Planned Programs Subtotals	107.294	-	-

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide* / BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605898E / *MANAGEMENT HQ - R&D*

COST ($ in Millions)	Prior Years	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total	FY 2023	FY 2024	FY 2025	FY 2026	Cost To Complete	Total Cost
Total Program Element	-	13.291	13.434	12.740	-	12.740	-	-	-	-	-	-
MH-01: *MANAGEMENT HQ - R&D*	-	13.291	13.434	12.740	-	12.740	-	-	-	-	-	-
Quantity of RDT&E Articles	-	-	-	-	-	-	-	-	-	-		

A. Mission Description and Budget Item Justification

The Management HQ - R&D Program Element provides funding for the administrative support costs of the Defense Advanced Research Projects Agency. This project provides funding for DARPA Management Headquarters Activities (MHA). The funds provide personnel compensation for management headquarters civilians as well as associated travel and support contract costs. Departmental Service Requirements Review Board (SRRB) reductions were taken in this PE. Mission support costs are reflected in PE 0605001E, Project MST-01.

B. Program Change Summary ($ in Millions)	FY 2020	FY 2021	FY 2022 Base	FY 2022 OCO	FY 2022 Total
Previous President's Budget	13.208	13.434	13.488	-	13.488
Current President's Budget	13.291	13.434	12.740	-	12.740
Total Adjustments	0.083	0.000	-0.748	-	-0.748
• Congressional General Reductions	0.000	0.000			
• Congressional Directed Reductions	0.000	0.000			
• Congressional Rescissions	0.000	0.000			
• Congressional Adds	0.000	0.000			
• Congressional Directed Transfers	0.000	0.000			
• Reprogrammings	0.083	0.000			
• SBIR/STTR Transfer	0.000	0.000			
• TotalOtherAdjustments	-	-	-0.748	-	-0.748

Change Summary Explanation

FY 2020: Increase reflects reprogrammings.
FY 2021: N/A
FY 2022: Decrease reflects travel reduction and minor repricing of management headquarters support contract costs.

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
Title: Management Headquarters	13.291	13.434	12.740
Description: Management Headquarters			

Exhibit R-2, RDT&E Budget Item Justification: PB 2022 Defense Advanced Research Projects Agency	Date: May 2021
Appropriation/Budget Activity 0400: *Research, Development, Test & Evaluation, Defense-Wide I* BA 6: *RDT&E Management Support*	**R-1 Program Element (Number/Name)** PE 0605898E *I MANAGEMENT HQ - R&D*

C. Accomplishments/Planned Programs ($ in Millions)	FY 2020	FY 2021	FY 2022
FY 2021 Plans: - Fund management headquarters civilian salaries, benefits, travel and support contract costs. ***FY 2022 Plans:*** - Fund management headquarters civilian salaries, benefits, travel and support contract costs. ***FY 2021 to FY 2022 Increase/Decrease Statement:*** The FY 2022 decrease reflects minor repricing.			
Accomplishments/Planned Programs Subtotals	13.291	13.434	12.740

D. Other Program Funding Summary ($ in Millions)

N/A

Remarks

E. Acquisition Strategy

N/A